MECH4880
Refrigeration and Air Conditioning

Assignment 1 Part A

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Executive Summary

This project is to estimate the heat load of two rooms in a two storey retail complex. The project information is given in the specification. Design day is selected to be December 22nd in summer and June 21st in winter since they are the summer and winter solstice.

External load calculation is performed in chapter 3. In order to get that, wall specification must be carried out firstly. Resistance coefficient of ceiling, floor, external wall and internal wall are found out and calculated according to tables in chapter 5 of DA09. In order to fulfil the minimum R-value requirement of BCA, a correction process is executed. The corrected R-value and U-values are listed in the following table.

Surfaces		Uncorrected R-values	Corrected R-values	Corrected U-values
Floor		0.725	1.725	0.580
Ceiling	T.0.6	2.496	3.496	0.286
	MM.0.3	0.588	3.588	0.279
External Wall		W: 0.5055	2.5055	0.399
		S: 0.5085	2.5085	0.399
Internal Wall		0.562	1.062	0.942

Based on the selected materials, the mass of roofs, floors and walls are computed. Then it is able to get the storage load factor.

$$SF_{T06} = 308\ kg/m^2,\ SF_{MM03} = 575.7\ kg/m^2$$

After determining the Equivalent temperature difference, the solar transmission loads from walls and windows in both summer and winter are carried out. Since there is no temperature difference between rooms in the shopping complex, the partition load is zero. The total external loads are found, which is listed below.

Heat Load for External Surface		
Room	Summer(W)	Winter(W)
T.0.6	909	1295
MM.0.3	5951	8890

Internal loads are divided into four parts: people, equipment, lights and infiltration. Computing according to chapter 7 in DA09, the internal loads of the two rooms in summer and winter are found.

Internal Load				
Division	T.0.6		MM.0.3	
	Sensible(W)	Latent(W)	Sensible(W)	Latent(W)
Summer	15313	6238	42576	16709
Winter	8375	9383	20129	23164

At last, the findings are summarized and psychrometric charts for both rooms are drawn. A CAMEL simulation is performed to verify our hand calculation result. The differences are acceptable. The results are listed below.

Season	Rooms	Load	CAMEL	HAND	Difference
Summer	T06	sensible	16471	16222	1.50%
		latent	6741	6238	7.50%
	MM03	sensible	53805	48528	4.90%
		latent	17950	16709	6.90%
winter	T06	sensible	10296	9670	6.10%
		latent	/	9383	/
	MM03	sensible	30850	29019	5.90%
		latent	/	23164	/

Contents

1. Introduction

The aim of this report is to estimate the heating and cooling load for shops in a two storey retail complex in order to design the HVAC system. A detailed calculation is performed to T.0.6 and MM.0.3 for both summer and winter. In addition, a CAMEL simulation is also performed on these two rooms for verification.

The building located in Temperate Town of capital territory, which is at 30° South latitude, climate zone 6. The building has two floors and the layout of first floor is shown in figure 1. The target rooms are Usual Shirts and JB Low-Fi.

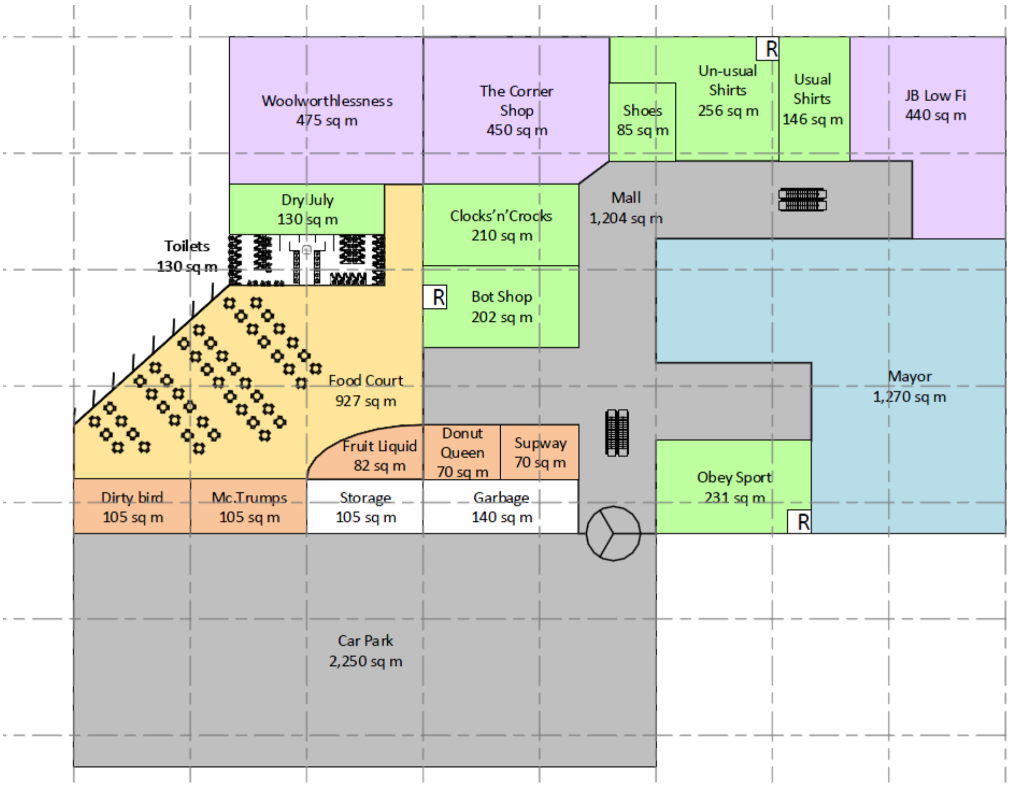


Figure 1: Building Layout

Assumptions are made during this project.

1. The hottest time in a year is 22nd December, while the coldest day is 21st June.
2. 3pm is peak hour. Most customer and equipment loads are seen at this time.
3. The thickness of thin marble is assumed to be 20mm.
4. Steel sash window is utilized, and k1 = 1.1.
5. Haze correction factor k2 is 1 since there is no haze in Australia.
6. The location is at 15 m elevation and the altitude correction factor is 1.
7. Windows are gasketed.
8. The shopping centre opens at 9 am and closed at 8pm.
9. Air pressure is fixed at 101kPa

Other assumptions are made when they are needed in the following section.

2. Design Day Selection and Specification Comprehension

2.1 Design Day Selection

A design day is defined as a day of outside and inside design conditions, when there is no haze in the air to reduce the solar heat and when all of the internal loads are normal. [1] It is selected to be the most severe days in a year in order to make sure the HVAC system is able to provide comfortable room conditions for the whole year. There are two aspects for the working condition, external loads and internal loads. Then it is simplified as the selection of the hottest day in summer and the coldest day in winter.

For our target, which is a shopping centre in southern hemisphere, the hottest day in summer is December 22nd in theory, which is the summer solstice, while the coldest day is the winter solstice, which is June 21st.

7 am is chosen as the coldest time in a day according to Table 14 in DA09, which specifies that the heat gain in 7am in June 21 is zero. According to Occupancy and Operation Profiles of a Class 6 Shop or Shopping Centre in NCC 2016[2], no customer is in the shopping centre at 7am, and leads to the lowest internal load.

According to Table 2 in DA09, which shows the correction of outdoor design temperature for time of a day, the hottest time in a day is 3pm. The quantity of people is also at its peak then.

2.2 Design Conditions

Seen from the specification provided for the task, the external condition for summer is 33.8°C DB, 22.9°C WB, and it is 2.1°C DB, 80%RH for winter. Inserting this information to CAMEL, it is able to get the yearly and daily temperature range, which is shown in Figure1.

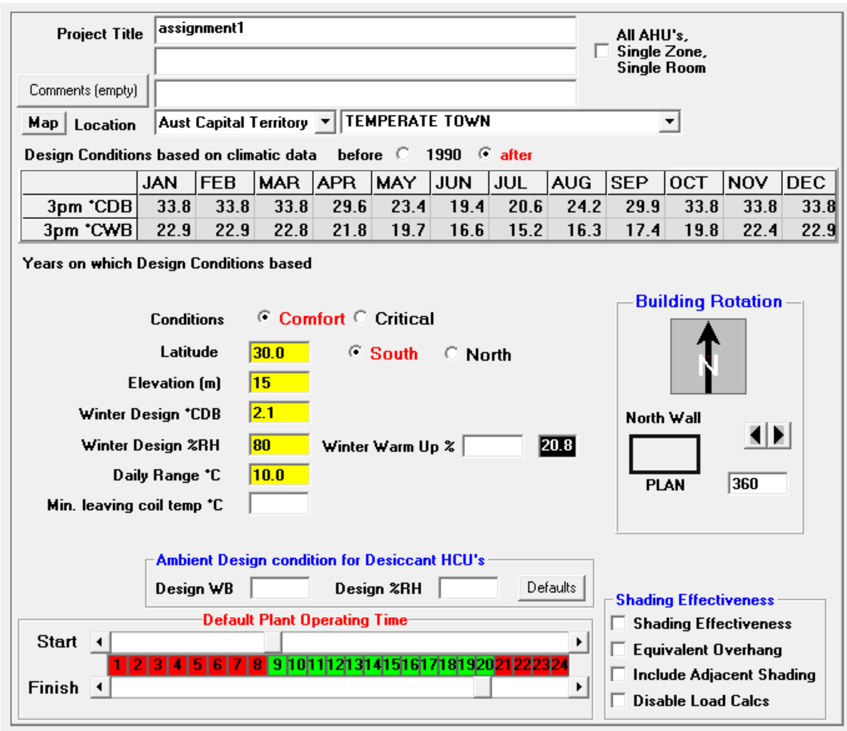


Figure 2: Temperature Range from CAMEL

The yearly range is calculated as:

$$\text{Yearly Range} = 33.8°C - 2.1°C = 31.7°C$$

The external condition need to be corrected according to Table 3 in DA09, which is shown in Table 1 below for this correction.

