Heating Ventilation and Air Conditioning

MECH 6181

Project on

Cooling Load Calculation for an Office Space

Submitted To

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Submitted by-

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TABLE OF CONTENTS

INTRODUCTION

Heating Ventilating and Air Conditioning (HVAC) plays a vital role in houses, most offices and commercial facilities to get a comfortable life without year-round control of the indoor environment. This is necessary for both a healthier and comfortable life and to produce better, faster and economically good products in a controlled environment. Nowadays, if we do not control proper temperature and humidity, we will not get our desired product in different commercial organizations. Historically, air conditioning indicated cooling and humidity control for developing the inside environment during the summer of the year. In the modern era, this term refers to year-round heating, cooling, humidity control and ventilating required for desired indoor conditions. Now, HVAC system modification and replacement are increasing rapidly for global environmental impact and economic condition.

It is crucial to design the HVAC system in building construction to be properly operated throughout the lifespan of the building. On the other hand, cooling load calculations may be used to accomplish one or more of the objectives: providing information for equipment selection, system sizing and system design, introducing data for evaluating the optimum possibilities for load reduction and permitting analysis of partial loads as required for system design, operation and control. In addition, two systems of units can be used to calculate this design system: British System and SI unit. Our calculation has been done by the British System. Again, the cost of running an HVAC system is often the biggest part of the utility bills for a building. Compressor, fan, boilers, furnaces and pumps account for that cost. In general, the highest cost usually occurs in July in the north part of the world because of the high-intensity sunlight. Besides, the ability to analyze the HVAC system largely depends on every design situation and psychrometric chart deals with the properties of moist air.

Moreover, common contaminants in the HVAC system may create serious problems in the human body and all mammal. Incomplete combustion of hydrocarbons and tobacco smoking are two significant sources of highly toxic carbon monoxide (CO). Sulfur oxide and nitrogen oxide enter into the conditioned space from the outside air. Radon, Volatile Organic Compound and mycotoxins are the serious and difficult cases of indoor air quality. However, solar radiation has an important effect on both the heat gain and the heat loss of a building. These effects mainly depend on the location of the sun in the sky, atmospheric clearness and building orientation. The estimation of heating loads is usually based on steady-state heat transfer. There might be a difference between the heat gain of the building and heat removed by the cooling equipment at a particular time. This difference is caused by the storage and subsequent energy transfer from the structure and circulated air. If not, the cooling and dehumidifying equipment will be oversized. It is not reasonable to design for the worst condition on the record because it will result in larger load capacity.

PROBLEM SPECIFICATIONS

Assumptions:

Location: Montreal (Latitude: 48^{o}N)

Month: July 21

Type of Building: Office

Floor Area: 88 ft* 96 ft = 8448ft^2

Floor to floor height: 15 ft

Floor: The floor just below of our designed floor is air conditioned at 72^{o}F db and relative humidity: 50%

Roof: Steel sheet with suspended ceiling and 25.4 mm insulation

Window size: 6 ft* 8 ft (i.e. 20% of the wall area)

Window type: Double glaze 0.25 inches air space (Table 5-5a Page- 144)

Wall - Outer surface air (7.5 mph) (emissivity= 0.9),

brick (density=120 lb/ft^3),

concrete block, normal weight aggregate 8 inches,

air gap (0.5-inch air space),

Gypsum or plasterboard thickness= 0.375 inch,

Inside surface: still air (Vertical horizontal)

Wall Type: Group A

Same construction material for both external and internal walls

Conduction of wall is equal to conduction of door

Window: (Aluminum with thermal break) U= 0.65 Btu/ft^{2}hrF (Table 5-5a, page-144)

Recommended ventilation: Number of air change per hour=1

Working hours: 8 hours of working from 10:00 am to 6:00 pm (Lights are ON for 8 hours)

Ordinary furniture, no carpet (0.55), 2-inch wood floor, Medium (A)

Inside design temperature:72^{O}F db and relative humidity: 50% comfort zone (Figure:4.18, page-90)

Outside Temperature:95^{O}F db and Relative humidity= 60 %

Outside Wind Velocity: 7.5 mph

No supply and exhaust fan have been considered.

TERMINOLOGY USED

R1 to R17 are 17 rooms (each room 16ft*16ft)

C1 and C2 are 2 cafeterias (each 16ft*16ft)

W1 to W4 are 4 washrooms (each 8ft*16ft)

P1 and P2 are 2 photocopy room (each 8ft*16ft)

Reception Area (16ft*16ft)

Conference Room (16ft*32ft)

SAMPLE COOLING LOAD CALCULATION AT 12:00 PM (IN BRITISH UNIT)

1. ROOF

Room:

Overall heat transfer coefficient for Steel sheet with suspended ceiling and 25.4 mm insulation,

U= 0.761 W/m^{2}C=0.134 Btu/hrft^{2}F, (Table 5: with suspended ceiling Roof no: 1)

Area of roof for one room, A= 16*16 ft^2=256 ft

CLTD=35* 1.8=63

CLTD$_c$= [(CLTD+LM) *K+(78-T_r)+ (T_o-85)] *f

LM = latitude-month correction from table 9 for a horizontal surface=0, (Table 3.12, for July)

K=1, (for dark colored)

T_r= inside design temperature=72^0F

T_o= outside temperature=95^0F

f= 0.75 for positive ventilation

$CLTD_c$= [(63+0) *1+(78-72) +(95-85)] *0.75= (63+6+10) *0.75= (63+16) *0.75=59.25

