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Course code: MECH4880 **Course name:** Refrigeration and Air Conditioning

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Assignment: Assignment 1 - Part A - Manual Calculations

Assignment due date: 18/09/2016 **Date submitted:** 18/09/2016

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MECH4880
Refrigeration and Air Conditioning
Assignment 1 – Part A

Robert J Biviano

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Contents

1. Introduction

The aim of this design project is to calculate the heating and cooling loads on two rooms as part of a large shopping mall. The two rooms in question are shop 212 and shop 213, which share a neighbouring wall and courtyard. Australian guidelines regarding building insulation and air condition estimation will be used. Assumptions will need to be made during the course of this analysis, all of which will be clearly document in the relevant sections.

2. Design Day Selection

2.1. Design Days

In order to estimate heating and cooling loads, design days must be selected. A design day is defined as ‘a day of outside and inside design conditions, where there is little or no haze in the air to reduce the solar heat and when all of the internal loads are normal’[1].

In determining the design days, we must consider the greatest heating and cooling loads. It goes without saying that the greatest cooling loads occur in summer, whilst the greatest heating loads apply in winter. In order to maximise the cooling load two approaches can be used. One approach is the peak load on the room, which in our scenario corresponds to the peak outside temperature (3pm). Alternatively, we could look at the peak solar load on the room. Both approaches were looking at with the decision to use the maximum outside temp at the peak room load – 3pm as this peak also corresponds with the peak internal load of the rooms in question.

Similarly, for winter we seek the coldest part of the day where the maximum heating must be applied. To achieve this, we look for minimal internal loads, and minimal solar transmission. Both minimal internal loads and minimal solar transmission occur in the early hours of the morning where the Sun is yet to rise and when minimal occupants will be within the building. This time also corresponds to the lowest ambient temperature, further increasing the heating load required.

Summer design day	January 21st - 3pm
Winter design day	June 21st – 6am

2.2. Design conditions

The design conditions for this project are as follows.

[1] AIRAH, DA09 Application Manual, pg 3

Internal design conditions for all shops except M02 and 208

	Dry bulb temperature	Relative humidity
Summer	24°C	55%
Winter	21°C	80%

Internal design conditions – shop M02

	Dry bulb temperature	Relative humidity
Summer	22°C	55%
Winter	20°C	80%

External design conditions

	Dry bulb temperature	Wet bulb temperature	Relative humidity
Summer	33°C	22.9°C	-
Winter	2.1°C	-	80%

Latitude: 30° South

2.3. Definitions

Ceiling height and true floor height: Buildings house the equipment necessary to maintain constant operation within the ceiling, these items can include lighting, fire protection equipment, air condition units and air conduction ducting. This space is separated from the shop floor by way of a false ceiling. The difference between the false ceiling and the floor is described as the ceiling height, whereas, the true floor height is the measurement from the floor to the true ceiling, which includes the dropped ceiling.

Glazing: Glazing is the glass that is part of a wall. Glazing is usually framed and referred to as a window. Several types of glazing can be used with the differences being in the type of glass, the number of sheets used, the air space between the sheets when multiple sheets exist and the thickness of the glazing itself.

Partition: Partitions are walls that divide or separate internal rooms. This is different to an external wall which is defined as any wall that is directly influenced by solar radiation. Partitions have no wind speed on either side of them and are subjected to half the height transfer compared to external walls. Furthermore, as partitions are internal walls, they do not undergo the direct effects of solar radiation.

Infiltration: Imperfect seals throughout a building allow external, unconditioned air to enter and mix with conditioned air without planning. This is called infiltration. Infiltration most commonly occurs through the opening of windows or external doors and through gaps in window frames.

AHU: An AHU is an Air Handling Unit. This is the device that is central to an air conditioning system and is responsible for regulation and supply of air into a building.

2.4. Temperature ranges

From 1.1 the design days are January 21st for Summer and June 21st for Winter. From the provided temperatures, we obtain a yearly range of $33 - 2.1 = 31℃$. Note that this temperature range was determined prior to the amendment assignment document.