Table 1: Corrections in Outdoor Design Conditions for Time of Year

Yearly Range	Dry or Wet Bulb	Jan	Feb	Mar	Apr	May	Sep	Oct	Nov	Dec
32°C	Dry-Bulb	0	0	-1	-3	-6	-4	-4	-2	0
	Wet-Bulb	0	0	0	-1	-2	-2	-2	0	0

As seen from the table the corrections for both dry-bulb and wet-bulb are zero in December.

Corrections for time of the day should also be carried out according to Table 2 in DA09. When the daily temperature range is 10°C, It is seen that the corrections for dry-bulb and wet-bulb are both zero in 3pm.

The design conditions are determined then, and shown in the following table.

Table 2: Design Conditions

Design condition	External conditions	Internal conditions	
		T.0.6	MM.0.3
Summer	33.8°C DB/22.9°C WB	23.5°C DB/55%RH	23.5°C DB/55%RH
Winter	2.1°C DB/80%RH	21°C DB/80%RH	21°C DB/80%RH

2.3 Ceiling Space

The ceiling space is the space between the ceiling and the above floor. The ventilation piles and other equipment are arranged in this area.
According to the specification, the ceiling space is:

$$6 - 4.5 = 1.5m$$

The equipment in the ceiling space is not given, thus is not taken into calculation in this project.

2.4 Definition of Terminologies

Some terms such as storage mass, AHU, glazing and partition are significant to be understand before calculating the heat load.

Storage mass is a term of the heat storage effect, which is the effect that part of the instantaneous heat is absorbed by solid surfaces, and to be released later. The heat storage capacity is proportional to the mass of the mass of material.

AHU is a system used to regulate air as part of the HVAC system.

Glazing is the glass part of windows and walls.

Partition is the internal wall between two rooms.

2.5 Temperature range

Based on the discussion in the former part and the calculation in CAMEL shown in figure 1, it is obvious that the yearly temperature range is 31.7°C and the daily range is 10°C.

3. External Loads

3.1 Wall Specifications

U value or transmission coefficient is the rate of heat transferred through a building structure. [1] While R value is the thermal resistance coefficient and it is the inverse of U value.

It takes the following steps to calculate the U value:

- Determine the resistance of each component and air surface;
- Add the resistances together;
- Take the reciprocal. U = 1/R [1]

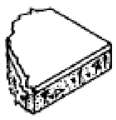
It should be note that the outdoor wind speed would affect the external thin air film coefficient and thus U value. While for the internal side of the walls, the air film is assumed to be still.

3.1.1 Floor (T.0.6 & MM.0.3)

The floor for the two rooms is the same, which is 100mm concrete and 25mm sand/topping with carpet and underlay.

The transmission coefficient for this kind of floor is listed in Table 27 in DA09, which is calculated based on the related resistance listed in Table 37 in DA09. This saved our calculation effort.

Table 3: Transmission Coefficient of Floor (Heat Flow up)

CONSTRUCTION			INTERIOR FINISH		
Description	Thickness mm*	Mass per Unit Area kg/m²*	None	Vinyl Tiles 3 mm (5)	Carpet and Underlay (11)
 Concrete: 100 mm + 25 mm sand and cement topping	125	287	3.14	3.07	1.38
150 mm + 25 mm topping	175	407	2.84	2.78	1.32
300 mm + 25 mm topping	325	767	2.18	2.15	1.16

As seen from Table 3 above, the U value for floor in these two rooms is 1.38 W/m2°C.

3.1.2 Ceiling

For MM.0.3, the ceiling construction is given as bituminous felt roof with 150mm of concrete and 25mm of sand and cements topping and plaster tiles. According to Table33 in DA09, its U values for summer and winter are 1.70 m2°C/W. The corresponding R values are 0.588.

For shop T.0.6, the ceiling structure is shown below.

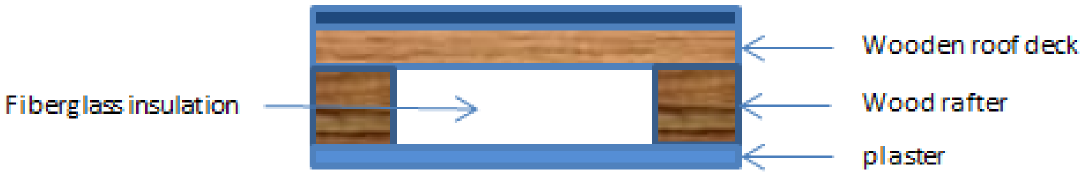


Figure 2: Ceiling structure of T.0.6

The resistance of each ceiling layer is listed in Table 4. The total resistance is calculated as:

$$R_{total} = R_{metal\ deck} + R_{wood\ deck} + R_{parallal} + R_{plaster}$$

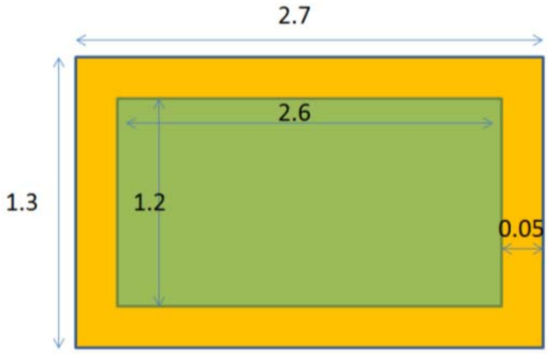


Figure 3: Wood rafter with fiberglass insulation structure

The wood rafter structure is shown below according to AS 1684 2010[3]. Calculating from the structure, area of insulation is 3.12 m2, area of wood rafter is 0.39 m2 and the total area is 3.51 m2. The parallel resistance is then:

$$R_{parallal} = \frac{1}{\frac{A1}{R1} + \frac{A2}{R2}} * A_{total} = \frac{1}{\frac{0.39}{0.722} + \frac{3.12}{3.15}} * 3.51$$
$$= 2.29\ m^2℃/W$$

The total resistance is:

$$R_{total} = 0 + 0.165 + 2.29 + 0.041$$
$$= 2.496\ m^2℃/W$$

The U-value:

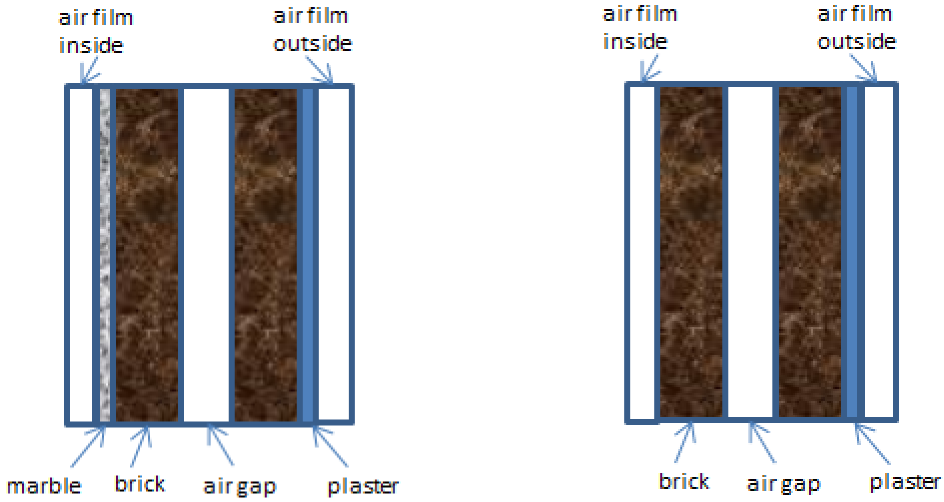
$$U = \frac{1}{R_{total}} = 0.401W/m^2℃$$

Table 4: Resistance properties of ceiling layers

Component	Thickness (mm)	R-values (m^2℃/W)	References
Metal deck	30	0	Table37 Page81 DA09
Wood deck	25	0.165	Table37 Page82 DA09
Wood rafter	100	0.722	Table37 Page82 DA09
Fiberglass	100	3.15	Table37 Page79 DA09
Plaster	15	0.041	Table37 Page78 DA09

3.1.3 External Wall

As given in the specification, the external wall of shop T.0.6 is 2×90mm brick with 60mm air gap + 15mm gypsum plaster + thin marble, while that for MM.0.3 is the same without the marble. Their structures are illustrated below.



Shop T.0.6 *MM.0.3*

Figure 4: External Wall Structure

As seen from Table 4, which is from Table 24 in DA09, the U value for 2×90mm brick with 60mm air gap + 15mm gypsum plaster is 2.02 in winter and 2.01 W/m2°C in summer. The difference is caused by different external wind speed as discussed in chapter 3.1. Taking their reciprocal, the correlated R values are 0.495 and 0.498 m2°C /W respectively. These are the R values for external wall of MM.0.3.

Table 5: Transmission Coefficient of External Wall

CONSTRUCTION				INTERIOR FINISH	
Description		Thickness mm‡	Mass per Unit Area kg/m²‡	None	15 mm Gypsum Plaster (21)
Claybrick 2 × 90 mm brick 60 mm air gap	W S	240 240	346 346	2.12 2.11	2.02 2.01
Claybrick: 2 × 110 mm brick 50 mm air gap	W S	270 270	423 423	1.97 1.96	1.88 1.88

As to shop T.0.6, the thickness of the thin marble is assumed as 15mm. According to Table 37 (p 79) in DA09, its resistivity is 0.77-0.6 m. °C/W. Take 0.7 into calculation, the R value for the thin marble is:

$$R_{marble} = 0.7 * 0.015 = 0.0105 \text{ m}^2\text{°C/W}$$

The external wall resistances for shop T.0.6 are calculated as:

$$\begin{aligned} R_{summer} &= R_{brick,s} + R_{marble} \\ &= 0.498 + 0.0105 \\ &= 0.5085 \text{ m}^2\text{°C/W} \end{aligned}$$

$$
\begin{aligned}
\mathrm{R_{winter}} &= \mathrm{R_{brick,w}} + \mathrm{R_{marble}} \\
&= 0.495 + 0.0105 \\
&= 0.5055\ \mathrm{m^2°C/W}
\end{aligned}
$$

The U-value is:

$$
\begin{aligned}
U_s &= \frac{1}{R_{summer}} \\
&= \frac{1}{0.5085} \\
&= 1.967\ W/m^2°\mathrm{C}
\end{aligned}
$$

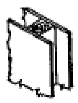
$$
\begin{aligned}
U_w &= \frac{1}{R_{winter}} \\
&= \frac{1}{0.5055} \\
&= 1.978\ W/m^2°\mathrm{C}
\end{aligned}
$$

3.1.4 Internal Wall

The structure of internal wall is shown below in figure 4. It is 12mm plaster board with 100mm air gap.

