ME 329 : THERMAL SYSTEMS DESIGN

DESIGN AN AIR HANDLING UNIT FOR AN AC APPLICATION

GROUP 05

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LIST OF ABBREVIATIONS

CLTD	**Cooling Load Temperature Difference**
SCL	Solar Cooling Load
CLF	Cooling Load Factor
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
RH	Relative Humidity
BPF	By-Pass Factor
ADP	Apparatus Dew Point
AHU	Air Handling Unit
GSHF	Grand Sensible Heat Factor

INTRODUCTION

The installation of a reliable central air conditioning system is essential in the effort to create a comfortable home atmosphere. This is particularly true for the First Floor of a three-story office structure, where the requirement for an efficient cooling system is critical. An air handling unit (AHU), which distributes air in the right amounts throughout the allocated spaces, is a crucial part of the system that helps achieve this.

The primary objective of this assignment is to specify the supply air flow rate of the AHU that can effectively meet the total cooling load required for the First Floor. By carefully analyzing the given spaces and their corresponding cooling requirements, the design of the AHU will aim to provide optimal comfort to the occupants while ensuring energy efficiency and cost-effectiveness.

The design process will involve a comprehensive evaluation of the cooling load in accordance with the provided drawing and floor plan. Factors such as the size and orientation of the spaces, the number of occupants, heat-generating equipment, and external factors will be taken into account to accurately determine the total cooling load. This load estimation will serve as the basis for calculating the required supply air flow rate, which is vital in achieving the desired indoor climate conditions.

The scope of this assignment is dedicated to specifying the supply air flow rate for the AHU, which will contribute significantly to the overall success of the central air-conditioning system. As the primary focus is on the design of the AHU, other aspects such as equipment selection, ductwork design, and control systems will be beyond the scope of this assignment.

By meticulously designing the AHU and tailoring it to the cooling needs of the First Floor, this project aims to provide an optimized solution that ensures occupant comfort, energy efficiency, and effective cooling performance. With the successful completion of this assignment, the central air-conditioning system will be equipped to create a pleasant and conducive environment for the occupants of the First Floor in the three-storied office building.

SECTION 1

INITIAL DATA AND DESIGN CONDITIONS

HEAT GAINS IN BUILDINGS

There are several ways to manage heat gains in buildings, including

Building Orientation: Proper building orientation can reduce the amount of solar radiation entering the building, which can help reduce heat gains. For example, orienting the building to the north or south can help minimize solar heat gain.

Shading: Installing shading devices such as awnings, louvers, and overhangs can reduce the amount of solar radiation entering the building and help control heat gains.

Insulation: Proper insulation can help reduce conductive heat transfer through the building envelope, which can help manage heat gains.

Air Sealing: Proper air sealing can reduce the infiltration of hot air into the building and help manage heat gains.

Ventilation: Proper ventilation can help remove heat generated by people, equipment, and lighting, which can help manage internal loads.

Efficient HVAC Systems: Installing energy-efficient HVAC systems can help manage heat gains by reducing energy consumption and improving the overall thermal comfort of the building.

Managing heat gains in buildings is essential for energy efficiency, thermal comfort, and indoor air quality. By implementing proper design and building practices, building owners and operators can reduce energy consumption, save money, and improve the overall performance of their buildings.

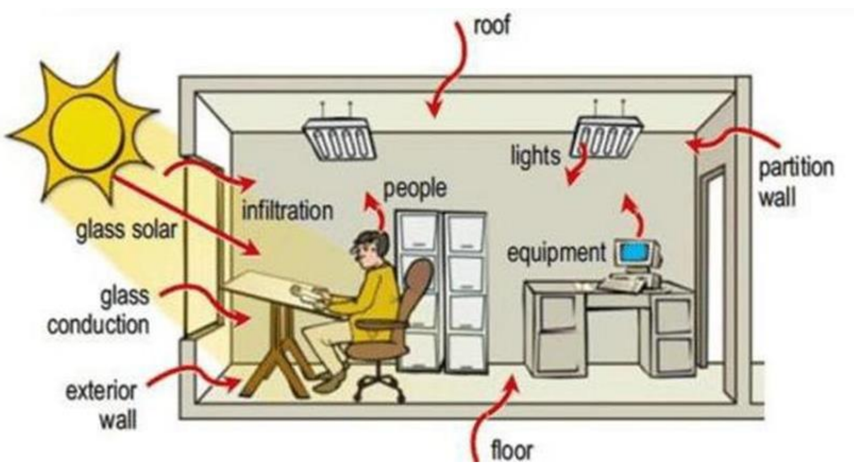

Figure 1.1: Sources of heat gains within a building

To manage heat gains in buildings, various strategies can be employed, such as:

1. Energy-efficient windows and doors
2. Insulation
3. Effective ventilation
4. Use of shading devices
5. High-efficiency lighting and equipment
6. Use of green roofs and walls

CLTD, SCL & CLF VALUES AND USAGE

The CLTD/CLF/SCL cooling load calculation was first introduced by the 1979 ASHRAE Cooling and Heating Load Manual. This was a reasonably good approximation of the total heat gains through a building. This method was a solution to the difficult calculation methods that existed before.

The CLTD factor or the Cooling Load Temperature Difference factor is used to represent the temperature difference between indoor and outdoor air with the heating effects of solar radiation.

The CLF coefficient or the Cooling Load Factor coefficient is used for the time lag between the outdoor and indoor temperature peaks.

The SCL or the Solar Cooling Load factor accounts for the variables associated with the solar heat load. This CLTD/CLF/SCL calculation method is the most precise method in calculating heat loads in buildings.

INITIAL DATA AND DESIGN CONDITIONS

Floor plan where the air conditioning system is designed

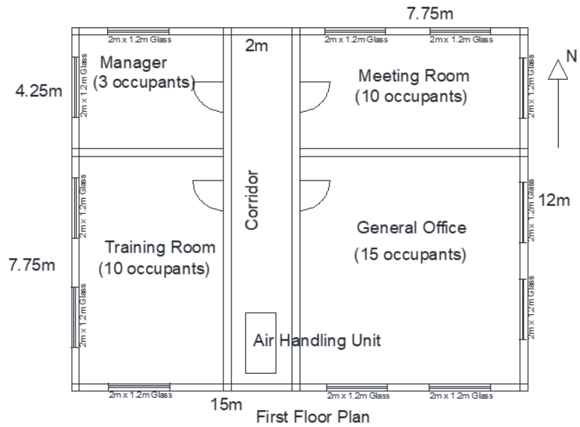

Figure 1.2: First floor plan view

External dimensions of the floor

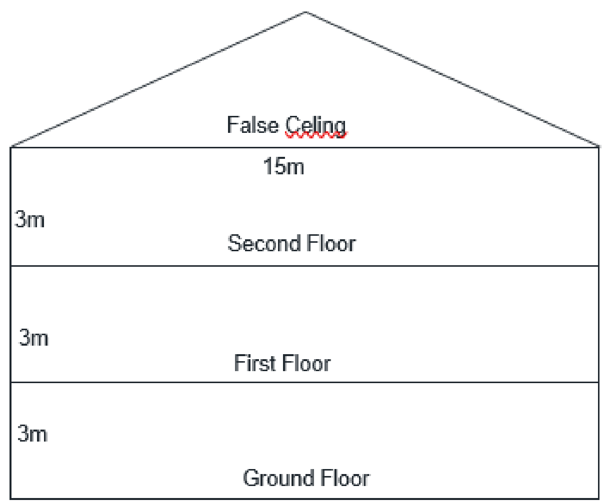

Figure 1.2: Front view of the building

The air condition system of the building is designed under the following data.

$Uceiling$ = 2.5$W/m2C0$
$Uglass$ = 6$W/m2C0$
$Uwall$ = 1.9$W/m2C0$
$Ufloor$ = 2.5$W/m2C0$
$Outdoor\ conditions$ = 33$C0$/ 80% RH
$Design\ conditions$ = 25$C0$/ 60 % RH
$Shading\ of\ window$ = 75%

SECTION 2

DIVISION OF THERMAL ZONES

Manager room
Meeting room
Training room
General office
Corridor

HEAT GAINED FROM CONDUCTION THROUGH ROOF, WALL, FLOOR AND GLASS

Conduction through the ceiling

Manager room

The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$

Area = $22.3125 m2$

Corr.CLTD at 1300h = 32.1

$q = U \times A \times Corr.\ CLTD$

$q = 2.5 \times 22.3125 \times 32.1$

$q = 1790.58 W$

Meeting room

The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$

Area = $32.9375 m2$

Corr.CLTD at 1300h = 32.1

$q = U \times A \times Corr.\ CLTD$

$q = 2.5 \times 32.9375 \times 32.1$

$q = 2643.23\ W$

Training room

The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$

Area = 40.6875 m2

Corr.CLTD at 1300h = 32.1

$q = U \times A \times Corr.\,CLTD$
q = 2.5×40.6875×32.1
q = 3265.17W

General office
The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$
Area = $60.0625 m2$
Corr.CLTD at 1300h = 32.1

$q = U \times A \times Corr.\,CLTD$
$q = 2.5 \times 60.0625 \times 32.1$
$q = 4820.02\ W$

Corridor
The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$
Area = $24 m2$
Corr.CLTD at 1300h = 33.1

$q = U \times A \times Corr.\,CLTD$
$q = 2.5 \times 24 \times 32.1$
$q = 1926 W$

Table 2.2: Heat loads of the ceiling in each zone

	13:00	**14:00**	**15:00**	**16:00**	**17:00**	
CLTD	**32.1**	**37.1**	**40.1**	**41.1**	**41.1**	
Manager	1790.58	2069.48	2236.83	2292.61	2292.61	
Meeting room	2643.23	3054.95	3301.98	3384.33	3384.33	
Training room	3265.17	3773.77	4078.92	4180.64	4180.64	**Heat Load**
General office	4820.02	5570.80	6021.27	6171.42	6171.42	
Corridor	1926	2226	2406	2466	2466	

Conduction through floor

Manager Room

The calculation is done for 1300 hrs.

