

## **Estimation of Cooling Load for a Computer Laboratory**

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**ABSTRACT:** *The Performance of an air conditioning system is closely related to heat generated inside a particular space which depends on several factors such as position of the room relative to solar orientation, wall material, electric appliances and number of occupants in the room. This paper presents the parameters that are considered in order to determine the heat gain in a computer laboratory. The method of heat gain determination is done by using Cooling Load Temperature Difference/Solar Cooling/Cooling Load Factor (CLTD/SCL/CLF) based on ASHRAE 1997 fundamental handbook. The Room Sensible Heat Factor (RSHF) was calculated to be 0.72 and the total cooling load for the laboratory is 20.608 kW (5.888 Ton).*

**KEYWORDS:** *Temperature, Ventilation, Heat gain, Space cooling load, Heat extraction, Cooling coil load.*

### **I. INTRODUCTION**

Cooling load is the rate at which heat must be removed from the space to maintain a specific space air temperature and moisture content. The parameters affecting cooling load calculations are numerous, for example, the outside air temperature, the humidity ratio, the number and activity of people etc. These parameters are often difficult to precisely define and always intricately interrelated. Many cooling load components vary in magnitude over a wide range during a 24 hour period. These cyclic changes in load components are not often in phase with each other and each must be analysed to establish the maximum cooling load for a building or zone. Moreover, the effect of thermal accumulation is also involved in calculating procedure and therefore various models and assumptions are developed.

This paper provides information for air conditioning design such as load profiles and in the case of an estate, the knowledge of cooling load helps to know the best power system to set up. Many cooling load components vary over a wide range during a 24hr period. Since these cyclic changes in load components are often in phase with each other, each must be analyzed to obtain the resultant maximum cooling load for a building or space. In calculating cooling load there are four related heat flows rate, each of which varies with time. They include; Space heat gain, Space cooling load, Space heat extraction, Cooling coil load. Cooling load can be classified in two ways - sensible heat gain and latent heat gain. Sensible heat gain is the heat added by the air through conduction, convection or radiation. While latent heat gain is the heat contained in water vapour which does not cause a rise in temperature but it's a load on the cooling equipment. Classifications by inside-outside environment are external and internal loads.

External loads include sensible load due to envelope assemblies, transparent/translucent envelopes such as windows, ventilation and infiltration and latent loads due to ventilation and infiltration. While internal loads include sensible load due to lighting, sensible load due to power load motors, sensible and latent load due to people and appliances. Classification by source are heat gain through building skin by conduction as a result of outdoor-indoor temperature difference, solar heat gains (radiation) through glass or other transparent materials, heat conduction through interior partitions, ceilings and floors, internal heat gains generated by occupants, lights and machinery and heat gain from ventilation air and/or infiltrations of outside air.

Hence cooling load has a direct impact on energy efficiency, occupant comfort, indoor air quality and building durability. This work aims at calculating the cooling load of a non-residential building with the objective of identifying outdoor/indoor condition, test house attributes and construction details and numerical modelling of the cooling load

## II. MATERIALS AND METHODS

### Calculation Procedure Using CLTD/SCL/CLF Method

Since the CLTD/SCL/CLF method has been adopted for this work, it is necessary to understand in details, the procedures for calculating the cooling load using this method. The following sections describe in greater details the principles of the CLTD/SCL/CLF method [3].

Space cooling load due to heat gain through exterior Walls

For an exterior sunlit wall or roof under the combined effect of solar radiation and the outdoor-indoor temperature difference, the one-step calculation of space sensible cooling load  $Q_{WS}$ , can be performed as

$$Q_{WS} = UA(CLTD) \quad (1)$$

U= overall heat-transfer coefficient of exterior wall or roof, ( $W/m^2\text{°C}$ )

A= area of exterior wall, roof or window including frame or sash, ( $m^2$ )

CLTD=cooling load temperature difference, ( $\text{°C}$ )

The CLTD values recommended by ASHRAE [D]for calculating the space sensible cooling load through walls of various constructions are tabulated in ASHAE fundamentals handbook. The values tabulated in ASHAE fundamentals handbook were calculated under the following conditions. In other words, these are the conditions under which the listed data can be applied directly without adjustments:

Dark surface

Indoor temperature of  $25.5\text{°C}$

Outdoor maximum temperature of  $35\text{°C}$  with mean temperature of  $29.5\text{°C}$  and daily range of  $11.6\text{°C}$