As seen in Table 26 in DA09, the transmission coefficient for partition of 12 mm plasterboard with 100 mm air inside and still air film on both sides is 1.78 W/m2°C. The chart is shown below in Table 5.

Table 5: Transmission Coefficient of Internal Wall

CONSTRUCTION: Description	Thickness mm*	Mass per Unit Area* kg/m²	INTERIOR FINISH: None	15 mm Gypsum Plaster (21)	12 mm Plaster Board (11)	6 mm Hard-Board (16)	12 mm Hard-Wood (11)
 100 mm air	100	11			1.78	1.51	1.70
50 mm air, 50 mm glass wool	100	14			0.560	0.530	0.550
100 mm glass wool	100	18			0.347	0.336	0.344
Aluminium Foil on one inner surface, and 100 mm of air	100	11			1.27	1.12	1.22

In summary, the U values for shops T.0.6 and MM.0.3 are listed below.

Table 6: R value and U value for all surfaces

Surfaces		R-value(m^2°C/W)	U-value(W/m^2°C)
Floor		0.725	1.38
Ceiling	T.0.6	2.496	0.401
	MM.0.3	0.588	1.7
External Wall		W: 0.5055	W: 1.978
		S: 0.5085	S: 1.967
Internal Wall		0.562	1.78

3.1.5 Correction

To save energy efficiency, BCA provide a minimum R-value for each structure. According to NCC, Table J1.6, the minimum R-value requirement of floor is 1.25 m2°C /W. As seen from Table 5, the R-value for floors of these two rooms is 0.725 m2°C /W. Two piece of insulations whose R-value equals 0.5 are needed to fulfil the minimum requirement. The corrected R-value is 1.725 m2°C /W.

Table 7: Minimum R-value Requirement of Floor

Location	Climate zone							
	1	2	3	4	5	6	7	8
Direction of heat flow	Upwards	Downwards and upwards		Downwards				
(c) A suspended floor with an in-slab or in-screed heating or cooling system where the non-conditioned space is— (i) enclosed; and (ii) where mechanically ventilated by not more than 1.5 air changes per hour	1.25	1.25	1.25	1.25	1.25	1.25	1.75	2.75
(d) For other than (a), (b) or (c)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.5
Note: A subfloor space with not more than 150% of the required subfloor ventilation is considered enclosed.								

As shown in Table 6, the minimum R-value requirement of the ceiling in zone 6 is 3.2 m2°C /W. As calculated in the former part, which is also shown in Table 5, the R-value of T.0.6 ceiling is 2.496. The R-value of MM.0.3 ceiling is 0.588. They are all smaller than the requirement. In this case, insulations with R-value of 0.5 need to be added. For T.0.6, 2 insulations are needed, while for MM.0.3, six insulations are required. Their new R-values are 3.496 and 3.588 m2°C /W respectively.

Table 8: Minimum R-value Requirement of Ceiling/Roof

Climate zone	1, 2, 3, 4 and 5	6	7	8
Direction of heat flow	Downwards		Upwards	
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of not more than 0.4	3.2	3.2	3.7	4.8
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of more than 0.4 but not more than 0.6	3.7	3.2	3.7	4.8
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of more than 0.6	4.2	3.2	3.7	4.8

(b) For compliance with Table J1.3a, roof and ceiling construction is deemed to have the thermal properties listed in Specification J1.3.

(c) Where, for operational or safety reasons associated with exhaust fans, flues or recessed downlights, the area of required ceiling insulation is reduced, the loss of insulation must be compensated for by increasing the R-Value of the insulation in the remainder of the ceiling in accordance with Table J1.3b.

For the external walls. Density is need to be calculated to determine the minimum requirement. The double clay brick structure of this external wall has a density 346 kg/m2. As shown in Table 8, which is a copy of Table J1.5a from NCC 2016 BCA, for a surface density larger than 220 kg/m2, the minimum R-value is 2.3 m^2°C /W. So two pieces of insulation are required for the external wall.

Table 9: Minimum R-value Requirement of External Walls

4, 5 and 6	(a) (i) Achieve a minimum *Total R-Value* of 2.8. (ii) The minimum *Total R-Value* in (i) is reduced— (A) for a wall with a surface density of not less than 220 kg/m^2, by 0.5; and (B) for a wall that is— (aa) facing the south orientation as described in **Figure J2.3**, by 0.5; or (bb) shaded with a projection shade angle in accordance with **Figure J1.5** of— (AA) 30 degrees to not more than 60 degrees, by 0.5; or (BB) more than 60 degrees, by 1.0.
	(b) Where the only space for insulation is provided by a furring channel, top hat section, batten or the like— (i) achieve a minimum *Total R-Value* of 1.4; and (ii) satisfy *glazing* energy index Option B of **Table J2.4a**.

Seen from Table J1.5b, the minimum requirement for internal wall is 1 m2°C /W. So 1 piece of insulation is required for of internal wall.

In summary, the correction for all surfaces is listed below in Table 10.

Table 10: Correction of R-values and U-values

Surfaces		R-values(m^2° C/W)	Increment of Insulation(m^2° C/W)	Corrected R-values	Corrected U-values
Floor		0.725	1	1.725	0.580
Ceiling	T.0.6	2.496	1	3.496	0.286
	MM.0.3	0.588	3	3.588	0.279
External Wall		W: 0.5055	2	2.5055	0.399
		S: 0.5085	2	2.5085	0.399
Internal Wall		0.562	0.5	1.062	0.942

3.1.6 Calculation of Storage Mass

Storage mass for shop T.0.6 and MM.0.3 is calculated below separately.

For shop T.0.6, floor mass is calculated in Table 10. The area of floor is given in the specification.

Table 11: Storage mass of Floor (T.0.6)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
100mm concrete with + 25mm sand/topping + carpet and underlay	125	/	287	146	41902
Batts*2	150	32	/	146	700.8
Total mass (kg)					42602.8

The mass of ceiling is calculated in Table 12 below. The area of ceiling is the same with floor.

Table 12: Storage mass of Ceiling (T.0.6)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
Metal deck	30	78.5	/	146	343.83
Wood deck	25	106	/	146	386.9
Wood rafter& fiberglass	100	177.89	/	146	2597.194
Plaster	15	1121	/	146	2454.99
Batts*2	150	32	/	146	700.8
Total mass (kg)					6483.714

The mass of external wall is calculated and demonstrate in Table 12. Only the north wall of T.0.6 is external wall. It has a length of 9 meters and a 6 meters' height. There is 3m*3m window on the north wall. So the area of external wall is 45 m^2.

Table 13: Storage mass of External Wall (T.0.6)

Component	Thickness (mm)	Density	Mass perunit area (Kg/m2)	Area (m2)	Mass (kg)
2 × 90mm brick with 60mm air gap	240	/	346	45	15570
Plaster	15	1121	/	45	756.675
Marble	20	2700	/	45	2430
Batts*4	300	32	/	45	432
Total mass (kg)					19188.675

The internal wall of T.0.6 is the east, west and the south wall. There should be a door on the south wall, but is neglected here for simplification. The length of the internal wall is 2*16+9, which times the height 6 m, gives the area of 246 m^2. The surface density could be found in Table 4.

Table 14: Storage mass of Internal Wall (T.0.6)

Component	Thickness (mm)	Density	Mass perunit area (Kg/m2)	Area (m2)	Mass (kg)
12mm plaster board + 100mm + 12mm plaster board	124	/	11	246	2706

For MM.0.3, the storage mass is calculated in the same way. The calculation of its floor, ceiling, external and internal wall is carried out in Table 14 to Table 17.

The area of floor and ceiling is given in the specification, which is 440 m^2. The north and east wall is the external wall, the east, south and the south-east corner walls are the internal wall. Their surface areas are calculated according to the layout in the specification. The window on the north and east wall are subtracted.

Table 15: Storage mass of Floor (MM.0.3)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
100mm concrete with + 25mm sand/topping + carpet and underlay	125	/	287	440	126280
Batts*2	150	32	/	440	2112
Total mass (kg)					128392

Storage mass of the ceiling:

Table 16: Storage mass of Ceiling (MM.0.3)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
Bituminous felt roof with 150mm of concrete and 25 mm of sand and cement topping and plaster tiles	187	/	437	440	192280
Batts*6	450	32	/	440	6336
Total mass (kg)					198616

The storage mass of the external wall:

Table 17: Storage mass of External Wall (MM.0.3)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
2 × 90mm brick with 60mm air gap	240	/	346	207	71622
Plaster	15	1121	/	207	3480.705
Marble	20	2700	/	207	11178
Batts*4	300	32	/	207	1987.2
Total mass (kg)					88267.905

The storage mass of the internal wall:

Table 18: Storage mass of Internal Wall (MM.0.3)

Component	Thickness (mm)	Density	Mass per unit area (Kg/m2)	Area (m2)	Mass (kg)
12mm plaster board + 100mm + 12mm plaster board	124	/	11	276	3036

The storage load factor is calculated based on the former mass information. The mass per unit area of floor is calculated firstly. These two rooms both have external walls, so it is:

$$\frac{\text{Mass of outside walls} + 0.5 * (\text{Mass of partitions, floor and ceiling})}{\text{Floor area in room}}$$

For shop T.0.6, it is:

$$\frac{19188.675 + 0.5 * (2706 + 42602.8 + 6483.714)}{146} = 308.8 \text{ kg/m}^2$$

Look into Table 6 of DA09, the storage load factor for the north wall of T.0.6 is 0.54.

