THE UNIVERSITY OF NEW SOUTH WALES

Faculty of Engineering

MECH4880

Refrigeration and Air Conditioning

Assignment No. 1-A

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Executive Summary

Category	212				213			
	Summer		Winter		Summer		Winter	
Design Day and Time	Jan 21, 3pm		Jun 21, 7am		Jan 21, 3pm		Jun 21, 7am	
External conditions	33.8°C DB / 22.9°C WB		2.1°C DB / 80%RH		33.8°C DB / 22.9°C WB		2.1°C DB / 80%RH	
Internal Conditions	24°C DB / 55%RH		21°C DB / 80%RH		24°C DB / 55%RH		21°C DB / 80%RH	
	Sensible, W	Latent, W	Sensible, W	Latent, W	Sensible, W	Latent, W	Sensible, W	Latent, W
External Load								
Exposed walls	1458	0	2079	0	1834	0	2908	0
Internal walls (partition)	-110	0	55	0	-204	0	102	0
Glass conduction	5589	0	11239	0	4192	0	8428	0
Solar heat gain	6311	0	0	0	4354	0	0	0
Total External Load	13248	0	13372	0	10176	0	11438	0
Internal Load								
People	5600	4450	0	0	7200	7200	0	0
Appliances	9990	3710	2200	0	88891	21748	9600	0
Light	11232	0	0	0	12557	0	0	0
Infiltration	6652	4265	12828	14599	7159	4590	13806	15712
Total Internal Load	33474	12425	15028	14599	115807	33538	23406	15712
Total Load								
Intenal+External	46722	12425	28400	14599	125983	33538	34845	15712
Total Cooling/Heating Load		**59147**		**42999**		**159521**		**50557**
Total Cooling Coil Load, Qref, in kW	**80**					**187**		

Contents

1 Introduction

The company has been contracted for designing the HVAC system for a 2 storey shopping mall with a basement carpark in Temperate Town. Part of the deliverables are calculation of heat loads, preliminary duct design documents and HVAC unit selection for the building.

This report will tackle the part A of the requirement which is cooling and heat load estimation for room 212 and 213 of the said retail complex using manual calculation.

2 Design Conditions

2.1 Specification

Below is the excerpt from the original main specification that is use for the calculation of cooling and heating load for room 212 and 213.

General Details:	
Latitude	30^0 South
Location	Temperate Town, Climate Zone 6
Orientation	Building north is defined as 30^o clockwise from true north
Minimum supply air temperature	12^0C
Cooling coil effectiveness	$\eta_c = 0.85$
Infiltration	For any external entrance to the mall allow 500l/s. For any external entrance to a shop allow 200l/s.

External Conditions:	
Summer	33^0C DB / 22.9 ^{0}C WB
Winter	2.1 ^{0}C DB/80% RH
External Glazing and Skylights	$Food\ court\ façade: U = 5.48\ SHGC = 0.435$ $Skylights: U = 5.26\ SHGC = 0.574$ $All\ other\ glazing: U = 5.62\ SHGC = 0.611$
External Walls, Floors and Roofing	External walls: R=2.6 Floors: R=1.5 Roofing: R=3.2 Absorbance = 0.5 (light colour) Values are as above unless the surface does not compliance with NCC2016 Section J then raise to minimum value as specified by Section J
Storage Mass	Can be assumed as 420 kg/m^2

Internal Conditions:	
Outside Air Requirement	10 $l/s.person$
Internal Walls	Internal Walls and Partitions: R=1 Internal Floors and Ceilings: See External Values are as above unless the surface does not compliance with NCC2016 Section J then raise to minimum value as specified by Section J
Internal Glazing	6mm plate glass as defined in DA 09

For Room 212:

Speciality Shops	
Summer Set Point	24^oC *dry bulb*/55% *RH*
Winter Set Point	21^oC *dry bulb*/80% *RH*
Lighting and Power (applicable to gross floor area)	$35\ W/m^2$
Occupancy	$3.5\ m^2/person$
Percentage of gross floor area assumed to be occupied	70%
Sensible/Latent Load Per person	70W / 60W

For Room 213:

Restaurants	
Summer Set Point	24^oC *dry bulb*/55% *RH*
Winter Set Point	21^oC *dry bulb*/80% *RH*
Lighting and Power (applicable to gross floor area)	$60\ W/m^2$
Occupancy	$1.5\ m^2/person$
Percentage of gross floor area assumed to be occupied	60%
Sensible/Latent Load Per person	80W / 80W

Variations are further discussed on relevant sections. All other details not mentioned here can be found on the main specification (not shown on this report).

2.2 Amendment to the specification and deviation

In amendment Rev. 2, the external temperature for summer is modified to 33.8°C which is applied on the calculation.

For deviation in the same amendment document pertaining to below:

- **Glass Type:** For Part A you can assume all glass (internal and external) as 6mm plate as defined by DA09.

This is not used in the glazing for room 212 and 213 in this report. Both window and external wall will use the same glass material with the U value and SHGC as per the original specification. Density is as per table 37 of DA09 for window glass sheet and thickness of 10mm as per industry standard which is used only in calculation of storage mass. Also, glazing for room 212 and 213 are single vertical glass.

2.3 Assumptions

1. The hottest time of summer is on Jan 21 and coldest time of winter is on Jun 21. Details of design day and time selection is discussed in next section.

2. In summer, cooling load is calculated by the sum of the heat gains inside the room and so heat gain is positive value while heat loss is negative value.
3. In winter, heating load is calculated by the sum of the heat losses inside the room and thus heat loss is positive value while heat gain is negative value.
4. The fan coil unit (FCU) and air handling unit (AHU) is integrated into one unit or has similar function and features and thus only AHU is used in this project.
5. AHU operational hours is 7am to 7pm (12 hours) and lights are turned on for 10 hours (Lights are turned on at 9:00am and turned off at 7:00pm.
6. Exposed type fluorescent lights are used in room 212 and 213.
7. The outdoor design temperature given in the specifications are comfort design temperature and thus the contribution of air vapor pressure to the load is negligible (see DA09 p. 3 No. 3 of Air conditioning load estimate section[1]).
8. Solar radiation during winter is minimal especially in the morning.
9. The wind speed in summer is 3.5m/s and for winter is 7m/s at all directions.
10. External glazing thermal transmission coefficient U and Solar heat gain coefficient (SHGC) is given on the specification. It is assumed that these value includes the resistance attributed by the frame or sash and shading device if there's any.
11. Both window and external wall will use the same glass material with the U value and SHGC as per specification. Density is as per table 37 of DA09 for window glass sheet and thickness of 10mm as per industry standard which is used only in calculation of storage mass. Also, glazing for room 212 and 213 are single vertical glass.
12. The glass walls in the west of both room 212 and 213 are completely shaded as per specification but it can see the sky. In addition, the courtyard adjacent to these walls are partially covered and thus these walls are considered external walls with external air film.
13. The true floor height is 6000mm. The false ceiling to roof or floor above it (for the case of room below 212 and 213) is 1500mm while the ceiling height is 4500mm. Both dimensions are measured slab to slab. The purpose of the drop ceiling is to cover the plenum space which house the air ducting, pipes, and cable try running through it[2].
14. For the partition, it is assumed that the temperature in the adjacent room and the room itself is homogeneous and uniform in the entire space and thus will not use the suggested heat gain/loss equation in DA09.
15. Marble thickness for east wall of 30mm is based on MG C1 Standard code for Granite and Marble Stonework[3].
16. All other material thickness not specified in the specs is based on thickness specified in DA09 tables 24-37 of DA09.
17. Concrete slab for the floor is assumed to be made of crushed rock aggregates 1:2:4 in DA09 table 37 of DA09 which is the typical cement mixed as per commercially available floor slab. In addition, the concrete slab shown in the floor ceiling system in DA09 tables 33-34 has the same density of 2400kg/m3 and is thus assumed to be made of the same material.
18. Carpet underlay is included together with carpet as per construction general practice.
19. Roof rafters spacing of 1.2m and span of 2.6m as per AS1684 2010[4]. Resistance, density and surface density shown in table 4 and 5 of this report are value for the composite material (wood+ fibreglass) and is calculated based on individual component as shown on section 3.1.1 and 3.1.2.
20. The roof is completely insulated and thus no adjustment for the minimum R-value for the roof given by NCC 2016 Table J1.3a[5].
21. Roof/ceiling materials that are not specified in the specs are assigned based on typical roof construction shown in NCC 2016 Spec J1.3 – 2.
22. The ceiling space is assumed to be void and only air space resistance is considered. This is for the reason that the surface area of heat transfer for materials in the ceiling space, i.e.

pipes, ducts and cable trays are minimal compared to the total area and volume occupied by air.
23. No haze in Temperate town for both season.
24. The elevation of the mall location is at sea level.
25. For winter, the design time is at 7:00 am and thus no occupants and consequently lights, appliances and equipment are not in operation except for few appliances that is identified to work continuously, i.e. freezer, display case and ice maker.
26. The cooling capacity can fully accommodate the room load and thus no space temperature swing correction for solar heat gains.
27. The rate of outside air supplied to the room equals the rate of exhaust air leaving the room thus no pressurization occurs in the room. Due to this, no correction due to pressurization for infiltration.
28. The false ceiling is sealed and so for the room volume, only the ceiling height (4.5m) is used.
29. The air pressure is fixed at 101.325kPa.

2.4 Design Day Selection

2.4.1 Summer Design Day

Design day for summer is the period of time wherein the outside condition (haze, temperature) contribute maximum heat to a room and the internal heat generation is at normal loads and thus is used for the design of the air conditioning system to maintain the required indoor temperature and humidity.

Based on the specification, the summer condition is given at 33.8°C DB and 22.9°C WB. To decide for the design day for summer, corrections for the outdoor design temperatures are corrected for time of year and time of day based on Table 3 and Table 2 of DA09 respectively.

To be able to get the correction, yearly range must be calculated.

$$Yearly\ Range = Summer\ dry\ bulb\ temperature - Winter\ dry\ bulb\ temperature$$

$$Yearly\ Range = 33.8°C - 2.1°C \approx 32°C$$

Using this value, the correction data is interpolated from Table 3 of DA09. For example, for Jan corrected dry bulb temperature at the given yearly range of 32 is calculated as follow:

$$Corrected\ Temp\ DB\ for\ Jan = 33.8°C - 0°C = 33.8°C$$

The summary of the outdoor design temperature corrected for each months is shown in Table 1.

Table 1: Outdoor design conditions corrected for time of the year.

Dry bulb									
Yearly Range	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Sep**	**Oct**	**Nov**	**Dec**
32	0	0	-1	-3	-6	-4	-4	-2	0
Corrected Temp DB	**33.8**	**33.8**	**32.8**	**30.8**	**27.8**	**29.8**	**29.8**	**31.8**	**33.8**
Wet bulb									
Yearly Range	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Sep**	**Oct**	**Nov**	**Dec**
32	0	0	0	-1	-2	-2	-2	0	0
Corrected Temp WB	**22.9**	**22.9**	**22.9**	**21.9**	**20.9**	**20.9**	**20.9**	**22.9**	**22.9**

With the above calculation, it is shown that the highest temperature occurs on Jan, Feb and Dec. For this reason, the design day for this project is to be selected on the month of January.