$\boldsymbol{q_{s1}}$= U*A*$CLTD_c$=0.134*256*59.25=2032.51 Btu/hr

There are 17 rooms in our design. So, total sensible heat transfer of roof for 17 roofs will be,

$\boldsymbol{q_{s17}}$=2032.51*17=34552.70 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q (Btu/hr)	No. of Rooms	Q_T(Btu/hr)
12	63.00	59.25	2,032.51	17.00	34,552.70
14	77.40	70.05	2,403.00	17.00	40,850.92
16	73.80	67.35	2,310.37	17.00	39,276.36

Cafeteria:

For 1 cafeteria,

A= 16 ft *16 ft =256ft^2

$\boldsymbol{q_{s1}}$= U*A*$CLTD_c$= 0.134 * 256 * 59.25= 2032.51 Btu/hr

For 2 cafeterias,

q_{s2}=2032.51* 2 = 4065.02 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q(Btu/hr)	No. of Cafe	Q_T(Btu/hr)
12	63.00	59.25	2,032.51	2.00	4,065.02
14	77.40	70.05	2,403.00	2.00	4,805.99
16	73.80	67.35	2,310.37	2.00	4,620.75

Reception:

A= 16 ft *16 ft= 256ft^2

q_{s1}=U*A*$CLTD_c$= 0.134 * 256 * 59.25 = 2032.51 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q (Btu/hr)	No. of Reception	Q_T(Btu/hr)
12	63.00	59.25	2,032.51	1.00	2,032.51
14	77.40	70.05	2,403.00	1.00	2,403.00
16	73.80	67.35	2,310.37	1.00	2,310.37

Photocopy

A= 16*8ft^2=128 ft^2

q_{s1}=U *A*$CLTD_c$= 0.134 * 128 * 59.25 = 1016.26 Btu/hr

For 2 photocopy area,

q_{s2}= 1016.26 * 2= 2032.51 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q (Btu/hr)	No. of Photocopy Area	Q_T(Btu/hr)
12	63.00	59.25	1,016.26	2.00	2,032.51
14	77.40	70.05	1,201.50	2.00	2,403.00
16	73.80	67.35	1,155.19	2.00	2,310.37

Conference Room

A= 16 ft *32 ft=512ft^2

q_{s1}=U*A*$CLTD_c$= 0.134 * 512 * 59.25= 4065.02 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q(Btu/hr)	No. of Conference Hall	Q_T(Btu/hr)
12	63.00	59.25	4,065.02	1.00	4,065.02
14	77.40	70.05	4,805.99	1.00	4,805.99
16	73.80	67.35	4,620.75	1.00	4,620.75

Total Heat gain of Roof (Btu/Hr)

Time of Day	Q_T(Btu/hr)
12	46,747.78
14	55,268.89
16	53,138.61

2. EXTERNAL WALL

	Item	Resistance(R) (hr-ft^2F/Btu)
1.	Outer surface of wall (Moving air, Wind 7.5mph	0.25 (Table 5-2a, Page-131)
2.	Brick, density=120 lbm/ft^3 Assuming thickness Δx =4 inch Δx/6.2=0.645	0.645, Table 5-1a, page-124
3.	Concrete blocks, normal weight aggregate 8 inch (1/0.95=1.05)	1.05 (Table5-1a, page-124)
4.	Air gap (0.5 inch),Orientation: Vertical-horizontal,	0.90 (Table 5-3a, page: 133)
5.	Gypsum or plaster board, thickness=0.375 inch	0.322 (Table 5-1a, page 122

	(1/3.10=0.322)	
6.	Inside surface, still air, vertical-horizontal emissivity=0.9	0.68 (Table 5-2a, page: 131)
	Total	R= 3.847

Overall heat transfer coefficient for wall construction, U=1/R=1/3.847= 0.26 Btu/hrft^2F

a) North wall

Room:

A= 16 ft *15 ft* 0.8 =240ft^2

CLTD=10, (table 3.10, north facing wall)

$CLTD_c$= (CLTD+LM)*K+(78-T_r)+ (T_o-85)

LM = latitude-month correction from table 9 for a horizontal surface=0, (Table 3.12, for July)

K=1, (for dark colored)

T_r= inside design temperature=72^o

T_o= outside temperature=95^oF

$CLTD_c$= (10+ 0) * 1 + (78-72) + (95-85)= (10+6+10) = 26

As actual wall area is 80 % of whole area of wall,

Therefore, A_{wall} = (240* 0.8) ft^2

q_{s1}=U*A*$CLTD_c$= 0.26* (240* 0.8)* 26 = 1297.92 Btu/hr

3 walls for 3 rooms in north direction

q_{s3}= 1297.92 * 3= 3893.76 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q(Btu/hr)	No. of Walls	Q_T(Btu/hr)
12	10.00	26.00	1,297.92	3.00	3,893.76
14	10.00	26.00	1,297.92	3.00	3,893.76
16	10.00	26.00	1,297.92	3.00	3,893.76

Cafeteria

q_{s1}=U*A*$CLTD_c$=0.26* (240* 0.8)* 26= 1297.92 Btu/hr

Time of Day	CLTD	CLTDc	Q(Btu/hr)	No. of Walls	Q_T(Btu/hr)
12	10.00	26.00	1,297.92	1.00	1,297.92
14	10.00	26.00	1,297.92	1.00	1,297.92
16	10.00	26.00	1,297.92	1.00	1,297.92