For shop MM.0.3, the mass per unit area of floor is:

$$\frac{88267.905 + 0.5 * (3036 + 128392 + 198616)}{440} = 575.7 \text{kg/m}^2$$

The storage load factor for of north wall is 0.59. For the east wall of MM.0.3, it is 0.18

3.2 Solar transmission

The external walls are exposed to sunlight, which brings the heat gain through solar transmission. For this case, the north wall of shop T.06, MM.03 and the east wall of MM.03 will experience solar transmission load. Since these rooms are on the ground floor, their ceilings and internal walls are not exposed to sunlight.

The solar transmission is separated as conduction and solar radiation. For solar radiation:

$$Q = Peak\ solar\ heat\ gain * A * SF * k1 * k2 * k3 * k4 * k5$$

Where SF is the storage factor;

k1 is sash correction factor;

k2 is haze correction factor;

k3 is altitude correction factor;

k4 is dew point correction factor;

k5 is glass factor.

The conduction for external surface is calculated as:

$$Q = U * A * \Delta T_e$$

Where Q is the total heat flow;

U is the U-value of glazing;

A is the area of glazing;

ΔT is the equivalent temperature difference.

3.2.1 Summer

For structures, heat flow through it is unsteady, so an equivalent temperature difference is applied in calculation. The equivalent temperature difference represents a combination of the variable solar radiation and outdoor temperature. The usage of equivalent temperature would decrease its heat load in calculation.

In summer, it is calculated as below for medium color wall:

$$\Delta T_e = 0.7 * \frac{\sigma_s}{\sigma_m} * \Delta T_{em} + \left(1 - 0.7 * \frac{\sigma_s}{\sigma_m}\right) * \Delta T_{es}$$

Where:

σ_s is the maximum solar heat gain of 30° South from Table 14 of DA09;

σ_m is the maximum solar heat gain of 40° South from Table 14 of DA09;

ΔT_{em} is the equivalent temperature in Table 21 from DA09 for exposed wall and roof;

ΔT_{es} is the equivalent temperature in Table 21 from DA09 for shaded wall and roof

When the daily range is 10 °C, there is no need for correction based on table 21 in DA 09.

Looking for Table 21 and 22 in DA09, the surface density is needed. For T.0.6 and MM.0.3, it is 426 kg/m^2. For the north wall, it could be found that for the north wall:

σ_s = 47 W/m^2

σ_m = 88 W/m^2

ΔT_{em} = 12.6 °C

ΔT_{es} = 4.9 °C

$$\Delta T_e = 0.7 * \frac{47}{88} * 12.6 + \left(1 - 0.7 * \frac{47}{88}\right) * 4.9 = 7.78°\text{C}$$

For the east wall of MM.03, it is found that:

σ_s = 44 W/m^2

σ_m = 44 W/m^2

ΔT_{em} = 11.9 °C

ΔT_{es} = 4.9 °C

$$\Delta T_e = 0.7 * \frac{44}{44} * 11.9 + \left(1 - 0.7 * \frac{44}{44}\right) * 4.9 = 9.8°\text{C}$$

Shop T.0.6 has a north wall of 45 m^2, and a 0.399 U value, which could be found in former tables. The heat load is then:

$$Q_{wall} = 0.399 * 45 * 7.78 = 140W$$

For the window on T.0.6, it has an area of 9 m^2 and the U-value I 5.62 according to the given specification. The heat load comes from conduction and radiation.

For conduction:

$$Q_c = 5.62 * 9 * (33.8 - 23.5) = 521W$$

For radiation:

$$Q_r = Peak\ solar\ heat\ gain * A * SF * k1 * k2 * k3 * k4 * k5$$

Where the peak solar heat gain is 47W/m^2 according to Table 14 in DA09

SF = 0.54

Sash correction factor k1 = 1.1

Haze correction factor k2 = 100%

Altitude correction factor k3 = 100%

Dew point correction factor k4 = 1+3/10*0.13=104%

Glass factor k5 = 0.94

This gives:

$$Q_r = 47 * 9 * 0.54 * 1.1 * 100\% * 100\% * 104\% * 0.94 = 248W$$

The solar heat load for shop T.0.6 is:

$$Q_s = Q_{wall} + Q_c + Q_r = 140 + 521 + 248 = 909W$$

For shop MM.0.3, it is calculated in the same way:

The area of north wall is 90 m^2, area of east wall is 117 m^2.

$$Q_{wall} = 0.399 * 90 * 7.78 + 0.399 * 117 * 9.8 = 738.7W$$

The area of window on north wall is 30 m^2, and the area of window on east wall is 39 m^2.

$$Q_c = 5.62 * 69 * (33.8 - 23.5) = 3994W$$

The peak solar heat gain is 47W/m^2 for the north wall and 44 W/m^2 for the east wall.

The SF is 0.59 for the north wall and 0.18 for the east wall.

The window area is 30 m2 for the north wall and 39 m^2 for the east wall.

This gives:

$$Q_r = 47 * 30 * 0.54 * 1.17 * 100\% * 101.4\% * 102.1\% * 0.94 + 44 * 39 * 0.18 * 1.17 * 100\% * 101.4\% * 102.1\% * 0.94 = 1218.6W$$

The total solar heat load is:

$$Q_s = Q_{wall} + Q_c + Q_r = 738.7 + 3994 + 1218.6 = 5951W$$

3.2.2 Winter

There are three significant differences for the external load calculation than summer. The first is obvious that the outdoor temperature is lower than the indoor design temperature. So the heat load is a heat loss rather than heat gain, which is the opposite of summer. The second is the difference of wind speed as discussed in the former section. The third difference is the calculation of temperature difference. In winter the temperature difference is simply Indoor temperature – outdoor temperature rather than the equivalent temperature difference in summer. Since the solar radiation in winter is minimal, the only heat transfer is by conduction of the external wall and window.

$$Q = U * A * \Delta T$$

ΔT = 21-2.1 = 18.9 °C

For shop T.0.6:

$$Q = 0.399 * 45 * 18.9 + 5.62 * 9 * 18.9 = 1295.3W$$

For shop MM.0.3:

$$Q = 0.399 * 207 * 18.9 + 5.62 * 69 * 18.9 = 8890.1W$$

3.2.3 Summary of heat load for External surfaces

The heat loads through the external walls are listed below in Table 18. Note that the heat transferred through external surfaces is not changing the moisture content, which makes it all sensible heat.

Table 17: Heat Load of External Surface

Heat Load for External Surface		
Room	Summer(W)	Winter(W)
T.0.6	909	1295
MM.0.3	5951	8890

3.3 External Loads of Partitions

Partition is the common wall between rooms. The difference between partition and external wall is that partitions are not exposed to sunlight and external environment. So the heat gain of partitions is only through conduction.

The heat load of the partition could be calculated as:

$$Q = U * A * \Delta T$$

For this case, there is no temperature difference between areas. So the heat load for partitions is zero. Since there is no partition load, Table 17 could be seen as to the total external load.

4. Internal Loads

Three sources are included in the calculation of internal loads: people, equipment and lights. Lights only provide sensible heat, while people and equipment give out both sensible and latent heat. Besides this, infiltration is also an important factor.

4.1 Internal Loads in Summer

4.1.1 People

According to the given specification, there are 50 people in shop T.0.6 and 140 people in MM.0.3 during peak hours as we selected 3pm. The sensible and latent heat gain for one person is 70W and 60W in summer according to Table 45 in DA09. Based on Table 13 in DA09, a diversity factor of 0.9 is used in the calculation. The functions are:

$$Q_S = sensible\ heat\ per\ person * number\ of\ people * diversity\ factor$$

$$Q_L = latent\ heat\ per\ person * number\ of\ people * diversity\ factor$$

So for T.0.6:

$$Q_S = 72 * 50 * 0.9 = 3240W$$

$$Q_L = 58 * 50 * 0.9 = 2610W$$

For MM.0.3:

$$Q_S = 72 * 140 * 0.9 = 9072W$$

$$Q_L = 58 * 140 * 0.9 = 7308W$$

4.1.2 Appliances and Equipment

Different kinds of appliances and equipment could generate sensible as well as latent heat. For example, computers contribute sensible heat only, while boilers contribute latent heat as well.

For shop T.0.6, the equipment loads are calculated as follows:

1) Refrigerator 500L -1

$$Q_S = 300 * 1 = 300W$$
$$Q_L = 0W$$

2) Coffee brewer -1

$$Q_S = 600 * 1 = 300W$$
$$Q_L = 300 * 1 = 300W$$

3) Cash register -4

$$Q_S = 48 * 4 = 192W$$

4) Microwave oven -1

$$Q_S = 1400 * 1 = 1400W$$

5) Water cooler -1

$$Q_S = 350 * 1 = 350W$$

For shop MM.0.3, the loads are shown in the following table:

Table 18: Equipment load for MM.0.3 in summer

MM.0.3			
Equipment	number	Sensible(W)	Latent(W)
Coffee machine 5L	1	2500	1100
Microwave oven	1	1400	0
Toaster	1	655	580
Desktop computer	1	180	0
Laptop computer	1	32.5	0
Flat-panel monitor 15''	5	95	0
Flat-panel monitor 30''	10	900	0
Flat-panel monitor 45''	15	1635	0
Flat-panel monitor 60''	10	1800	0
Cash register	4	192	0

The equipment load information is based on the ASHRAE,45’’ and 60’’ plat panel load could not be found in the document. Assumption is made that load of 45’’ is combine of 15’’ and 30, while load of 60’’ equals two 30’’.

4.1.3 Lighting

Lights only generate sensible heat. Similar to the solar transmission, part of the heat is stored and thus correction is required. The heat load is calculated as:

$$Q_S = light\ power * A * SF$$

The storage factor could be found from Table 11 based on the type of light, equipment operating hours, storage mass and number of hours after lights are turned on. Assume that the light operation time is 10 hours, the equipment operating hours are 12 hours, and the lights are turned on at 9am. Note that the design time is 3pm in summer.