$Uceiling$	=	2.5$W/m2C$0
Area	=	22.3125m^2
Corr.CLTD at 1300h	=	32.1

q = U x A × $Corr.\ CLTD$
q = 2.5 × 22.3125 × 32.1
q = 1790.58 W

Meeting room

The calculation is done for 1300 hrs.

$Uceiling$	=	2.5$W/m2C$0
Area	=	32.9375m2
Corr.CLTD at 1300h	=	32.1

$q = U \times A \times Corr.\ CLTD$
q = 2.5 × 32.9375 × 32.1
q = 2643.23 W

Training room

The calculation is done for 1300 hrs.

$Uceiling$	=	2.5$W/m2C$0
Area	=	32.9375m2
Corr.CLTD at 1300h	=	32.1

$q = U \times A \times Corr.\ CLTD$
q = 2.5 × 32.9375 × 32.1
q = 3265.17 W

General office

The calculation is done for 1300 hrs.

$Uceiling$	=	2.5$W/m2C$0
Area	=	60.0625m2
Corr.CLTD at 1300h	=	32.1

$q = U \times A \times Corr.\ CLTD$
q = 2.5 × 22.3125 × 32.1
q = 4820.02W

Corridor

The calculation is done for 1300 hrs.

$Uceiling$ = $2.5 W/m2C0$

Area = $24m2$

Corr.CLTD at 1300h = 32.1

$q = U \times A \times Corr.\ CLTD$

$q = 2.5 \times 24 \times 32.1$

$q = 1926\ W$

Table 2.3: Heat loads of the floor in each zone

	13:00	**14:00**	**15:00**	**16:00**	**17:00**	
CLTD	**32.1**	**37.1**	**40.1**	**41.1**	**41.1**	**Heat Load**
Manager	1790.58	2069.48	2236.83	2292.61	2292.61	
Meeting room	2643.23	3054.95	3301.98	3384.33	3384.33	
Training room	3265.17	3773.77	4078.92	4180.64	4180.64	
General office	4820.02	5570.80	6021.27	6171.42	6171.42	
Corridor	1926	2226	2406	2466	2466	

Conduction through walls

Manager Room

The calculation is done for 1300 hrs.

Uwall = $1.9 W/m2C$

North Wall: Corr.CLTD = 12.1

Area = 15.75-2.4 = 13.35 m^2

$q = U \times A \times Corr.\ CLTD$

$q = 1.9 \times 13.35 \times 12.1$

$q = 306.92\ W$

West Wall: Corr.CLTD = 4.988889

Area = 12.75-2.4 = 10.35m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 10.35 × 4.988889
q = 198.11W

Meeting Room

The calculation is done for 1300 hrs.

Uwall = 1.9$W/m2C$

North Wall: Corr.CLTD = 12.1
Area = 23.25-4.8 = 18.45m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 18.45 × 12.1
q = 424.17 W

East Wall: Corr.CLTD = 25.98889
Area = 12.75-2.4 = 10.35m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 10.35 × 25.989
q = 511.07 W

Training room

The calculation is done for 1300 hrs.

Uwall = 1.9$W/m2C$

South wall : Corr.CLTD = 7.211111
Area = 15.75-2.4 = 13.35m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 13.35 × 7.211111
q = 182.91 W

West Wall: Corr.CLTD = 4.988889
Area = 23.25-4.8 = 18.45m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 18.45 × 4.988889
q = 174.89 W

General office

The calculation is done for 1300 hrs.

Uwall = 1.9$W/m2C$

East wall : Corr.CLTD = 25.98889
Area = 23.25-4.8 = 18.45m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 18.45 × 25.98889
q = 911.04 W

South wall : Corr.CLTD = 7.211111
Area = 23.25-4.8 = 18.45m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 18.45 × 7.211111
q = 252.79 W

Corridor

The calculation is done for 1300 hrs.
Uwall = 1.9$W/m2C$

North wall : Corr.CLTD = 12.1
Area = 6m^2

q = U x A × $Corr.\ CLTD$
q = 1.9×6×12.1
q = 137.94 W

South wall : Corr.CLTD = 7.211111
Area = 6m^2

q = U x A × $Corr.\ CLTD$
q = 1.9 × 6 × 7.211111
q = 82.21 W

Table 2.4: Heat loads of the walls in each zone

		13:00	14:00	15:00	16:00	17:00	
CLTD	**N**	**12.1**	**14.1**	**16.1**	**17.1**	**18.1**	
	E	**25.98889**	**24.98889**	**22.98889**	**20.98889**	**19.98889**	
	S	**7.211111**	**12.21111**	**15.21111**	**19.21111**	**20.21111**	
	W	**4.988889**	**6.988889**	**10.98889**	**15.98889**	**20.98889**	
Manager	**N**	306.92	357.65	408.38	433.74	459.11	**Heat Load**
	W	98.11	137.44	216.10	314.42	412.75	
Meeting room	**N**	424.17	494.28	564.39	599.44	634.5	
	E	511.07	491.41	452.08	412.08	393.08	
Training room	**S**	182.91	309.73	385.83	487.29	512.65	
	W	174.89	245.0	385.22	560.50	735.77	
General office	**E**	911.04	875.99	805.88	735.77	700.71	
	S	252.79	428.06	533.23	673.45	708.50	
Corridor	**N**	137.94	160.74	183.54	194.94	206.34	
	S	82.21	139.21	173.41	219.01	230.41	

Conduction through Glass

Manager Room

The calculation is done for 1300 hrs.

$Uglass \quad = \quad 6 W/m^2.C$

North Wall: Corr.CLTD = 7
Area = $2.4m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 2.4 \times 7$
$q = 100.8W$

West Wall: Corr.CLTD = 7
Area = $2.4m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 2.4 \times 7$
$q = 100.8\ W$

Meeting Room

The calculation is done for 1300 hrs.

$Uglass$ = $6W/m^2.\ C$

North Wall: Corr.CLTD = 7
Area = $4.8m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 4.8 \times 7$
$q = 201.6\ W$

East Wall: Corr.CLTD = 7
Area = $2.4m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 2.4 \times 7$
$q = 100.8\ W$

Training room

The calculation is done for 1300 hrs.

$Uglass$ = $6W/m^2.\ C$

West Wall: Corr.CLTD = 7
Area = $4.8m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 4.8 \times 7$
$q = 201.6\ W$

South Wall: Corr.CLTD = 7
Area = $2.4m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 2.4 \times 7$
$q = 100.8\ W$

General Office

The calculation is done for 1300 hrs.

$Uglass$ = $6 W/m^2.C$

East Wall: Corr.CLTD = 7
Area = $4.8 m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 4.8 \times 7$
$q = 201.6\ W$

South Wall: Corr.CLTD = 7
Area = $4.8 m^2$

$q = U \times A \times Corr.\ CLTD$
$q = 6 \times 4.8 \times 7$
$q = 201.6\ W$

Table 2.8: Conduction through the glass in each zone

		13:00	**14:00**	**15:00**	**16:00**	**17:00**	
CLTD		**7**	**7**	**8**	**8**	**7**	
Manager	**N**	100.8	100.8	115.2	115.2	100.8	**Heat Load**
	W	100.8	100.8	115.2	115.2	100.8	
Meeting room	**N**	201.6	201.6	230.4	230.4	201.6	
	E	100.8	100.8	115.2	115.2	100.8	
Training room	**W**	201.6	201.6	230.4	230.4	201.6	
	S	100.8	100.8	115.2	115.2	100.8	
	E	201.6	201.6	230.4	230.4	201.6	

General office	**S**	201.6	201.6	230.4	230.4	201.6	

HEAT LOAD FROM SOLAR RADIATION TROUGH GLASS

Manager room

Solar radiation through glass.
$q = A(SC)(SCL)$
With 75% of shading glass,

SCL in North wall (at 1300 hrs.) = $142 W/m2$

$q = A \times (SC) \times (SCL)$
$q = 2.4 \times 0.75 \times 142$
$q = 255.6\ W$

SCL in West wall (at 1300 hrs.) = $185 W/m2$

$q = A \times (SC) \times (SCL)$
$q = 2.4 \times 0.75 \times 185$
$q = 333\ W$

Meeting room

Solar radiation through glass.
$q = A(SC)(SCL)$
With 75% of shading glass,

SCL in North wall (at 1300 hrs.) = $142 W/m2$

q = $A \times (SC) \times (SCL)$
$q = 4.8 \times 0.75 \times 142$
$q = 511.2\ W$

SCL in East wall (at 1300 hrs.) = $175 W/m2$

$q = A \times (SC) \times (SCL)$
$q = 2.4 \times 0.75 \times 175$
$q = 315\ W$

Training room

Solar radiation through glass.
q = A(SC)(SCL)
With 75% shading glass,
98.6 W/m

SCL in South wall (at 1300 hrs.) = 98.6 $W/m2$

$q = A \times (\text{SC}) \times (SCL)$
$q = 2.4 \times 0.75 \times 98.6$
$q = 177.48\ W$

SCL in West wall (at 1300 hrs.) = 185 $W/m2$
$q = A \times (\text{SC}) \times (SCL)$
$q = 4.8 \times 0.75 \times 185$
$q = 666\ W$

General Office

Solar radiation through glass.
$q = A(SC)(SCL)$
With 75% of shading glass,

SCL in East wall (at 1300 hrs.) = 175$W/m2$
$q = A \times (\text{SC}) \times (SCL)$
$q = 4.8 \times 0.75 \times 175$
$q = 630\ W$

SCL in South wall (at 1300 hrs.) = 98.6$W/m2$
$q = A \times (\text{SC}) \times (SCL)$
$q = 4.8 \times 0.75 \times 98.6$
$q = 354.96\ W$

Table 2.10: Radiation through the glass in each zone

		13:00	14:00	15:00	16:00	17:00	
SCL	**N**	**142**	**138.1**	**130.3**	**117.3**	**117.3**	**Heat Load**
	E	**175**	**163**	**147**	**134**	**116**	
	S	**98.6**	**87.4**	**67**	**49.4**	**40.6**	
	W	**185**	**308**	**415**	**481**	**490**	
Manager	**N**	**255.6**	**248.58**	**234.54**	**211.14**	**211.14**	
	W	**333**	**554.4**	**747**	**865.8**	**882**	
Meeting room	**N**	**511.2**	**497.16**	**469.08**	**422.28**	**422.28**	

	E	**315**	**293.4**	**264.6**	**241.2**	**208.8**	
Training room	**S**	**177.48**	**157.32**	**120.6**	**88.92**	**73.08**	
	W	**666**	**1108.8**	**1494**	**1731.6**	**1764**	
General office	**E**	**630**	**586.8**	**529.2**	**482.4**	**417.6**	
	S	**354.96**	**314.64**	**241.2**	**177.84**	**146.16**	

HEAT LOAD FROM OCCUPANTS, LIGHTS AND APPLIANCES

Heat load from occupants (sensible + latent)

Manager room

The calculation is done for 1300 hrs.