The daily range is defined as 'the difference between the average daily maximum and the average daily minimum dry bulb temperature' [2]

	Summer	**Winter**
Dry Bulb	$33°C$	$2.1°C$
Wet Bulb	$22.9°C$	-
Relative Humidity	-	0.80%

[2] DA09 Pg 17

3. External loads – wall specifications

3.1. U-Value and R-value definition

A U-value is ‘a measure of the heat transmission through a building part, (as a wall or window) or a given thickness of a material (as insulation) with lower number indicating better insulation properties’[3]. The units for a U-Value is ‘watts per meter degrees Celsius’[4]

An R-value is ‘a measure for resistance to the flow of heat through a given thickness of a material (as insulation) with higher numbers indication better insulation properties’[5].

The above definitions show that both U-values and R-values measure the same thing, that is, the rate of heat flow or transmission through a material. The differences between the two lie in the units with the U and R values being mathematical reciprocals of each other.

3.2. U Value series calculations

When calculating U-values for walls made from series layers of different materials the R-value for each material must first be found. Once the R-values are found they can be added together. The U-value is the reciprocal of the sum of the R-values of each material.

$$U_{total} = \frac{1}{R_1 + R_2 + R_3}$$

Equation 1- U-Value

3.3. Difference between Summer and Winter U-values

Summer and Winter U-values different from each other. The reason for this is due to wind speed, during winter conditions it is assumed that the external wind speed is greater. This effects the overall heat transfer, and thus the U-value of the item in question.

3.4. U-Values shop 212

3.4.1. Assumptions

For the calculation of shop 212, the following assumptions were made.

- All brick Veneer is 90mm with a 150mm air gap
- All plaster is 9mm unless specified below
- The east wall contains 12mm marble
- Double brick is 2x90mm Claybrick with a 60mm air gap and 15mm plaster both sides
- Roof has an interior ceiling finish of 12mm Plaster Tiles
- Mineral fibre insulation has the same U-value is fibreglass insulation
- All glazing is 6mm plate glass

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[3] http://www.merriam-webster.com/dictionary/U%E2%80%93value
[4] DA9 pg63
[5] http://www.merriam-webster.com/dictionary/r-value

3.4.2. Calculation of U-Values, shop 212

3.4.2.1. Windows - Reference 6mm plate glass

- $5.89\frac{w}{m^2°C}$ Summer
- $6.42\frac{w}{m^2°C}$ Winter

3.4.2.2. East Wall - Brick Veneer with plaster and marble.

- Summer U-Value of Brick Veneer wall with plaster = $2.2\frac{w}{m^2°C}$.
- Winter U-Value of Brick Veneer wall with plaster = $2.28\frac{w}{m^2°C}$
- R-value of 12mm marble = $0.00882\frac{m^2°C}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{2.2} + 0.00882} = 2.158\frac{w}{m^2°C}$$

$$U_{winter} = \frac{1}{\frac{1}{2.28} + 0.00882} = 2.235\frac{w}{m^2°C}$$

3.4.2.1. West wall and door - Reference 6mm plate glass

- $5.89\frac{w}{m^2°C}$ Summer
- $6.42\frac{w}{m^2°C}$ Winter

3.4.2.2. South wall - Double brick with plaster on both side

- Summer U-value of Double brick wall with one side of plaster = $2.01\frac{w}{m^2°C}$,
- Winter U-value of Double brick wall with one side of plaster = $2.02\frac{w}{m^2°C}$,
- Additional layer of plaster R-value = $0.041\frac{m^2°C}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{2.01} + 0.041} = 1.857\frac{w}{m^2°C}$$

$$U_{winter} = \frac{1}{\frac{1}{2.02} + 0.041} = 1.865\frac{w}{m^2°C}$$

3.4.2.3. North Wall - Brick veneer with plaster.

- U-value of Brick Veneer wall with plaster = $2.2\frac{w}{m^2°C}$.
- U-value of Brick Veneer wall with plaster = $2.28\frac{w}{m^2°C}$.