For shop T.0.6:

Area= 146 m^2;

Light power= 35 W/m^2

Storage mass = $308.8\ \mathrm{kg/m^2}$

SF is found to be 0.94, and then:

$$Q_S = 35 * 146 * 0.94 = 4803.4W$$

It is calculated in the same way for shop MM.0.3:

$$Q_S = 30 * 440 * 0.92 = 12144W$$

4.1.4 Infiltration

Infiltration is the leakage of outside air into the conditioned space through windows, doors or other openings. It is counted as another internal load, although it is not actually. The infiltration rate could be found according to Table 44 in DA09. It is affected by factors like: exposure, construction, location and type of window and partitioning.

For T.0.6:

The north window is exposed:	+0.5 ch/h
Dry construction:	+0.5 ch/h
Located on 1 wall:	+0 ch/h
Gasketed window:	+0 ch/h
Less than 25% fenestration:	+0 ch/h
Nil partitioning:	+0 ch/h

$$I = \sum I_x = 1\ ch/h$$

Covert it to l/s:

$$I = \frac{1 * 146 * 4.5 * 1000}{3600} = 182.5\ l/s$$

Adding another 200 l/s infiltration from the gate as given in the specification, the total infiltration is:

$$I_{total} = 182.5 + 200 = 382.5\ l/s$$

For MM.0.3:

The window is exposed :	+0.5 ch/h
Dry construction:	+0.5 ch/h
Located on 2 adjacent wall:	+0 ch/h
Gasketed window:	+0 ch/h
More than 25% fenestration:	+0.25 ch/h
Nil partitioning:	+0 ch/h

$$I = \sum I_x = 1.25\ ch/h$$

Covert it to l/s:

$$I = \frac{1.25 * 440 * 4.5 * 1000}{3600} = 687.5\ l/s$$

The total infiltration of MM.0.3:

$$I_{total} = 687.5 + 200 = 887.5\ l/s$$

The sensible and latent heat gain due to the infiltration is calculated as:

$$Q_S = 1.2 * I_{total} * \Delta T$$

$$Q_L = 2.9 * I_{total} * \Delta W$$

ΔT is the temperature difference, while ΔW is the moisture content difference, which is found out from the psychrometric chart.

For shop T.0.6:

$$Q_S = 1.2 * 382.5 * (33.8 - 23.5) = 4728W$$
$$Q_L = 2.9 * 382.5 * (13 - 10) = 3328W$$

For shop MM.0.3:

$$Q_S = 1.2 * 887.5 * (33.8 - 23.5) = 11970W$$
$$Q_L = 2.9 * 887.5 * (13 - 10) = 7721W$$

4.2 Internal Loads in Winter

The internal loads in winter are divided into four parts the same as that in summer: people, equipment, lights and infiltration. But there still exits some key differences. The first difference is the design time. In summer, the design time is 3pm, which is expected to be the hottest time and the maximum internal load including customers, lights and equipment. In winter, it is 7am taken into consideration. At that time, there is no occupant, the lights are off and most of the equipment is switched off. Note that these loads provide heat, so they should be subtracted from the heating load in winter.

Another key difference is that the load for winter is heating load, other than the cooling load in summer. As for infiltration, the temperature difference and moisture content difference are changed to inside minus outside on the opposite of summer.

4.2.1 People

There should have no people in the shop on 7am according to our assumption that the shopping center open from 9am to 8pm. Thus the internal load caused by people for both two shops should be zero.

4.2.2 Appliances and Equipment

Since the shops are not open, most of the equipment is not turned on at 7am. For shop T.0.6, only the 500L refrigerator is on. Same as that in summer, the heat load for the refrigerator is:

$$Q_S = 300 * 1 = 300W$$

For shop MM.0.3, no equipment is turned on at 7am.

4.2.3 Lighting

Lights are not turned on at 7am.

4.2.4 Infiltration

Infiltration load in winter is calculated the same as that in summer:

$$Q_S = 1.2 * I_{total} * \Delta T$$
$$Q_L = 2.9 * I_{total} * \Delta W$$

The difference is that the indoor temperature and moist content are higher than those of outdoor in winter.

The infiltration rates are the same as those in summer, thus the infiltration load for shop T.0.6 is calculated as:

$$Q_S = 1.2 * 382.5 * (21 - 2.1) = 8675W$$
$$Q_L = 2.9 * 382.5 * (12.6 - 3.6) = 9383W$$

For MM.0.3:

$$Q_S = 1.2 * 887.5 * (21 - 2.1) = 20129W$$
$$Q_L = 2.9 * 887.5 * (12.6 - 3.6) = 23164W$$

4.3 Internal Loads in Summary

The internal loads of shop T.0.6 and MM.0.3 for both summer and winter are summarized in the following table.

Table 19: Internal Cooling Load in Sumer

Internal cooling load in summer				
Division	T.0.6		MM.0.3	
	Sensible(W)	Latent(W)	Sensible(W)	Latent(W)
People	3240	2610	9072	7308
Equipment	2542	300	9390	1680
Lights	4803	0	12144	0
Infiltration	4728	3328	11970	7721
Total	15313	6238	42576	16709

Table 20: Internal Heating Load in Winter

Internal heating load in winter				
Division	T.0.6		MM.0.3	
	Sensible(W)	Latent(W)	Sensible(W)	Latent(W)
People	0	0	0	0
Equipment	-300	0	0	0
Lights	0	0	0	0
Infiltration	8675	9383	20129	23164
Total	8375	9383	20129	23164

5. Load Summary and Psychrometric Charts

Throughout all the calculation in the former sections, the external and internal loads for shop T.0.6 and MM.0.3 in both summer and winter are found out. Now it is able to have an integrated understanding of them.

5.1 Load Summary

The total loads for each room are summarized in the following table.

Cooling load in summer is:

Table 21: Total Heating Load in Summer

Cooling Load in Summer				
Load Type	T.0.6		MM.0.3	
	Sensible	Latent	Sensible	Latent
External Load	909	0	5878	0
Internal Load	15313	6238	42576	16709
Total	16222	6238	48454	16709

Heating load in winter is:

Table 22: Total Heating Load in Winter

Heating Load in Winter				
Load Type	T.0.6		MM.0.3	
	Sensible	Latent	Sensible	Latent
External Load	1295	0	8890	0
Internal Load	8375	9383	20129	23164
Total	9670	9383	29019	23164

5.2 Psychrometric Charts

The psychrometric chart is used to demonstrate the thermal properties of air, including dry bulb temperature, wet bulb temperature, moisture content, relative humidity, specific volume, dew point temperature and enthalpy. When the atmospheric pressure is fixed, two given properties are enough to define all the other properties.

5.2.1 Room T.0.6

The outside air and room air condition are defined in the specification.

OA: 33.8°C DB/22.9°C WB

RA: 23.5°C DB/55%RH

The heat loads are calculated in the former section:

Q_S = 16222W

Q_L = 6238 W

Calculate the sensible heat factor:

$$SHF = \frac{Q_s}{Q_s + Q_L} = \frac{16222}{16222 + 6238} = 0.72$$

The minimum temperature of supply air is 12°C. Calculate the supply air mass flow rate:

$$m_s = \frac{Q_s}{C_p * \Delta T} = \frac{16222 * 10^{-3}}{1.02 * (23.5 - 12)} = 1.38\ kg/s$$

Outside air requirement is 10 l/s as given in the specification. Then the outside air mass flow rate is:

$$m_O = \frac{V_O}{v_o} = \frac{10 * 50 * 10^{-3}}{0.8875} = 0.563\ kg/s$$

The ratio of outside air mass to the supply air mass:

$$\frac{m_O}{m_S} = \frac{0.563}{1.38} = 0.408$$

Then it is able to find the mix air point by calculating its moisture content.

$$\frac{W_{MA} - W_{RA}}{W_{OA} - W_{RA}} = \frac{W_{MA} - 10}{13 - 10} = 0.408$$

$$W_{MA} = 11.2\ g/kg$$

The cooling coil efficiency is given by the specification, which is 0.85.

$$\eta_c = \frac{W_{MA} - W_s}{W_{MA} - W_{ADP}}$$

$$0.85 = \frac{11.2 - 8.2}{11.2 - W_{ADP}}$$

$$W_{ADP} = 7.7\ g/kg$$

The apparatus dew point could be found on the psychrometric chart. Based on the chart, the supply air point is on the cooling load line. Therefore no reheat is needed.

Calculate the cooling coil load:

$$Q_{ref} = m_s * (h_{MA} - h_s) = 1.38 * (58 - 33) = 34.5kW$$

The psychrometric chart is shown below.