For corrections to outdoor design conditions for time of the day, Table 2 of DA09 is used. Due to the lack of information about the daily average of temperature for Temperate Town in DA09, the data is obtained from Camel at a given location. The daily range of dry bulb temperature for Temperate Town is 10°C. Then the outside design temperature is corrected for the time between 8am to 12mn as shown in below calculation and in Table 2.

$$Corrected\ Temp\ DB\ for\ Jan\ at\ 3pm = 33.8°C - 0°C = 33.8°C$$

Table 2: Outdoor design conditions corrected for time of the day.

		Time (AM)			Time (PM)						
Daily Range (°C)		**8**	**10**	**12**	**2**	**3**	**4**	**6**	**8**	**10**	**12**
	DB	-7	-5	-3	-1	0	-1	-2	-4	-6	-8
10	WB	-2	-2	-1	0	0	0	-1	-1	-2	-3
Corrected Temp DB		**26.8**	**28.8**	**30.8**	**32.8**	**33.8**	**32.8**	**31.8**	**29.8**	**27.8**	**25.8**
Corrected Temp DB		**20.9**	**20.9**	**21.9**	**22.9**	**22.9**	**22.9**	**21.9**	**21.9**	**20.9**	**19.9**

Based on these 2 corrections, we can see that the peak of temperature will be experience at 3pm. Therefore, the **design day and time for summer is selected on the month of January at 3pm.**

2.5 Winter Design Day

The heating load estimation is based on the coldest time of the year and at the time where the internal heat generated is at minimum. This occurs at early in the morning before people arrived in the building and where most equipment/appliance and lights are not operational. For this rationale, **the design day and time for winter is selected on the month of June at 7am** which will be the basis of the heating load calculation.

3 External Loads

In this section, all the transmission loss; conduction, radiation and convection, are discussed. These transmission losses /gains will contribute to the sensible heat inside the room.

3.1 Wall, Roof and Floor Specifications

The minimum R-values is specified in NCC 2016 section J[5] for the wall, roof and floor. Below is the summary of the requirement

Table 3: Minimum R-value for structures as per NCC 2016

Structure	Condition	Minimum R (m2°C/W)	Reference
External wall	SD<220kg/m2	2.8	NCC 2016 Table J1.5a
	SD>220kg/m2 or wall with south exposure	2.3	NCC 2016 Table J1.5a
Internal wall		1	NCC 2016 Table J1.5b
Floor		1.5	NCC 2016 Table J1.6
Roof		3.2	NCC 2016 Table J1.3a

Note that for glass walls, such as the west walls of 212 and 213, the external wall minimum R-value does not apply. Also, in case where the NCC minimum R-values is lower than what is given in the specification, the minimum R-value in the specification will supersede the one prescribed in the NCC 2016.

Below are the layers and corresponding materials use for walls, roof and floors of room 212 and 213. Below figures doesn't include the additional insulation.

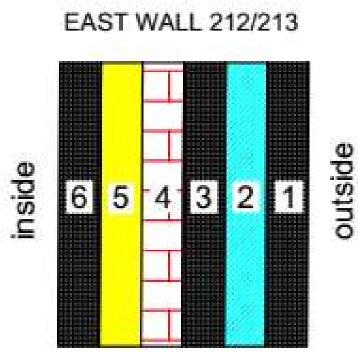


Figure 1

1. External air film
2. Gypsum plaster
3. Air space
4. Brick
5. Thin marble
6. Internal air film

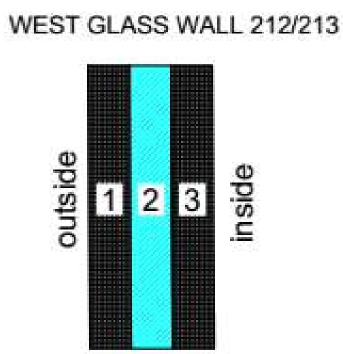


Figure 2

1. External air film
2. Glass
3. Internal air film

*Note the same applies for the windows in South wall of 213 as per amendment revision 2.

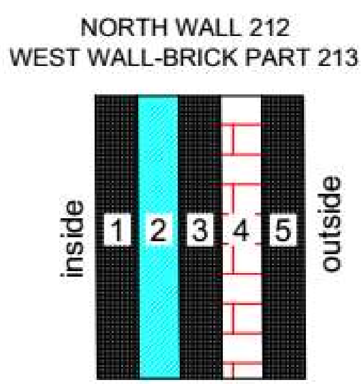


Figure 3

1. Internal air film
2. Plaster
3. Airspace
4. Brick
5. Internal air film

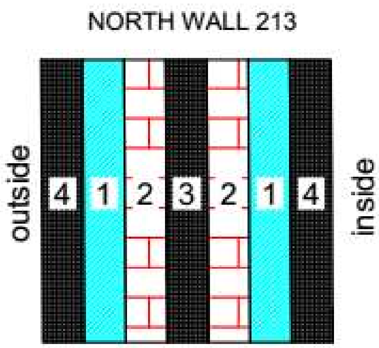


Figure 4

1. Gypsum plaster
2. Brick
3. Air space
4. Internal Air film

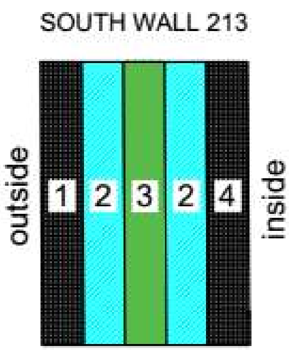


Figure 5

1. External air film
2. Gypsum plaster
3. Crushed rock aggregate
4. Internal air film

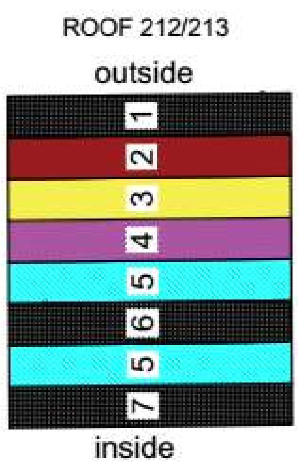


Figure 6

1. External air film
2. Metal deck
3. Wooden deck
4. Rafter-insulation composite layer
5. Gypsum plasterboard
6. Air space
7. Internal air film

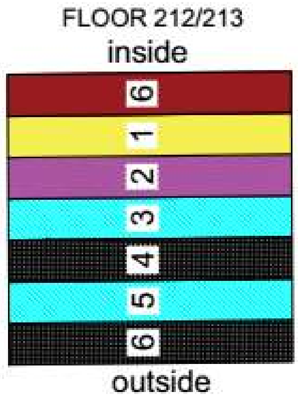


Figure 7

1. Carpet
2. Carpet underlay
3. Concrete slab
4. Airspace
5. Gypsum plasterboard
6. Internal air film

3.1.1 Transmission Coefficient

The transmission coefficient U, also called thermal transmittance, is the rate of heat transfer per unit area of a given structure (Unit is W/m^2°C). Another related constant is the thermal resistance R is a measure of how materials resist heat transfer. The relationship between U and R is given on below equation:

$$U = \frac{1}{R_{total}}$$

Where R_{total} is the total resistance of any wall (or any general surface) to heat flow is the summation of the resistance in each component of the structure. Individual R value of each component is defined by the equation:

$$R = \frac{x}{k}$$

Where x = is the thickness of the material and k is the thermal conductivity thus has the unit of m2°C/W. This should not be confused with the absolute thermal resistance which is an intrinsic property of material and is represented by the equation below and with unit of °C/W.

$$R_a = \frac{x}{kA} = \frac{R}{A}$$

Note for external walls, the U value is different for summer and winter in DA09 and this is because of the different wind speed for the two season as stated in the assumption. The external thin air film will give different R value for summer and winter.

Additionally, still air thin film is assumed to contribute to the total resistance of internal side of the walls (one side for external wall, two sides for internal partition). For this reason, the internal partition's U value is the same for both season.

For roof/ceiling and floor, the horizontal still air film has different resistance depending on the heat flow direction, heat flow up if upper side's temperature is lower than the lower side and heat flow down if upper side's temperature is higher.

3.1.1.1 East Wall -212 and 213 (external wall)

For the east wall of Room 212 and 213, the components are shown in the Figure 1. To calculate the total R value and U value, we use the equation below which is applicable for composite material in series and with the same heat transfer area.

$$R_{total} = R_1 + R_2 + R_3 + .. = \sum R_i$$

The U value in DA09 table 24-25 is for external walls and thus includes still air film inside and external film air (Summer and Winter). Table 37, gives k and R value at a specified thickness of each building material.

Brick veneer wall- in table 25, the U value is 1.96 for summer and 2.02 for winter. The R of brick veneer (summer) is

$$R_1 = \frac{1}{U_1} = \frac{1}{1.96} = 0.510\text{m2°C/W}$$

For winter, R_1 is 0.495m^2°C/W

Marble – k is given in table 37 with a thickness of 30mm (see assumptions).

$$R_2 = \frac{x}{k} = \frac{30 \times 0.77}{1000} = 0.023 \text{ m}^2\text{°C/W}$$

In order to check compliance with NCC 2016 minimum R value

$$R_{total} = R_1 + R_2 \;=\; 0.510 + 0.023 = 0.533$$

The surface density of the composite material is:

$$SD_1 = 222\frac{kg}{m^2}\text{for brick veneer wall}$$

$$SD_2 = \frac{\rho x}{1000} = \frac{2643x3}{1000} = 79.29\; kg/m^2 \text{for marble}$$

Where ρ is the density from table 37.

$$SD_{total} = 222 + 79.29 = 301.29\; kg/m^2$$

Based on Table 3, R minimum is 2.3 so additional insulation is required at an increment of R=0.5. Fiberglass (mineral fiber batts) is to be used for insulation. From table 37,

$$\frac{1}{k} = 31.52$$

So for every R=0.5,

$$x = R * k * 1000 = 0.5 * \left(\frac{1}{31.52}\right) * 1000 = 15.9mm$$

Thus, to meet the minimum R=2.3

$$R_3 = \frac{x}{k} = \frac{(15.9 * 4) \times 31.52}{1000} = 2.005 \text{ m}^2\text{°C/W}$$

The total resistance of the east wall (212&213)

$$R_{total} = R_1 + R_2 + R_3 \;=\; 0.510 + 0.023 + 2.005 = \mathbf{2.538m^2°C/W} \text{ for summer}$$

= 0.495 + 0.023 +2.005 = **2.523m^2°C/W** for winter

$$U = \frac{1}{2.538} = \mathbf{0.394} \quad \mathbf{/m^2°C} \text{ for summer}$$

$$= \frac{1}{2.523} = \mathbf{0.396 W/m^2 {}^{\circ}C} \text{ for winter}$$

3.1.1.2 North wall of 212 (partition)

The north wall of Room 212 is an internal wall; the components are shown in Figure 6.

