Cooling Load Estimation for Library

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Abstract – Objective for calculation of Thermal load (heat gain) of room is done for the selection of right size of air conditioner, in order to achieve optimize energy at required temperature, humidity and proper distribution of air. Heat gain into the room depends on many factors such as orientation of the room, latitudes, size of room, number of person, electrical equipment, materials used in construction of wall and roof, numbers of doors and window and their sizes. Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF) method based on ISHRAE (Indian Society of Heating, Refrigerating, and Air-Conditioning Engineers) Handbook is used for determining heat gain in the room. In this paper load calculation is done for the library. Through the calculation it is obtained that total heat gain in the library is about 165880.977 Btu/hr (48614.91 W).

Index Terms – Cooling load, heating load, Air Conditioning

1. INTRODUCTION

This Delhi lies in plan of north India. Delhi has different types of season. Its climate is greatly affected by the Himalayas and Thar Desert in Rajasthan. In Delhi summer starts from the beginning of the April and continues to the July. During summers the air remains dry and low humidity level. This is due to hot air moving from thar desert to Delhi. With the increasing temperature, there is need of HVAC (heating, ventilation, and air conditioning) systems. Air conditioning maintains, control the room temperature, relative humidity and purifies the air.

The designing of HVAC system started in 19th century. In 1834, Dr. Boswell Reid designed HVAC system for British House of commons [1]. In 1855, Robert Briggs designed and installed, improved HVAC system in U.S. House of Representitatives. In 1884, Frank Kidder launched his book named “Architect’s and Builder’s Handbook” [1]. In 1906, Carrier developed a system which controls the absolute humidity of the air. He patent it and named it “ apparatus for treating air”. Later, after two years in 1908 he published a psychrometric chart [1]. In 1948, James P. Stewart developed a method for calculating heat gain and named it as ETD (Equivalent Temperature Differentials) method. This method was used by experienced engineers only. Later on some other methods such as Total Equivalent Temperature Difference / Time Averaging methods (TETD/TA) were introduced for average engineers. In mid 1950, P.R. Hill, S.G. Reque developed the thermal Response Factor Method (RFM) [1]. In 1951, ASHVE guide book was launched. In 1955, TRANE Air Conditioning Manual (TRANE,1955) guide book was launched. Then in 1960, Carrier Handbook of Air Conditioning System Design was launched. First version of ASHRAE handbook was introduced in 1967[1].

In 1974, William Rudoy and Fernando Duran introduced Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF). This method was introduced to simplify the complexity of TFM and TETD/TA method [2]. In 1993, Solar Cooling Load (SCL) was introduced by Jeffery Spitler et al. SCL method helped in calculating heat gain through fenestration [1]. In 1997, J. Spitler introduced Radiant Time Series (RTS) method. After that many other methods were developed such as Residential Heat Balance (RHB), Residential Load Factor (RLF) method. Computer software were used for the calculation of heat in the building [1].

Nowadays three methods are used in the industry: 1. Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF), 2. Total Equivalent Temperature Difference / Time Averaging method (TETD/TA), 3. Transfer Function Method (TFM) [3]. In this paper cooling/ heating load for the library is calculated and required tonnage capacity for the library is determined.

2. BUILDING LOCATION And SPECIFICATION

In this paper for the calculation of cooling/ heating load library located at Sharda University in Greater Noida, is selected. Sharda University is located at a distance of 42 KM from New Delhi at a Latitude 28.35 ^{0}N. The Dry bulb temperature and Wet bulb temperature is 110 ^{0}F and 75 ^{0}F respectively and average relative humidity for summers is 20

$^0/_0$. All windows have metal frame and window glasses are single pane ordinary glass. There are three different sizes of window. Specification of library has been listed in table 1.

Room size	length (70 ft) × width (30 ft) × Height(12 ft)
Number of doors	3
Door size	7 ft × 3.60 ft
Window 1	3.60 ft × 3.60 ft (number of window = 2)
Window 2	7 ft × 1.5 ft (number of window = 6)
Window 3	7 ft × 7.2 ft (number of window = 6)
Size of Wall bricks	9 inch
Size of plaster on each side	½ inch
Roof is made of concrete	6 inch
Number of computer	10 (150 W each)
Number of lights	10 (40 W each)
Number of people	30

Table 1 Specification of the library

3. HEAT TRANSFER ANALYSIS

In this paper following two types of heat gains are calculated:

1. Effective Room Sensible Heat (ERSH)
2. Effective Room Latent Heat Gain (ERLH)

3.1. Solar heat gain through glass

Solar radiation coming from the sun enters into the room after passing through the window glasses. When these radiations enter into the room they get absorbed by the air and material kept inside the room. There is less heat gain through other sides of the window of the room. Solar radiations heat gain through the window glasses depend on many factors such as orientations of the building, latitudes, month of the year and the time of the day which we have already mentioned. These all values can be found from ISHRAE Handbook. For different directions of window solar heat gain is calculated separately. The heat gain through the glass varies with different conditions such as if glass is colored or the glass is double panel or if the glass is shaded or ventilation blind is used then less heat will enter in the room as compared with the ordinary glass[4]. There is heat gain by window frames as these solar radiations are also falling on them. So, those factors are also considered. If the frame is wooden the then multiplying factor is 1 and for metal frame 1.17.The value of solar heat gain is taken from ISHRAE Handbook 2014,Table 1-T-12[5].

