

# Cooling load calculation procedure engineering essay



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The total amount of heat energy that must be removed from a system by a cooling mechanism in a unit time, equal to the rate at which heat is generated by people, machinery, and processes, plus the net flow of heat into the system not associated with the cooling machinery.

[1] The sensible and latent heat transfer between the space air and the surroundings can be classified as follows:

1. Space heat gain  $q_e$ , in Btu/h (W), represents the rate at which heat enters a conditioned space

from an external source or is released to the space from an internal source during a given time interval.

2. Space cooling load, often simply called the cooling load  $Q_{rc}$ , Btu /h (W), is the rate at which

heat must be removed from a conditioned space so as to maintain a constant temperature and acceptable relative humidity. The sensible cooling load is equal to the sum of the convective heat transfer from the surfaces of the building envelope, furnishings, occupants, appliances, and equipment.

4. Space heat extraction rate  $Q_{ex}$ , Btu /h (W), is the rate at which heat is actually removed from

the conditioned space by the air system. The sensible heat extraction rate is equal to the sensible

cooling load only when the space air temperature remains constant.

5. Coil load  $Q_c$ , Btu /h (W), is the rate of heat transfer at the coil. The cooling coil load  $Q_{cc}$ ,

Btu/h (W), is the rate at which heat is removed by the chilled water flowing through the coil or is

absorbed by the refrigerant inside the coil.

Cooling load usually can be classified into two categories:

external and internal.

#### External Cooling Loads[1]

These loads are formed because of heat gains in the conditioned space from external sources through the building envelope or building shell and the partition walls.

Sources of external loads include the following cooling loads:

1. Heat gain entering from the exterior walls and roofs
2. Solar heat gain transmitted through the fenestrations
3. Conductive heat gain coming through the fenestrations
4. Heat gain entering from the partition walls and interior doors
5. Infiltration of outdoor air into the conditioned space

#### Internal Cooling Loads[1]

These loads are formed by the release of sensible and latent heat from the heat sources inside the conditioned space. These sources contribute internal cooling loads:

1. People
2. Electric lights
3. Equipment and appliances

For [1-1] & [1] see the section of references

## **CHAPTER 2**

### **COOLING LOAD CALCULATION PROCEDURE**

[2]The estimation of cooling load for a space involves calculating a surface by surface conductive, convective, and radiative heat balance for each room surface and a convective heat balance for the room air. Based on the same underlying principles, the following methods have been developed for calculating the cooling load.

Cooling Load by Transfer Function Method (TFM).

Total Equivalent Temperature Difference (TETD) method.

Cooling Load Temperature Difference (CLTD) method.

Transfer Function Method (TFM)[1]

The transfer function method or weighting factor method is a simplification of the laborious heat balance method. The wide application of the TFM is due

to the user-friendliness of the inputs and outputs of the TFM software and the saving of computing time. In the transfer function method, interior surface temperatures and the space cooling load were first calculated by the exact heat balance method for many representative constructions. The transfer function coefficients (weighting factors) were then calculated which convert the heat gains to cooling loads. Sometimes, transfer function coefficients were also developed through test and experiments.

## Calculation Procedure

The calculation of space cooling load using the transfer function method consists of two

steps. First, heat gains or heat loss from exterior walls, roofs, and floors is calculated using response factors or conduction transfer function coefficients; and the solar and internal heat gains are calculated directly for the scheduled hour. Second, room transfer function coefficients or room weighting factors are used to convert the heat gains to cooling loads, or the heat losses to heating loads. As described in Sec. 6. 2, the sensible infiltration heat gain is the instantaneous sensible cooling load. All latent heat gains are instantaneous latent cooling loads.

The TFM is limited because the cooling loads thus calculated depend on the value of transfer

function coefficients as well as the characteristics of the space and how they are varied from those used to generate the transfer function coefficients. In addition, TFM assumed that the total cooling load can be calculated by

simply adding the individual components-the superposition principle.

However, this assumption can cause some errors.

#### Total Equivalent Temperature Difference (TETD) Method[1]

In the total equivalent temperature difference (TETD)/time-averaging (TA) method, heat gains of a number of representative exterior wall and roof assemblies are calculated. The internal heat gains and conductive heat gain are calculated in the same manner as in the TFM.