Brick veneer wall - to calculate the total R value and U value, we use the U value for brick veneer shown again in table 25, same as in east walls. However, as the said U value includes the still air and external air film, the R-value attributed to external air film is deducted. Also, additional R-value of still air is added since both side of the wall will have thin air film.

$$R_1 = \frac{1}{U_1} = \frac{1}{1.96} = 0.510 \text{m2°C/W}$$

For winter, R_1 is 0.495m^2°C/W

External air film:

R_2= 0.044 m^2°C/W for summer

= 0.030 m^2°C/W for winter

Internal air film:

R_3 = 0.120 m^2°C/W

Fiberglass (mineral batt) – for additional insulation to meet NCC requirement of minimum R=1.0. Calculation of R is same as in the east walls but with thickness of 15.9 (R=0.5)

R_4 = 0.501 m^2°C/W

So for north wall of 212,

$$R_{total} = R_1 - R_2 + R_3 = 0.510 - 0.044 + 0.120 + 0.501 = \mathbf{1.087 m^2 {}^{\circ}C/W}$$ (same for summer and winter)

$$U = \frac{1}{1.087} = \mathbf{0.920 W/m^2 {}^{\circ}C}$$

3.1.1.3 Roof (212/213)

The roof composition is as shown in Figure 7.

Rafters and insulation layer

A different approach is done for the calculation of the R value of the composite layer of rafters and insulation. The rafters and insulation layer is designed like a mesh or chessboard-like frame of wood and fiberglass. Rafters spacing of 1.2m and span of 2.6m is as per AS 1684 2010[4]. To get the R-value of the composite layer, use the absolute thermal resistance. The resistivity value (1/k) is from DA09 table 37. Oak timber is assumed to be the material for the rafters.

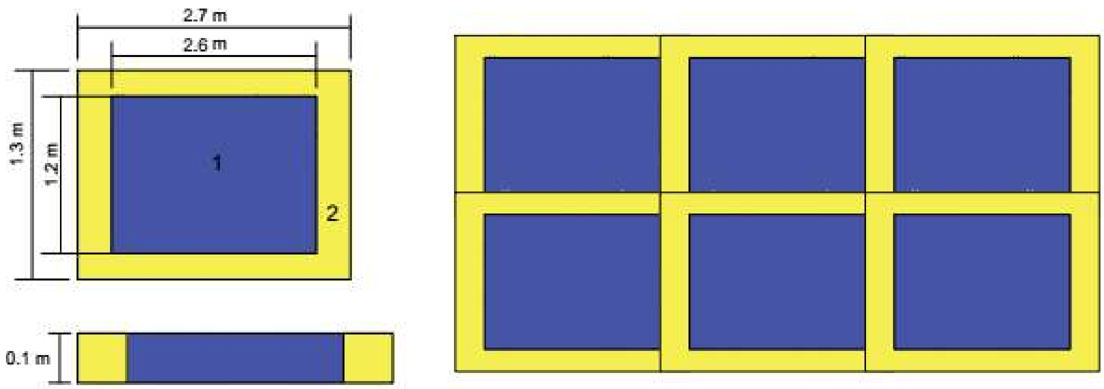


Figure 8: Rafter and insulation composite layer, 1-fiberglass and 2-oak timber

Fiberglass data (insulation):

x_1 = 0.1m

A_1 = 1.2*2.6 = 3.12m^2

$1/k_1$ =31.52 m°C/W

Oak timber (rafters):

X_2 = 0.1m

A_2 = 1.3*2.7-1.2*2.6 = 0.39m^2

$1/k_2$ =6.25m°C/W

$$\frac{1}{R_a} = \frac{1}{R_{a1}} + \frac{1}{R_{a2}} = \frac{A_1}{x_1(\frac{1}{k_1})} + \frac{A_2}{x_2(\frac{1}{k_2})}$$

$$\frac{1}{R_a} = \frac{3.12}{0.1 * 31.52} + \frac{0.39}{0.1 * 6.25} = 1.6138$$

$$R_a\text{=0.620°C/W}$$

$$R_{composite} = R_a A_{total} = 0.62 * (3.12 + 0.39)$$

$$R_{composite} = R_8 = 2.175\text{m}^2\text{°C/W}$$

Other layers

Metal deck (mild steel): R_1 = 1.05x10^{-5} m^2°C/W

Wood deck (fibre and pulp boards): R2 = 0.423 m^2°C/W

Gypsum plasterboard (insulation support): R3 = 0.071 m^2°C/W

1.5 m air space (dropped ceiling space): R4 = 3.255 m^2°C/W

Gypsum plasterboard (false ceiling): R5 = 0.071 m^2°C/W

Still air: R6 = 0.162m^2°C/W summer (heat flow down)

= 0.107m^2°C/W winter (heat flow up)

External air film: R7 = 0.044 $m^2°C/W$ summer

= 0.030 $m^2°C/W$ winter

$$R_{total} = R_1 + R_2 + R_3 + .. = \sum R_i$$

$$R_{total} = 1.05x10^{-5} + 0.423 + 0.071 + 3.255 + 0.071 + 0.162 + 0.044 + 2.175 \text{ (summer)}$$

$$R_{total} = \mathbf{6.20m^2°C/W} \quad U = \mathbf{0.161}\boldsymbol{W}\mathbf{/m^2°C} \text{ (summer)}$$

$$R_{total} = 1.05x10^{-5} + 0.423 + 0.071 + 3.255 + 0.071 + 0.107 + 0.030 + 2.175 \text{ (winter)}$$

$$R_{total} = \mathbf{6.13m^2°C/W} \quad U = \mathbf{0.163W/m^2°C} \text{ (winter)}$$

3.1.1.4 Other structures

For other structures; walls (external and internal), windows and roofs/ceilings, same equations are used and the result is summarized in Table 4 and5.

Table 4: Calculation of R, U and surface density of Room 212

Building Structure	Construction materials	Qty	Area, m2	Density, kg/m3	Thickness, mm	Surface density (Mass/area)	R, m2°C/W		U, W/m2°C		Ref
						kg/m2	Summer	Winter	Summer	Winter	
Room 212											
East Wall	Brick veneer 110mm block with 150 mm air gap, plasterboard 12mm	1	117	-	260	222	0.510	0.495	1.960	2.020	T25
external	Marble	1	117	2643	30	79.29	0.023	0.023			T37
	fiberglass (mineral fiber batts), insulation	1	117	104	63.6	6.6144	2.005	2.005			T37
	Total				353.6	307.9044	2.538	2.523	0.394	0.396	
East wall windows	glazing	1	39	2515	10	25.15	0.178	0.178	5.620	5.620	spec
external	internal air film (vertical)	1	39	1.2	-	-	0.120	0.120			T37
	external air film	1	39	1.2	-	-	0.044	0.030			T37
	Total					25.15	0.342	0.328	2.925	3.049	
West Wall	glazing	1	156	2515	10	25.15	0.178	0.178	5.620	5.620	spec
external	internal air film (vertical)	1	156	1.2	-	-	0.120	0.120			T37
	external air film	1	156	1.2	-	-	0.044	0.030			T37
	Total					25.15	0.342	0.328	2.925	3.049	
North Wall	Brick veneer 110mm block with 150 mm air gap, plasterboard 12mm, with still air film	1	90	-	260	222	0.510	0.495	1.960	2.020	T25

internal	external air film (minus)	1	90	1.2	-	-	-0.044	-0.030			T37
	internal air film (vertical)	1	90	1.2	-	-	0.120	0.120			T37
	fiberglass (mineral fiber batts), insulation	1	90	104	15.9	1.6536	0.501	0.501			T37
					275.9	223.6536	1.087	1.086	0.920	0.921	
South Wall	Double brick, 2x110 mm brick, 50mm air gap, 15mm gypsum plaster on one side	1	90	-	270	423	0.532	0.532	1.880	1.880	T24
(North wall of 213)	Gypsum plaster (other side)	1	90	1217	15	18.255	0.041	0.041			T37
internal	external air film (minus)	1	90	1.2	-	-	-0.044	-0.030			T37
	internal air film (vertical)	1	90	1.2	-	-	0.120	0.120			T37
	fiberglass (mineral fiber batts), insulation	0	90	104	15.9	1.6536	0.501	0.501			T37
	Total				300.9	442.9086	1.150	1.164	0.870	0.859	
Floor	Concrete slab (crushed rock 1:2:4)	1	390	2400	150	360	0.104	0.104			T37
heat flow down	Carpet	1	390	-	-	-	0.119	0.119			T37
internal	Carpet underlay	1	390	-	-	-	0.400	0.400			
	Airspace	1	390	1.2	1500	1.8	3.255	3.255			T37
	Gypsum plasterboard (suspended ceiling)	1	390	881	12	10.572	0.071	0.071			T37

	internal air film (heat flow down)	2	390	1.2	-	-	0.324	0.324			T37
	Total				1662	372.372	4.273	4.273	0.234	0.234	
Roof	Metal deck (steel)	1	390	7849	0.5	3.9245	1.05E-05	1.05E-05			T37
external	wood (fibre and pulp boards	1	390	320	25	8	0.423	0.423			T37
	fiberglass (mineral fiber batts)+ 100mm oak rafters (spacing=1.2m, span, 2.6m)	1	390	177.89	100	17.789	2.175	2.175			T37
	Gypsum plasterboard below rafters	1	390	881	12	10.572	0.071	0.071			T37
	Airspace	1	390	1.2	1500	1.8	3.255	3.255			T37
	Gypsum plasterboard (suspended ceiling)	1	390	881	12	10.572	0.071	0.071			T37
	internal air film	1	390	1.2	-	-	0.162	0.107			T37
	external air film	1	390	1.2	-	-	0.044	0.030			T37
	Total				1649.5	52.6575	6.20	6.13	0.1613	0.1631	