Solar radiation typical of clear day on 21st day of month

Outside surface film resistance of  $0.059m^2K/W$

The following formula can be used for adjustments when the conditions are different from those mentioned:

Design temperatures:

$$CLTD_{wall\ corrected} = CLTD + (25.5 - TR) + (TM - 29.4) \quad (2)$$

Where

- $t_t = \text{inside temperature}$
- $t_m = \text{mean outdoor temperature}$
- $t_m = \text{maximum outdoor temperature} - (\text{daily range})/2$
- No adjustment recommended for color
- No adjustment recommended for ventilation of air space above a ceiling

Space cooling load due to solar load through Glass

Solar load through glass has two components:

Conductive

Solar Transmission

The absorbed and then conductive portion of the radiation through the windows is treated like the roof and walls where CLTD values for standard glazing are tabulated in ASHAE fundamentals handbook. For solar transmission, the cooling load is calculated by the cooling load SCL factor and shading coefficient (SC) which can also be found in chapter 28 of 1997 ASHRAE fundamental handbook [5].

The cooling load equations for glass are:

$$\text{Conductive } Q_{conductive} = U * A * CLTD_{corrected} \quad (3)$$

$$\text{Solar Transmission } Q_{solar} = A * SC * SCL \quad (4)$$

SC=Shading coefficient

SCL=Solar cooling load factor

Space cooling load due to heat gain through roof

The heat gain through the roof is given by:

$$Q = U * A * CLTD_{corrected} \quad (5)$$

$$CLTD_{corrected} = \{CLTD + (25.5 - t_r) + (t_m - 29.4)\} \quad (6)$$

**Partition, ceilings and floors:** Whenever a conditioned space is adjacent to a space with a different temperature, transfer of heat through the separating physical section must be considered.

$$Q = UA (t_a - t_{ic}) \quad (7)$$

$U$  = Coefficient of overall heat transfer between adjacent and conditioned space in

$A$  = Area of partition in  $m^2$ , ceiling or floor calculated from building plans

$t_a$  = Temperature of adjacent space in  $^{\circ}C$

$t_{ic}$  = Inside design temperature of conditioned space in  $^{\circ}C$  (assumed constant)

**Ventilation and infiltration air load :** Ventilation air is the amount of outdoor air required to make-up for air leaving the space due to equipment exhaust, infiltration and/or as required to maintain Indoor Air Quality for the occupants., ventilation for this building is established at 10L/s from 1997 ASHRAE handbook [4]. The ventilation cooling load is calculated using equation the following equations

$$Q_s = 0.0204V(\Delta t) \quad (8)$$

$$Q_l = 50V(\Delta x) \quad (9)$$

$$Q_{total} = Q_s + Q_l \quad (10)$$

$Q$  = Ventilation from ASHRAE standard 62; infiltration/s

$\Delta t = (t_o - t_r)$  Difference in outside and inside air temperature  $^{\circ}C$

$\Delta x = (x_o - x_r)$  difference in outside and inside air humidity ratio,  $kg \frac{water}{kg}$  (dry air)

**Internal cooling load from occupants (people) :** Latent heat gains are considered instantaneous cooling loads. The total sensible heat gain from people is not converted directly to cooling load. The radiant portion is first absorbed by the surroundings (floor, ceiling, partitions, and furniture) then converted to the space at a later time, depending on the thermal characteristics of the room. The radiant portion of the sensible heat gain from people varies widely depending on the circumstances. The instantaneous sensible cooling load is thus:

$$Q_s = N(SHG_p)(CLF_p) \quad (11)$$

The latent cooling load is:

$$Q_l = N(LHG_p) \quad (12)$$

$Q_s$  = sensible cooling load due to people

$N$  = number of people

$SHG_p$  = sensible heat gain per person

$CLF_p$  = cooling load factor for people

$Q_l$  = latent cooling load due to people

$LHG_p$  = latent heat gain per person

**Internal cooling load from lighting:** The primary source of heat from lighting comes from light-emitting elements, or lamps, although significant additional heat may be generated from associated appurtenances in the light fixtures that house such lamps. At any time, the space cooling load from lighting can be estimated as:

$$Q_{el} = HG_{el}(CLF_{el}) \quad (13)$$

$Q_{el}$  = cooling load from lighting,  $W$

$$HG_{el} = \text{heat gain from lighting, } W, \text{ as } WF_{ul}F_{sa} \quad (14)$$

$W$  = total lamp watts

$F_{ul}$  = lighting usem factor

$F_{sa}$  = lighting special allowance factor

$CLF_{el}$  = lighting cooling load factor

The special allowance is the ratio of the wattage in use for the conditions under which the load estimate is being made, to the total installed wattage. For the purpose of this work the light usage factor will be assumed to be 1 (ASHRAE, 1997).