The radiant fraction of each of the sensible heat gains is then allocated to a period including the current and successive hours, a total of 1 to 3 h for light construction and 6 to 8 h for heavy construction. The TETD/ TA method is also a member of the TFM family and is developed primarily for manual calculation. TETD/TA is simpler in the conversion of heat gains to cooling loads. However, the time-averaging calculation procedure is subjective-it is more an art than a rigorous scientific method. Also the TETD/TA method inherits the limitations that a TFM possesses if the TFM is used to calculate the TETD.

#### Cooling Load Temperature Difference (CLTD) Method [2]

CLTD is the method we used to calculate the cooling load of the project we were assigned. The CLTD method accounts for the thermal response in the heat transfer through the wall or roof, as well as the response due to radiation of part of the energy from the interior surface of the wall to objects and surfaces within the space. The CLTD method makes use of (a) the temperature difference in the case of walls and the roofs and (b) the cooling

load factors (CLF) in the case of solar heat gain through windows and internal heat sources, i. e ,

$$Q = U \times A \times CLTDC$$

Where

Q is the net room conduction heat gain through roof, wall or glass (W)

A is the area of the roof , wall or glass (m<sup>2</sup>)

U is the overall heat transfer co efficient (kW/m<sup>2</sup>. K)

CLTDC is the cooling load temperature difference (oC)

For [1] & [2] see the section of references

## **CHAPTER 3**

### **CALCULATING COOLING LOADS USING CLTD**

Outdoor Design Conditions[2]

ASHRAE Table A 2, F1980, provides the outdoor design conditions for various locations in many countries including India, Malaysia and Singapore. The summer design column lists hourly temperature which is exceeded by 1%, 2.5 % and 5% of all the hours in the year.

Selection of Indoor Conditions[2]

In private homes, the indoor conditions may be chosen by the owner. But in public premissis, various codes and regulations and ordinances dictate the limits of the specific indoor design conditions. For some critical occupancy,

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such as, hospitals, nursing homes, computer rooms, clean rooms, etc.

specific indoor design conditions will usually be established by the regulating authorities or the owners.

### Transmission gains[2]

Heat transfer through the different components of the building envelop occurs primarily the process of conduction and convection and is generally referred to as transmission load. Transmission heat transfer is given by the following equation:

$$Q = U A (T_D)$$

Where,

Q is the heat transfer rate (W)

R<sub>t</sub> is the sum of the individual thermal resistances (m<sup>2</sup>. °C/W)

A is the surface area perpendicular to heat flux (m<sup>2</sup>)

T<sub>D</sub> is the design temperature difference between indoors and outdoors

U = 1/R<sub>t</sub> is the overall heat transfer co efficient (W/m<sup>2</sup>. °C)

With, R<sub>t</sub> = R<sub>1</sub> + R<sub>2</sub> + ¼ + R<sub>m</sub> for resistance in series.

The values of thermal resistances are provided for specific thickness for typical building materials usually designated by U. For materials that vary in thickness according to the application, specific conductivity k is listed in terms of unit thickness. The relation between the two is



$R =$

Where

$k$  is the coefficient of thermal conductivity (W/m. K)

$L$  is the length of the conduction path (m).

CLTD/CLF calculation[2]

To account for the temperature and the solar variations, the concept of cooling load temperature difference (CLTD) is introduced. The CLTD is a steady state representation of the complex heat transfer involving actual temperature difference between indoors and outdoors, mass and solar radiation by the building materials, and the time of day.

The following relation makes corrections in the CLTDs for walls and roofs for deviations in design and solar conditions are as follows:

$$CLTD_c = [(CLTD + LM)k + (25.5 - T_r) + (T_o - 29.4)] f$$

Where

$CLTD_c$  is the corrected value of CLTD.

$LM$  is the colour adjustment for light coloured roof.

$T_r$  is the design room temperature

$T_o$  is average outdoor temperature, computed as the design temperature less half the daily range.

f is attic fan factor

Solar heat gain[2]

When solar rays impinge on a glass surface, some of the radiation is reflected back outside before penetrating the glass. Of that radiation which is not reflected, some is transmitted through the glass and some is absorbed by the glass. The remaining radiation is refracted slightly and goes on to heat the contents of the room. If there is external shading, such as with blinds or drapes or shades, a portion of the radiation entering the room is confined to the area immediately adjacent to the window and has a diminished effect on the conditioning of the room.