Photocopy area

A= 15 ft * 8 ft =120ft^2

q_{s1}=U*A*CLTD$_c$=0.26* (120*0.8)* 26= 648.96 Btu/hr

Time of Day	CLTD	CLTDc	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	10.00	26.00	648.96	1.00	648.96
14	10.00	26.00	648.96	1.00	648.96
16	10.00	26.00	648.96	1.00	648.96

b) West wall

A= 16 ft * 15 ft * 0.8=192 ft^2

CLTD =19, (Table 3.10, north facing wall)

CLTD$_c$= (CLTD+LM)*K + (78-T_r) + (T_o-85)

LM = latitude-month correction from table 9 for a horizontal surface = 1, (Table 3.12, for July)

K=1, (for dark colored)

T_r= inside design temperature=72^0

T_o= outside temperature=95^0F

CLTD$_c$=(19+1)*1 + (78-72)+ (95-85)= (20+6+10) = 36

q_{s1}=U*A*CLTD$_c$= 0.26*(240*0.8)*36 =1797.12 Btu/hr

6 walls for 6 rooms to west direction

q_{s6}=1797.12 * 6= 10,782.72 Btu/hr

Time of Day	CLTD	CLTDc	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	19.00	36.00	1,797.12	6.00	10,782.72
14	18.00	35.00	1,747.20	6.00	10,483.20
16	18.00	35.00	1,747.20	6.00	10,483.20

c) South Wall

Room

A= 16*15*0.8=192 ft^2

CLTD=14, (table 3.10, north facing wall)

$CLTD_c$= (CLTD+LM)*K+ (78-T_r)+ (T_o-85)

LM = latitude-month correction from table 9 for a horizontal surface = 4, (Table 3.12, for July)

K=1, (for dark colored)

T_r= inside design temperature=72^0F

T_o= outside temperature=95^0F

$CLTD_c$=(14+4)*1 + (78-72) + (95-85)= (18+6+10)= 34

q_{s1}=U* A*$CLTD_c$= 0.26* 192* 34= 1697.28 Btu/hr

3 walls for 3 rooms in the south direction

q_{s3}=1697.28 * 3= 5091.84 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	14.00	34.00	1,697.28	3.00	5,091.84
14	14.00	34.00	1,697.28	3.00	5,091.84
16	15.00	35.00	1,747.20	3.00	5,241.60

Cafeteria

q_{s1}= U* A*$CLTD_c$= 0.26* (240*0.8)* 34= 1697.28 Btu/hr

Time of Day	CLTD	$CLTD_c$	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	14.00	34.00	1,697.28	1.00	1,697.28
14	14.00	34.00	1,697.28	1.00	1,697.28
16	15.00	35.00	1,747.20	1.00	1,747.20

Photocopy Area

A= 15* 8ft^2=120ft^2

q_{s1}=U* A*$CLTD_c$=0.26 * (120*0.8) * 34=848.64 Btu/hr

Time of Day	CLTD	CLTD$_c$	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	14.00	34.00	848.64	1.00	848.64
14	14.00	34.00	848.64	1.00	848.64
16	15.00	35.00	873.60	1.00	873.60

d) East wall

Room

A= 16 ft * 15 ft* 0.8 =192 ft^2

CLTD= 19 (table 3.10, north facing wall)

CLTD$_c$= (CLTD + LM) * K + (78-T_r) + (T_o-85)

LM = latitude-month correction from table 9 for a horizontal surface=1, (Table 3.12, for July)

K=1 (for dark colored)

T_r= inside design temperature=72^{o}F

T_o= outside temperature=95^{o}F

CLTD$_c$= (19+1) * 1+ (78-72) + (95-85) = (20+6+10) = 36

q_{s1}=U*A*CLTD$_c$=0.26 * 192* 36=1797.12 Btu/hr

4 walls for 4 rooms to west direction

q_{s4}= 1797.12* 4= 7188.48 Btu/hr

Time of Day	CLTD	CLTD$_c$	Q(Btu/hr)	No. of Walls	Q_T(Btu/hr)
12	19.00	36.00	1,797.12	4.00	7,188.48
14	21.00	38.00	1,896.96	4.00	7,587.84
16	23.00	40.00	1,996.80	4.00	7,987.20

Conference

A= 0.8*32*15ft^2=384ft^2

q_{s1}=U*A*CLTD$_c$=0.26* 384* 36= 3594.24 Btu/hr

Time of Day	CLTD	CLTD$_c$	Q(Btu/hr)	No. of Walls	Q_T(Btu/hr)
12	19.00	36.00	3,594.24	1.00	3,594.24
14	21.00	38.00	3,793.92	1.00	3,793.92
16	23.00	40.00	3,993.60	1.00	3,993.60

Total Heat gain of Wall in (Btu/Hr)

Time of Day	Q_T(Btu/hr)
12	35,043.84
14	35,343.36
16	36,167.04

3. WINDOW:

Conduction:

Room

A= 8 ft *6 ft =48 ft^2

U= 0.55 Btu/hrft^2F, Double glazing, ¼ inch air space, centre of glass, Table-5-5a, page: 144

$\boldsymbol{T_0}$= Outside Air Temperature

T_i= Inside Air Temperature

q_{s1}=U *A* (T_0-T_i)= 0.55* 48* (95-72)= 607.2 Btu/hr

For 17 rooms,

q_{s17}= 607.2* 17= 10,322.4 Btu/hr

Time of Day	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Window	Q_T(Btu/hr)
12	72.00	95.00	607.20	17.00	10,322.40
14	72.00	95.00	607.20	17.00	10,322.40
16	72.00	95.00	607.20	17.00	10,322.40