( $F_u$ ). Thus the sensible heat gain  $Q_{sensible}$

**Internal cooling load from equipment and appliances :**The average rate of appliance energy consumption can be estimated from the name plate or rated energy input  $Q_{input}$  by applying a duty cycle or usage factor ( $F_u$ ). Thus the sensible heat gain  $Q_{sensible}$  for generic types of electric, steam and gas appliances installed under a hood can be estimated using the following equation from ASHRAE fundamental Handbook.

$$Q_{sensible} = Q_{input} F_u F_R \quad (15)$$

Or

$$Q_{sensible} = Q_{input} F_L \quad (16)$$

$F_L =$  defined as the ratio of sensible heat gain to the manufacturers rated energy input

$F_u =$  is the usage factor

$F_R =$  radiation factor

**Design specification :**The following specifications and assumptions were considered in order to effectively and easily calculate the cooling load for the building under consideration.

Wall; the walls (6m by 3.6m) are made of 200mm Light Coloured Heavy. Concrete Block, 16mm plaster on walls  $U = 2.73W/m^2.K$ , wall number 10 as stated in 1997 ASHRAE fundamental handbook table 32.

Roof construction; the building is made of flat roof  $36m^2$ , roof number 10 as stated in 1997 ASHRAE fundamental handbook table 30 ( $U = 4.6W/m^2.K$ ).

Windows construction; the windows (1.8m by 1.2m) are made of glass with ( $U=4.6 W/m^2.K$ ) and also of the zone C conditions as stated in 1997 ASHRAE fundamental handbook table 35B and 36.

Door construction; the door (2.1m by 1.2m) is made of wall number 2 as stated in 1997 ASHRAE fundamental handbook table 32 ( $U = 1.08W/m^2.K$ ).

Outdoor design conditions; the dry-bulb temperature is  $35^\circ C$  and  $25^\circ C$  wet-bulb with daily range of  $11^\circ C$ .

Indoor design conditions; the indoor dry-bulb temperature is  $24^\circ C$  with 50% relative humidity.

Lights; the office is considered to have 3 fluorescent bulb of 200watts kept on for 8hours with a use factor of 1 and special allowance factor of 1.25 and zone type C as stated in ASHRAE fundamental handbook table 35B and 38.

Occupancy; the laboratory is meant for 20 occupants and zone type C as stated in 1997 ASHRAE fundamental handbook table 35B and 37.

Appliances; the basic appliances are 20 computers, 1 printer, 1 stabilizer and computer desks and chairs as well as curtains.

Ventilation; 10L/s per person

**Roof cooling load :**The roof cooling was calculated using equations 3.5 and 3.6 with the aid of Microsoft excel at every hour of the day from 800hrs to 1600hrs. The indoor and outdoor correction factors for fenestrations were calculated as follow;

$$T_{max} = \text{Maximum outdoor temperature} = 35^\circ C$$

$$T_m = T_{max} - \frac{\text{daily Range}}{2} = 35 - \frac{35 - 24}{2} = 29.5^\circ C$$

Indoor design temperature correction =  $(25.5 - TR) = 25.5 - 24 = 1.5^\circ C$

Outdoor design temperature correction =  $(TM - 29.4) = 29.5 - 29.4 = 0.1^\circ C$

Therefore, the  $CLTD_{corrected}$  ;

$$CLTD_{corrected} = CLTD + (25.5 - TR) + (TM - 29.4) = CLTD + 1.5 + 0.1$$

$$CLTD_{corrected} = CLTD + 1.6 \quad (17)$$

The CLTD for the roof was read from table 30 in 1997 ASHRAE fundamental handbook ( $U=4.6W/m^2.K$ ) at roof number 10.