Table 5: Calculation of R, U and surface density of Room 213

Building Structure	Construction materials	Qty	Area, m2	Density, kg/m3	Thickness, mm	Surface density (Mass/area)	R, m2°C/W		U, W/m2°C		Ref
						kg/m2	Summer	Winter	Summer	Winter	
Room 213											
East Wall	Brick veneer 110mm block with 150 mm air gap, plasterboard 12mm	1	130.5	-	260	222	0.510	0.495	1.960	2.020	T25
external	Marble	1	130.5	2643	30	79.29	0.023	0.023			T37
	fiberglass (mineral fiber batts), insulation	1	130.5	104	63.6	6.6144	2.005	2.005			T37
	Total				353.6	307.9044	2.538	2.523	0.394	0.396	
East wall windows	glazing	1	43.5	2515	10	25.15	0.178	0.178	5.620	5.620	spec
external	internal air film (vertical)	1	43.5	1.2	-	-	0.120	0.120			T37
	external air film	1	43.5	1.2	-	-	0.044	0.030			T37
	Total					25.15	0.342	0.328	2.925	3.049	
West Wall	glazing	1	84	2515	10	25.15	0.178	0.178	5.620	5.620	spec
glass part	internal air film (vertical)	1	84	1.2	-	-	0.120	0.120			T37
external	external air film	1	84	1.2	-	-	0.044	0.030			T37
	Total					25.150	0.342	0.328	2.925	3.049	
West Wall	Brick veneer 110mm block with 150 mm air gap, plasterboard 12mm, with still air film	1	90	-	260	222	0.510	0.495	1.960	2.020	T25

brick part	external air film (minus)	1	90	1.2	-	-	-0.044	-0.030			T37
internal	internal air film (vertical)	1	90	1.2	-	-	0.120	0.120			T37
	fiberglass (mineral fiber batts), insulation	1	90	104	15.9	1.6536	0.501	0.501			T37
					275.9	223.6536	1.087	1.086	0.920	0.921	
North Wall	Double brick, 2x110 mm brick, 50mm air gap, 15mm gypsum plaster on one side	1	90	-	270	423	0.532	0.532	1.880	1.880	T24
internal	Gypsum plaster (other side)	1	90	1217	15	18.255	0.041	0.041			T37
	external air film (minus)	1	90	1.2	-	-	-0.044	-0.030			T37
	internal air film (vertical)	1	90	1.2	-	-	0.120	0.120			T37
	fiberglass (mineral fiber batts), insulation	0	90	104	15.9	1.6536	0.501	0.501			T37
	Total				300.9	442.9086	1.150	1.164	0.870	0.859	
South wall windows	glazing	1	18.75	2515	10	25.15	0.178	0.178	5.620	5.620	spec
external	internal air film (vertical)	1	18.75	1.2	-	-	0.120	0.120			T37
	external air film	1	18.75	1.2	-	-	0.044	0.030			T37
	Total					25.15	0.342	0.328	2.925	3.049	
South wall	crushed rock aggreggate (1:2:4) with internal gypsum plaster (15mm)	f	71.25	2400	100	240	0.2558	0.2410	3.910	4.150	T24

external	Gypsum plaster (external)	1	71.25	1217	15	18.255	0.041	0.041			T37
	fiberglass (mineral fiber batts), insulation	0	71.25	104	63.6	6.6144	2.005	2.005			T37
	Total				178.6	264.8694	2.3009	2.2861	0.435	0.437	
Floor	Concrete slab (crushed rock 1:2:4)	1	436	2400	150	360	0.104	0.104			T37
heat flow down	Carpet	1	436	-	-	-	0.119	0.119			T37
internal	Carpet underlay	1	436	-	-	-	0.400	0.400			
	Airspace	1	436	1.2	1500	1.8	3.255	3.255			T37
	Gypsum plasterboard (suspended ceiling)	1	436	881	12	10.572	0.071	0.071			T37
	internal air film (heat flow down)	2	436	1.2	-	-	0.324	0.324			T37
	Total				1662	372.372	4.273	4.273	0.234	0.234	
Roof	Metal deck (steel)	1	436	7849	0.5	3.9245	1.05E-05	1.05E-05			T37
external	wood (fibre and pulp boards	1	436	320	25	8	0.423	0.423			T37
	fiberglass (mineral fiber batts)+ 100mm oak rafters (spacing=1.2m, span, 2.6m)	1	436	177.89	100	17.789	2.175	2.175			T37
	Gypsum plasterboard below rafters	1	436	881	12	10.572	0.071	0.071			T37
	Airspace	1	436	1.2	1500	1.8	3.255	3.255			T37
	Gypsum plasterboard (suspended ceiling)	1	436	881	12	10.572	0.071	0.071			T37

	internal air film	1	436	1.2	-	-	0.162	0.107			T37
	external air film	1	436	1.2	-	-	0.044	0.030			T37
	Total				1649.5	52.6575	6.20	6.13	0.161	0.163	

3.1.2 Storage Mass

Storage mass or thermal mass is the property of the material to absorb and retain the heat. In the cooling load estimation, the calculated storage mass is to be used for the storage load factors shown in Table 6-10 of DA09, which is one of the factor in computing the solar heat gain. It is also used for the storage load factor for equipment heat gain and lights.

The storage mass in DA09 is defined as the mass per square meter of floor area.

$$mass\ per\ unit\ floor\ area = \frac{\sum m_{ext,kg} + \sum(0.5 * m_{int,kg})}{floor\ area, m^2}$$

Where m_{ext} = mass of external walls, kg

m_{int} = mass of internal walls, kg

the mass of internal walls is multiplied by a factor of 0.5 since the thermal mass is divided between the adjacent room.

3.1.2.1 Surface Density

$$surface\ density(sd)of\ wall, kg/m^2 = sd_1 + sd_2 + \cdots = \sum sd_i$$

Where surface density is the mass per unit area of the wall/structure taken from table 24-36 of DA09. Take note that this is different from the mass per unit floor area which is mentioned above.

If table 37 of DA09 is used, where density is given instead of surface density, use below formula

$$sd = \frac{\rho x}{1000}$$

The total surface density of the east wall of 212:

$$sd_1 = \frac{222kg}{m^2} \text{for brick veneer wall}$$

$$sd_2 = \frac{\rho x}{1000} = \frac{2643x30}{1000} = 79.29kg/m^2 \text{ for marble}$$

$$sd_3 = \frac{\rho x}{1000} = \frac{104x63.6}{1000} = 6.6144kg/m^2 \text{ for fibreglass insulation}$$

Where ρ is the density from table 37 of DA09.

$$sd = 222 + 79.29 + 6.6144 = 307.9044\ kg/m^2$$

Surface density of insulation-rafters layer in roof of 212 (parallel)

In case of the layer of rafters and insulation on the roof (see figure 8), calculate the composite density as follow:

ρ_1 = 104 fiberglass (mineral fiber batts), insulation

ρ_2 = 769 oak timber, rafters

by mass balance:

$$\rho_1 V_1 + \rho_1 V_2 = \rho_3 V_3$$

Where V = volume (see Figure 8 for dimensions)

And ρ_3 is the density of the composite material.

$$\rho_3 = \frac{104 * (3.12 * 0.1) + 769 * (0.39 * 0.1)}{0.1 * 1.3 * 2.7}$$

$$\rho_3 = 177.89\ kg/m^3$$

Then the surface density of the combine rafter and insulation is:

$$sd_3 = \frac{\rho x}{1000} = \frac{177.89x100}{1000} = 17.789\ kg/m^2$$

The summary of calculated surface density for each structure of room 212 and 213 is shown in Table 4 and 5.

3.1.2.2 Calculation of the mass per unit floor area

For Room 212

To calculate the mass per structure

$$m = sd \times A$$

Where A is the area of the wall.

For east wall:

$$m = 307.9044 * 117 = 36024.81 \text{ kg}$$

Other structure data

East wall windows: m_{ext} = 980.85kg

West wall: m_{ext} = 3923.4kg

North wall: 0.5m_{int} = 10064.41kg

South wall: m_{ext} = 19930.89 kg

Roof: m_{ext} = 20536.43kg

Floor: 0.5m_{int} = 72612.54kg

Floor area = 390m^2

$$\frac{mass}{floor\ area} = \frac{36024.81 + 980.85 + 3923.4 + 10064.41 + 19930.89 + 20536.43 + 72612.54}{390}$$

$$\frac{mass}{floor\ area} = \mathbf{420.7} \frac{\boldsymbol{kg}}{\boldsymbol{m^2\ of\ floor\ area}}$$

The summary of the calculation of the storage mass per floor area is shown in Table 6.

Table 6: Storage mass per floor area of room 212 and 213

Structure	Type	Factor	Room 212			Factor	Room 213		
		1 if external, 0.5 if internal	Surface Density, kg/m2	Area, m2	Mass*factor, kg	1 if external, 0.5 if internal	Surface Density, kg/m2	Area, m2	Mass, kg
East wall	External	1	307.90	117	36,024.81	1	307.90	130.5	40,181.52
East windows	External	1	25.15	39	980.85	1	25.15	43.5	1,094.03
West wall (glazing part)	External	1	25.15	156	3,923.40	1	25.15	84	2,112.60
West wall (brick)	internal				0.00	0.5	223.65	90	10,064.41
North wall	Internal	0.5	223.65	90	10,064.41	0.5	442.91	90	19,930.89
South windows	External	1			0.00	1	25.15	18.75	471.56
South wall	External(213) Internal(212)	0.5	442.91	90	19,930.89	1	264.87	71.25	9,435.97
Roof	External	1	52.66	390	20,536.43	1	52.66	436	22,958.67
Floor	Internal	0.5	372.37	390	72,612.54	0.5	372.37	436	81,177.10
			Total Mass, kg		164,073.33				187,426.75
			Storage Mass, total mass/m2 floor area		420.70				429.88

3.2 Solar Transmission of External Surfaces

3.2.1 Summer

3.2.1.1 Equivalent Temperature

The formula for the solar transmission of heat for external surface is given below

$$Q = UA\Delta T_e$$

Where Q = total heat flow, W

ΔT_e = equivalent temperature difference, °C

The equivalent temperature difference is the temperature difference used for external surface which is attributed to the combine heat transfer by conduction (temperature difference) and radiation (solar) thus results to a higher heat transfer (higher cooling load). In DA09, the equivalent temperature based on the surface density, orientation of exposure, design time and location of the building as well as the design conditions.

For the light colours wall, 30° South latitude, and selected design day and time of Jan 21 at 3pm:

$$\Delta T_e = 0.55\frac{\sigma_s}{\sigma_m}(\Delta T_{em}) + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right)(\Delta T_{es})$$

Where:

σ_s = maximum solar heat gains from Table 14 of DA09 p. 43, 30° South, Jan 21 @ 3pm, W/m^2.

σ_m = maximum solar heat gains from Table 14 of DA09 p. 44, 40° South, Jan 21 @ 3pm, W/m^2.

ΔT_{em} = equivalent temperature difference from Table 21/22 of DA09 pp. 60-61 for exposed wall/roof, °C

ΔT_{es} = equivalent temperature difference from Table 21/22 of DA09 pp. 60-61 for shaded wall/roof, °C

No need for correction to equivalent temperatures in Table 21/22 of DA09 for Tout-Tin =10°C, daily range=10°C

Calculation of ΔT_e of the roof of Room 212 and 213

Sd = 52.6575 kg/m^2 to be used in the selection of equivalent temperature difference in Table 21/22 of DA09

σ_s = 590 W/m^2

σ_m = 580 W/m^2

ΔT_{em} = 23.3°C

ΔT_{es} = 9.4°C

$$\Delta T_e = 0.55 * \frac{590}{580}(23.3) + \left(1 - 0.55 * \frac{590}{580}\right)(9.4)$$

$$\Delta T_e = 17.18°C$$

Other external walls of room 212 and 213

Table 7, show the calculated equivalent temperature for the other external walls using the same formula used in calculation of ΔT_e of the roof.