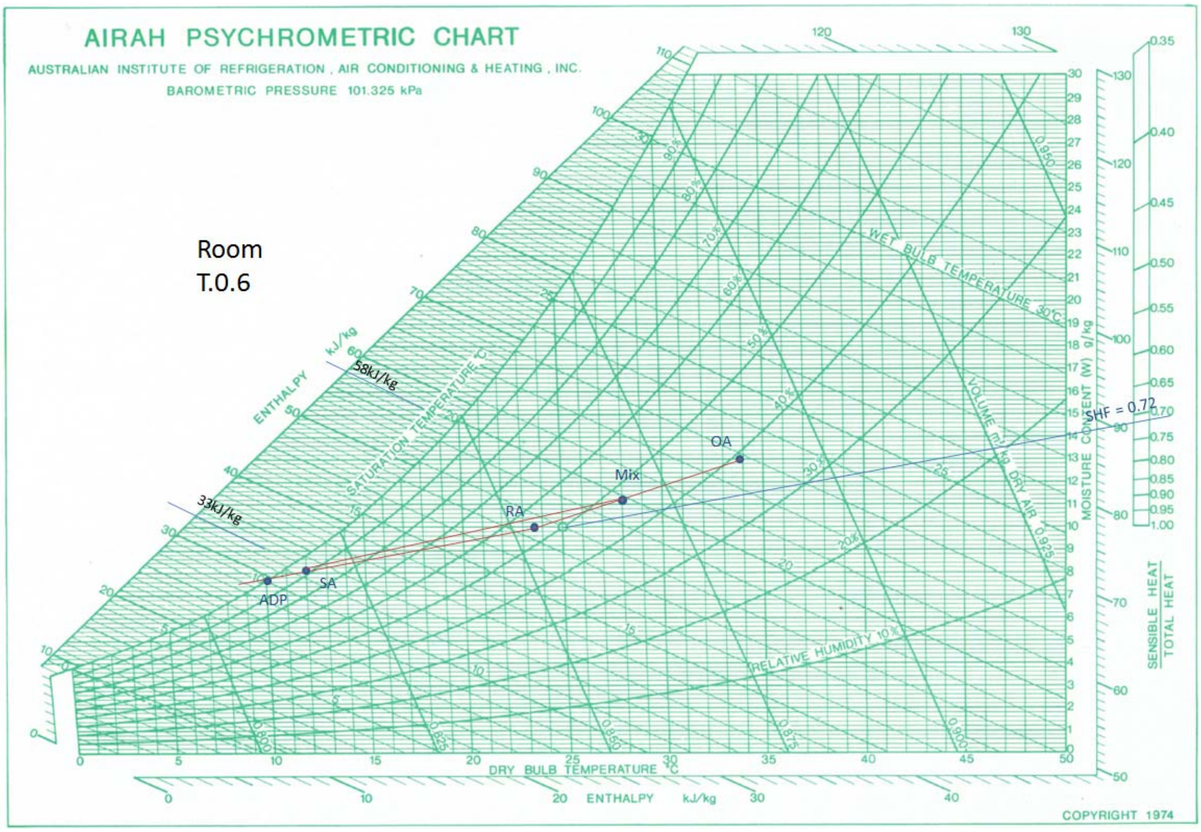


Figure 5: Psychrometric Chart for Room T.0.6

5.2.2 Room MM.0.3

The chart for MM.0.3 is performed in the same way as in T.0.6. Data for MM.0.3 is listed below.

OA: 33.8°C DB/22.9°C WB

RA: 23.5°C DB/55%RH

Q_S = 48454W

Q_L = 16709 W

$$SHF = \frac{Q_s}{Q_s + Q_L} = \frac{48454}{48454 + 16709} = 0.74$$

Supply air mass flow:

$$m_s = \frac{Q_s}{C_p * \Delta T} = \frac{48454 * 10^{-3}}{1.02 * (23.5 - 12)} = 4.13\ kg/s$$

Outside air mass flow:

$$m_O = \frac{V_O}{v_o} = \frac{10 * 140 * 10^{-3}}{0.8875} = 1.58\ kg/s$$

$$\frac{m_O}{m_S} = \frac{1.58}{4.13} = 0.383$$

$$\frac{W_{MA} - W_{RA}}{W_{OA} - W_{RA}} = \frac{W_{MA} - 10}{13 - 10} = 0.383$$

$$W_{MA} = 11.1\ g/kg$$

The cooling coil efficiency:

$$\eta_c = \frac{W_{MA} - W_s}{W_{MA} - W_{ADP}}$$

$$0.85 = \frac{11.2 - 8.3}{11.2 - W_{ADP}}$$

$$W_{ADP} = 7.8\ g/kg$$

Same as T.0.6, no reheat is needed.

The cooling coil load:

$$Q_{ref} = m_s * (h_{MA} - h_s) = 4.13 * (57.5 - 33) = 101.2kW$$

The psychrometric chart is shown below.

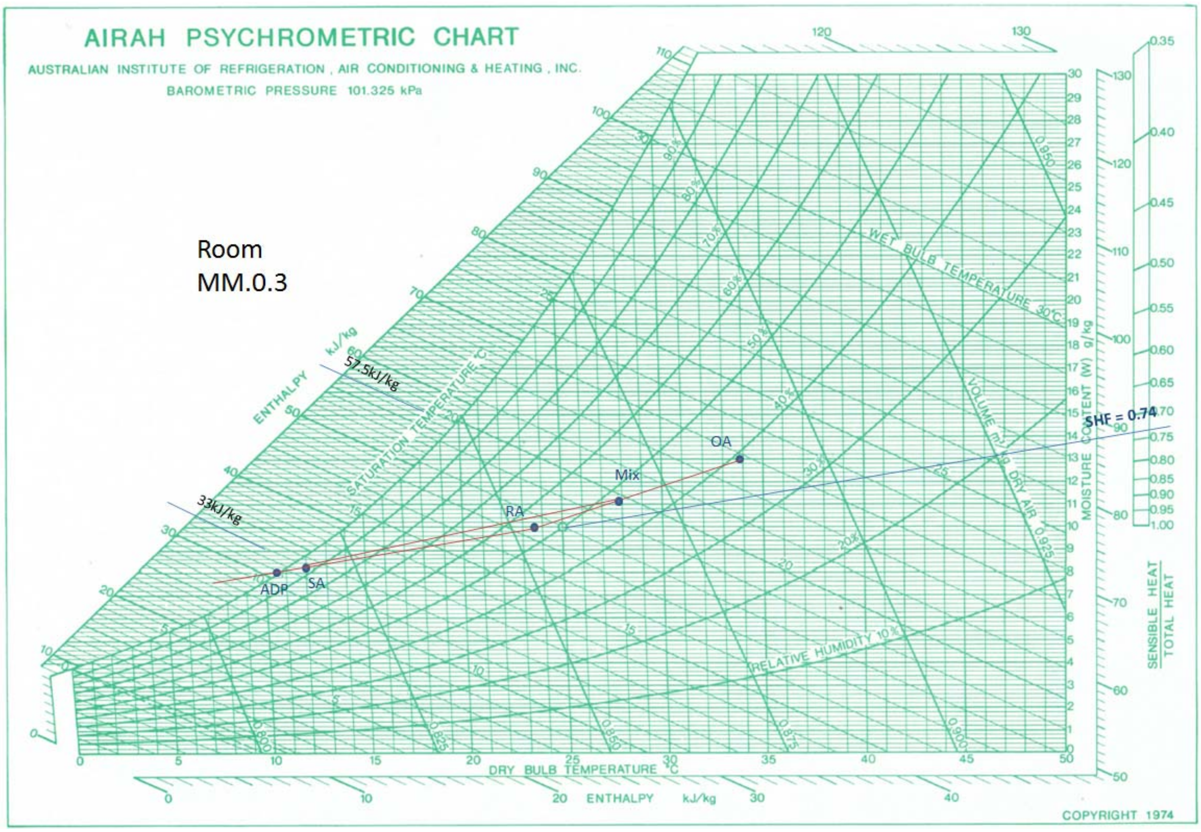


Figure 6: Psychrometric Chart for Room MM.0.3

6. CAMEL simulation

The CAMEL simulation is carried out in this section. Input data are demonstrated in section 6.1, and the simulation report is pasted in appendix A.

6.1 Simulation Process

The outdoor design condition is defined as following figure.

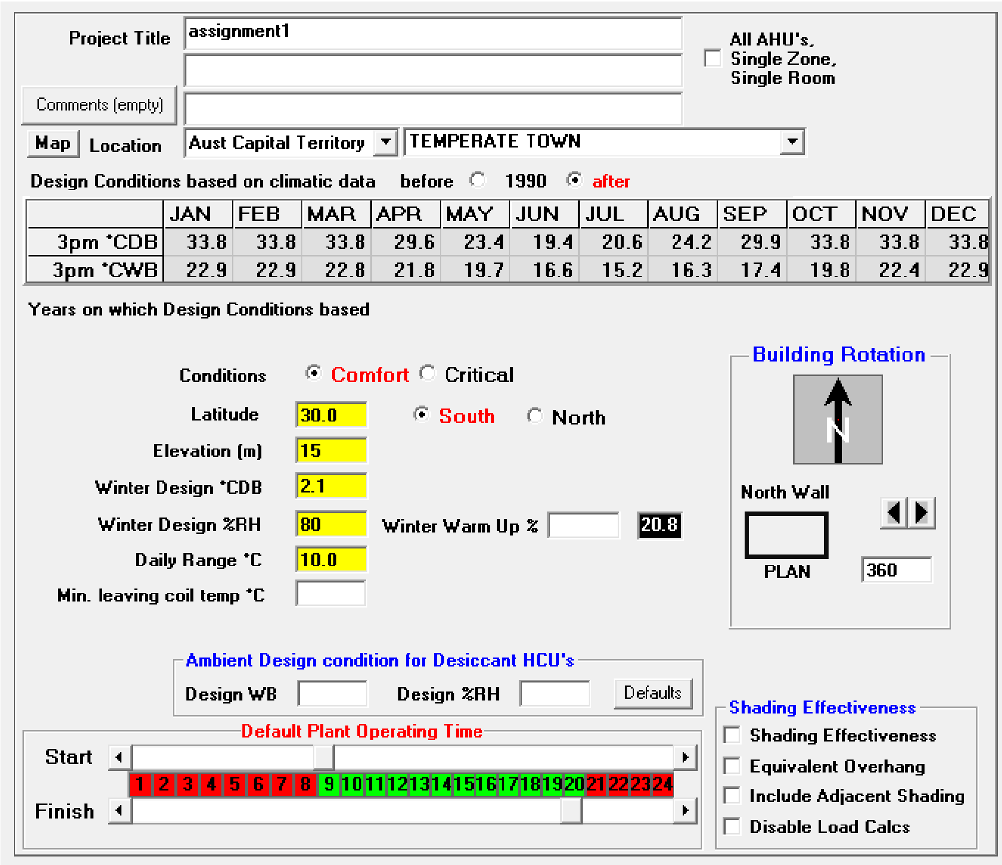


Figure 7: Project Title & Outdoor Design Conditions

The windows are defined as:

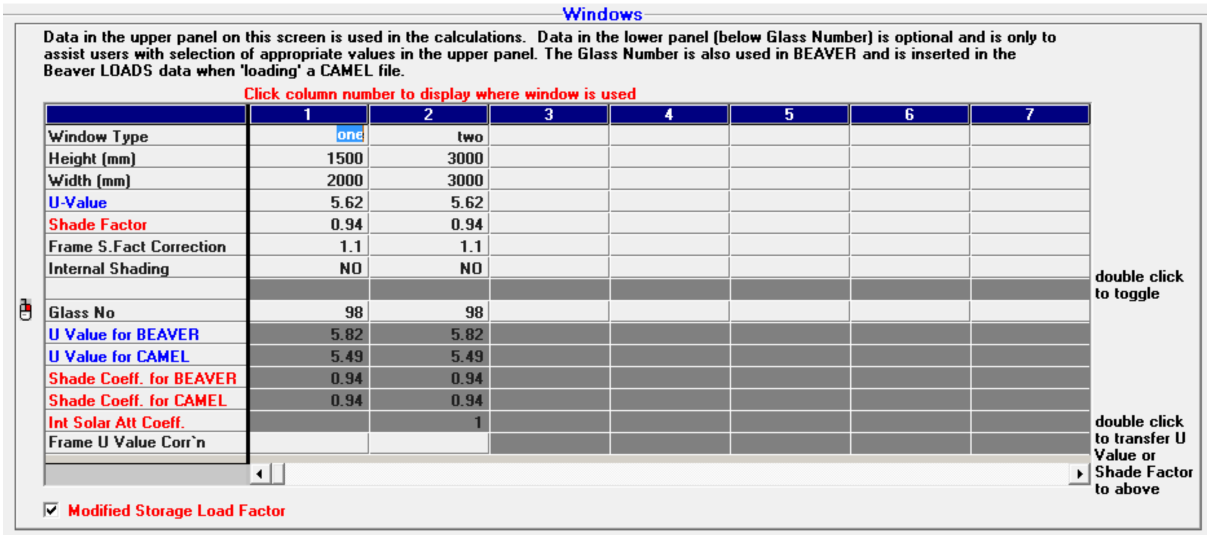


Figure 8: Window Properties

Walls properties are inserted.

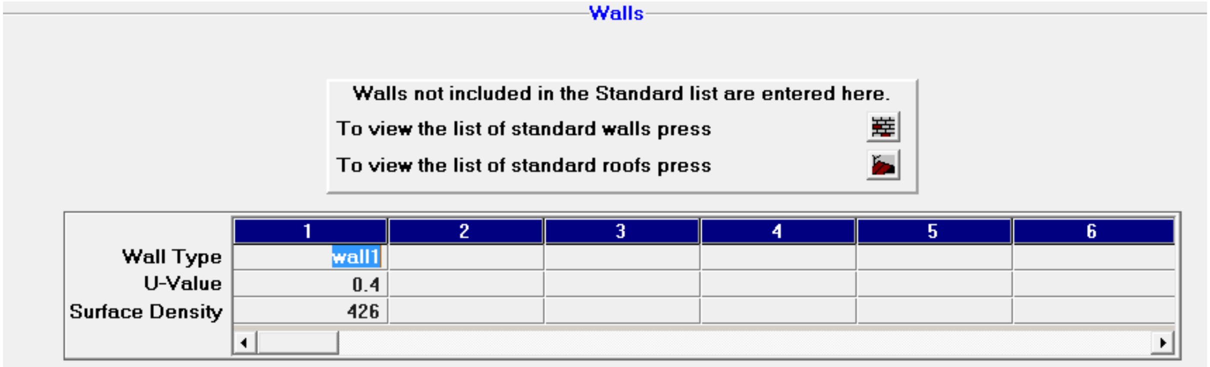


Figure 9: Wall Properties

Indoor design conditions are inserted.

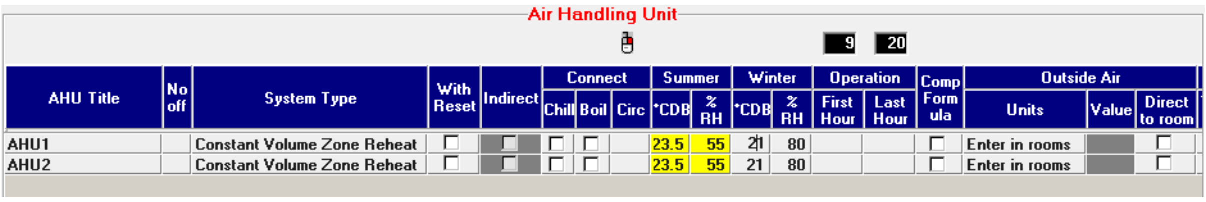


Figure 10: Room Air Design Point

Supply air conditions:

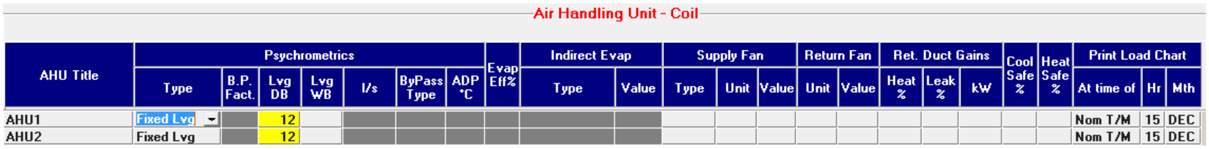


Figure 11: AHU Coil Properties

Room properties:

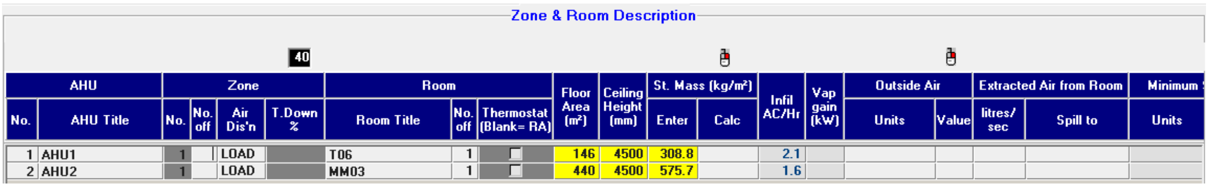


Figure 12: Room Description

External walls' and windows' properties:

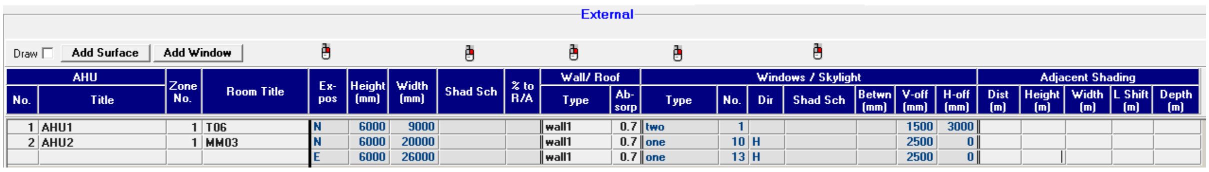


Figure 13: External Properties

Internal loads

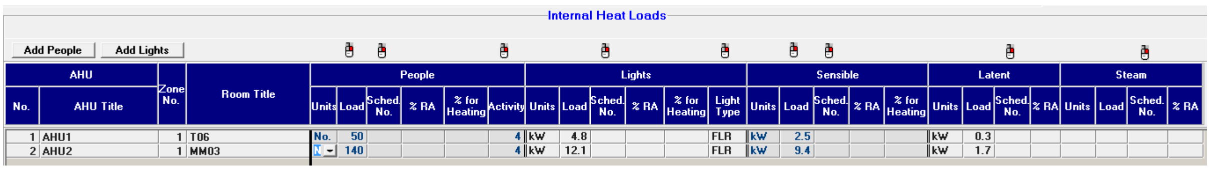


Figure 14: Internal Loads

6.2 CAMEL Results and Comparing

The heat load is summarized below in the table. The full report is shown in appendix A.

As seen from the table, the difference between CAMEL simulation and hand calculation is acceptable. The difference between each division is minimal. The highest difference is seen in radiation and people heat load, which may be caused by different choice of solar gain and diversity factor.

For room T.0.6, the difference in sensible load is:

$$\frac{16471 - 16222}{16471} = 1.5\%$$

The difference of latent load is:

$$\frac{6741 - 6238}{6741} = 7.5\%$$

For room MM.0.3, the difference in sensible load is:

$$\frac{48528 - 46264}{46264} = 4.9\%$$

The difference of latent load is:

$$\frac{17950 - 16709}{17950} = 6.9\%$$

Other reasons for the differences are that:

1. The assumptions made in hand calculation are different from those settings in CAMEL.
2. CAMEL is based on hourly data. Part of them is different from the choices made from DA09 tables.
3. Some numeric errors exist.

Table 23: CAMEL Results and Comparing for T.0.6

T.0.6		**CAMEL**		**Hand Calculation**	
		Sensible	Latent	Sensible	Latent
External	Wall	94	0	140	0
	Radiation	572	0	248	0
	Glass	521	0	521	0
Internal	People	3600	2900	3240	2610
	Appliances	2500	300	2542	300
	Lights	4408	0	4803	0
	Infiltration	4776	3541	4728	3328
Total		16471	6741	16222	6238

Table 24: CAMEL Results and Comparing for MM.0.3

MM.0.3		**CAMEL**		**Hand Calculation**	
		Sensible	Latent		
External	Wall	626	0	739	0
	Radiation	834	0	1219	0
	Glass	3995	0	3994	0
Internal	People	10080	8120	9072	7308
	Appliances	9400	1700	9390	1680
	Lights	10602	0	12144	0
	Infiltration	10967	8130	11970	7721
Total		46264	17950	48528	16709

For the heating load in winter, CAMEL only gives out the sensible load, which is shown below. The latent load is unable to be compared.

The comparing table is shown below. The difference between sensible heat load for T.0.6 is:

$$\frac{10296 - 9670}{10296} = 6.1\%$$

Difference for MM.0.3 is:

$$\frac{30850 - 29019}{30850} = 5.9\%$$

Table 25: Heating Load in Winter

Load Type	camel		hand calculation	
	T06	MM03	T06	MM03
sensible	10296	30850	9670	29019
latent	/	/	9383	23164

7. Conclusion

Throughout the calculation and simulation of the heat load of shop T.0.6 and MM.0.3, a comprehensive understanding of their conditions is gained. The design conditions are listed and explained in chapter 2. Wall specifications and external loads were carried out in chapter 3. Internal load calculation was performed in chapter 4. The overall loads are summarized and verified by CAMEL simulation in chapter 5 and chapter 6.