All of these effects are accounted for to some degree by the following relation for calculation of cooling loads due to solar radiation:

$$Q_{SHG} = A(SC)(SHGF)(CLF)$$

Where

$Q_{SHG}$  is the solar radiation cooling load (W)

A is the open glass area (m<sup>2</sup>)

SC is the shading coefficient for various types of glasses and shadings

SHGF is the maximum solar heat gain factor for specific orientation of surface, latitude and month (W/m<sup>2</sup>)

CLF is the cooling load factor, dimensionless.

## Internal Loads[2]

Lighting is often is the major space cooling load component. The rate of heat gain at any instant, however, is not the same as the heat equivalent of power supplied instantaneously to these lights. Only part of the energy from lights is transferred to the room air by convection, and thus becomes the cooling load. The remaining portion is the radiant heat that affects the conditioned space only after having been absorbed by walls, floor, furniture, upholstery, etc. and released after a time lag. The cooling load imposed by these sources is given by

$$Q_{\text{appliances}} = P(\text{CLF})$$

Where

$Q_{\text{appliances}}$  is the cooling load due to equipment of appliances (W)

$P$  is the input operating power rating of the appliance or equipment (W)

$\text{CLF}$  is the cooling load factor (dimensionless) depending on operating hours, room construction, and air circulation.

## Occupancy[2]

The people who occupy the building give off thermal energy continuously, the rate of which depend on the level and type of activity in which they are engaged. For the sensible portion of the heat released, a cooling load factor similar the one applied to lights and appliances has been developed to

account for the lag in time between occupancy and the observed cooling load. The sensible cooling load due to people is therefore,

$$Q_S = (N)(GS)(CLFS)$$

Where

$Q_S$  is the sensible cooling load due to occupants (W)

$N$  is the number of occupants

$GS$  is the sensible heat gain depending on activity and time for entry (W)

$CLFS$  is the cooling load factor (dimensionless) for people.

The latent heat gain from occupants is found by

$$Q_L = (N)(GL)$$

Where

$Q_L$  is the latent heat gain

$N$  is the number of occupants

$GL$  is the latent heat gains from occupants depending on activity and time from entry

## **Ventilation/Infiltration[2]**

Heat gain from ventilation and infiltration needs to be considered in the cooling load calculations.

## General Design Guidelines[2]

The general procedure required to calculate the space cooling load is as follows:

**Building configuration and characteristics:** Determine the building location, orientation and external shading, building materials, external surface colour and shape. These details are usually obtained from building plans and specifications.

**Outdoor design conditions:** Obtain the outdoor weather data for the building location and select the outdoor design conditions.

**Indoor design conditions:** Specify temperature, humidity, air velocity, etc.

**Operating schedules:** obtain a schedule of lighting, occupancy, internal equipment, appliances and processes generating heat load.

**Date and time:** Select the time of the day and month to estimate the cooling load. Several different times of the day and several different months need to be analyzed to determine the peak load time. The particular day and month are often dictated by peak solar conditions.

For [2] see the section of references

## **CHAPTER 4**

### **DATA FOR THE MAIN MOSQUE**

Mosque 1st Floor

**Figure 4. 1 First floor**

**Figure 4. 2 Window type 1 (WT1)**

**Figure 4. 3 Window type 2 (WT2)**

**Figure 4. 4 Doors 1 (D1)**

4. 2 Mosque Ground Floor

**Figure 4. 5 Ground floor**

**Figure 4. 6 Window Type 3 (WT3)**

**Figure 4. 7 Window Type 4 (WT4)**

**Figure 4. 8 Door 2 (D2)**

General Information

Latitude 32°E, Longitude 72°E [7]

Main Mosque, College of Electrical and Mechanical Engineering, Rawalpindi,  
Pakistan

Walls

33cm brick, 1.5 cm cement on both sides

Roof

15 cm concrete

Construction

Cream color paint on both sides

Glass

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0. 5cm black shaded

Lighting 1

76 tubes each 18W, 8hrs per day

Lighting 2

4 tubes each 40W, 8hrs per day

Occupancy

300 people moderately active

Ceiling fan

18 ceiling fans each 75 W, 8hrs per day

Bracket fan

9 bracket fans, each 40W, operating 8hrs per day

Ventilation

$7.5 \times 300 = 2200$  liters/sec

Note: Suspended ceiling was broken therefore; we considered it as the refrigerating space.