**Wall cooling load calculations:** The wall cooling load was also calculated at every hour of the day from 0800hrs to 1600hrs using Microsoft Excel. Equations 1 and 14 were used to calculate the wall cooling load and the  $CLTD_{corrected}$ . The values of the CLTD were obtained from table 32 in 1997 ASHRAE fundamental handbook with wall number 10 ( $U = 2.73W/m^2.K$ ).

The north wall area =  $6 \times 3.6 - (1.8 \times 1.2 \times 2) = 17.28m^2$

The east wall area =  $6 \times 3.6 - (1.8 \times 1.22) = 17.28m^2$

The west wall area =  $6 \times 3.6 - (2.1 \times 1.2 \times 2) = 16.56m^2$

The south wall area =  $6 \times 3.6 = 21.6m^2$

**Door cooling load calculations :**The door cooling load was calculated using equations 1 and 14. Microsoft Excel spread sheet was used to calculate the cooling load at every hour of the day between 0800hrs to 1600hrs. The values of CLTD were read from table 32 in 1997 ASHRAE fundamental handbook.

The area of the doors =  $2.1 \times 1.2 = 2.52m^2$

**Window cooling load calculations (Radiation and Conduction)**

The window cooling load with radiation and conduction load were also calculated using Microsoft Excel for conduction and radiation using equations 4 and 5 for conduction and radiation respectively. The values of CLTD and SCL were read from tables 34 and 36 respectively at zone type C ( $U = 4.6W/m^2.K$ ). The shading coefficient was considered to be 0.82.

The area of each windows =  $1.8 \times 1.2 = 2.16m^2$

Occupants cooling load calculations (latent and sensible)

The cooling load of the occupants was calculated using 75W per person, sensible heat gains, and 55W per person, latent heat gains from tables 3 and 37 in 1997 ASHRAE fundamental handbook.

**Light cooling load calculations**

The space was considered to have 3 fluorescent bulb of 200watt each. The cooling load of the light was calculated using tables 35B and 38 zone type 2 in 1997 ASHRAE fundamental handbook.

**Appliance cooling load calculations**

The appliance cooling load was estimated from table 9A in 1997 ASHRAE handbook. It was estimated to be 135W per computer and 292W for the printer, therefore for a total of 20 computers and one printer the heat gain is 2992W and is considered constant from 0800hrs to 1600hrs.

Ventilation cooling load calculations

Ventilation for this building is established at  $12m^3/min$  from 1997 ASHRAE handbook.

Supply cooling load calculations

$$0.2M_s h_0 + 0.8M_s h_r = M_s h_m \tag{18}$$

$$h_s = h_r - RTH/M_s \tag{19}$$

$$M_s = M_0 / (0.2 \times 60) \tag{20}$$

$M_s$  = mass flow rate of supply air (kg/s)

$M_0$  = Mass flow rate of outdoor air (kg/s)

$h_0$  = outdoor air enthalpy (kJ/kg Dry Air)

$h_r$  = indoor air enthalpy (kJ/kg Dry Air)

$h_m$  = mixing point enthalpy (kJ/kg Dry Air)

**Ventilation cooling load :** Using equation 8, 9 and 10 and reading off the values of  $X_0$  and  $X_r$  at point O and R on the psychometric chart in Fig.1

$$Q_s = 0.0204 \times 12(35 - 24) = 2.69KW = 2692W$$

$$Q_l = 50 \times 12(0.016 - 0.0092) = 4.08KW = 4080W$$

$$Q_{v_{total}} = 2692 + 4080 = 6772W$$

Total cooling load =  $12336 + 4080 + 2692 + 1500 = 20608W$

Total sensible load +  $12336 + 2692 = 15028W$

$$\text{Room Sensible Heat Factor (RSHF)} = \frac{SH}{RTH} = \frac{15028}{20608} = 0.72$$

**Supply condition calculation:** Point O and R were located using outdoor and indoor conditions, using equation 18 to get the mixing point M and drawing a line through RSHF to point A (alignment point). A parallel line was drawn through point R, using equation 19 and 20 to get  $h_s$ , also a line was drawn from  $h_s$  to meet the parallel line at point S.

$$0.2M_s h_0 + 0.8M_s h_r = M_s h_m$$

$$0.2 \times 76.5 + 0.8 \times 48 = 53.7 \text{ kJ/kg Dry Air.}$$

$$h_s = h_r - \frac{RTH}{M_s}$$

$$h_s = 48 \text{ kJ/kg} - (20.608 \text{ kJ/s} / 1 \text{ kg/s})$$

$$= 27.39 \text{ kJ/s.}$$

The value of  $t_s$  which is  $10^\circ C$  is read from the psychometric chart at point S.