Occupancy loading = 3 people

Total floor area = 22.3125m2

CLF(at 1300 hrs.) = 0.79

Assuming the 3 Occupancy, moderately active office work,

Sensible heat = 75 W

Latent heat = 55 W

$Sensible\ Load = N \times sensible\ heat\ gain \times CLF$

q = 3 ×75× 0.79

q = 177.75 W

Latent $Load = N \times$ *Latent* $heat\ gain$

q = 3 × 55

q = 165 W

Meeting room

The calculation is done for 1300 hrs.

Occupancy loading = 10 people

Total floor area = 32.94m2

CLF(at 1300 hrs.) = 0.79

Assuming the 10 Occupancy, moderately active office work,

Sensible heat = 75 W

Latent heat = 55 W

$Sensible\ Load = N \times sensible\ heat\ gain \times CLF$

q = 10 ×75× 0.79

q = 592.5 W

Latent $Load = N \times$ *Latent* $heat\ gain$

q = 10 × 55

q = 550 W

Training room

The calculation is done for 1300 hrs.

Occupancy loading = 10 people

Total floor area = 40.68 $m2$

CLF(at 1300 hrs.) = 0.79

Assuming the 10 Occupancy, moderately active office work,

Sensible heat = 75 W

Latent heat = 55 W

$Sensible\ Load = N \times sensible\ heat\ gain \times CLF$

q = 10 ×75× 0.79

q = 592.5 W

Latent $Load = N \times$ Latent $heat\ gain$

q = 10 × 55

q = 550 W

General Office

The calculation is done for 1300 hrs.

Occupancy loading = 15 people

Total floor area = 60.06$m2$

CLF(at 1300 hrs.) = 0.79

Assuming the 15 Occupancy, moderately active office work,

Sensible heat = 75 W

Latent heat = 55 W

$Sensible\ Load = N \times sensible\ heat\ gain \times CLF$

q = 15 ×75× 0.79

q = 888.75 W

Latent $Load = N \times$ Latent $heat\ gain$

q = 15 × 55

q = 825 W

Table 2.12: Rates of heat gain from occupants of conditions spaces

Degree of Activity		Total Heat, W Adult Male	Total Heat, W Adjusted, M/F[a]	Sensible Heat, W	Latent Heat, W	% Sensible Heat that is Radiant[b] Low V	% Sensible Heat that is Radiant[b] High V
Seated at theater	Theater, matinee	115	95	65	30		
Seated at theater, night	Theater, night	115	105	70	35	60	27
Seated, very light work	Offices, hotels, apartments	130	115	70	45		
Moderately active office work	Offices, hotels, apartments	140	130	75	55		
Standing, light work; walking	Department store; retail store	160	130	75	55	58	38
Walking, standing	Drug store, bank	160	145	75	70		
Sedentary work	Restaurant[c]	145	160	80	80		
Light bench work	Factory	235	220	80	140		
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking 4.8 km/h; light machine work	Factory	295	295	110	185		
Bowling[d]	Bowling alley	440	425	170	255		
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285		
Athletics	Gymnasium	585	525	210	315		

Table 2.12: Occupancy sensible heat load at each zone

	13:00	14:00	15:00	16:00	17:00	
CLTD	**0.79**	**0.83**	**0.86**	**0.89**	**0.91**	**Sensible Heat Load**
Manager	177.75	186.75	193.5	200.25	204.75	
Meeting room	592.5	622.5	645	667.5	682.5	
Training room	592.5	622.5	645	667.5	682.5	
General office	888.75	933.75	967.5	1001.25	1023.75	
Corridor						

Table 2.12: Occupancy Latent heat load at each zone

	13:00	14:00	15:00	16:00	17:00	
Manager	165	165	165	165	165	**Latent Heat Load**
Meeting room	550	550	550	550	550	

Training room	550	550	550	550	550	
General office	825	825	825	825	825	
Corridor						

Heat load from lights

Manager room

Area = 22.3125$m2$
Lighting loads = 10$W/m2$

Total lighting load in zone = 223.125W

Assuming a standard lighting output that subject to normal temperatures a normal ballast factor is considered. (FSA = 0.88)
For a modern office building, FUT = 0.9 is assumed.
At 1300 hrs. CLF = 0.87

$Qsensible = W.\ F^{UT}.\ F^{SA}.\ (CLF)$
$q = 223.125 \times 0.9 \times 0.88 \times 0.87$
$q = 153.74\ W$

Meeting room

Area = 32.9375$m2$
Lighting loads = 10$W/m2$

Total lighting load in zone = 329.375W

Assuming a standard lighting output that subject to normal temperatures a normal ballast factor is considered. (FSA = 0.88)
For a modern office building, FUT = 0.9 is assumed.
At 1300 hrs. CLF = 0.87

$Qsensible = W.\ F^{UT}.\ F^{SA}.\ (CLF)$
$q = 329.375 \times 0.9 \times 0.88 \times 0.87$
$q = 226.95\ W$

Training room

Area = 40.6875$m2$
Lighting loads = 10$W/m2$

Total lighting load in zone = 406.875W

Assuming a standard lighting output that subject to normal temperatures a normal ballast factor is considered. (FSA = 0.88)
For a modern office building FUT = 0.9 is assumed.
At 1300 hrs. CLF = 0.87

$Qsensible = W.\, F^{UT}.\, F^{SA}.\, (CLF)$
q = 406.875 × 0.9 × 0.88 × 0.87
q = 280.35 W

General Office

Area = 60.0625$m2$
Lighting loads = 10$W/m2$

Total lighting load in zone = 600.625W

Assuming a standard lighting output that subject to normal temperatures a normal ballast factor is considered. (FSA = 0.88)
For a modern office building, FUT = 0.9 is assumed.
At 1300 hrs. CLF = 0.87

$Qsensible = W.\, F^{UT}.\, F^{SA}.\, (CLF)$
q = 600.625 × 0.9 × 0.88 × 0.87
q = 413.85 W

Table 2.13: Lights sensible heat load at each zone

	13:00	**14:00**	**15:00**	**16:00**	**17:00**	
CLTD	**0.87**	**0.88**	**0.89**	**0.90**	**0.91**	**Heat Load**
Manager	**153.74**	**155.51**	**157.28**	**159.04**	**160.81**	
Meeting room	**226.95**	**229.56**	**232.17**	**234.78**	**237.39**	
Training room	**280.35**	**283.58**	**286.80**	**289.02**	**293.24**	
General office	**413.85**	**418.61**	**423.37**	**428.13**	**432.88**	

Heat load from appliance

$Qsensible = W.\,F^{U}.\,F^{R}.\,(CLF) \times n$

W : Watts input by appliance
F^{U} : Usage factor
F^{R} : Radiation factor
n : Number of appliances

For a usage factor of 0.9 and a radiation factor of 0.8

Manager room

The calculation is done for 1300 hrs.

Appliances	=	1 desktop computer of 200W
Usage factor	=	0.9
Radiation factor	=	0.8
CLF at 1300 hrs.	=	0.79

No latent heat load from computers Q (latent) = 0

$q = W.\,F^{U}.\,F^{R}.\,(CLF).\,n$
q = 200 × 0.9 × 0.8 × 0.79 × 1
q = 113.76 W

Meeting room

The calculation is done for 1300 hrs.

Appliances	=	2 desktop computers of 200W
Usage factor	=	0.9
Radiation factor	=	0.8
CLF at 1300 hrs.	=	0.79

No latent heat load from computers Q (latent) = 0

$q = W.\,F^{U}.\,F^{R}.\,(CLF).\,n$
q = 200 × 0.9 × 0.8 × 0.79 × 2
q = 227.52 W

Training room

The calculation is done for 1300 hrs.

Appliances	=	1 desktop computer of 200W
Usage factor	=	0.9
Radiation factor	=	0.8
CLF at 1300 hrs.	=	0.79

No latent heat load from computers Q (latent) = 0

$q = W.\,F^{U}.\,F^{R}.\,(CLF).\,n$
q = 200 × 0.9 × 0.8 × 0.79 × 1

q = 113.76 W

General Office

The calculation is done for 1300 hrs.