‘ U’ Value Calculation

**Roof****Components****L/k****m/(W/m. K)****R****W/m<sup>2</sup>. K****Reference Table****Table title**

Outside air

—

0. 044

Table A6

Surface conductance (W/m<sup>2</sup>. °C) and resistance (m<sup>2</sup>. °C/W) for air

Concrete 10cm

0. 15/0. 51

0. 294

[3]

Inner air

—

0. 160



Table A6

Surface conductance (W/m<sup>2</sup>. °C) and resistance (m<sup>2</sup>. °C/W) for air

Total

0. 498

$$U = 1/R = 1/0. 498 = 2. 01$$

**Wall**

**Component**

**L/k**

**m/(W/m. K)**

**R**

**W/m<sup>2</sup>. K**

**Reference Table**

**Table title**

Outer air

—

0. 044

Table A6

Surface conductance (W/m<sup>2</sup>. °C) and resistance (m<sup>2</sup>. °C/W) for air

Brick

0. 33/0. 32

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1. 0315

Table A7

Typical thermal properties of common building and insulating materials

Cement

$2 \times 0.015 / 0.72$

0.0417

Table A7

Typical thermal properties of common building and insulating materials

Inside air film

—

0.120

Table A6

Surface conductance (W/m<sup>2</sup>·°C) and resistance (m<sup>2</sup>·°C/W) for air

Total

1.237

$$U = 1/R = 1/1.237 = 0.808$$

For [3] see references

**Glass****Component****L/k****m/(W/m. K)****R****W/m<sup>2</sup>. K****Reference Table****Table title**

Glass material

0.005/0.05

0.1

Table A7

Typical thermal properties of common building and insulating materials

Outer air

—

0.044

Table A6

Surface conductance (W/m<sup>2</sup>. °C) and resistance (m<sup>2</sup>. °C/W) for air

Inner air

—

0. 12

Table A6

Surface conductance (W/m<sup>2</sup>. °C) and resistance (m<sup>2</sup>. °C/W) for air

Total

0. 264

$$U = 1/R = 1/0.264 = 3.79$$

Description of appliances

## Items

### Ground floor (Qty)

### First Floor (Qty)

Ceiling fans

12

6

Tube lights

76 (small)

4 (large)

Wall fan

9

—

## Area Calculations

### **Eastern Wall Areas**

Wall area

108. 11514 m<sup>2</sup>

Door area

26. 3 m<sup>2</sup>

Windows area

12. 76 m<sup>2</sup>

Actual wall area

69. 055 m<sup>2</sup>

Actual glass area

30. 4 m<sup>2</sup>

Note: The area for aluminum in the windows is not accounted for.

### **4. 6. 2 Western Wall Areas**

Wall area

88. 4816 m<sup>2</sup>

Windows area

6. 583 m<sup>2</sup>

Actual wall area

81. 899 m<sup>2</sup>

Actual glass

6. 003 m<sup>2</sup>

Note: The area for aluminum in the windows is not accounted for.

#### **4. 6. 3 Northern Wall Areas**

Wall area

52. 45 m<sup>2</sup>

Windows area

12. 61 m<sup>2</sup>

Actual wall area

39. 84 m<sup>2</sup>

Actual glass area

11. 62 m<sup>2</sup>

Note: The area for aluminum in the windows is not accounted for.

#### **4. 6. 4 Southern Wall Areas**

Wall area

52. 45 m<sup>2</sup>

Windows area

6. 58 m<sup>2</sup>

Door area

1. 86 m<sup>2</sup>

Actual wall area

44. 01 m<sup>2</sup>

Actual glass area

7. 58 m<sup>2</sup>

Note: The area for aluminum in the windows is not accounted for.

## **4. 6. 5 Roof Areas**

Total roof area

m<sup>2</sup>

### **4. 7 CLTD Correction Calculation**

$$T_o = 47 - 16/2 = 39$$

$T_o$  is the average outside temperature on design day equal to our design temperature minus half of daily temperature range.

**Exposure****CLTD****LM[4]****K[5]****25. 5****Tr****To****29. 4****F[6]****CLTDc**

North

7

0. 5

0. 5

25. 5

25. 5

39

29. 4

1

13. 35

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East

15

0

0.5

25.5

25.5

39

29.4

1

17.1

South

11

-2.2

0.5

25.5

25.5

39

29. 4

1

14

West

11

0

0. 5

25. 5

25. 5

39

29. 4

1

15. 1

Roof

36

1. 1

0. 5

25. 5

25. 5

39

29. 4

1

27. 05

For [4], [5] & [6] see references.