3.4.2.4. Floor - 150mm concrete slab covered with carpet

- U-Value Heat flow up = U-value = $0.994\frac{w}{m^2°C}$.
- U-Value Heat flow down = U-value = $0.895\frac{w}{m^2°C}$.

3.4.2.5. Ceiling - 100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking.

- U-Value heat flow down 12mm hardwood with 100mm insulation = 0.345 $\frac{w}{m^2°C}$
- U-Value heat flow down Plaster Tiles = 1.81 $\frac{w}{m^2°C}$
- U-Value heat flow up 12mm hardwood with 100mm insulation = 0.353 $\frac{w}{m^2°C}$
- U-Value heat flow up Plaster Tiles = 2.08 $\frac{w}{m^2°C}$

$$U_{heat\ flow\ down} = \frac{1}{\frac{1}{0.345}+\frac{1}{1.81}} = 0.2898\frac{w}{m^2°C}$$

$$U_{heat\ flow\ up} = \frac{1}{\frac{1}{0.353}+\frac{1}{2.08}} = 0.322\frac{w}{m^2°C}$$

Table 1- U -Values shop 212

	Material	**U-Value (Summer)** $\frac{w}{m^2°C}$	**U-Value (Winter)** $\frac{w}{m^2°C}$	**DA09 Table reference**
Windows (East)	plate glass with metal frame	5.890	6.420	Table 36
Wall (East)	brick veneer, plastered outside and thin marble inside	2.158	2.235	Table 25
Wall and Door (West)	Glazing	5.890	6.420	Table 36
Wall (North)	Brick cavity, plastered inside	2.184	2.263	Table 25
Wall (South)	Double brick, plastered both sides	1.857	1.865	Table 24
Ceiling	100mm rafters with plaster below, fibreglass insulation between the rafters, topped by 25mm wooden roof deck and covered by metal decking (clip-lock style).	0.29	0.32	Table 29/30
Floor	150mm concrete slab covered with carpet above and a false ceiling space (0.4m) below	0.895	0.895	Table 33/34

Floor (top of M02)	150mm concrete slab covered with carpet above and a false ceiling space (0.4m) below	0.895	0.895	Table 33/34

3.5. U-Values shop 213

3.5.1. Assumptions

For the calculation of shop 213, the following assumptions were made.

- All brick Veneer is 90mm with a 150mm air gap
- All plaster is 9mm unless specified below
- The east wall contains 12mm marble
- Double brick is 2x90mm Claybrick with a 60mm air gap and 15mm plaster both sides
- The South wall has 15mm Gypsum Plaster
- Roof has an interior ceiling finish of 12mm Plaster Tiles
- Mineral fibre insulation has the same U-value is fibreglass insulation
- The west brick veneer wall has a plaster finish on both sides
- All glazing is 6mm plate glass

3.5.2. Calculation of U-Values, shop 213

3.5.2.1. Windows - Reference 6mm plate glass

- $5.89\frac{w}{m^2°\text{C}}$ Summer
- $6.42\frac{w}{m^2°\text{C}}$ Winter

3.5.2.2. East Wall - Brick Veneer with plaster and marble.

- Summer U-Value of Brick Veneer wall with plaster = $2.2\frac{w}{m^2°\text{C}}$.
- Winter U-Value of Brick Veneer wall with plaster = $2.28\frac{w}{m^2°\text{C}}$
- R-value of 12mm marble = $0.00882\frac{m^2°\text{C}}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{2.2} + 0.00882} = 2.158\,\frac{w}{m^2°\text{C}}$$

$$U_{winter} = \frac{1}{\frac{1}{2.28} + 0.00882} = 2.235\,\frac{w}{m^2°\text{C}}$$