Cafeteria

A= 6* 8 ft = 48 ft^2

q_s=U*A*(T_0-T_i)=0.55 * 48*(95-72)= 607.2 Btu/hr

For 2 Cafeteria,

q_{s2}= 607.2* 2=1214.40 Btu/hr

Time of Day	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q (Btu/hr)	No. of Window	Q_T(Btu/hr)
12	72.00	95.00	607.20	2.00	1,214.40
14	72.00	95.00	607.20	2.00	1,214.40
16	72.00	95.00	607.20	2.00	1,214.40

<u>Photocopy area</u>

Window area, A= 4*6=24ft^2

q_{s2}=U*A*(T_0-T_i)= 0.55*2 * 24* (95-72) = 607.2 Btu/hr

Time of Day	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Window	Q_T(Btu/hr)
12	72.00	95.00	303.60	2.00	607.20
14	72.00	95.00	303.60	2.00	607.20
16	72.00	95.00	303.60	2.00	607.20

<u>Conference Room</u>

q_{s2}=U*A* (T_0-T_i)= 0.55* 48* 2* (95-72) =1214.4 Btu/hr

Time of Day	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	72.00	95.00	607.20	2.00	1,214.40
14	72.00	95.00	607.20	2.00	1,214.40
16	72.00	95.00	607.20	2.00	1,214.40

Solar heat transfer for windows:

1. **North Window**

Room

q_s=A* SC * SHGF* CLF

A=48 ft^2

SC=0.71, open weave (I), light color (M), insulating glass ¼ inch air space Table: 22

SHGF=37, 48^0 latitude Table:3.25

CLF= 0.89, with interior shedding, Table: 14

q_s=A* SC* SHGF* CLF= 48* 0.71* 37* 0.89 = 1122.25 Btu/hr

For 3 rooms,

q_{s3}=1122.25*3= 3,366.75 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.89	37.00	0.71	1,122.25	3.00	3,366.76
14	0.86	37.00	0.71	1,084.43	3.00	3,253.28
16	0.75	37.00	0.71	945.72	3.00	2,837.16

Cafeteria

For 1 window,

q_{s1}= A* SC* SHGF* CLF= 48* 0.71* 37* 0.89= 1122.25 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.89	37.00	0.71	1,122.25	1.00	1,122.25
14	0.86	37.00	0.71	1,084.43	1.00	1,084.43
16	0.75	37.00	0.71	945.72	1.00	945.72

<u>Photocopy Area</u>

A=24ft^2

q_{s1}=A* SC* SHGF* CLF= 24* 0.71* 37* 0.89= 561.13 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.89	37.00	0.71	561.13	1.00	561.13
14	0.86	37.00	0.71	542.21	1.00	542.21
16	0.75	37.00	0.71	472.86	1.00	472.86

b) West Windows

<u>Room:</u>

q_{s1}=A* SC* SHGF* CLF= 48* 0.71* 214* 0.17= 1239.83 Btu/hr

For 6 windows

q_{s6}= 1239.83* 6= 7438.98 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.17	214.00	0.71	1,239.83	6.00	7,438.98
14	0.53	214.00	0.71	3,865.35	6.00	23,192.12
16	0.82	214.00	0.71	5,980.36	6.00	35,882.15

c) South Windows

<u>Room</u>

q_{s1}=A* SC* SHGF* CLF = 48 *0.71* 146* 0.83= 4129.81 Btu/hr

3 windows for 3 rooms,

q_{s3}= 4129.81* 3= 12389.44 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.83	146.00	0.71	4,129.81	3.00	12,389.44
14	0.68	146.00	0.71	3,383.46	3.00	10,150.39
16	0.35	146.00	0.71	1,741.49	3.00	5,224.46

<u>Cafeteria</u>

q_{s1}=A* SC* SHGF* CLF = 48 *0.71* 146* 0.83= 4129.81 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.83	146.00	0.71	4,129.81	1.00	4,129.81
14	0.68	146.00	0.71	3,383.46	1.00	3,383.46
16	0.35	146.00	0.71	1,741.49	1.00	1,741.49

<u>Photocopy</u>

A=24ft^2

q_{s1}=A* SC* SHGF* CLF= 24* 0.71* 146* 0.83 = 2,064.91 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.83	146.00	0.71	2,064.91	1.00	2,064.91
14	0.68	146.00	0.71	1,691.73	1.00	1,691.73
16	0.35	146.00	0.71	870.74	1.00	870.74

d) East windows

<u>Room:</u>

q_{s1}=A*SC*SHGF*CLF=48*0.71*214*0.27=1,969.14 Btu/hr

4 windows for 4 rooms

q_{s4}=1969.14* 4=7,876.57 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.27	214.00	0.71	1,969.14	4.00	7,876.57
14	0.22	214.00	0.71	1,604.49	4.00	6,417.95
16	0.17	214.00	0.71	1,239.83	4.00	4,959.32

Conference:

q_{s1}=A*SC*SHGF*CLF=48*0.71*214*0.27=1,969.14 Btu/hr

For 2 windows,

q_{s2}= 1969.14* 2= 3938.28 Btu/hr

Time of Day	CLF	SHGF	Shading Coefficient	Q(Btu/hr)	No. of Window	Q_T (Btu/hr)
12	0.27	214.00	0.71	1,969.14	2.00	3,938.28
14	0.22	214.00	0.71	1,604.49	2.00	3,208.97
16	0.17	214.00	0.71	1,239.83	2.00	2,479.66