Appliances = 5 desktop computers of 200W

Usage factor = 0.9

Radiation factor = 0.8

CLF at 1300 hrs. = 0.79

No latent heat load from computers Q (latent) = 0

$q = W.\,F^{U}.\,F^{R}.\,(CLF).\,n$

q = 200 × 0.9 × 0.8 × 0.79 × 5 q = 568.8 W

Table 2.14: Appliances sensible heat load at each zone

	13:00	**14:00**	**15:00**	**16:00**	**17:00**	
CLF	**0.79**	**0.83**	**0.86**	**0.89**	**0.91**	**Heat Load**
Manager	113.76	119.52	123.84	128.16	131.04	
Meeting room	227.52	239.04	247.68	256.32	262.08	
Training room	113.76	119.52	123.84	128.16	131.04	
General office	568.8	597.6	619.2	640.8	655.2	
Corridor						

HEAT LOAD FROM AIR INFILTRATION (for whole room, sensible + latent)

The below calculations are done using air change method.

$$q_{sensible} = 1.23 \times Q \times (T_0 - Ti)$$

T_0	=	Outside temperature in C
Ti	=	Inside temperature in C
Q	=	In l/s
q	=	Watts

$$q_{latent} = 3010 \times Q \times (w_0 - wi)$$

w_0	=	Outside humidity ratio $kg(water)/kg(dry\ air)$
w_i	=	Inside humidity ratio $kg(water)/kg(dry\ air)$

Shown in table 2.15 is ASHRAE recommended air changes per hour for specific room conditions

Table 2.15: ASHRAE recommended air changes per hour

Location Type	Suggested Outdoor Air Ventilation Rate (air changes per hour)
Homes	0.35–1
Hotel Rooms	1–2
Offices	2–3
Retail Shops	2–3
Schools (except lecture halls)	5–6
Sports Facilities	4–8
Restaurants	6–8

Manager room

For air change method,

Number of air changes per hour = $2 \times Room\ volume$

= $2 \times 5.25 \times 4.25 \times 3$

Number of changes = 133.875 $m3/hr$

Airflow rate Q (L/s) = ACH x Room Volume(m^3/hr) x 1000 / 3600

ACH for room two walls exposed = 1.5

= 1.5 x 5.25 × 4.25 × 3 x 1000 / 3600

Q = 27.89 l/s

$Qsensible$ = 1.23 × 27.89 × (33 – 25)

= 274.4376 W

From psychometric charts,

w_0 = 0.026 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 33C and 80% RH]

wi = 0.015$kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 25C and 60% RH]

$Qlatent$ = 3010 × 27.89 × (0.026-0.015)

= 923.44 W

$Qinfiltratuin = Qlatent + Qsensible$

= 923.44+274.44

= 1197.88 W

Meeting room

For air change method,

Number of air changes per hour = $2 \times Room\ volume$

= $2 \times 7.75 \times 4.25 \times 3$

Number of changes = 197.625 $m3\ /hr$

Airflow rate Q (L/s) = ACH x Room Volume(m^3/hr) x 1000 / 3600

ACH for room two walls exposed = 1.5

= 1.5 x 7.75 × 4.25 × 3 x 1000 / 3600

Q = 41.17 l/s

$Qsensible$ = 1.23 × 41.17 × (33 − 25)

= 405.11W

From psychometric charts,

w_0 = 0.026 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 33C and 80% RH]

wi = 0.015$kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 25C and 60% RH]

$Qlatent$ = 3010 × 41.17 × (0.026-0.015)
= 1363.14 W

$Qinfiltratuin$ = $Qlatent + Qsensible$
= 405.11+1363.14
= 1768.25W

General Office

For air change method,

Number of air changes per hour	=	2 × $Room\ volume$
	=	2 × 7.75 × 7.75 × 3
Number of changes	=	360.38 $m3\ /hr$
Airflow rate Q (L/s)	=	ACH x Room Volume(m^3/hr) x 1000 / 3600
ACH for room two walls exposed	=	1.5
	=	1.5 x 7.75 × 7.75 × 3 x 1000 / 3600
Q	=	75.08 l/s

$Qsensible$ = 1.23 × 75.08 × (33 − 25)
= 738.79 W

From psychometric charts,
w_0 = 0.026 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 33$C\ and$ 80% RH]
wi = 0.015 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 25$C\ and$ 60% RH]

$Qlatent$ = 3010 × 75.08 × (0.026-0.015)
= 2485.90 W

$Qinfiltratuin$ = $Qlatent + Qsensible$
= 738.79+2485.90
= 3224.69 W

Training room

For air change method,

Number of air changes per hour	=	2 × $Room\ volume$
	=	2 × 7.75 × 5.25 × 3
Number of changes	=	244.13 $m3\ /hr$
Airflow rate Q (L/s)	=	ACH x Room Volume(m^3/hr) x 1000 / 3600
ACH for room two walls exposed	=	1.5
	=	1.5 x 7.75 × 5.25 × 3 x 1000 / 3600
Q	=	50.86 l/s

$Qsensible$ = 1.23 × 50.86 × (33 − 25)
= 500.46 W

From psychometric charts,
w_0 = 0.026 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 33C and 80% RH]
wi = 0.015 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 25C and 60% RH]

$Qlatent$ = 3010 × 50.86 × (0.026-0.015)
= 1683.97 W

$Qinfiltratuin$ = $Qlatent + Qsensible$
= 1683.97+500.46
= 2184.43 W

Corridor

For air change method,

Number of air changes per hour	=	2 × $Room\ volume$
	=	2 × 2 × 12 × 3
Number of changes	=	144m3 /hr
Airflow rate Q (L/s)	=	ACH x Room Volume(m^3/hr) x 1000 / 3600
ACH for room two walls exposed	=	1.5
	=	1.5 x 2 × 12 × 3 x 1000 / 3600
Q	=	30 l/s

$Qsensible$ = 1.23 × 30 × (33 − 25)
= 295.2 W

From psychometric charts,
w_0 = 0.026 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 33C and 80% RH]
wi = 0.015 $kg(water)/kg(dry\ air)$ [$for\ and\ outside\ temparature\ of$ 25C and 60% RH]

$Qlatent$ = 3010 × 30 × (0.026-0.015)
= 993.3 W

$Qinfiltratuin$ = $Qlatent + Qsensible$
= 993.3+295.2
= 1288.5 W

HEAT GAIN THROUGH VENTILATION (for whole room, sensible + latent)

Manager room

10 l/s per person ventilation air supply is assumed.

Q = 10 l/s × 3

= 30 l/s

$Qsensible = 1.23 \times Q \times (T_0 - Ti)$

$= 1.23 \times 30 \times (33 - 25)$

$= 295.2\ W$

$Qlatent = 3010 \times Q \times (w_0 - wi)$

= 3010 × 30 × (0.026-0.015) = 993.3 W

Meeting room

10 l/s per person ventilation air supply is assumed.

Q = 10 l/s × 10

= 100 l/s

$Qsensible = 1.23 \times Q \times (T_0 - Ti)$

$= 1.23 \times 100 \times (33 - 25)$

$= 984\ W$

$Qlatent = 3010 \times Q \times (w_0 - wi)$

= 3010 × 100 × (0.026-0.015)

= 3311 W

General Office

10 l/s per person ventilation air supply is assumed.

Q = 10 l/s × 15

= 150 l/s

$Qsensible = 1.23 \times Q \times (T_0 - Ti)$

$= 1.23 \times 150 \times (33 - 25)$

$= 1476\ W$

$Qlatent = 3010 \times Q \times (w_0 - wi)$

= 3010 × 150 × (0.026-0.015)

= 4966.5 W

Training room

10 l/s per person ventilation air supply is assumed.

Q $= 10\ l/s \times 10$
$= 100\ l/s$

$Qsensible = 1.23 \times Q \times (T_0 - Ti)$

$= 1.23 \times 100 \times (33 - 25)$

$= 984\ W$

$Qlatent = 3010 \times Q \times (w_0 - wi)$

$= 3010 \times 100 \times (0.026\text{-}0.015)$

$= 3311W$

ZONAL COOLING LOAD SUMMARY (without infiltration and ventilation)

Show in table 2.16 zonal cooling load summary without infiltration and ventilation

Table 2.16: Zonal cooling load summary

	Total Cooling Load									
	Manager Room		**Meeting room**		**Training room**		**General office**		**Corridor**	
	Sensible	**Latent**	**Sensible**	**Latent**	**Sensible**	**Latent**	**Sensible**	**Latent**	**Sensible**	**Latent**
1300h	5221.64	165	8397.27	550	8427.71	550	14063.43	825	4072.15	0
1400h	6100.41	165	9279.65	550	10696.39	550	15700.25	825	4751.95	0
1500h	6784.7	165	9824.56	550	11334.43	550	16622.92	825	5168.95	0
1600h	7128.17	165	9947.86	550	12659.87	550	16642.98	825	5345.95	0
1700h	7248.42	165	9911.69	550	12855.96	550	16830.84	825	5368.75	0

SUMMARY ON OVERALL SENSIBLE AND LATENT PEAK COOLING DEMAN

Peak sensible cooling demands and peak latent cooling demands for total floor is shown under 1700 hrs. in table 2.17 (without ventilation and infiltration)

Table 2.17: Summary of peak cooling demand

For 17:00 Hour/Peak Hour	Loads in watts			
	Naturally generated (Room) load		Purposely introduced (ventilation) load	
	Sensible	Latent	Sensible	Latent
Roof	18495	0	0	0
Perimeter Wall	4993.82	0	0	0
Glass(Conduction)	1209.6	0	0	0
Glass(Radiation)	4125.06	0	0	0
Partition wall	0	0	0	0
Floor	18495	0	0	0
Occupants	2593.5	2090	0	0
Lights	1124.32	0	0	0
Appliances	1179.36	0	0	0
Infiltration	2213.998	7449.75	0	0
Ventilation		0	3739.2	12581.8
Floor Load	63969.41			
Grand total	80290.41			

SUPPLY AIR TEMPERATURE AND COOLING COIL CAPACITY

Peak load hour is 1700 hrs. Therefore the next calculations are dependent on the value present at 17:00 hrs.