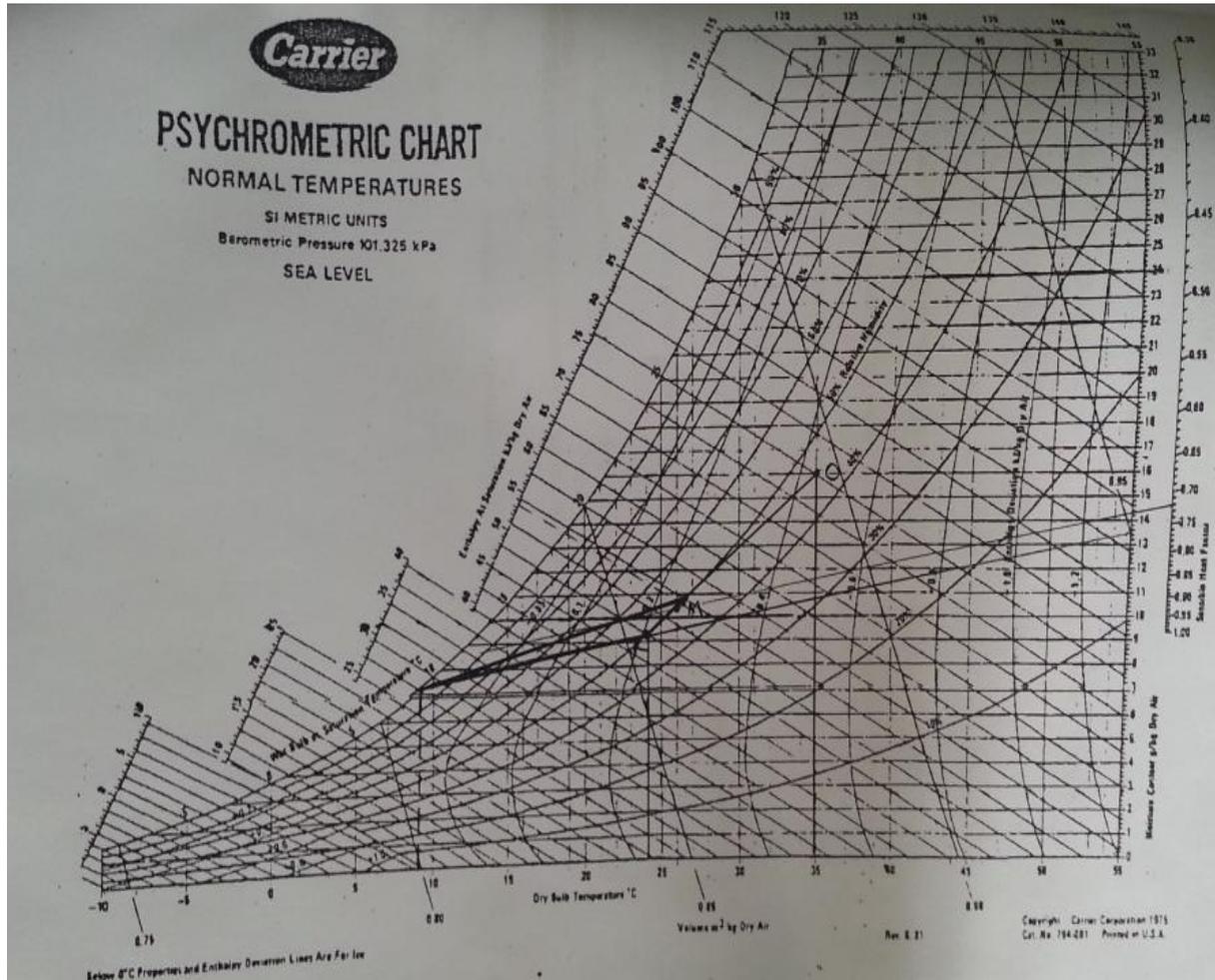


Fig. 1: Psychrometric Chart (RSES, 2009)

### III. RESULTS AND DISCUSSION

Table 1 below shows the total cooling load from all sources of heat in the laboratory except heat gain from ventilation. The graph in Fig. 2 shows the peak load at 1600hrs.