Table 7: Calculated equivalent temperature for external walls of Room 212 and 213

		Summer					Winter		
Structure	**mass/area (kg/m²)**	**σ_s (W/m²)**	**σ_m (W/m²)**	**Δt_{em} (exposed) (°C)**	**Δt_{es} (shaded) (°C)**	**Δt_e (°C)**	**T_{in} (°C)**	**T_{out} (°C)**	**Δt (°C)**
				212					
East wall	307.9044	44	44	9.4	6.7	8.19	21	2.1	18.9
Roof	52.6575	590	580	23.3	9.4	17.18	21	2.1	18.9
				213					
East wall	307.9044	44	44	9.4	6.7	8.19	21	2.1	18.9
South wall	264.8694	44	44	6.7	6.7	6.70	21	2.1	18.9
Roof	52.6575	590	580	23.3	9.4	17.18	21	2.1	18.9

3.2.1.2 Calculation of Solar Transmission of External Wall (Summer)

For the roof of Room 212

U = 0.1613 W/m^2°C (summer)

A = 390 m^2

ΔT_e = 17.18°C

$$Q = UA\Delta T_e$$

$$Q = 0.1613 * 390 * 17.18 = 1080.54\ W$$

The same equation will be used for the calculation of heat gain through roof of 213, east walls (212 and 213) and south wall of 213 and the results are summarized in Table 11.

3.2.2 Winter

In the case of the external walls shown in table 24-27 of DA09 and for the roofs in table 29-32 of DA09, the equation to be used for heat loss is shown in the notes of the table.

There are three key difference in calculating external loads for heating in winter and cooling in summer. First and most obvious is that the outdoor design temperature is lower than inside the room. Since heating load is being calculated during winter, heat loss is positive value while heat gain is negative value which is opposite of the case for summer cooling load calculation (refer to Assumption 2 and 3 for the convention use in heat gain/loss calculations. The second differences are the effect of wind speed in the U value of the external walls as discussed in previous section.

The equation to be used for heat transfer(loss) for external surface is

$$Q = UA\Delta T$$

$$\Delta T = T_{indoor} - T_{outdoor}$$

The third key difference between of winter heat loss calculation versus summer heat gain calculation is ΔT instead of equivalent temperature difference ΔT_e is used in winter solar transmission because the solar radiation during winter is minimal and the design day and time for winter is June at 7:00am thus only heat transfer by conduction across the external wall. This will also make the calculation of heating load more conservative.

3.2.2.1 Calculation of Solar Transmission of External Wall (Winter)

For the roof of Room 212

U = 0.161 W/m^2°C (winter)

A = 390 m^2

T_{indoor} = 21°C

$T_{outdoor}$ = 2.1°C

$$Q = UA\Delta T$$

$$Q = 0.163 * 390 * (21 - 2.1) = 1202.21\ W$$

The same equation will be used for the calculation of winter heat loss through roof of 213, east walls (212 and 213) and south wall of 213 and the results are summarized in Table 11.

3.3 Partition heat transmission

Partition are internal walls dividing the two adjacent rooms. It also applies to floor of the room with room underneath it and to ceiling of rooms with rooms above it. The difference between the heat load calculation of partition to the external surface is that the partition will have still air on both sides while the external surface will have the external air film due to the wind. The heat transmission for partition is govern by below equation.

$$Q = UA\Delta T$$

$$\Delta T = T_{outside} - T_{inside} \text{ for summer}$$

$$\Delta T = T_{inside} - T_{outside} \text{ for winter}$$

Where: T_{inside} = temperature inside the room

$T_{outside}$ = temperature of the adjacent room

Note that the assumption is that the adjacent room has homogeneous temperature in the entire space.

The calculation of ΔT of partitions for summer and winter is summarized in Table 8.

Table 8: ΔT of partitions for summer and winter

212						
Structure	**Summer**			**Winter**		
	T_{in}, °C	**T_{out}, °C**	**ΔT, °C**	**T_{in}, °C**	**T_{out}, °C**	**ΔT, °C**
North Wall	24	24	0	21	21	0
South Wall	24	24	0	21	21	0
Floor	24	22.8	-1.2	21	20.4	0.6
213						
Structure	**Summer**			**Winter**		
	T_{in}, °C	**T_{out}, °C**	**ΔT, °C**	**T_{in}, °C**	**T_{out}, °C**	**ΔT, °C**
West Wall	24	24	0	24	24	0
North Wall	24	24	0	24	24	0
Floor	24	22.0	-2.0	21	20.0	1.0

3.3.1.1 Calculation of Partition Heat Transmission

For the floor of Room 212 (Summer)

Room 212 is above two rooms, MM15(T=24°C, summer) and M02(T=22°C). The percentage of floor area of Room 212 under Room MM15 is 38% and 62% of the floor area is under M02. To get the $T_{outside}$ of room 212, simply use the percentage.

$$T_{outside} = 24 * 0.38 + 22 * 0.62 = 22.8°C$$

T_{inside} = 24°C of room 212

U = 0.234 W/m^2°C

A = 390 m^2

$$Q = UA\Delta T$$

$$Q = 0.234 * 390 * (22.8 - 24) = -109.51\ W \text{ (summer)}$$

The negative heat for the floor of room 212 indicates that this is a heat loss.

For the floor of Room 212 (Winter)

$T_{outside} = 21 * 0.38 + 20 * 0.62 = 20.4°C$

T_{inside} = 21°C of room 212

U = 0.234 W/m^2°C

A = 390 m^2

$$Q = UA\Delta T$$

$$Q = 0.234 * 390 * (21 - 20.4) = 54.76\ W \text{ (winter)}$$

The same equations will be used for the calculation of heat gain/loss through other internal walls and floor for room 212 and 213. The results are summarized in Table 11.

3.4 Glazing – Transmission

Glazing are glass walls and windows. The solar transmission through glass walls and windows is governed by below equation

$$Q = UA\Delta T$$

$$\Delta T = T_{outdoor} - T_{indoor} \text{ (summer)}$$

$$\Delta T = T_{indoor} - T_{outdoor} \text{ (winter)}$$

Where: T_{indoor} = temperature inside the room

$T_{outdoor}$ = outdoor design temperature

Note that ΔT instead of equivalent temperature difference ΔT_e is used in for both summer and winter solar transmission because the solar radiation for glazing is treated separately as solar heat gain by radiation and will be discussed on next section.

Table 9: ΔT of glazing for summer and winter

212						
Structure	**Summer**			**Winter**		
	Tin, °C	**Tout, °C**	**ΔT, °C**	**Tin, °C**	**Tout, °C**	**ΔT, °C**
East windows	24	33.8	9.8	21	2.1	18.9
West wall	24	33.8	9.8	21	2.1	18.9
213						
Structure	**Summer**			**Summer**		
	Tin, °C	**Tout, °C**	**ΔT, °C**	**Tin, °C**	**Tout, °C**	**ΔT, °C**
East windows	24	33.8	9.8	21	2.1	18.9
West wall	24	33.8	9.8	21	2.1	18.9
South windows	24	33.8	9.8	21	2.1	18.9

3.4.1.1 *Calculation of Glazing Solar Transmission*

For the west wall of Room 212 (Summer)

T_{indoor} = 24°C of room 212

$T_{outdoor}$ = 33.8°C outdoor design temperature

U = 2.925 W/m^2°C

A = 156 m^2

$$Q = UA\Delta T$$

$$Q = 2.925 * 156 * (33.8 - 24) = 4470.98\ W \text{ (summer)}$$

For the west wall of Room 212 (winter)

T_{indoor} = 21°C of room 212

$T_{outdoor}$ = 2.1°C outdoor design temperature

U = 3.049 W/m^2°C

A = 156 m^2

$$Q = UA\Delta T$$

$$Q = 3.049 * 156 * (21 - 2.1) = 8890.85\ W \text{ (winter)}$$

The same equations will be used for the calculation of heat gain/loss through other glass walls and windows for room 212 and 213. The results are summarized in Table 11.

3.5 Glazing - Solar Heat Gain

Solar heat gain is due to the heat transfer by radiation through glass. There are 2 components of the solar heat gain; direct radiation and diffuse or sky radiation. The former is due to direct exposure to sunray while the diffuse radiation component results in heat transfer even when the window is not facing the sun(shaded), assuming that the sky can be viewed from it. The equation for the solar heat gain through glass is as follow:

$$Q_{SHG} = PSHG \times A \times SHGC \times SF \times HF \times DF \times SA \times AF$$

where,

PSHG =Peak solar heat gain obtained from DA09-Table14 p.43 for 30° South latitude, Jan21 at 3pm for summer and Jun21 at 7am for winter, W/m2.

A= heat transfer area, m2

SHGC = 0.611, given from the specification. Solar heat gain coefficient is the fraction of solar heat (solar radiation) that transmits through the glazing with a value of between 0 to 1. This is the same with the glass factor discussed in DA09. In most case, particularly in the US, SHGC includes the value attributed to the frame, sash, shading device and other parts of the window/door. In this project, it is assumed that the SHGC includes both the glass factor and the solar factor due to shading device also known as the overall solar factors.

SF = storage load factor, selected on Table 10 of DA09 p. 30, 12-hour operation, based on storage mass per floor area which is calculated in 3.1.2 and Table 6 of this report, design time of 3pm (summer) and exposure of the glazing.

HF = haze correction factor, assumed no haze so factor is 1.

DF = dew point correction factor. In summer, condition of outside is 33.8°C DB / 22.9℃ WB, so dew point temperature could be obtained from using Psychrometrics chart which value is 18.1℃. In this case, dew point temperature is decreasing from 20 ℃, therefore, using below equation to calculate dew point factor which comes from DA09.

$$DP\ Factor = 1 + (20℃ - 18.1℃) \times 13\% = 1.247$$

SA = sash factor, use 1.17 for no sash on the window and walls.

AF= altitude factor, assumed sea level for temperate town thus equal to 1.

Note **that for winter, the PSHG on Jun21 at 7:00 am are all zero thus no solar heat gain will be calculated for this report.** This is consistent with the assumption made for the solar transmission through other external surfaces where solar radiation is minimal (winter season) and thus only heat transfer through conduction is considered during winter.

In the case of west walls, where it is assumed as fully shaded, the solar heat gain is calculated using the southern exposure data for PSHG and storage mass. The rationale for this is that shaded portion of the glass will have only diffused part of the solar radiation similar to southern exposure.

3.5.1.1 Calculation of Glazing Solar Transmission

For the east windows of Room 212

PSHG = 44 W/m2

A= 1.5*26 =39 m2

SHGC = 0.611

SF = 0.28

DP = 1.247

HF = 1

SA = 1.17

AF =1

$$Q_{SHG} = PSHG \times A \times SHGC \times SF \times HF \times DF \times SA \times AF$$

$$Q_{SHG} = 44 \times 39 \times 0.611 \times 0.28 \times 1 \times 1.247 \times 1.17 \times 1$$

$$Q_{SHG} = 429.16\,W$$

Same calculation is done for the other glass windows in room 212 and 213 and the summary is shown in below Table 10.

Table 10: Summary of solar heat gains through glasses

Structure	PSHG (w/m²)	area (m²)	storage factor	SHGC	DP correlation	haze factor	sash correction	altitude correction	solar heat gain (W)
212									
east window	44	39	0.281	0.611	1.247	1	1.17	1	429.16
west walls	44	156	0.961	0.611	1.247	1	1.17	1	5882.24
Total									6311.39
213									
east window	44	43.5	0.284	0.611	1.247	1	1.17	1	484.49
west walls	44	84	0.960	0.611	1.247	1	1.17	1	3163.04
south window	44	18.75	0.960	0.611	1.247	1	1.17	1	706.04
Total									4353.56

3.6 Summary of Transmission Loads and Total External Loads

In Table 11, all the calculated heat gain/loss due to transmission is summarized.