3.5.2.3. West wall and door - Reference 6mm plate glass

- $5.89\frac{w}{m^2°\text{C}}$ Summer
- $6.42\frac{w}{m^2°\text{C}}$ Winter

3.5.2.4. West wall - Brick veneer with plaster

- Summer U-Value of Brick Veneer wall with plaster = $2.2 \frac{w}{m^2 °C}$.
- Winter U-Value of Brick Veneer wall with plaster = $2.28 \frac{w}{m^2 °C}$
- R-Value of 9mm plaster = $0.0033 \frac{m^2 °C}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{2.2} + 0.0033} = 2.18 \frac{w}{m^2 °C}$$

$$U_{winter} = \frac{1}{\frac{1}{2.28} + 0.0033} = 2.26 \frac{w}{m^2 °C}$$

3.5.2.5. North wall - Double brick with plaster on both side

- Summer U-value of Double brick wall with one side of plaster = $2.01 \frac{w}{m^2 °C}$,
- Winter U-value of Double brick wall with one side of plaster = $2.02 \frac{w}{m^2 °C}$,
- Additional layer of plaster R-value = $0.041 \frac{m^2 °C}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{2.01} + 0.041} = 1.857 \frac{w}{m^2 °C}$$

$$U_{winter} = \frac{1}{\frac{1}{2.02} + 0.041} = 1.865 \frac{w}{m^2 °C}$$

3.5.2.6. South Wall – Crushed Rock aggregate, plaster both sides

- Summer U-value of Crushed Rock aggregate wall = $3.91 \frac{w}{m^2 °C}$.
- Winter U-value of Crushed Rock aggregate wall = $4.15 \frac{w}{m^2 °C}$.
- R-value of 15mm Gypsum plaster = $0.041 \frac{m^2 °C}{w}$

$$U_{Summer} = \frac{1}{\frac{1}{3.91} + 0.041} = 3.37 \frac{w}{m^2 °C}$$

$$U_{winter} = \frac{1}{\frac{1}{4.15} + 0.041} = 3.55 \frac{w}{m^2 °C}$$

3.5.2.7. Floor - 150mm concrete slab covered with carpet

- U-Value Heat flow up = U-value = $0.994 \frac{w}{m^2 °C}$.
- U-Value Heat flow down = U-value = $0.895 \frac{w}{m^2 °C}$.

3.5.2.8. Ceiling - 100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking.

- U-Value heat flow down 12mm hardwood with 100mm insulation = 0.345 $\frac{w}{m^2℃}$
- U-Value heat flow down Plaster Tiles = 1.81 $\frac{w}{m^2℃}$
- U-Value heat flow up 12mm hardwood with 100mm insulation = 0.353 $\frac{w}{m^2℃}$
- U-Value heat flow up Plaster Tiles = 2.08 $\frac{w}{m^2℃}$

$$U_{heat\ flow\ down} = \frac{1}{\frac{1}{0.345} + \frac{1}{1.81}} = 0.2898\,\frac{w}{m^2℃}$$

$$U_{heat\ flow\ up} = \frac{1}{\frac{1}{0.353} + \frac{1}{2.08}} = 0.322\,\frac{w}{m^2℃}$$

Table 2- U-Values shop 213

	Material	**U-Value(Summer)** $\frac{w}{m^2℃}$	**U-Value(Winter)** $\frac{w}{m^2℃}$	**DA09 Table reference**
Windows (East)	plate glass with metal frame	5.89	6.42	Table 36
Wall (East)	brick veneer, plastered outside and thin marble inside	2.158	2.235	Table 25/37
Windows (South)	plate glass with metal frame	5.89	6.42	Table 3
Wall (South)	Crushed Rock Aggregate with 100mm thickness plastered both sides	3.4	3.5	Table 24/37
Wall (North)	Double brick, plastered both sides	1.86	1.86	Table 24
Wall (West)	Brick cavity, plastered inside	2.18	2.26	Table 25
Wall and Door (West)	Glazing	5.890	6.420	Table 36
Floor (top of Supermarket)	150mm concrete slab covered with carpet above	0.895	0.895	Table 33-34

Ceiling	100mm rafters with plaster below, fibreglass insulation between the rafters, topped by 25mm wooden roof deck and covered by metal decking (clip-lock style).	0.289	0.323	Table 29/30

3.6. Minimum R-Values for a typical wall, roof and floor

Reading from table J1.3, J1.5, J1.6 from NCC 2016 Volume 6, with a Climate Zone of 6, we can obtain the following table of Typical R-values.