Solar heat gain through glass:

Q = Area × solar heat gain (R) × Multiplying factors for ordinary of glasses (1)

$Q = 365.4 \times 1.17 \times 12 \times 1 = 5130.316$ Btu/hr

3.2. Solar heat gain through roofs and wall

Solar radiation from the sun falls on the walls and roof. As these radiation falls on the roof and walls it get absorbed. This increases the temperature of wall and roof above the ambient temperature. Now due to this there is temperature difference between wall and the room and there is heat transfer from wall to room[4].

Solar heat gain through roofs and wall :

$$Q_{WALL} = U \times A \times EqTD \quad (2)$$

$$R_{TOTAL} = R_{AIR} + R_{PLASTER} + R_{BRICK} + R_{PLASTER} + R_{AIR} \quad (3)$$

$$U = 1/ R_{TOTAL} \quad (4)$$

R_{TOTAL} =Total Thermal Resistance (hr – ft^2 – ^{0}F)/ Btu

R_{AIR} = Thermal Resistance of air (hr– ft^2 – ^{0}F)/ Btu

$R_{PLASTER}$ = Thermal Resistance of plaster (hr – ft^2 – ^{0}F)/ Btu

R_{BRICK} = Thermal Resistance of brick (hr – ft^2 – ^{0}F)/ Btu

A= Wall area (ft^2)

EqTD = corrected equivalent Temperature Difference (^{0}F) (for different types of shading , there is different values of correction factors)

$Q = 474.6 \times 36 \times 0.37$

$= 6321.672$ Btu/hr

The value of R is taken from ISHRAE Handbook 2014,Table 1-T-20[5].

3.3. Heat gain through the glass and partition due to conduction

When the solar radiations enters in our environment it get absorbed by the surroundings. This makes the surrounding warm due to increase in temperature. Now there is temperature difference between surrounding and the room to be conditioned. This type of heat can enter into the conditioned space through the wall, roof and glass.

Heat gain through the glass :

$$Q = U \times A \times \Delta T \quad (5)$$

U = Overall heat transfer coefficient (Btu / (hr – ft^2 – ^0F)

A= area (ft^2)

Δ T = Temperature Difference (^0F)

Q_{GLASS} = 365.4 × 35× 1.13

= 14451.57 Btu/hr

Heat gain through the glass and partition :

The value of U for glass is taken from ISHRAE Handbook 2014,Table 1-T-9 [5]

Q_{WALL} = 0.32 × 32 × 1458.48

= 14934.8352 Btu/hr

3.4. Heat gain through infiltration

Air can enter into room through cracks or through window or through doors. But this heat gain can be ignored as this heat gain is small and it is merged with the heat gain through ventilation. If one interested in calculating heat gain through infiltration it can be calculated as follow. The value of infiltration rate is calculated separately.

Heat gain through infiltration:

For sensible heat

Q = infiltration rate × temperature difference × 1.08 (6)

Q = 521.24 × 35 × 1.08

Q = 19885.641 Btu/hr

For latent heat

Q = infiltration rate × humidity × 0.68 (7)

= 521.24 cfm × 6 gr/lb × 0.68

= 2126.6592 Btu/hr

3.5. Heat gain through by passed air

The bypass air is containing both sensible heat load and latent heat load. This air does not come in contact with the cooling coil. So, it is carrying both sensible and latent heat load. The value of volume of air required by per person is taken from ISHRAE Handbook 2014, Table 1-T-53, public assembly spaces.

Ventilation rate = number of person × volume of air required by per person (8)

Ventilation rate = 30 people × 17 CFM/ person = 510 cfm

The sensible heat due to by pass fresh air = ventilation air × air density × specific heat of air ×by pass factor × temperature difference

The sensible heat due to by pass fresh air = 1.08 ×cfm × BF × Δ T (^0F) (9)

The value of by pass factor is taken from ISHRAE Handbook 2014,Table 1-T-26 [5]

The sensible heat due to by pass fresh air = 510 cfm × 35 ^0F × 0.10 × 1.08 = 1945.65 Btu/hr

The latent heat gain due to by pass fresh air = fresh air quantity × 60 × density of air × latent heat of condensation of water vapour × bypass factor × difference between moisture content at outside and inside conditions.