Table 11: Calculated Heat Gain/Loss Due to Transmission

212								
Structure		**U (W/m2-℃)**		**T or ∆Te (℃)**		**Area (m2)**	**Heat gain (W)**	**Heat loss (W)**
	Type	**Summer**	**Winter**	**Summer**	**Winter**		**Summer**	**Winter**
East Wall	external	0.394	0.396	8.2	18.9	117.00	377.31	876.56
East wall windows	external/gazing	2.925	3.049	9.8	18.9	39.00	1117.74	2247.71
West Wall	external/glazing	2.925	3.049	9.8	18.9	156.00	4470.98	8990.85

North Wall	internal	0.920	0.921	0.0	0.0	90.00	0.00	0.00
South Wall	internal	0.870	0.859	0.0	0.0	90.00	0.00	0.00
Floor	internal	0.234	0.234	-1.2	0.6	390.00	-109.51	54.76
Roof	external	0.161	0.163	17.2	18.9	390.00	1080.54	1202.21
Total							**6937.06**	**13372.09**

213								
Structure		**U (W/m2-℃)**		**T or ΔTe (℃)**		**Area (m2)**	**Heat gain (W)**	**Heat loss (W)**
	Type	**Summer**	**Winter**	**Summer**	**Winter**		**Summer**	**Winter**
East Wall	external	0.394	0.396	8.2	18.9	130.50	420.85	976.71
East wall windows	external/glazing	2.925	3.049	9.8	18.9	43.50	1246.93	2506.74
West Wall - glass	external/glazing	2.925	3.049	9.8	18.9	84.00	2407.86	4840.59
West Wall - brick	internal	0.920	0.921	0.0	0.0	90.00	0.00	0.00
North Wall	internal	0.870	0.859	0.0	0.0	90.00	0.00	0.00
South wall windows	external/glazing	2.925	3.049	9.8	18.9	18.75	537.47	1080.49
South wall	external	0.435	0.437	6.7	18.9	71.25	207.66	588.48
Floor	internal	0.234	0.234	-2.0	1.0	436.00	-204.05	102.02
Roof	external	0.161	0.163	17.2	18.9	436.00	1205.74	1343.19
Total							**5822.46**	**11438.22**

Below is the summary of all the external load including the solar heat gain through glasses for summer and winter in room 212 and 213. The formula of total external load is below:

$$Q_{gain} = \sum Q_{transmission\ gains\ during\ summer} + Q_{SHG}$$

$$Q_{loss} = \sum Q_{transmission\ losses\ during\ winter}$$

Table 12: Total External Load for 212 and 213

		External Load	
Room	**Type**	**Summer**	**Winter**
212	Heat transmission	6937	13372
	Solar heat gain	6311	0
	Total	**13248**	**13372**
213	Heat transmission	5822	11438
	Solar heat gain	4354	0
	Total	**10176**	**11438**

Note that the total external load will contribute to the cooling/heat load in the form of sensible heat.

4 Internal Loads

4.1 People

People occupying the building contributes to the internal loads in the form of sensible heat (temperature difference) and latent heat (phase change, i.e. moisture content change). Sensible and latent heat gain per person varies depending on the activity as shown in DA09 table 45, p. 98. The equation for heat gain due to people is as follow:

$$Q_s = sensible\ heat\ per\ person \times no.of\ person$$

$$Q_L = latent\ heat\ per\ person \times no.of\ person$$

For Room 212 during summer

no. of person standing = 45

Sensible heat per person, standing = 70 W

Latent heat per person, standing = 60 W

$$Q_S = 70 \times 45 = 3150\ W$$

$$Q_L = 60 \times 45 = 3150\ W$$

Same calculation is done for people who are seating at room 212 and the occupancy for room 213. Take note that for winter, the design time is at 7:00am and thus it is assumed that the occupants of the building are not yet arriving so will not contribute to the heating load. The summary is shown in Table 17 together with other internal loads.

4.2 Appliances and Equipment

The appliances and equipment inside the room also contribute to the heat generation. Depending on the type of appliances, some contributes in the form of sensible heat only like computer and others contributes both to sensible and latent heat like boiler.

Heat generation rate data for each type of equipment can be found both in DA09 and ASHRAE manual. For this project, all data are extracted from ASHRAE.

Similar to the heat generated calculated for people, below:

$$Q_s = sensible\ heat\ of\ equipment\ per\ unit \times no.of\ unit$$

$$Q_L = latent\ heat\ of\ equipment\ per\ unit \times no.of\ unit$$

For the griddle in room 213 during summer:

No. of griddle = 4

Sensible heat per griddle = 970 W

Latent heat per person, standing = 540 W

$$Q_S = 970 \times 4 = 3880\ W$$

$$Q_L = 540 \times 4 = 2160\, W$$

Similar calculation is done for other appliances/equipment in room 212 and 213 and is shown in Table 17.

For winter, as mentioned previously, all equipment is not operating at the winter design time (7:00am) except for a few equipment (e.g. freezer) which runs continuously as this is the general practice.

4.3 Lighting

Lights generate heat in the form of sensible heat only. Part of the heat is stored and thus correction is necessary based on table 11 of DA9. Assumption of light operation is 10 hours and 12 hours AHU operation and that lights are turned on at 9:00 am. The storage factor is selected based on type of lights, AHU operating hours, storage mass, and number of hours after lights are turned on (from turned on up to the design time, 3pm for the case of summer).

$$Q_s = h_L \times A \times SF$$

Where h_L = heat rate/unit floor area, W/m^2

A = floor area, m^2

SF = storage load factor, selected on Table 11 of DA09 p. 31, 12-hour AHU operation, based on storage mass per floor area which is calculated in 3.1.2 and Table 6 of this report, design time of 3pm (summer) and exposure of the glazing.

For room 212 at summer:

h_L = 30 W/m^2

A = 390 m^2

SF =0.96

$$Q_s = 30 \times 390 \times 0.96 = 11232\, W$$

Same procedure is done to get the heat load due to lights for room 213 and this is shown in below table. Again for winter, it is assumed that all lights are off at 7:00am (design time) and thus will not contribute to the heating load of the room

Table 13: Lighting load calculation for room 212 and 213

	212	**213**
capacity	30	30
area	390	436
storage factor (10 Hr)	0.96	0.96
Mass/unit area of floor	420.7	429.88
Load (W)	11232	12556.8

4.4 Infiltration

4.4.1 Infiltration rate calculation

Infiltration is the amount of outside air that enters the building through openings like windows, doors and other leakage (partially sealed) which contributes to the cooling/heating load of the room in the form of sensible and latent heat. There are two factors affecting the amount of infiltration; the pressure difference between the room and outside surroundings, and the resistance from these openings to let the air in. In DA09, table 44 listed the conditions and the corresponding infiltration rate (in air change per hour, Ch/h) due to the wind forces. This mainly applies to windows and leakages. In addition, the specification gives the infiltration of 200l/s for each shop external entrance and mall entrance.

The formula for infiltration rate due to wind forces using table 44 of DA09 is:

$$I_w = \sum x_i$$

Where:

I_w = sum of all the value of infiltration of each condition (x) specified in table 44 of DA9, Ch/h

A x 4.5 = room volume

Converting I_w from Ch/h to l/s

$$I_{w,l/s} = \frac{I_{wc,Ch/h} \times Room\ volume \times 1000}{3600}$$

Room volume = floor area x ceiling height (4.5m). Refer to assumption list for details.

The total infiltration rate is given below:

$$I_{total} = I_{w,l/s} + I_d$$

Where

$I_{w,\,l/s}$ = infiltration due to wind, l/s

I_d = infiltration through door, l/s, as per specification.

For room 212:

A = 390 m^2 (floor area)

Exposure:	+0.25	(half sheltered, half exposed)
Construction:	+0.50	(dry)
Location of windows:	+0.00	(1 wall)
Type of window:	+0.00	(gasketed)
Degree of fenestration:	+0.00	(less than 25%)

Partitioning: +0.00 (Nil)

Total(I_w) 0.75 Ch/h

Converting to l/s

$$I_{w,l/s} = \frac{0.75 \times 390 \times 4.5 \times 1000}{3600} = \mathbf{366\ l/s}$$

Then the total infiltration rate is

$$I_{total} = 366 + 200 = \mathbf{566\ l/s}$$

The same way is the infiltration rate for room 213 is calculated as shown in Table 14.

Table 14: Infiltration rate for room 212 and 213

Parameter	**Condition**	**212**	**213**
		Ch/h	**Ch/h**
Exposure	Half sheltered and half exposed	0.25	0.25
Construction	Dry	0.5	0.5
Location of windows	1 wall or 2 adjacent walls	0	0
Type of windows	Gasketed	0	0
Degree of fenestration	Less 25%	0	0
Partitioning	Nil	0	0
Total		0.75	0.75
Calculation of total infiltration rate			
Room volume	in m^3	1755	1962
Infiltration rate (leakage)	in L/s	366	409
Infiltration rate (door)	in L/s	200	200
total infiltration rate	in L/s	566	609

4.4.2 Calculation of heat gain due to infiltration

To calculate the sensible and latent heat due to infiltration, below formula is used:

For summer,

$$Q_S = 1.2 \times I_{total} \times (T_{out} - T_{in})$$

$$Q_L = 2.9 \times I_{total} \times (w_{out} - w_{in})$$

For winter,

$$Q_S = 1.2 \times I_{total} \times (T_{in} - T_{out})$$

$$Q_L = 2.9 \times I_{total} \times (w_{in} - w_{out})$$

Where:

T_{in} = room temperature, °C

T_{out} = outside temperature, °C

w_{in} = moisture content of room air, g/kgDA

w_{out} = moisture content of outside air, g/kgDA

I_{total} = infiltration rate, l/s

Notice that summer and winter have different outdoor and indoor design conditions and thus the temperature and moisture use to calculate the heat is different. There is also a difference in convention as mentioned in the assumption since cooling load is calculated during summer and heating load for winter.

For room 212 during summer:

T_{in} = 24 °C

T_{out} = 33.8 °C

w_{in} = 10.4 g/kgDA

w_{out} = 13 g/kgDA

I_{total} = 253.125 l/s

$$Q_S = 1.2 \times 566 \times (33.8 - 24) = 6652\ W$$

$$Q_L = 2.9 \times 566 \times (13 - 10.4) = 4265\ W$$

For room 212 during winter:

T_{in} = 21 °C

T_{out} = 2.1 °C

w_{in} = 12.5 g/kgDA

w_{out} = 3.6 g/kgDA

I_{total} = 566 l/s

$$Q_S = 1.2 \times 566 \times (21 - 2.1) = 12828\ W$$

$$Q_L = 2.9 \times 566 \times (12.5 - 3.6) = 14599\ W$$

The calculated sensible heat and latent heat for summer and winter for both rooms are calculated in the same way and is summarized in Table 16.