## **CHAPTER 5**

# **COOLING LOAD CALCULATIONS FOR THE MAIN MOSQUE**

## **Building**

Main mosque

## **Location**

EME College, RWP

## **Month**

June Day 22 Time 0200hrs

## **Psychrometric analysis**

**Item**

**Tdb**

**Twb**

**RH**

**Enthalpy (h)**

**Sp. Humidity (w)**

**Outside**

47

41

70%

183. 87

0. 0528

**Inside**

25. 5

17. 82

50%

57. 35

0. 012

**Difference**

21. 5

23. 18

20%

126. 52

0. 041

Daily range = 16

**Transmission Load****Item****Description****Area(m<sup>2</sup>)****U factor****CLTDc (oC)****Q<sub>transmission</sub>(W)****Walls**

North

39. 84

0. 808

13. 35

429. 75

South

44. 01

0. 808

14

497. 8

East

69. 005

0. 808

17. 1

953. 4

West

81. 899

0. 808

15. 1

999. 2

## **Roof**

194. 15

2. 01

27. 05

10556. 03

## **Glass**

North

11. 62

3. 79

20. 1

885. 2

South

7. 58

3. 79

20. 1

577. 44

East

30. 4

3. 79

20. 1

2315. 84

West

6. 008

3. 79

20. 1

457. 3

Total transmission cooling load (W)

17671. 89

## **Solar Radiation**

### **Description**

**Area(m<sup>2</sup>)**

**SC**

**SHGF**

**CLF**

**QSHG**

**North**

0



**South**

7. 58

0. 94

189

0. 36

484. 8

**East**

0

**West**

6. 003

0. 94

695

0. 55

2228. 6

Total solar radiation gain cooling (W)

2713. 4

**Internal loads****Item****Input (W)****CLF****Qappliance****Lights**

1528

0.08

122.2

**Appliances**

1710

1

1710

Total internal gain cooling (W)

1832.24

**Occupancy****Number****SHG/LHG****CLF****Ql****Qs****Sensible**

300

75

0. 49

11025

**Latent**

300

55

1

16500

Total Occupancy gains, Q<sub>occupancy</sub> (W)

27525

**Ventilation/Infiltration****m<sup>3</sup>/s****CFM** **$\hat{I}'' T / \hat{I}'' w$** **Q<sub>I</sub>****Q<sub>s</sub>****Sensible**

2. 2

1. 23

 $\hat{I}'' T = 21. 5$ 

58. 18

**Latent**

2. 2

3010

 $\hat{I}'' w = . 041$ 

7180

Total Infiltration / Ventilation load (W)

7238. 2

## **Grand total cooling loads**

**Ql**

**Qs**

**Total latent load (W)**

23680

**Total sensible load (W)**

33300. 61

**Total load (kW)**

56. 98

**Tons of refrigeration**

16. 3

## **CHAPTER 6**

### **RESULTS AND RECOMMENDATIONS**

#### **Results**

Following the CLTD method we calculated cooling load to be 16. 3 Tons. In which main contribution was from people present in the mosque (almost half the contribution) and heat conduction through walls and windows' glass. The contribution from each mode is shown in fig 6. 1.

Fig 6. 1 Contribution from each mode of heat transfer in cooling load

#### **Recommendations**

Use 6 ACs each of 2. 5 Ton and one of 1. 5 ton, we will need all the ACs

switched ON during Jumma prayers only. On normal days we will switch ON 3

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or 4 ACs depending on the number of occupants. As the number of occupants decreases the required cooling load also decreases. For different values of occupants required cooling load has been calculated and shown in the fig 6. 2.

Fig 6. 2 Relation between number of occupants and cooling load

Normally 30 people are present in the mosque at prayer times so we need only 9. 2 tons of refrigeration. We will switch ON three ACs of 2. 5 tons and one of 1. 5 tons

### **We can minimize the Cooling load by**

Increasing the glass thickness

By using opaque sheets on the outer side of the windows and doors

By using reflecting and insulating material on the roof, reflective material will reduce solar radiation and insulating material will minimize conduction

Growing trees on southern side