Room sensible heat factor $= \dfrac{Room\ sensible\ load}{Room\ load}$

$= \dfrac{54429.66}{63969.41}$

$= 0.8509$

Grand sensible heat factor $= \dfrac{Room\ sensible\ load + sensible\ ventilation}{Grand\ load}$

$= \dfrac{58168.86}{80290.41}$

$= 0.7245$

Determine supply air quantity (Q)

$$Q = \frac{Room\ Sensible}{1.23 \times (T_R - T_S)}$$

$$Ts = T_R - (1 - BPT) * (T_R - ADP)$$

With the assumption of the number of the cooling coil as 4 and face velocity is 2.5 m/s and 14 pins per inches BPF = 0.1

Use of psychometric chart to find ADP

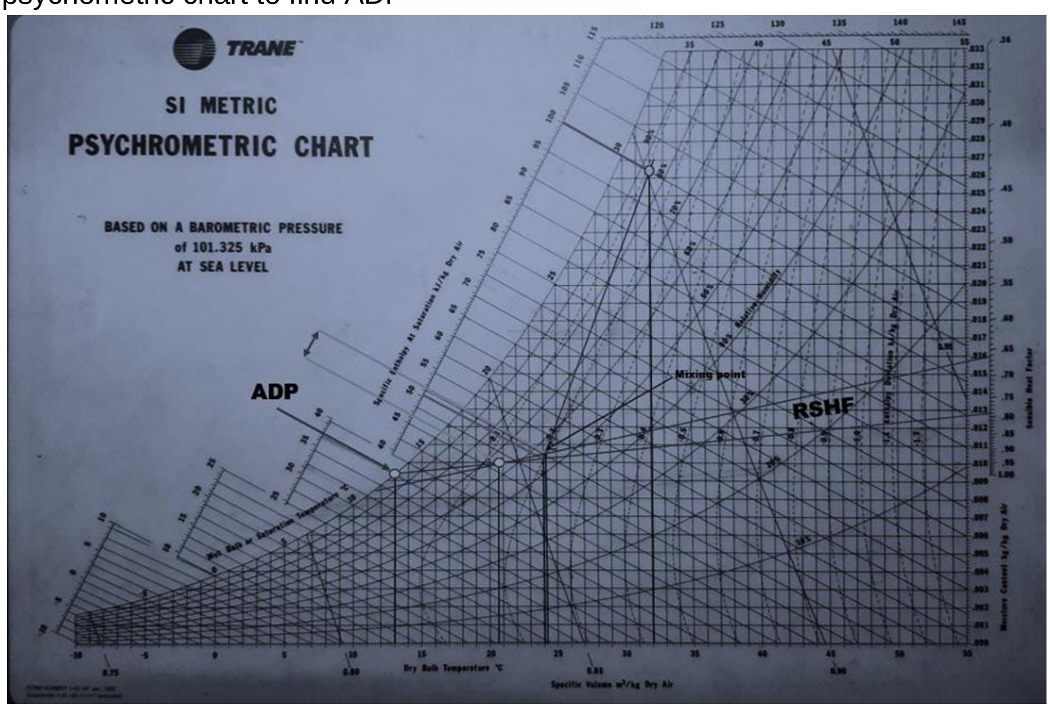

Figure 2.1: Use of psychometric chart

Room condition, 25C, 60% RH

RSH = 0.79
ADP = 17C

$$Ts = TR - (1 - BPT)(TR - ADP)$$
$$Ts = 25 - (1 - 0.1)(25 - 17)$$
$$Ts = 18.7\ C$$

Supply air RH is 90%

Supply air quantity ofr Manager Room,

$$Q = \frac{Room\ Sensible}{1.23 \times (T_R - T_S)}$$

$$= \frac{7248.42}{1.23 \times (25-18.7)}$$

$$Q = 935.40 l/s$$

$$Q = 0.9354\ m3/s$$

	Manager room	Meeting room	Training room	General office	Corridor
Supply Air Quantity	0.9354	1.279	1.659	2.17	0.693

SECTION 3

DUCT LAYOUT

Show in figure 3.1 is the basic duct layout with the necessary dimensions for the air conditioning system for the office room.

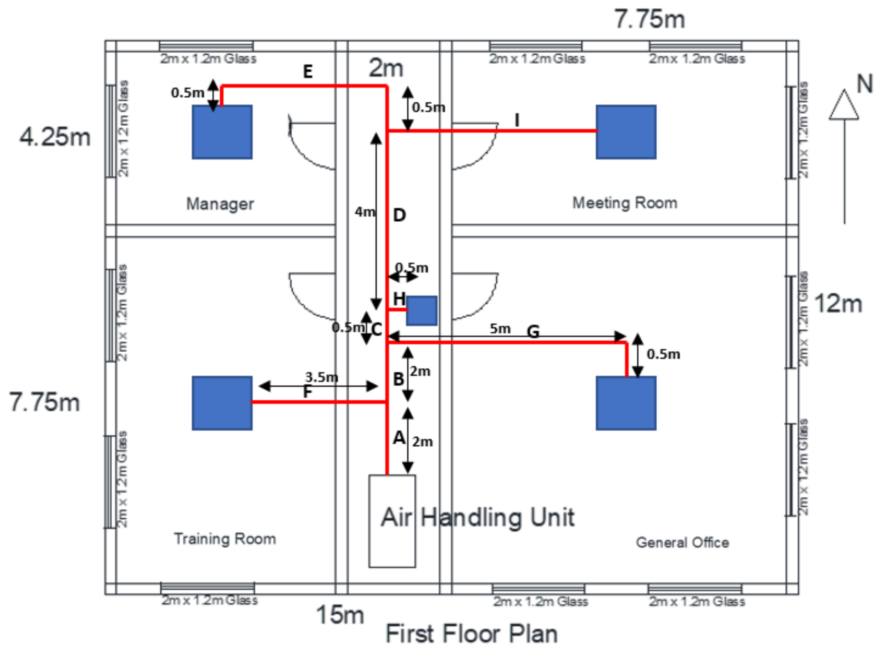

Figure 3.1: Duct layout

AIR FLOW REQUIREMENT FOR EACH THERMAL ZONE

Shown in table 3.1 is the summary of the zonal sensible room cooling load requirement for the peak 1700 hrs.

Table 3.1: Zonal sensible room cooling load requirement at 1700 hrs. peak

Zone	Manager room	Meeting room	Training room	General office	Corridor

Total sensible cooling load without infiltration and ventilation/ W	7248.2	9911.69	12855.96	16642.98	5368.75

To find volumetric flow rate.

$$\dot{m} = \frac{q}{Cp \times \Delta T}$$

$\dot{m}$ - Mass flow rate
q – Room cooling load (kW)
C_p – Specific heat capacity of air (1.026 $kJ/kg.K$)
ΔT – Temperature difference between design supply and design return air temperature

$$\Delta T = T_R - T_S = 25 - 18.7 = 6.3K$$

$$\dot{V} = \frac{\dot{m}}{\rho}$$

$\dot{V}$ - Volumetric flow rate
ρ – Density of air (1.204kg/m^3)

For Manager room,

$$\dot{m} = \frac{q}{Cp \times \Delta T}$$

$$\dot{m} = \frac{7248.42}{1.026 \times 6.3}$$

$$\dot{m} = 1.121 \text{ kg/s}$$

$$\dot{V} = \frac{\dot{m}}{\rho}$$

$$\dot{V} = \frac{1.121}{1.204}$$

$$\dot{V} = 0.93\ m^3/s$$

Similarly, airflow requirement can be calculated for all zones as above. Shown in table 3.2 is the summary of the zonal airflow requirement for the peak hour (1700 hrs.)

Table 3.2: Zonal air flow requirement

Zones	Manager room	Meeting room	Training room	General office	Corridor
q/W	7248.42	9911.69	12855.96	16830.84	5368.75
$\dot{m}$	1.12	1.53	1.99	2.6	0.83
$\dot{v}$	0.93	1.27	1.65	2.16	0.69

DIMENSIONS OF THE DUCT SYSTEM (VELOCITY METHOD)

For upstream section, velocity = 8 m/s
For branches and downstream section, velocity = 5m/s
For H branch, velocity = 4m/s

$$Q = Av$$

Q – volume flow rate
v - velocity
A – area

Decided duct is a circular shape.

$$\frac{\pi d^2}{4} = \frac{Q}{v}$$

$$d = \sqrt{\frac{4Q}{\pi v}}$$

For Manager Room,

$$d = \sqrt{\frac{4 \ x \ 0.93}{\pi \ x \ 8}}$$

$$d = 0.384 \ m$$

Similarly, dimensions of the ducts can be calculated for all sections of the duct design. Shown in table 3.3 are the dimensions of the respective duct sections

Table 3.3: Duct dimensions

Section	Q (m3)	V (m/s)	Diameter (m)
A	6.7383	8	1.0359
B	5.0793	8	0.8993
C	2.9073	8	0.6804
D	2.2145	8	0.5938
E	0.9354	5	0.4882
F	1.6590	5	0.6501
G	2.1720	5	0.7439
H	0.6928	4	0.4697
I	1.2791	5	0.5709