The latent heat gain due to by pass fresh air = cfm × BF × (w_0-w_1) × 0.68 (10)

Difference between moisture content at outside and inside conditions is calculated from psychrometric chart.

The latent heat gain due to by pass fresh air = 510 cfm × 6 gr/lb × 0.10 × 0.68 = 208.08 Btu/hr

Δ T = Temperature Difference (^0F)

BF = By pass Factor of the cooling coil

w = moisture content (grams of water vapour / kg of dry air)

Air density = 0.075 lb/cft

Specific heat of air = 0.24 Btu/lb

3.6. Heat gain through (1-BF) air

The fresh air which is used as ventilation purpose carries sensible and latent heat as explained above. The by pass air does not come in contact is carrying heat load and it is considered in above section. Now the air which comes in contact which with cooling coil is also carrying sensible heat and latent heat.

Heat gain through (1-BF) air :

$Q_{SENSIBLE}$ = ventilation air (cfm) × CLTD ×1.08 ×(1- by pass factor) (11)

= 510 cfm × 35 ^0F × (1-0.10) × 1.09

= 17510.85 Btu/hr

Q_{LATENT} = ventilation air (cfm) × moisture content (gr/lb) × 0.68 ×(1- by pass factor) (12)

= 510 cfm × 6 gr/lb × (1-0.10) × 0.68

= 1872.72 Btu/hr

3.7. Heat gain from people

Human bodies are also responsible in contributing heat to the conditioning space. Because of metabolism human body generate heat. Human body generate both sensible heat and latent heat. Heat generated by the human body depends on the human activity. If a person is running or dancing will generate more heat as compared to a person sitting. The value of latent heat factor and sensible heat factor is taken from ISHRAE Handbook 2014, Table 1-T-24.

Heat gain from people :

$$Q_{PEOPLE} = \text{Number of people} \times \text{latent heat factor} \tag{13}$$

$$Q_{PEOPLE} = 30 \times 205 = 6150 \text{ Btu/hr}$$

$$Q_{PEOPLE} = \text{Number of people} \times \text{sensible heat factor} \tag{14}$$

$$Q_{PEOPLE} = 30 \times 245 = 7350 \text{ Btu/hr}$$

3.8. Heat gain from light

Light bulbs and tube light are also responsible for heat gain in the room. It depends on the watt of the bulb or time duration of bulb use[4].

Heat gain from light :

$$Q_{\text{Incandescent bulb}} = \text{Total light in watt} \times 3.4 \tag{15}$$

$$Q_{\text{Fluorescent light}} = \text{Total light in watt} \times 1.25 \times 3.4 \tag{16}$$

$$Q_{\text{Fluorescent light}} = 10 \times 40 \times 1.25 \times 3.4$$

$$= 1700 \text{ Btu/hr}$$

3.9. Heat gain from appliances

There are many appliances which gives both sensible heat and latent heat such as while using oven, while cooking food or while drying clothes in dryer.

Heat gain from appliances:

$$Q_{APPLIANCES} = \text{Number of computer} \times \text{watts of each computer} \times \text{efficiency(load factor)} \times 3.4 \tag{17}$$

$$Q_{APPLIANCES} = 10 \times 150 \times 0.9 \times 3.4 = 4590 \text{ Btu/ hr}$$

3.10. Safety factor

For the project calculation 5% safety factor is considered as there can be air leak in ducts etc. Safety factor is calculated for sensible heat and latent heat separately.

4. RESULT

Effective Room Total Heat (ERTH) = Effective Room Latent Heat + Effective Room Sensible Heat = 146497.407 Btu/hr

$$\text{Grand Total Heat (GTH)} = \text{ERTH} + Q_{SENSIBLE} + Q_{LATENT}$$

$$= (146497.407 + 17510.85 + 1872.72) \text{ Btu/hr}$$

$$= 165880.977 \text{ Btu/hr}$$

Since 12000 Btu/hr = 1 TR

So, 165880.977 Btu/hr = 13.82 TR

5. CONCLUSION

There are two different types of heat gain in the library i.e. internal heat gain (lights, fan, people etc) and external heat gain (conduction, convection and radiation). The sensible heat load, latent heat load and total heat gain of the library is 155109.6855 Btu/hr (45458.15 W), 10771.29 Btu/hr (3156.75 W) and 165880.977 Btu/hr (48614.91 W) respectively. So there is requirement of 13.83 TR (or 14 TR) air conditioner is required for Sharda University library which provide comfort cooling for occupancy of 30 people. For 14 TR AC is easily available in the market. In order to maintain uniform temperature in the library it is necessary to fix AC unit in different places.

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