Table 15: Temperature and moisture content of air

Season	T_{out}, °C	T_{in}, °C	ΔT, °C
Summer	33.8	24	9.8

Winter	2.1	21	18.9
	w_{out}, g/kgDA	w_{in}, g/kgDA	Δw, g/kgDA
Summer	13	10.4	2.6
Winter	3.6	12.5	8.9

Table 16: Summary of heat gain/loss due to infiltration

Room	Summer		Winter	
	Sensible heat, W	Latent heat, W	Sensible heat, W	Latent heat, W
212	6652	4265	12828	14599
213	7159	4590	13806	15712

4.5 Summary of Internal loads

Below is the summary of the sensible heat and latent head classified as internal loads: people, appliances/equipment, lights and infiltration. The key difference between the internal load for summer and winter are the following: design conditions (outdoor and indoor) thus different temperature and moisture content, the number of occupants and the number of operating equipment and lights.

Table 17: Summary of Internal loads for room 212 and 213

212										
		summer				winter				
Unit	Qty	Sensible heat (W)	Total (W)	latent heat (W)	Total (W)	Sensible (W)	Total (W)	Latent heat (W)	Total (W)	Reference
people (steated)	35	70	2450	50	1750	0	0	0	0	DA09-T45
people (standing/walking)	45	70	3150	60	2700	0	0	0	0	DA09-T45
desktop computer	20	97	1940	0	0	0	0	0	0	2009 ASHRAE Handbook-T8
laptop computer	15	65	975	0	0	0	0	0	0	2009 ASHRAE Handbook-T8
colour A3 laser printers	1	130	130	0	0	0	0	0	0	2009 ASHRAE Handbook-T9
large plotter	1	250	250	0	0	0	0	0	0	2009 ASHRAE Handbook-T8
small steam kettle	1	735	735	490	490	0	0	0	0	2001 ASHRAE Handbook-T5
toaster	2	1310	2620	1160	2320	0	0	0	0	2001 ASHRAE Handbook-T5
microwave oven	1	600	600	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
freezer(small)	2	320	640	0	0	1100	2200	0	0	2001 ASHRAE Handbook-T5
coffee maker	2	1050	2100	450	900	0	0	0	0	2009 ASHRAE Handbook-T10
lighting			11232							see Table 13
Infiltration			6652		4265		12828		14599	see Table 15
Total			**33474**		**12425**		**15028**		**14599**	
213										
		summer				winter				
Unit	Qty	Sensible heat (W)	Total (W)	latent heat (W)	Total (W)	Sensible (W)	Total (W)	Latent heat (W)	Total (W)	Reference
occupancy summer	90	80	7200	80	7200	0	0	0	0	DA09-T45
occupancy winter	60	0	0	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
barbeque pit	6	2850	17100	1550	9300	0	0	0	0	2001 ASHRAE Handbook-T5
blender	2	620	1240	320	640	0	0	0	0	2001 ASHRAE Handbook-T5
coffee heater	1	132	132	68	68	0	0	0	0	2001 ASHRAE Handbook-T5

dishwasher	1	500	500	1100	1100	0	0	0	0	2001 ASHRAE Handbook-T5
display case	2	960	1920	0	0	640	1280	0	0	2001 ASHRAE Handbook-T5
food warmer	8	2330	18640	600	4800	0	0	0	0	2001 ASHRAE Handbook-T5
griddle/grill	4	970	3880	540	2160	0	0	0	0	2001 ASHRAE Handbook-T5
Ice maker	2	2730	5460	0	0	2730	5460	0	0	2001 ASHRAE Handbook-T5
Microwave oven (20L)	1	2630	2630	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
mixer (large)	1	2233	2233	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
steam kettle (200L)	1	1400	1400	1000	1000	0	0	0	0	2001 ASHRAE Handbook-T5
waffle iron	2	700	1400	940	1880	0	0	0	0	2001 ASHRAE Handbook-T5
broiler	1	24200	24200	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
fryer	2	228	456	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
oven	4	410	1640	0	0	0	0	0	0	2001 ASHRAE Handbook-T5
freezer (large)	4	540	2160	0	0	540	2160	0	0	2001 ASHRAE Handbook-T5
water cooler	2	700	1400	0	0	350	700	0	0	2001 ASHRAE Handbook-T5
hot water urn	1	2500	2500	800	800	0	0	0	0	2001 ASHRAE Handbook-T5
lighting			12556.8							see Table 13
infiltration			7159		4590		13806		15712	see Table 15
Total			**115807**		**33538**		**23406**		**15712**	

5 Cooling and Heating Load

Below is the summary of the cooling(summer) and heating(winter) load for room 212 and 213. External load only contributes to the sensible heat while internal load heat gain/loss is both in the form of sensible and latent heat.

Table 18: Total cooling and heating load for room 212 and 213

Cooling Load (Summer)				
	212		213	
Load type	**Sensible**	**Latent**	**Sensible**	**Latent**
External load	13248	0	10176	0
Internal load	33474	12425	115807	33538
Total heat	46722	12425	125983	33538
Total cooling load		59147		159521
Heating Load (Winter)				
	212		**213**	
Load type	**Sensible**	**Latent**	**Sensible**	**Latent**
External load	10176	0	11438	0
Internal load	15028	14599	23406	15712
Total heat	25204	14599	34844	15712
Total cooling load		39803		50556

6 Psychrometric Charts

A psychrometric chart is the graph which contains the psychrometric properties and values of air. Below is the information provided in the psychrometric chart

1. Dry bulb temperature, °C
2. Wet bulb temperature, °C
3. Relative humidity
4. Specific volume, g/kgDA (dry air)
5. Dew point or saturation temperature
6. Moisture content, g/kgDA
7. Enthalpy, kJ/kgDA

The air mixture has 3 degrees of freedom (2 components, 1 phase) and since the pressure is fixed at 101.325kPa, given 2 of the above properties can define the other properties of the air.

For the calculation of the cooling coil load, it is assumed that room 213 have a dedicated AHU due to high cooling load. Thus, individual AHU is assigned for both room.

6.1 Room 212 psychrometric chart

The minimum supply air temperature is 12°C but 15°C is used due to psychrometric chart limitation. When the 12°C is used. The supply air almost touched the saturation curve and finding the right ADP point is difficult. The temperature of 15°C is acceptable supply air temperature and this will also secure more comfort specially for the occupants near the supply air inlet to the room which will experience discomfort due to the current of air with low temperature (draught) albeit the negative consequences of additional cost due to ducting size increasing. This issue will be discussed on the part B of this assignment.

1. Plot the points for RA (room air) and OA (outside air) based on the following given properties below then connect this 2 lines
   RA: 24°C DB / 55%RH
   OA: 33.8°C DB / 22.9 WB
2. Compute the sensible heat factor (SHF).
   Qs = 46722 W
   QL = 12425 W

$$\text{SHF} = \frac{Q_S}{Q_S + Q_L}$$

$$\text{SHF} = \frac{46722}{46722 + 12425} = 0.79$$

3. Given the SHF value, draw the SHF line from the scale to the reference point (25°C DB, 50%RH)
4. From RA draw a line with the same slope as the SHF line up to 15°C which is the supply air point SA. This is the room load line.
5. Calculate the supply air mass flow rate
   T_{SA} = 15°C

$$Q_S = 1.2V_{SA}(T_{RM} - T_{SA})$$

$$V_{SA} = \frac{Q_S}{1.2(T_{RM} - T_{SA})} = \frac{46722}{1.2(24 - 15)} = 4326\ l/s$$

$$m_{SA} = V_{SA}\rho = 4326(1.17 \times 10^{-3}) = 5.06\ kg/s$$

6. Calculate the outside air mass flow rate

$$V_{OA} = p \times OAR$$

p = number of occupants, 80 person

OAR = outside air requirements, 10l/s per person

$$V_{OA} = 80 \times 10 = 800 l/s$$

From psychrometric chart, take the specific volume *v* at point OA

$$v_{OA} = \ 0.8875\ m^3/kgDA$$

$$m_{OA} = \frac{V_{oa}}{v_{OA}} = \frac{800 \times 10^{-3}}{0.8875} = 0.901 kg/s$$

7. Calculate the ratio of m_{OA} to m_{SA}.

$$\frac{m_{OA}}{m_{SA}} = \frac{0.901}{5.06} = 0.178$$

8. Using the ratio calculated in No. 7 as a factor, measure the distance from point RA and tag it as point MA. This is the mixed air point.
   Length of RA to OA = 48mm
   48 x 0.178 =8.5mm from RA

9. Read the moisture content of MA and SA from psychrometric chart and solve for the moisture content of ADP (apparatus dew point) given the coil contact factor of 0.85.
   w_{MA} = 10.9 g/kgDA
   w_{SA}= 9.3 g/kgDA = w_W