APPENDIX

APPENDIX A

Table 1: CLTD corrected for roof for Colombo conditions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
8	R	4	10.1	7.1	5.1	3.1	2.1	0.1	-0.9	-0.9	1.1	5.1	10.1	17.1			
9																	
10		Hour	13	14	15	16	17	18	19	20	21	22	23	24		-1	
11	Roof Type	1	47.1	50.1	50.1	47.1	42.1	34.1	25.1	15.1	9.1	6.1	4.1	2.1		180	
12		2	42.1	47.1	49.1	48.1	45.1	40.1	32.1	23.1	15.1	9.1	6.1	4.1	U value	2.5	
13		3	33.1	38.1	41.1	42.1	42.1	38.1	34.1	28.1	22.1	18.1	14.1	10.1			
14		4	24.1	31.1	37.1	42.1	44.1	44.1	42.1	38.1	32.1	26.1	20.1	14.1			
15																	
16																	
17																	
18																	
19		Hour	1	2	3	4	5	6	7	8	9	10	11	12			
20	Roof Type	1	0.1	-0.9	-1.9	-2.9	-2.9	-2.9	0.1	7.1	16.1	25.1	33.1	41.1			
21		2	1.1	0.1	-0.9	-1.9	-2.9	-2.9	-1.9	2.1	9.1	18.1	27.1	34.1			
22		3	7.1	4.1	3.1	1.1	0.1	-0.9	0.1	3.1	7.1	13.1	19.1	26.1			
23		4	9.1	6.1	4.1	2.1	1.1	-0.9	-1.9	-1.9	0.1	4.1	9.1	16.1			
24																	
25		Hour	13	14	15	16	17	18	19	20	21	22	23	24			
26	Roof Type	1	46.1	49.1	49.1	46.1	41.1	33.1	24.1	14.1	8.1	5.1	3.1	1.1			
27		2	41.1	46.1	48.1	47.1	44.1	39.1	31.1	22.1	14.1	8.1	5.1	3.1			
28		3	32.1	37.1	40.1	41.1	41.1	37.1	33.1	27.1	21.1	17.1	13.1	9.1			
29		4	23.1	30.1	36.1	41.1	43.1	43.1	41.1	37.1	31.1	25.1	19.1	13.1			
30		Room	Area	1300h	1400h	1500h	1600h	1700h									
31		Manager	22.3125	1790.578	2069.484	2236.828	2292.609	2292.609									
32		Training	40.6875	3265.172	3773.766	4078.922	4180.641	4180.641									
33		Meeting	32.9375	2643.234	3054.953	3301.984	3384.328	3384.328									
34		General	60.0625	4820.016	5570.797	6021.266	6171.422	6171.422									
35		Corridor	24	1926	2226	2406	2466	2466									

Roof CLTD Corrected | Conduction Through walls | Conduction Through glass | Solar Radiation Through Glass | CLF ...

APPENDIX B

Table 2: CLTD corrected for external walls for Colombo conditions

22	NW	9.322222	11.32222	14.32222	16.32222	20.32222	24.32222	28.32222	30.32222	30.32222	26.32222	21.32222	17.32222
23													
24													
25													
26	Hr	1	2	3	4	5	6	7	8	9	10	11	12
27	N	11.1	9.1	8.1	7.1	6.1	5.1	5.1	6.1	7.1	8.1	9.1	11.1
28	NE	8.322222	6.322222	5.322222	4.322222	3.322222	2.322222	2.322222	4.322222	9.32222	14.32222	18.32222	20.32222
29	E	4.988889	2.988889	1.988889	0.988889	-0.01111	-0.01111	-0.01111	1.988889	6.988889	13.98889	19.98889	23.98889
30	SE	1.655556	-0.34444	-1.34444	-2.34444	-3.34444	-3.34444	-4.34444	-3.34444	-0.34444	4.655556	10.65556	15.65556
31	S	2.211111	0.211111	-0.78889	-1.78889	-2.78889	-2.78889	-3.78889	-2.78889	-3.78889	-2.78889	-0.78889	3.211111
32	SW	5.655556	2.655556	0.655556	-1.34444	-2.34444	-3.34444	-4.34444	-4.34444	-4.34444	-3.34444	-1.34444	-0.34444
33	W	10.98889	6.988889	4.988889	2.988889	0.988889	-0.01111	-0.01111	-1.01111	-0.01111	-0.01111	1.988889	2.988889
34	NW	12.32222	9.32222	7.322222	5.322222	4.322222	3.322222	2.322222	2.322222	2.322222	3.322222	4.322222	6.322222
35													
36	Hr	13	14	15	16	17	18	19	20	21	22	23	24
37	N	12.1	14.1	16.1	17.1	18.1	19.1	20.1	20.1	19.1	17.1	16.1	13.1
38	NE	20.32222	20.32222	19.32222	19.32222	19.32222	18.32222	18.32222	16.32222	15.32222	13.32222	11.32222	9.32222
39	E	25.98889	24.98889	22.98889	20.98889	19.98889	17.98889	16.98889	14.98889	12.98889	10.98889	7.988889	6.988889
40	SE	19.65556	21.65556	21.65556	19.65556	18.65556	16.65556	14.65556	12.65556	9.65556	7.655556	5.655556	3.655556
41	S	7.211111	12.21111	15.21111	19.21111	20.21111	19.21111	18.21111	15.21111	13.21111	9.21111	7.211111	4.211111
42	SW	2.655556	5.655556	10.65556	15.65556	21.65556	24.65556	27.65556	27.65556	23.65556	18.65556	13.65556	9.65556
43	W	4.988889	6.988889	10.98889	15.98889	20.98889	26.98889	1.988889	34.98889	31.98889	26.98889	20.98889	15.98889
44	NW	8.322222	10.32222	13.32222	15.32222	19.32222	23.32222	27.32222	29.32222	29.32222	25.32222	20.32222	16.32222

General	Area	1300h	1400h	1500h	1600h	1700h
South	18.45	252.7855	428.0605	533.2255	673.4455	708.5005
East	18.45	911.0405	875.9855	805.8755	735.7655	700.7105

Corridor	Area	1300h	1400h	1500h	1600h	1700h
North	6	137.94	160.74	183.54	194.94	206.34
South	6	82.20667	139.2067	173.4067	219.0067	230.4067

Roof CLTD Corrected | Conduction Through walls | Conduction Through glass | Solar Radiation Through Glass | CLF ...

NE	9.322222	7.322222	6.322222	5.322222	4.322222	3.322222	3.322222	5.322222	10.32222	15.32222	19.32222	21.32222
E	5.988889	3.988889	2.988889	1.988889	0.988889	0.988889	0.988889	2.988889	7.988889	14.98889	20.98889	24.98889
SE	2.655556	0.655556	-0.34444	-1.34444	-2.34444	-2.34444	-3.34444	-2.34444	0.655556	5.655556	11.65556	16.65556
S	3.211111	1.211111	0.211111	-0.78889	-1.78889	-1.78889	-2.78889	-1.78889	-2.78889	-1.78889	0.211111	4.211111
SW	6.655556	3.655556	1.655556	-0.34444	-1.34444	-2.34444	-3.34444	-3.34444	-3.34444	-2.34444	-0.34444	0.655556
W	11.98889	7.988889	5.988889	3.988889	1.988889	0.988889	0.988889	-0.01111	0.988889	0.988889	2.988889	3.988889
NW	13.32222	10.32222	8.322222	6.322222	5.322222	4.322222	3.322222	3.322222	3.322222	4.322222	5.322222	7.322222

Hr	13	14	15	16	17	18	19	20	21	22	23	24
N	13.1	15.1	17.1	18.1	19.1	20.1	21.1	21.1	20.1	18.1	17.1	14.1
NE	21.32222	21.32222	20.32222	20.32222	20.32222	19.32222	19.32222	17.32222	16.32222	14.32222	12.32222	10.32222
E	26.98889	25.98889	23.98889	21.98889	20.98889	18.98889	17.98889	15.98889	13.98889	11.98889	8.988889	7.988889
SE	20.65556	22.65556	22.65556	20.65556	19.65556	17.65556	15.65556	13.65556	10.65556	8.655556	6.655556	4.655556
S	8.211111	13.21111	16.21111	20.21111	21.21111	20.21111	19.21111	16.21111	14.21111	10.21111	8.211111	5.211111
SW	3.655556	6.655556	11.65556	16.65556	22.65556	25.65556	28.65556	28.65556	24.65556	19.65556	14.65556	10.65556
W	5.988889	7.988889	11.98889	16.98889	21.98889	27.98889	2.988889	35.98889	32.98889	27.98889	21.98889	16.98889
NW	9.322222	11.32222	14.32222	16.32222	20.32222	24.32222	28.32222	30.32222	30.32222	26.32222	21.32222	17.32222

Hr	1	2	3	4	5	6	7	8	9	10	11	12
N	11.1	9.1	8.1	7.1	6.1	5.1	5.1	6.1	7.1	8.1	9.1	11.1
NE	8.322222	6.322222	5.322222	4.322222	3.322222	2.322222	2.322222	4.322222	9.32222	14.32222	18.32222	20.32222
E	4.988889	2.988889	1.988889	0.988889	-0.01111	-0.01111	-0.01111	1.988889	6.988889	13.98889	19.98889	23.98889
SE	1.655556	-0.34444	-1.34444	-2.34444	-3.34444	-3.34444	-4.34444	-3.34444	-0.34444	4.655556	10.65556	15.65556
S	2.211111	0.211111	-0.78889	-1.78889	-2.78889	-2.78889	-3.78889	-2.78889	-3.78889	-2.78889	-0.78889	3.211111
SW	5.655556	2.655556	0.655556	-1.34444	-2.34444	-3.34444	-4.34444	-4.34444	-4.34444	-3.34444	-1.34444	-0.34444
W	10.98889	6.988889	4.988889	2.988889	0.988889	-0.01111	-0.01111	-1.01111	-0.01111	-0.01111	1.988889	2.988889

-1						
U value	1.9					
Manager	Area	1300h	1400h	1500h	1600h	1700h
North	13.35	306.9165	357.6465	408.3765	433.7415	459.1065
West	10.35	98.1065	137.4365	216.0965	314.4215	412.7465
Meeting	Area	1300h	1400h	1500h	1600h	1700h
North	18.45	424.1655	494.2755	564.3855	599.4405	634.4955
East	10.35	511.0715	491.4065	452.0765	412.7465	393.0815
Training	Area	1300h	1400h	1500h	1600h	1700h
South	13.35	182.9098	309.7348	385.8298	487.2898	512.6548
West	18.45	174.8855	244.9955	385.2155	560.4905	735.7655
General	Area	1300h	1400h	1500h	1600h	1700h
South	18.45	252.7855	428.0605	533.2255	673.4455	708.5005
East	18.45	911.0405	875.9855	805.8755	735.7655	700.7105
Corridor	Area	1300h	1400h	1500h	1600h	1700h
North	6	137.94	160.74	183.54	194.94	206.34
South	6	82.20667	139.2067	173.4067	219.0067	230.4067

Roof CLTD Corrected | Conduction Through walls | Conduction Through glass | Solar Radiation Through Glass | CLF ...