Total Heat gain of Window in (Btu/Hr),

Time of Day	Q_T (Btu/hr)
12	56,246.55
14	66,282.94
16	68,771.97

4. PARTITION FOR INTERNAL WALLS UNCONDITIONED

Room

A= 16 ft * 15 ft = 240 ft^2

q_{s1}=U*A*(T_o-T_i)= 0.26* 240* (86-72)= 873.60 Btu/hr

No of internal walls = 26

q_{s26}= 873.6* 26 = 22,713.60 Btu/hr

Time of Day	Room Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	72.00	86.00	873.60	26.00	22,713.60
14	72.00	86.00	873.60	26.00	22,713.60
16	72.00	86.00	873.60	26.00	22,713.60

Cafeteria

A= 16 ft * 15 ft = 240 ft^2

q_{s1}=U*A*(T_o-T_i)= 0.26* 240* (86-72)= 873.60 Btu/hr

No of internal walls = 2

q_{s2}= 873.6* 2 = 1,747.20 Btu/hr

Time of Day	Cafeteria Temperature	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	72.00	86.00	873.60	2.00	1,747.20
14	72.00	86.00	873.60	2.00	1,747.20
16	72.00	86.00	873.60	2.00	1,747.20

Photocopy Area

A= 8 ft * 15 ft = 120 ft^2

q_{s1}=U*A*(T_o-T_i)= 0.26* 120* (86-72)= 836.80 Btu/hr

No of internal walls = 2

q_{s2}= 436.80* 2 = 873.60 Btu/hr

Time of Day	Photocopy Area Temperature	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	72.00	86.00	436.80	2.00	873.60
14	72.00	86.00	436.80	2.00	873.60
16	72.00	86.00	436.80	2.00	873.60

Reception

A= 16 ft * 15 ft = 240 ft^2

q_{s1}=U*A*(T_o-T_i)= 0.26* 240* (86-72)= 873.60 Btu/hr

No of internal walls = 2

q_{s2}= 873.6* 2 = 1,747.20 Btu/hr

Time of Day	Reception Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	72.00	86.00	873.60	2.00	1,747.20
14	72.00	86.00	873.60	2.00	1,747.20
16	72.00	86.00	873.60	2.00	1,747.20

Conference Room

A= 32 ft * 15 ft = 480 ft^2

q_{s1}=U *A*(T_o-T_i)= 0.26* 480* (86-72)= 1747.20 Btu/hr

Time of Day	Conference Room Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	Q(Btu/hr)	No. of Walls	Q_T (Btu/hr)
12	72.00	86.00	1,747.20	1.00	1,747.20
14	72.00	86.00	1,747.20	1.00	1,747.20
16	72.00	86.00	1,747.20	1.00	1,747.20

Total Heat gain in Internal Walls in Btu/hr,

Time of Day	QT(Btu/hr)
12	28,828.80
14	28,828.80
16	28,828.80

5. INTERNAL LIGHTS:

Room

Time of Day	Input (Btu/hr-ft2)	CLF	Q(Btu/hr)	No. of Room	Q_T (Btu/hr)
12	7.924	0.65	1,318.55	17.00	22,415.41
14	7.924	0.77	1,561.98	17.00	26,553.64
16	7.924	0.85	1,724.26	17.00	29,312.46

Cafeteria

Time of Day	Input (Btu/hr-ft2)	CLF	Q(Btu/hr)	No. of cafe	Q_T (Btu/hr)
12	7.924	0.65	1,318.55	2.00	2,637.11
14	7.924	0.77	1,561.98	2.00	3,123.96
16	7.924	0.85	1,724.26	2.00	3,448.52

Photocopy Area

Time of Day	Input (Btu/hr-ft2)	CLF	Q(Btu/hr)	No. of Photocopy area	Q_T (Btu/hr)
12	7.924	0.65	659.28	2.00	1,318.55
14	7.924	0.77	780.99	2.00	1,561.98
16	7.924	0.85	862.13	2.00	1,724.26

Reception Area

Time of Day	Input (Btu/hr-ft2)	CLF	Q(Btu/hr)	No. of reception	Q_T (Btu/hr)
12	7.924	0.65	1,318.55	1.00	1,318.55
14	7.924	0.77	1,561.98	1.00	1,561.98
16	7.924	0.85	1,724.26	1.00	1,724.26

Conference Room

Time of Day	Input (Btu/hr-ft2)	CLF	Q(Btu/hr)	No. of Conference	Q_T (Btu/hr)
12	7.924	0.65	2,637.11	1.00	2,637.11
14	7.924	0.77	3,123.96	1.00	3,123.96
16	7.924	0.85	3,448.52	1.00	3,448.52

Conditioning lighting area,

A= 17 room area+2 cafeteria area+1 reception area+1 conference room area+2 photocopy area

= (17*16*16+2*16*16+16*16+16*32+2*16*8) ft^2

=5888 ft^2=5888*0.3048^2=547.01m^2

q_{light}=Input*CLF=25*547.01*0.65=8888.91 watt, (for normal condition 25 watt/m^2)

=8888.91*3.412 Btu/hr=30,328.96 Btu/hr

Total Heat gain through Internal lights in Btu/hr,

Time of Day	Q_T (Btu/hr)
12	30,326.73
14	35,925.51
16	39,658.04

6. PEOPLE

Total number of people people=50 (50% male and 50% female)