$$\eta_c = \frac{w_{MA} - w_w}{w_{MA} - w_{ADP}}$$

$$w_{ADP} = 10.9 - \frac{(10.9 - 9.3)}{0.85} = 9.02\ g/kgDA$$

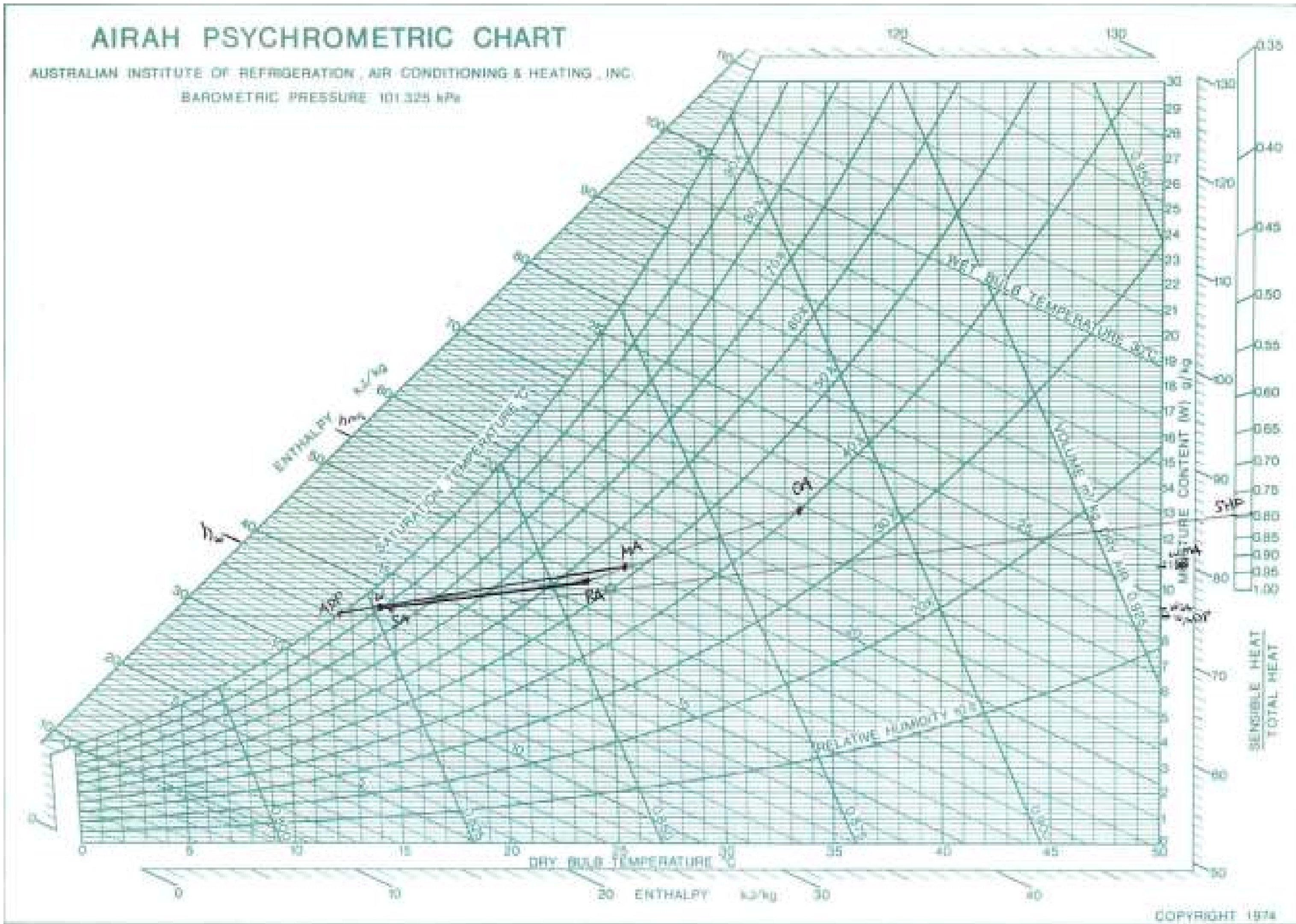
10. Plot the ADP point given the w_{ADP} at saturation curve (100%RH).
11. Draw the coil loading line by connecting the point MA and ADP.
12. From SA, draw a horizontal line (constant moisture) until it touched the coil loading line. This is the actual condition of the air leaving the coil (point W).
13. From psychrometric chart, take the enthalpy of MA and W.
    h_{MA} = 53.8 kJ/kgDA
    h_W = 37.9 kJ/kgDA
14. Calculate the cooling coil load

$$Q_{ref} = m_{SA}(h_{MA} - h_{W)} = 5.06(53.8 - 37.9)$$

$$Q_{ref} = 80.45\ kW$$

The manual psychrometric process chart for room 212 is shown in Figure 9. As point W and SA almost coincide and so the temperature and enthalpy difference between SA and W is small (around 1kW difference if calculated as heat) and thus no reheating is required.

Figure 9: Psychrometric chart of room 212



6.2 Room 213 psychrometric chart

The minimum supply air temperature is 12°C but 15°C is used due to psychrometric chart limitation.

1. Plot the points for RA (room air) and OA (outside air) based on the following given properties below then connect this 2 lines
   RA: 24°C DB / 55%RH
   OA: 33.8°C DB / 22.9 WB
2. Compute the sensible heat factor (SHF).
   Qs = 125983 W
   QL = 33538 W

$$\text{SHF} = \frac{Q_S}{Q_S + Q_L}$$

$$\text{SHF} = \frac{125983}{125983 + 33538} = 0.79$$

3. Given the SHF value, draw the SHF line from the scale to the reference point (25°C DB, 50%RH)
4. From RA draw a line with the same slope as the SHF line up to 15°C which is the supply air point SA. This is the room load line.
5. Calculate the supply air mass flow rate
   T_{SA} = 15°C

$$Q_S = 1.2V_{SA}(T_{RM} - T_{SA})$$

$$V_{SA} = \frac{Q_S}{1.2(T_{RM} - T_{SA})} = \frac{125983}{1.2(24 - 15)} = 11665\ l/s$$

$$m_{SA} = V_{SA}\rho = 11665(1.17 \times 10^{-3}) = 13.65\ kg/s$$

6. Calculate the outside air mass flow rate

$$V_{OA} = p \times OAR$$

p = number of occupants, 90 person

OAR = outside air requirements, 10l/s per person

$$V_{OA} = 90 \times 10 = 900 l/s$$

From psychrometric chart, take the specific volume *v* at point OA

$$v_{OA} = \ 0.8875\ m^3/kgDA$$

$$m_{OA} = \frac{V_{oa}}{v_{OA}} = \frac{900 \times 10^{-3}}{0.8875} = 1.01 kg/s$$

7. Calculate the ratio of m_{OA} to m_{SA}.

$$\frac{m_{OA}}{m_{SA}} = \frac{1.01}{13.65} = 0.074$$

8. Using the ratio calculated in No. 7 as a factor, measure the distance from point RA and tag it as point MA. This is the mixed air point.
   Length of RA to OA = 48mm
   48 x 0.074 =3.6mm from RA
9. Read the moisture content of MA and SA from psychrometric chart and solve for the moisture content of ADP (apparatus dew point) given the coil contact factor of 0.85.
   w_{MA} = 10.6 g/kgDA
   w_{SA}= 9.4 g/kgDA = w_W
$$\eta_c = \frac{w_{MA} - w_w}{w_{MA} - w_{ADP}}$$
$$w_{ADP} = 10.6 - \frac{(10.6 - 9.4)}{0.85} = 9.19\ g/kgDA$$
10. Plot the ADP point given the w_{ADP} at saturation curve (100%RH).
11. Draw the coil loading line by connecting the point MA and ADP.
12. From SA, draw a horizontal line (constant moisture) until it touched the coil loading line. This is the actual condition of the air leaving the coil (point W).
13. From psychrometric chart, take the enthalpy of MA and W.
    h_{MA} = 52.2 kJ/kgDA
    h_W = 38.5kJ/kgDA
14. Calculate the cooling coil load
$$Q_{ref} = m_{SA}(h_{MA} - h_{W)} = 13.65(52.2 - 38.5)$$
$$Q_{ref} = 187\ kW$$

The manual psychrometric process chart for room 212 is shown in Figure 10. Same with room 212, point W and SA almost coincide and so the temperature and enthalpy difference between SA and W is too small (around 2kW of heat difference) and thus no reheating is required.

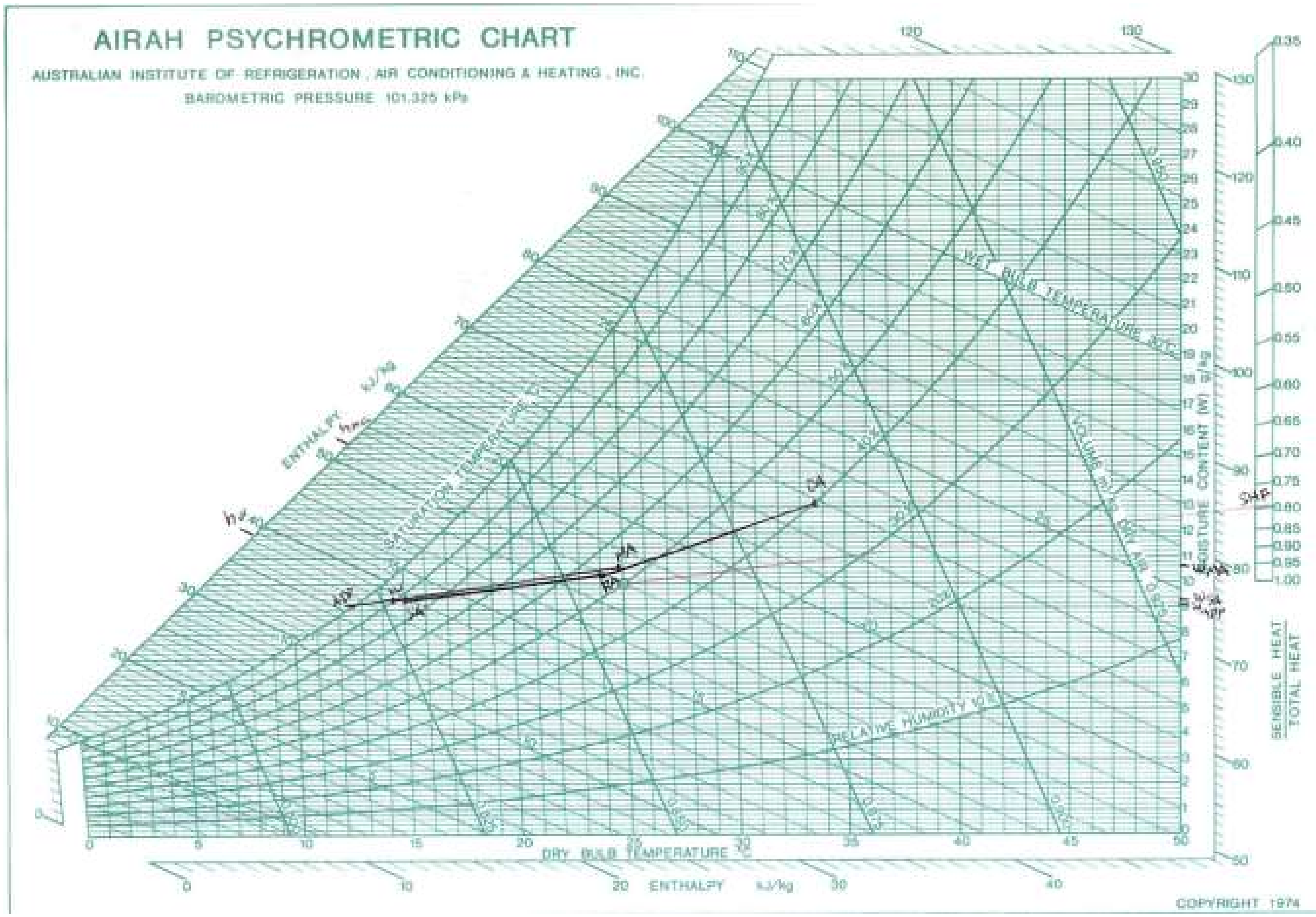


Figure 10: Psychrometric chart of room 213

7 Conclusion

The cooling and heating load of Room 212 and 213 is calculated manually and using psychrometric chart. As shown in the result, the cooling and heating load is mainly attributed to the internal load particularly the heat contribution of the appliances/equipment during summer and infiltration in both season.

The summer cooling load for room 212 and 213 is 80.45kW and 187kW respectively. Since room 213 is a restaurant, the bulk of the heat is produced by the appliances use for cooking specially the broilers, barbeque pits and the food warmers.

As a recommendation, the cooling load can be optimized by the following:

1. Use of more energy efficient appliance.
2. For room 213, a partition for cooking (kitchen or hot room) can be installed with a higher internal temperature and external force ventilation (air not passing through the AHU).

For the heating load, below is recommended

1. Proper sealing of the windows
2. Installation of automatic doors.
3. The ventilation system to be optimized to give a positive pressure inside the room.

As this is just the first part of the design, further optimization will be considered during the course of the detail engineering.

8 References

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