Based on the result, an efficient HVAC system is able to be designed in the following procedure.

For room T.0.6, the sensible load is 16.2 kW, the latent load is 6.2kW in summer, the cooling coil load is 34.5 kW.

For room MM.0.3, the sensible load is 48.5 kW, while the latent load is 16.7 kW in summer. Its cooling coil load is 101.2 kW.

Some optimization could be performed, such as taking use of more energy efficient appliances, replacing lights with more efficient LED and so on.

References

[1] F. (AIRAH) Wickham, Ed., AIRAH DA09: Air Conditioning Load Estimation, Hill Inc, 1994. 3rd editio. McGraw-
[2] NCC 2016, Section J –Energy Efficiency.
[3] AS 1684.3 Residential Timber Frame Construction, 3rd ed. 2010.

Appendix A

ACADS BSG Program

CAMEL

Version Number 5.11.1

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AHU 1 AHU1

Type ~ CV Zone Reheat without Reset No. Off ~ 1

Connected to ~ Chiller No Boiler No
Floor Area ~ 146 m2 Volume ~ 657.0 m3 Average Ceiling Height ~ 4500. mm

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 24.7 kW AT 3PM MAR

DESIGN COOLING LOAD IS AT PEAK AHU GTH
AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

			CDB	**CWB**	**g/kg**	**%RH**
GTSH	18.2 kW	AVERAGE ROOM AIR	23.5	17.4	9.93	55.0
GTLH	6.57 kW	AHU O/A	33.8	22.8	12.89	
AHU SH FACT	0.73					
SUPPLY AIR	1306 l/s	COIL DEW POINT	10.8		8.06	
AHU O/A	0 l/s	COIL LEAVING AIR	12.0 (N)	11.5	8.24	
DEHUMID AIR	1306 l/s	COIL ENTERING AIR	23.5	17.4	9.93	
AIR ch/hr	7.2	RETURN AIR	23.5	17.4	9.93	
l/s/m2	8.9	AVERAGE ROOM ENT.	12.0	11.5	8.24	
l/s/kW	52.8	BYPASS FACTOR	0.09			
W/m2	169	MIX R/A AND O/A	23.5	17.4	9.93	

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT NOMINATED TIME 3PM DEC

AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

ADJUSTED ROOM SENSIBLE	=	16471
SUM OF ZONE REHEAT	=	1701
ADJUSTED ROOM LATENT	=	6741
ADJUSTED TOTAL HEAT	=	24913
COOLING GRAND TOTAL HEAT	**=**	**24913**
COOLING GRAND TOTAL SENSIBLE HEAT	=	18172
COOLING GRAND TOTAL LATENT HEAT	=	6741

ZONE REHEAT

NO.	kW
1	1.70

AHU 2 AHU2

Type ~ CV Zone Reheat without Reset No. Off ~ 1

Connected to ~ Chiller No Boiler No
Floor Area ~ 440 m2 Volume ~ 1980.0 m3 Average Ceiling Height ~ 4500. mm

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 75.7 kW AT 4PM MAR

DESIGN COOLING LOAD IS AT PEAK AHU GTH
AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

CDB	**CWB**	**g/kg**	**%RH**

GTSH	58.2 kW	AVERAGE ROOM AIR	23.5	17.4	9.93	55.0
GTLH	17.6 kW	AHU O/A	32.8	22.5	12.89	
AHU SH FACT	0.77					
SUPPLY AIR	4180 l/s	COIL DEW POINT	11.5		8.47	
AHU O/A	0 l/s	COIL LEAVING AIR	12.0 (N)	11.8	8.52	
DEHUMID AIR	4180 l/s	COIL ENTERING AIR	23.5	17.4	9.93	
AIR ch/hr	7.6	RETURN AIR	23.5	17.4	9.93	
l/s/m2	9.5	AVERAGE ROOM ENT.	12.0	11.8	8.52	
l/s/kW	55.2	BYPASS FACTOR	0.04			
W/m2	172	MIX R/A AND O/A	23.5	17.4	9.93	

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT NOMINATED TIME 3PM DEC

AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

ADJUSTED ROOM SENSIBLE	=	53805
SUM OF ZONE REHEAT	=	4365
ADJUSTED ROOM LATENT	=	17950

ADJUSTED TOTAL HEAT =	76120
COOLING GRAND TOTAL HEAT =	**76120**
COOLING GRAND TOTAL SENSIBLE HEAT =	58170
COOLING GRAND TOTAL LATENT HEAT =	17950

ZONE REHEAT

NO.	kW
1	4.36

AHU 1 AHU1, Zone 1, Rm 1 T06

ROOM COOLING LOAD CHART AT NOMINATED TIME 3PM DEC

(SUN POSITION ~ ALTITUDE = 49.3 AZIMUTH =268.1)
AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

SOLAR GAIN GLASS (309 kg/m2. Modified storage load factors used)

No	**SUN**	**EXPOSE**	**AREA**	**GAIN**	**FRAME S.FAC**	**DEW**	**STOR**	**SHADE**	**ROOM**		**WATTS**
#1	OFF	0.0	9.00	70	1.10	1.02	.857	0.94	100%	=	572

SOLAR AND TRANSMISSION GAINS WALLS AND ROOFS (Using light wt roof data)

No	**SUN**	**EXPOSE**	**S.DENS**	**ABS**	**AREA**	**T-DIFF**	**UVALUE**	**ROOM**		
#1	OFF	0.0	(426	0.70)	45.00	5.2	0.40	100%	=	94

TRANSMISSION GAIN EXCEPT WALLS AND ROOFS

No	**ITEM**	**AREA**	**T-DIFF**	**UVALUE**	**ROOM**		
#1	GLASS	9.00	10.3	5.62	100%	=	521
	INFILTRATION	383.	10.3	1.21		=	4776

INTERNAL HEAT GAIN

PEOPLE (ACTIV = 4)	50.0	72.	100%	=	3600
LIGHTS (FLR 309 kg/m2)	4800	0.92	100%	=	4408
APPLIANCES	2.5	1000.	100%	=	2500
			ROOM SENSIBLE HEAT	**=**	**16471**

ADJUSTED ROOM SENSIBLE HEAT = 16471

LATENT HEAT GAIN

INFILTRATION	383	3.1	2.97	=	3541
PEOPLE (ACTIV = 4)	50.0	58.	100%	=	2900
APPLIANCES	0.3	1000.	100%	=	300

ROOM LATENT HEAT = 6741

ADJUSTED ROOM LATENT HEAT = 6741

AHU 1 AHU1, Zone 1, Rm 1 T06

ROOM HEATING LOAD CHART

No	EXPOSE	AREA	T-DIFF	UVALUE	WATTS
SENSIBLE					
WALLS AND ROOFS					
#1	0.0	45.0	20.3	0.40 =	367
WINDOWS					
#1	0.0	9.0	20.3	6.10 =	1114
INFILTRATION	383. l/s		20.3	1.21 =	9414
		ROOM SENSIBLE HEAT =			**10896**

AHU 2 AHU2, Zone 1, Rm 1 MM03

ROOM COOLING LOAD CHART AT NOMINATED TIME 3PM DEC

(SUN POSITION ~ ALTITUDE = 49.3 AZIMUTH =268.1)
AHU OPERATING HOURS 9AM TO 8PM. CALCS BASED ON 16 HOURS OPERATION FROM 6AM

SOLAR GAIN GLASS (576 kg/m2. Modified storage load factors used)

No	SUN	EXPOSE	AREA	GAIN	FRAME S.FAC	DEW	STOR	SHADE	ROOM	WATTS
#1	OFF	0.0	30.00	70	1.10	1.02	.762	0.94	100% =	1696
#2	ON	270.0	39.00	70	1.10	1.02	.289	0.94	100% =	834

SOLAR AND TRANSMISSION GAINS WALLS AND ROOFS (Using light wt roof data)

No	SUN	EXPOSE	S.DENS ABS	AREA	T-DIFF	UVALUE	ROOM	
#1	OFF	0.0	(426 0.70)	90.00	5.2	0.40	100% =	188
#2	ON	270.0	(426 0.70)	117.00	9.4	0.40	100% =	438

TRANSMISSION GAIN EXCEPT WALLS AND ROOFS

No	ITEM	AREA	T-DIFF	UVALUE	ROOM	
#1	GLASS	30.00	10.3	5.62	100% =	1737
#2	GLASS	39.00	10.3	5.62	100% =	2258
	INFILTRATION	880.	10.3	1.21	=	10967

INTERNAL HEAT GAIN

PEOPLE (ACTIV = 4)	140.0	72.	100% =	10080
LIGHTS (FLR 576 kg/m2)	12100	0.88	100% =	10602
APPLIANCES	9.4	1000.	100% =	9400

ROOM SENSIBLE HEAT = 46264

ADJUSTED ROOM SENSIBLE HEAT = 46264

LATENT HEAT GAIN

INFILTRATION	880	3.1	2.97 =	8130
PEOPLE (ACTIV = 4)	140.0	58.	100% =	8120
APPLIANCES	1.7	1000.	100% =	1700

ROOM LATENT HEAT = 17250

ADJUSTED ROOM LATENT HEAT = 17250

AHU 2 AHU2, Zone 1, Rm 1 MM03

ROOM HEATING LOAD CHART

No	EXPOSE	AREA	T-DIFF	UVALUE		WATTS
SENSIBLE						
WALLS AND ROOFS						
#1	0.0	90.0	20.3	0.40	=	735
#2	270.0	117.0	20.3	0.40	=	955
WINDOWS						
#1	0.0	30.0	20.3	6.10	=	3715
#2	270.0	39.0	20.3	6.10	=	4829
INFILTRATION	880. l/s		20.3	1.21	=	21615
		ROOM SENSIBLE HEAT			=	**30850**