APPENDIX C

Table 3: CLTD for glass conditions

CLTD for Glass Conduction

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLTD.Corr	2	1	0	0	0	0	0	1	2	3	5	6
Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLTD.Corr	8	8	9	9	8	8	7	5	4	3	3	2

CLTD for Glass Conduction

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLTD.Corr	1	0	-1	-1	-1	-1	-1	0	1	2	4	5
Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLTD.Corr	7	7	8	8	7	7	6	4	3	2	2	1

Corr.CLTD	-1					
U value	6					
Manager	Area	1300h	1400h	1500h	1600h	1700h
North	2.4	100.8	100.8	115.2	115.2	100.8
West	2.4	100.8	100.8	115.2	115.2	100.8
Meeting	Area	1300h	1400h	1500h	1600h	1700h
North	4.8	201.6	201.6	230.4	230.4	201.6
East	2.4	100.8	100.8	115.2	115.2	100.8
Training	Area	1300h	1400h	1500h	1600h	1700h
South	2.4	100.8	100.8	115.2	115.2	100.8
West	4.8	201.6	201.6	230.4	230.4	201.6
General	Area	1300h	1400h	1500h	1600h	1700h
South	4.8	201.6	201.6	230.4	230.4	201.6
East	4.8	201.6	201.6	230.4	230.4	201.6

Roof CLTD Corrected | Conduction Through walls | Conduction Through glass | Solar Radiation Through Glass | CLF ...

APPENDIX D

Table 4: SCL corrected for Colombo conditions

SCL corrected for Colombo (Latitude 8N) conditions

Hr	1	2	3	4	5	6	7	8	9	10	11	12
N	19.8	19.8	15.9	15.9	15.9	97.8	92.6	97.8	109.5	122.5	134.2	138.1
NE	25.4	21.8	21.8	18.2	21.8	282.2	399.8	403.4	331.4	229.4	183.8	176.6
E	27	24	24	21	24	260	409	465	456	390	279	194
SE	17.2	15.25	13.3	11.35	11.35	91.3	166.7	218.05	246.65	246.65	218.05	166.7
S	7.8	7.8	6.6	5.4	5.4	14.2	21.8	27.8	44.2	67	87.4	98.6
SW	16.6	14.2	13	11.8	10.2	17.8	25.4	31.8	35.4	40.6	44.2	71
W	53	46	40	37	34	53	68	84	97	106	112	116
NW	44.6	41	37.4	32.6	29	51.8	74.6	93.8	108.2	120.2	127.4	134.6
Horr	82.6	71.6	65	58.4	54	116.7	234.4	369.7	498.4	605.1	688.7	733.8

Hr	13	14	15	16	17	18	19	20	21	22	23	24
N	142	138.1	130.3	117.3	117.3	138.1	56.2	40.6	31.5	27.6	23.7	23.7
NE	169.4	161	150.2	134.6	116.6	93.8	59	48.2	41	37.4	32.6	29
E	175	163	147	134	116	94	62	53	46	40	37	34
SE	119.9	103.65	95.2	84.8	72.45	58.15	38	31.5	27.6	25.65	21.75	19.8
S	98.6	87.4	67	49.4	40.6	31.8	19	15.4	14.2	11.8	10.2	9
SW	107.4	137.8	155.4	156.6	139	99.8	45.8	34.2	27.8	24.2	20.6	17.8
W	185	308	415	481	490	402	157	109	87	75	65	59
NW	134.6	165.8	275	384.2	445.4	403.4	146.6	97.4	78.2	63.8	55.4	48.2
Horr	743.7	716.2	653.5	553.4	424.7	286.1	182.7	151.9	131	116.7	103.5	92.5

Manager	Area	SC	1300h	1400h	1500h	1600h	1700h
North	2.4	0.75	255.6	248.58	234.54	211.14	211.14
West	2.4	0.75	333	554.4	747	865.8	882

Meeting	Area	SC	1300h	1400h	1500h	1600h	1700h
North	4.8	0.75	511.2	497.16	469.08	422.28	422.28
East	2.4	0.75	315	293.4	264.6	241.2	208.8

Training	Area	SC	1300h	1400h	1500h	1600h	1700h
West	4.8	0.75	666	1108.8	1494	1731.6	1764
South	2.4	0.75	177.48	157.32	120.6	88.92	73.08

General	Area	SC	1300h	1400h	1500h	1600h	1700h
East	4.8	0.75	630	586.8	529.2	482.4	417.6
South	4.8	0.75	354.96	314.64	241.2	177.84	146.16

Roof CLTD Corrected | Conduction Through walls | Conduction Through glass | Solar Radiation Through Glass | CLF ...

APPENDIX E

Table 5: CLF values for occupancy and unhooded equipment for general office applications

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLF	0.08	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.61	0.69	0.75

Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLF	0.79	0.83	0.86	0.89	0.91	0.32	0.26	0.21	0.17	0.14	0.11	0.09

CLF values for Occupancy and Unhooded Equipment (derived from ASHRAE Table 37)

For General Office Application (8 hour office from 0900 hrs to 1700 hrs)

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLF	0.08	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.61	0.69	0.75

Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLF	0.79	0.83	0.86	0.89	0.91	0.32	0.26	0.21	0.17	0.14	0.11	0.09

Sensible Heat

Rooms	N(Occupa)	Sensi.heat	1300h	1400h	1500h	1600h	1700h
Manager	3	75	177.75	186.75	193.5	200.25	204.75
Meeting	10	75	592.5	622.5	645	667.5	682.5
Training	10	75	592.5	622.5	645	667.5	682.5
General	15	75	888.75	933.75	967.5	1001.25	1023.75

Latent heat

Rooms	N(Occu)	Latent	1300h	1400h	1500h	1600h	1700h
Manager	3	55	165	165	165	165	165
Meeting	10	55	550	550	550	550	550
Training	10	55	550	550	550	550	550
General	15	55	825	825	825	825	825

... | Conduction Through glass | Solar Radiation Through Glass | CLF values for general office | Heat load from lights | H ...

APPENDIX F

Table 6: CLF values for lighting for general office applications

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLF	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.72	0.8	0.84

Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLF	0.87	0.88	0.89	0.9	0.91	0.23	0.15	0.11	0.09	0.08	0.07	0.07

Heat load from lights

Rooms	Area	Ligt.Load	FUT	FSA	1300h	1400h	1500h	1600h	1700h
Manager	22.3125	10	0.9	0.88	153.74205	155.5092	157.2764	159.0435	160.8107
Meeting	32.9375	10	0.9	0.88	226.95255	229.5612	232.1699	234.7785	237.3872
Training	40.6875	10	0.9	0.88	280.35315	283.5756	286.7981	290.0205	293.243
General	60.0625	10	0.9	0.88	413.85465	418.6116	423.3686	428.1255	432.8825

CLF values for Lighting

For General Office Application (8 hour office from 0900 hrs to 1700 hrs)

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLF	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.72	0.8	0.84

Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLF	0.87	0.88	0.89	0.9	0.91	0.23	0.15	0.11	0.09	0.08	0.07	0.07

Solar Radiation Through Glass | CLF values for general office | **Heat load from lights** | Heat from des.computer | Zoı ...

CLF values for Occupancy and Unhooded Equipment (derived from ASHRAE Table 37)

For General Office Application (8 hour office from 0900 hrs to 1700 hrs)

Hr	1	2	3	4	5	6	7	8	9	10	11	12
CLF	0.08	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.61	0.69	0.75

Hr	13	14	15	16	17	18	19	20	21	22	23	24
CLF	0.79	0.83	0.86	0.89	0.91	0.32	0.26	0.21	0.17	0.14	0.11	0.09

Rooms	App.Powe	FU	FR	n	1300h	1400h	1500h	1600h	1700h
Manager	200	0.9	0.8	1	113.76	119.52	123.84	128.16	131.04
Meeting	200	0.9	0.8	2	227.52	239.04	247.68	256.32	262.08
Training	200	0.9	0.8	1	113.76	119.52	123.84	128.16	131.04
General	200	0.9	0.8	5	568.8	597.6	619.2	640.8	655.2

Solar Radiation Through Glass | CLF values for general office | Heat load from lights | **Heat from des.computer** | Zoı ...

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Manager Room											
2													
3	1300h	1790.58	1790.58	306.92	98.11	100.8	100.8	255.6	333	177.75	153.74	113.76	5221.64
4	1400h	2069.48	2069.48	357.65	137.44	100.8	100.8	248.58	554.4	186.75	155.51	119.52	6100.41
5	1500h	2236.83	2236.83	408.38	216.1	115.2	115.2	234.54	747	193.5	157.28	123.84	6784.7
6	1600h	2292.61	2292.61	433.74	314.42	115.2	115.2	211.14	865.8	200.25	159.04	128.16	7128.17
7	1700h	2292.61	2292.61	459.11	412.75	100.8	100.8	211.14	882	204.75	160.81	131.04	7248.42
8													
9		Meeting Room											
10													
11	1300h	2643.23	2643.23	424.17	511.07	201.6	100.8	511.2	315	592.5	226.95	227.52	8397.27
12	1400h	3054.95	3054.95	494.28	491.41	201.6	100.8	497.16	293.4	622.5	229.56	239.04	9279.65
13	1500h	3301.98	3301.98	564.39	452.08	230.4	115.2	469.08	264.6	645	232.17	247.68	9824.56
14	1600h	3384.33	3384.33	599.44	412.08	230.4	115.2	422.28	241.2	667.5	234.78	256.32	9947.86
15	1700h	3384.33	3384.33	634.5	393.08	201.6	100.8	422.28	208.8	682.5	237.39	262.08	9911.69
16													
17		Training Room											
18													
19	1300h	3265.17	3265.17	182.91	174.89	201.6	100.8	177.48	73.08	592.5	280.35	113.76	8427.71
20	1400h	3773.77	3773.77	309.73	245	201.6	100.8	157.32	1108.8	622.5	283.58	119.52	10696.39
21	1500h	3773.77	3773.77	385.83	385.22	230.4	115.2	120.6	1494	645	286.8	123.84	11334.43
22	1600h	4180.64	4180.64	487.29	560.5	230.4	115.2	88.92	1731.6	667.5	289.02	128.16	12659.87
23	1700h	4180.64	4180.64	512.65	735.77	201.6	100.8	73.08	1764	682.5	293.24	131.04	12855.96
24													
25		General Office											
26	1300h	4820.02	4820.02	911.04	252.79	201.6	201.6	630	354.96	888.75	413.85	568.8	14063.43
27	1400h	5570.8	5570.8	875.99	428.06	201.6	201.6	586.8	314.64	933.75	418.61	597.6	15700.25
28	1500h	6021.27	6021.27	805.88	533.23	230.4	230.4	529.2	241.2	967.5	423.37	619.2	16622.92
29	1600h	6021.27	6021.27	735.77	673.45	230.4	230.4	482.4	177.84	1001.25	428.13	640.8	16642.98