Moderately active office Table8-2, page-222 and Table.4.6 ,0ffice hour- 8, office opens at 10:00am calculated at 12:00pm)

q_{s50}= No. of people *Sens H.G*CLF

= {25*250*0.61}+{25*(250*0.85) *0.61} =7053.13Btu/hr

Time of Day	Gender	No. of People	Hour after each entry into space	SHF	CLF	Sensible Q (Btu/Hr)	Sensible Q (Btu/hr)
12	Male	25	2	250.00	0.61	3812.5	7053.125
	Female	25	2	212.50	0.61	3240.625	
14	Male	25	2	250.00	0.72	4500	8325
	Female	25	2	212.50	0.72	3825	
16	Male	25	2	250.00	0.80	5000	9250
	Female	25	2	212.50	0.8	4250	

q_{l50}= No*Lat.H. G

= {25*200}+{25*200*0.85}

=9250 Btu/hr

Time of Day	Gender	No. of People	Hour after each entry into space	LHF	CLF	Latent Q (Btu/Hr)	Latent Q (Btu/Hr)
12	Male	25	2	200.00	0.61	5000	9250
	Female	25	2	170.00	0.61	4250	
14	Male	25	2	200.00	0.72	5000	9250
	Female	25	2	170.00	0.72	4250	
16	Male	25	2	200.00	0.80	5000	9250
	Female	25	2	170.00	0.8	4250	

7. APPLIANCES

Sensible

q_s= Heat gain* CLF,

(CLF=0.66, Table 4.11, 8 hours office, open at 10:00 am calculated at 12:00 pmunhooded appliances)

2 refrigerator (Table 5 2001 ASHRAE Fundamental Handbook (SI) each 310 watt= 310* 3.412= 1057.76 Btu/hr),

2 microwaves (Table 5 each 2630 watt=2630*3.412=8973.93 Btu/hr),

2 coffee makers (Table 5, each 79 watts=79*3.412=269.56Btu/hr)

22 computers (Table 8, each 65 watts= 65*3.412=221.79 Btu/hr)

4 office copiers (Table 9, each 1100 watt=1100*3.412=3753.36 Btu/hr)

q_s=Heat gain* CLF

= {(2*1057.76) +(2* 8973.93)+(2* 269.56)+ (22*221.79)+(4*3753.36) * 0.66

= 26,726.90 Btu/hr

Time of Day	Appliances	Heat Gain (Btu/Hr)	Hour after appliances are on	Total operation al hour	CLF	Sensible Q (Btu/Hr)	No. of appliances	Total Q (Btu/Hr)
12	Refrigerator	1,057.76	2	8.00	0.66	698.12	2	26,726.90
	Microwave	8,973.93	2	8.00	0.66	5922.80	2	
	Copiers	3,753.36	2	8.00	0.66	2477.21	4	

	Computer	221.79	2	8.00	0.66	146.38	22	
	Coffee Maker	269.56	2	8.00	0.66	177.91	2	
14	Refrigerator	1,057.76	4	8.00	0.76	803.90	2	30,776.43
	Microwave	8,973.93	4	8.00	0.76	6820.19	2	
	Copiers	3,753.36	4	8.00	0.76	2852.55	4	
	Computer	221.79	4	8.00	0.76	168.56	22	
	Coffee Maker	269.56	4	8.00	0.76	204.86	2	
16	Refrigerator	1,057.76	6	8.00	0.82	867.37	2	33,206.14
	Microwave	8,973.93	6	8.00	0.82	7358.62	2	
	Copiers	3,753.36	6	8.00	0.82	3077.75	4	
	Computer	221.79	6	8.00	0.82	181.87	22	
	Coffee Maker	269.56	6	8.00	0.82	221.04	2	

Latent

q_l=Heat gain

2 coffee makers(Table 5, each 41 watts=79* 3.412=269.56 Btu/hr)

q_l= (2* 269.56)=539.12 Btu/hr

Time of Day	Appliances	Heat Gain (Btu/Hr)	Hour after appliances are on	Total operational hour	CLF	Latent Q (Btu/Hr)	No. of appliances	Total Q (Btu/Hr)
12	Refrigerator	0.00	2	8.00	0.66	0	2	539.12
	Microwave	0.00	2	8.00	0.66	0	2	
	Copiers	0.00	2	8.00	0.66	0	4	
	Computer	0.00	2	8.00	0.66	0	22	
	Coffee Maker	269.56	2	8.00	0.66	269.56	2	
14	Refrigerator	0.00	4	8.00	0.76	0	2	539.12

	Microwave	0.00	4	8.00	0.76	0	2	
	Copiers	0.00	4	8.00	0.76	0	4	
	Computer	0.00	4	8.00	0.76	0	22	
	Coffee Maker	269.56	4	8.00	0.76	269.56	2	
16	Refrigerator	0.00	6	8.00	0.82	0	2	539.12
	Microwave	0.00	6	8.00	0.82	0	2	
	Copiers	0.00	6	8.00	0.82	0	4	
	Computer	0.00	6	8.00	0.82	0	22	
	Coffee Maker	269.56	6	8.00	0.82	269.56	2	

8. VENTILATION AND INFILTRATION AIR

Sensible

Room

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Conditioned Area Temperature(ºF)	Non-Conditioned Area Temperature (ºF)	No. of room	Q_T (Btu/hr)
12	108.74	1.00	30.20	22.22	35.00	17.00	27,580.65
14	108.74	1.00	30.20	22.22	35.00	17.00	27,580.65
16	108.74	1.00	30.20	22.22	35.00	17.00	27,580.65

Cafeteria

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	No. of room	Q_T (Btu/hr)
12	108.74	1.00	30.20	22.22	35.00	2.00	3,244.78
14	108.74	1.00	30.20	22.22	35.00	2.00	3,244.78
16	108.74	1.00	30.20	22.22	35.00	2.00	3,244.78