Table 1: Total cooling load results

Time	Appliances	Roof	Wall	Glass	Door	Glass	People	Light	Total
0800hr	2992	1258.5	1327.9	15.8	19.6	960	1500	0	7553.58
0900hr	2992	1092.9	1316.1	25.8	30.4	960	2171	540	7947.90
1000hr	2992	1258.5	1318.1	35.7	35.9	861	2259	600	7997.91
1100hr	2992	1424.1	1518.6	55.6	41.3	680	2325	630	8063.44
1200hr	2992	1755.3	1719.1	65.5	52.2	530	2369	652.5	8358.86
1300hr	2992	2417.7	1931.3	85.4	63.1	506	2413	660	9226.01
1400hr	2992	3080.1	2188.8	85.4	74.0	480	2446	667.5	10122.0
1500hr	2992	3742.5	2505.3	95.3	79.4	441	2479	675	11051.3
1600hr	2992	4239.3	2760.8	95.3	84.9	400	2501	682.5	11740.5

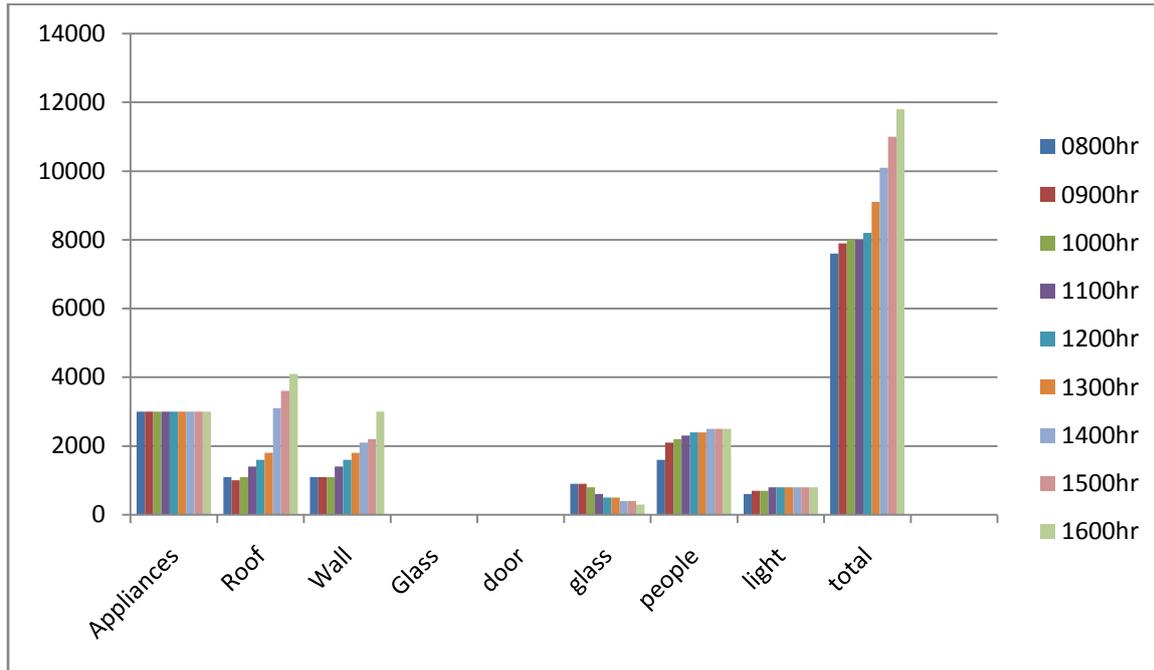


Fig.2. Profile of cooling load from 0800hrs – 1600hrs.

#### IV. CONCLUSION

The concept of cooling load for a given building must be kept in perspective. Variation in the heat transmission coefficients of typical building materials, composite assemblies, the differences in motivations, skills of those who physically construct the building and the manner in which the building actually operates are some of the variables that make a numerically precise calculation impossible. The design engineer must use reasonable procedures to account for these factors, the calculation can never be more than a good estimate of the actual cooling load, but not withstanding it is very necessary to estimate cooling of a building so that there will be energy savings and cost reduction. The total cooling load for the laboratory is 20.608kW(5.888 Ton). Therefore an air condition of approximately 6 Ton capacity will be suitable for the laboratory.

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