	P	R	S	T	U
2		Naturally		ventilation	
3	Peak 1700h	Sensible	Latent	Sensibl	Latent
4	Roof	18495			
5	Perimeter wall	4993.82			
6	Glass(Conduction)	1209.6			
7	Glass(Radiation)	4125.06			
8	Partition wall	0			
9	Floor	18495			
10	Occupants	2593.5	2090		
11	Lights	1124.32			
12	Appliances	1179.36			
13	Infiltration	2213.998	7449.75		
14	Ventilation			3739.2	12581.8
15	Floor load				
16	Grand load				
17	Floor load	63969.41			
18	Grand load	80290.41			
22	Sensible	54429.66			
23	Sensible total	58168.86			

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APPENDIX G

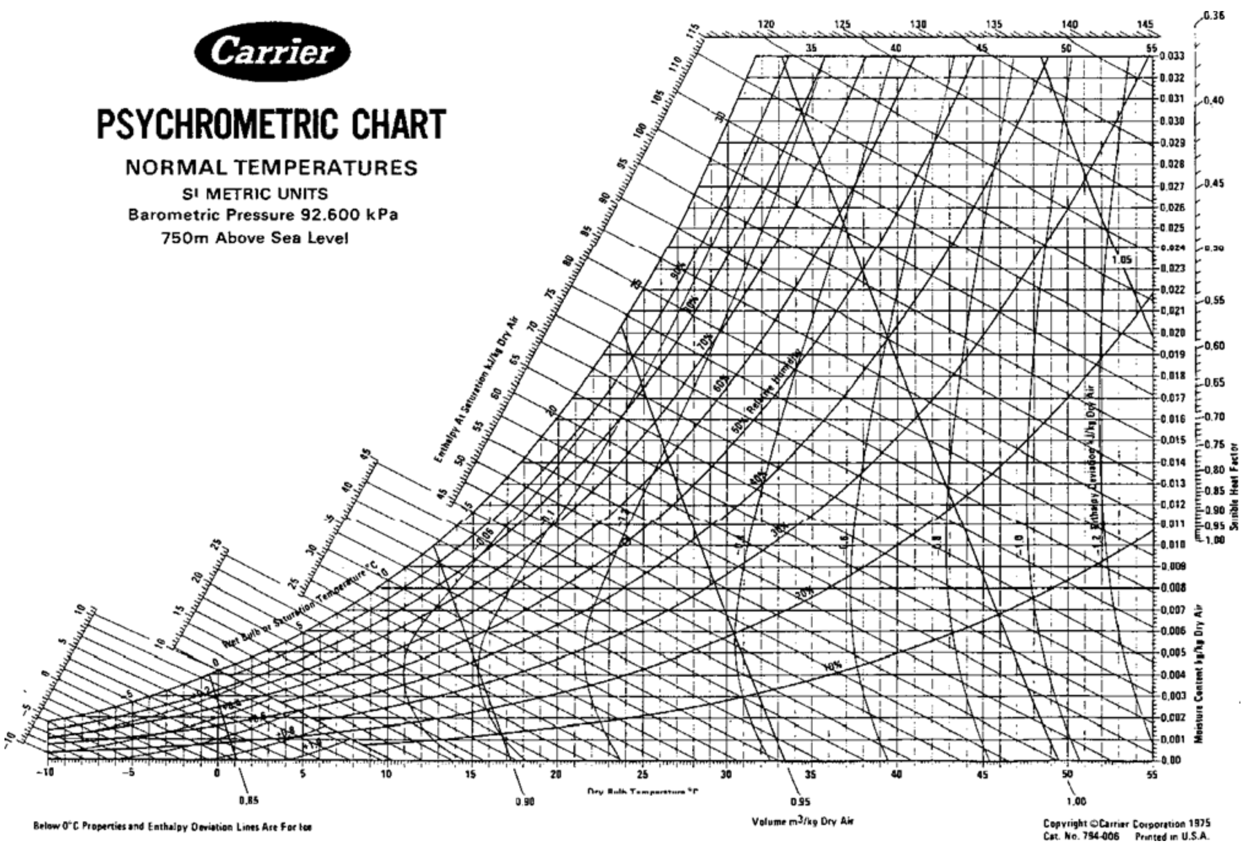

Figure 1: Psychometric chart

APPENDIX H

Table 16: Typical coil bypass factor.

Row Deep	14 fins/inch		
	Face velocity= 2 m/s	2.5 m/s	3 m/s
1	0.52	0.56	0.59
2	0.274	0.31	0.35
4	0.076	0.10	0.12
6	0.022	0.03	0.04

APPENDIX I

Table 17: Duct and joint losses.

ID	Type	Volume Flow rate (m3/s)	Velocity (m/s)	Diameter (m)	Length (m)	ΔP (Pa/m)	Duct loss (Pa)	T joint loss (Pa)
A	Duct	2.663	8	0.651	1.5	1.01	1.515	
N	T joint		5					12
B	Branch	0.369	5	0.306	1	1.05	1.05	
A1	Duct	2.294	5	0.764	1	0.339	0.339	
P	T joint		5					12
C	Branch	0.359	5	0.302	1	1.06	1.06	
D	Duct	1.936	5	0.702	4	0.379	1.516	
Q	T joint		5					12
E	Branch	0.276	5	0.265	1	1.24	1.24	
D1	Duct	1.66	5	0.65	1	0.416	0.416	
R	T joint		5					12
F	Branch	0.266	5	0.26	1	1.28	1.28	
G	Duct	1.394	5	0.596	4	0.461	1.844	
S	T joint		5					12
H	Branch	0.276	5	0.265	1	1.24	1.24	
G1	Duct	1.119	5	0.534	1	0.527	0.527	
T	T joint		5					12
J	Branch	0.266	5	0.26	1	1.28	1.28	
K	Duct	0.853	5	0.466	4	0.624	2.496	
U	T joint		5					12
L	Branch	0.431	5	0.331	1	0.95	0.95	
V	90 bend		5					12
M	Branch	0.421	5	0.328	1	0.951	0.951	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
21	1500h	3773.77	3773.77	385.83	385.22	230.4	115.2	120.6	1494	645	286.8	123.84	11334.43					
22	1600h	4180.64	4180.64	487.29	560.5	230.4	115.2	88.92	1731.6	667.5	289.02	128.16	12659.87			Sensible		54429.66
23	1700h	4180.64	4180.64	512.65	735.77	201.6	100.8	73.08	1764	682.5	293.24	131.04	12855.96			Sensible total		58168.86
24																		
25		General Office																
26	1300h	4820.02	4820.02	911.04	252.79	201.6	201.6	630	354.96	888.75	413.85	568.8	14063.43					
27	1400h	5570.8	5570.8	875.99	428.06	201.6	201.6	586.8	314.64	933.75	418.61	597.6	15700.25					
28	1500h	6021.27	6021.27	805.88	533.23	230.4	230.4	529.2	241.2	967.5	423.37	619.2	16622.92					
29	1600h	6021.27	6021.27	735.77	673.45	230.4	230.4	482.4	177.84	1001.25	428.13	640.8	16642.98					
30	1700h	6171.42	6171.42	700.71	708.5	201.6	201.6	417.6	146.16	1023.75	432.88	655.2	16830.84					
31																		
32		Corridor																
33	1300h	1926	1926	137.94	82.21								4072.15					
34	1400h	2226	2226	160.74	139.21								4751.95					
35	1500h	2406	2406	183.54	173.41								5168.95					
36	1600h	2466	2466	194.94	219.01								5345.95					
37	1700h	2466	2466	206.34	230.41								5368.75					
38																		
39																		
40																		
41																		
42		supply air qua																
43			Manager	935.4007	0.935401													
44			Meeting	1279.093	1.279093													
45			Training	1659.048	1.659048													
46			General	2172.002	2.172002													
47			Corridor	692.8313	0.692831													
48		7.749																
49																		

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	A	B	C	D	E	F	G
47		Corridor		692.8313	0.692831		
48		7.749					
51		Manager	7248.42	6.4638	1121.387	1.121387	0.931384
52		Meeting	9911.69	6.4638	1533.415	1.533415	1.273601
53		Training	12855.96	6.4638	1988.917	1.988917	1.651924
54		General	16830.84	6.4638	2603.862	2.603862	2.162676
55		Corridir	5368.75	6.4638	830.5873	0.830587	0.689857
57		Sec	Q(m3)	V(ms-1)		Dia .Squa	
58		A	6.738374	8	3.369187	1.072989	1.035852
59		B	5.079326	8	2.539663	0.80881	0.899339
60		C	2.907325	8	1.453662	0.46295	0.680404
61		D	2.214493	8	1.107247	0.352626	0.593824
62		E	0.935401	5	0.748321	0.238319	0.488179
63		F	1.659048	5	1.327238	0.422687	0.650144
64		G	2.172002	5	1.737602	0.553376	0.743893
65		H	0.692831	4	0.692831	0.220647	0.469731
66		I	1.279093	5	1.023274	0.325884	0.570862
68			3.14				

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