Photocopy Area

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Conditioned Area Temperature (ºF)	Non-Conditioned Area Temperature (ºF)	No. of room	Q_T (Btu/hr)
12	54.37	1.00	15.10	22.22	35.00	2.00	1,622.39
14	54.37	1.00	15.10	22.22	35.00	2.00	1,622.39
16	54.37	1.00	15.10	22.22	35.00	2.00	1,622.39

Conference Room

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Conditioned Area Temperature(ºF)	Non-Conditioned Area Temperature (ºF)	No. of room	Q_T (Btu/hr)
12	217.47	1.00	60.41	22.22	35.00	1.00	3,244.78
14	217.47	1.00	60.41	22.22	35.00	1.00	3,244.78
16	217.47	1.00	60.41	22.22	35.00	1.00	3,244.78

Q_s =1.232*L/S* ∆T

Air-conditioned volume=(Air-conditioned area *height)

=547.01*(15*0.3048)m^3=2500.93m^3=2500.93*1000 L=2500930L

Volumetric flow rate,

V=(2500930*1)/3600=694.7 L/S,

(Assuming number of air change 1 per hour)

Q_s =1.232* L/S* (T_0-T_i)=1.232* 694.7* (35-22.22)

=1 0938.02 watt= 10938.02* 3.412Btu/hr

= 37,314.99 Btu/hr

Total Sensible Heat gain through Ventilation Qt (Btu/Hr),

Time of Day	Q_T (Btu/hr)
12	37,314.99
14	37,314.99
16	37,314.99

Room

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Outside air Humidity ratio	Inside air Humidity ratio	No. of room	Q_T (Btu/hr)
12	108.74	1.00	30.20	0.331	0.123	17.00	93,935.60
14	108.74	1.00	30.20	0.331	0.123	17.00	93,935.60
16	108.74	1.00	30.20	0.331	0.123	17.00	93,935.60

Q_L =3012*L/S* ΔW

=3012* L/S* (W_2-W_1)

= 3012 *694.7* (0.331-0.123)

=435226.77 watt= 435226.77* 3.412=1484993.74 Btu/hr

Cafeteria

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Outside air Humidity ratio	Inside air Humidity ratio	No. of room	Q_T (Btu/hr)
12	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25
14	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25
16	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25

Photocopy Area

Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Outside air Humidity ratio	Inside air Humidity ratio	No. of room	Q_T (Btu/hr)
12	54.37	1.00	15.10	0.331	0.123	2.00	5,525.62
14	54.37	1.00	15.10	0.331	0.123	2.00	5,525.62
16	54.37	1.00	15.10	0.331	0.123	2.00	5,525.62

Conference Room

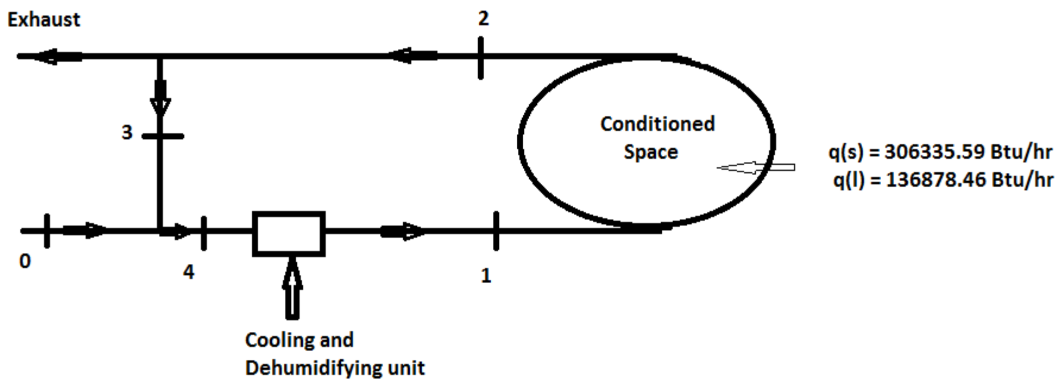
Time of Day	Volume (m3)	ACH	Volume flow rate (l/s)	Outside air Humidity ratio	Inside air Humidity ratio	No. of room	Q_T (Btu/hr)
12	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25
14	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25
16	217.47	1.00	60.41	0.331	0.123	1.00	11,051.25

Total Sensible Heat gain through Ventilation Qt (Btu/Hr)

Time of Day	Q_T (Btu/hr)
12	121,563.72
14	121,563.72
16	121,563.72

TOTAL SENSIBLE AND LATENT HEAT GAIN

Time of Day	Q_{Roof}	Q_{Walls}	Q_{Glass}	$Q_{partitions}$	$Q_{Internal\ lights}$	Q_{People}		$Q_{infiltration}$		$Q_{Appliances}$		Q_{Total} (Btu/hr)	Q_{Total} (ton)
						Sensible	Latent	Sensible	Latent	Sensible	Latent		
12	46748	35044	56247	28829	30327	7053	9250	37315	127089	26727	539	405167	34
14	55269	35343	66283	28829	35926	8325	9250	37315	127089	30776	539	434944	36
16	53139	36167	68772	28829	39658	9250	9250	37315	127089	33206	539	443214	37



COOLING LOAD CALCULATION:

Total Cooling Load Q_T= 443214.05 Btu/Hr

Total Sensible Cooling Load Q_{Ts}= 306335.59 Btu/hr

Total Latent Cooling Load Q_{Tl}= 136878.46 Btu/hr

Sensible Heat Gain Factor S.H.F = Q_{Ts} / (Q_{Ts} + Q_{Tl})

= 306335.59 / (306335.59 + 136878046)

= 0.6911 ~ 0.7

Mass flow rate of air required ($\dot{m}_1$=$\dot{m}_2$=$\dot{m}_4$) = Q_T/ (h_2 - h_1)

= 443214.05 / (26.4 - 18.1)

= 53399.28 lb/hr

Total Conditioner Area Volume   V = Condition Area * Height

= 5888 * 15 = 88320 ft^3

Specific Volume $\dot{V}_0$ = 14.37 ft^3/ lb

Density of outside air ρ_0 = 1/$\dot{V}_0$

= 1/ 14.37 = 0.06958lb/ft^3

Mass flow rate of outside air,$\dot{m}_0$= V* ρ_0

=   88320 * 0.0695= 6,145.305lb/hr

Mixing Point will lie at

$\dot{m}_0/\dot{m}_2 = \overline{42}/\ \overline{02}$

$6145.305 / 53399.28 = \overline{42} / 8.9$

$\overline{42} = 1.017$

From Psychrometric Chart: -

h_0= 46.7 btu/ lb h_1= 18.1 btu/ lb h_2= 26.4 btu/ lb h_4= 28.85 btu/ lb

Cooling Load = $\dot{m}_1 (h_2 - h_1)$

= 53399.28 (26.4 - 18.1)

= 443214.024 btu/hr = 36.93 ton

Cooling Capacity = $\dot{m}_1(h_4 - h_1)$

= 53399.28 (28.85 - 18.1)

= 574042.26 btu/hr = 47.83 ton

DUCT DESIGN:

Mass flow rate, m1=m2=m4=53399.283 lb/hr
Outside air supply, mo=6107.328 lb/hr
Recirculation mass flow rate m3=m4-mo=53399.283-6107.328=47291.95 lb/hr
Recirculation volume flow rate Q3= m3/ ρ =47291.95/(0.076474*3600)= 171.78 ft3/sec
Our total rooms= 23
Recirculation/room=171.78/23=7.468 ft3/sec, (each room 16ft*16ft*15ft)
Total volume flow rate, Qt2=7.468+16*16*15/3600, (ACH=1)
=8.53ft3/sec
Velocity=6m/sec=19.685ft/sec

Duct area for 1 room, A2= Qt2/v=8.53/19.685=0.43ft2

Total volume flow rate, Qt3=2* Qt2=2*8.53=17.06ft3/sec
Area, A3= Qt3/v=17.06/19.685=0.867ft3

Total volume flow rate for Qt4= 3*Qt3+ Qt2=3*17.06+8.53=59.71ft3/sec
Area A4=59.71/19.685=3.03ft2

Volume flow rate for Qt5=4* Qt2=4*8.53=34.12ft3/sec
Area A5=34.12/19.685=1.733ft2

Volume flow rate, Qt6= Qt5+ Qt4=34.12+59.71=93.83ft3/sec
Area, A6=93.83/19.685=4.767 ft2

Volume flow rate Qt7=Qt2/2=4.265ft3/sec
Area A7=4.265/19.685=0.217

Volume flow rate, Qt12= Qt7+3* Qt2=4.265+3*8.53=29.8555ft3/sec
Area, A12=29.855/19.685=1.517ft2

Volume flow rate, Qt8= Qt7+3* Qt2=4.265+3*8.53=29.8555ft3/sec
Area, A8=29.855/19.685=1.517ft2

Total volume flow rate, Qt3=2* Qt2=2*8.53=17.06ft3/sec
Area, A3= Qt3/v=17.06/19.685=0.867ft3

Volume flow rate, Qt9= Qt3+2* Qt2=17.06+2*8.53=34.12ft3/sec
Area, A9=34.12/19.685=1.733ft2

Volume flow rate, Qt11= Qt9+ Qt2=34.12+8.53=42.65ft3/sec
Area, A11=42.65/19.685=2.167ft2

The main supply ducts
Volume flow rate, Qt1= Qt11+ Qt12+Q8+Q6=42.65+29.8555+29.8555+93.83=196.191ft3/sec
Area A1=196.191/19.685=9.967ft2

RESULTS AND DISCUSSION:

The calculation has been done at three different times a day (12:00 pm, 2:00 pm and 4:00 pm) and the maximum heat gain has been observed at 16:00 hour that is around 37 tons. Ventilation and infiltration air play a significant role in this case. External walls and roof gain more heat because of high sunlight intensity. Appliances and people also dissipate huge sensible heat. We did not consider supply and exhaust fan, but, in real life, fans are required to move the air and some energy may be gained from the supply fan located after cooling unit and from exhaust fan situated in exhaust duct. We consider same conduction through doors and internal walls. In practical life, it will be different to some extents but not significantly. Here, the construction of the external and internal walls is same, but, in real case, this will also different and affect the costing of the building construction. However, our calculated cooling capacity for machine is 47.83 ton and space cooling load is 36.93 ton. We have got this result mainly because of air infiltration and ventilation. Heat generation and dissipation by the human body may vary in the building based on activities, size, age, gender, geographical location and total number of people. This calculation may vary based on clothing of people, air velocity, radiation, relative humidity ratio, wall orientation and the ceiling of the roof.

Cooling loads vary from time to time and our calculation has been done at three different times a day, but, in physical world, the loads are calculated at every hour. The major reason behind it is that heat gain is usually greater than the cooling load during the morning hours when sunlight first hits a building and the internal loads come to play. Heat begins to store in the building structure, furnishings, etc. that may affect later. Late at night when occupants are not present, lights and equipment are off and there is no solar radiation, the building gives up stored heat to the air. The heat gain may be quite small, zero, or negative. At some time during the day, probably early evening, as heat gain is decreasing, and equilibrium condition can be established when heat gain and cooling load are equal.

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