Table 3- Typical R-Values under NCC

Surface	**Typical R-Value** ($\frac{m^2 °C}{w}$)	**Typical U-Value** ($\frac{w}{m^2 °C}$)
External Wall (with surface density greater than 220 kg/m^2	2.3	0.435
Roof	3.2	0.3125
Floor	2	0.5

3.7. Adjusted U-values

Adjusting the R-values in 0.5 steps to achieve the minimums required in 2.6 yields the following.

Table 4- Adjust R-values

Shop	**Original R-Value Summer** ($\frac{m^2 °C}{w}$)	**Original R-Value Winter** ($\frac{m^2 °C}{w}$)	**Adjusted R-value** ($\frac{m^2 °C}{w}$)
212 East wall	0.46	0.44	2.46
213 East wall	0.46	0.44	2.46
213 South wall	0.3	0.28	2.3

3.8. Storage mass definition

Storage masses are items that retain heat/energy that has been radiated to it, usually from lighting and solar transmission. These items then slowly dissipate this heat/energy back into the room. They form a type of 'buffer' as radiation does not immediately add heat to a room, but rather slowly heat the storage masses, until which point where the storage masses release this heat in the form of conduction and convection back into the room. The end effect is the room temperature has less fluctuations associated with it.

3.9. Storage mass calculation

As room 212 and 213 both have at least one wall on the building exterior, the following formula can be used to calculate the storage mass of each room.

$$Storage\ mass^{6} = \frac{(Mass\ of\ outside\ walls) + 0.5\ (Mass\ of\ partitions, floor\ and\ ceiling)}{Floor\ area\ in\ room}$$

Equation 2- Storage mass

3.9.1. Storage mass calculation room 212

The assumptions in 2.5.1 also hold here.

3.9.1.1. East Wall - Brick Veneer with plaster and marble.

- Mass per unit area of Brick Veneer = 184 $\frac{kg}{m^2}$
- Mass per unit area of 9mm Plaster = 9.9 $\frac{kg}{m^2}$
- Mass per unit area of 12mm marble = ($\frac{12}{1000}m \times 2643\frac{kg}{m^3}$) = 31.716 $\frac{kg}{m^2}$

$$Mass_{East\ Wall} = 184 + 9.9 + 31.716\ = 225.62\ \frac{kg}{m^2}$$

3.9.1.2. North wall - Brick Veneer with plaster

- Mass per unit area of Brick Veneer = 184 $\frac{kg}{m^2}$
- Mass per unit area of 9mm Plaster = 9.9 $\frac{kg}{m^2}$

$$Mass_{North\ Wall} = 184 + 9.9 + 9.9\ = 203.8\ \frac{kg}{m^2}$$

3.9.1.3. South Wall – Double brick with plaster both sides

- Mass per unit area of Double brick = 346 $\frac{kg}{m^2}$
- Mass per unit area of 15mm Plaster = 21 $\frac{kg}{m^2}$

$$Mass_{South\ Wall} = 346 + 21 + 21\ = 388\ \frac{kg}{m^2}$$

3.9.1.4. Floor - 150mm concrete slab covered with carpet

- Mass per unit area of floor = 418 $\frac{kg}{m^2}$

$$Mass_{Floor} = 418\frac{kg}{m^2}$$

[6] DD09 Table 6- pg 26

3.9.1.5. *Ceiling - 100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking.*

- Mass per unit area of wood roof = 62 $\frac{kg}{m^2}$
- Mass per unit area of 12mm Plaster = 24 $\frac{kg}{m^2}$
- Mass per unit area of Mineral fibre = 6 $\frac{kg}{m^2}$

$$Mass_{Ceiling} = 62 + 24 + 6 = 92 \frac{kg}{m^2}$$

The above mass per unit areas can then be multiplied by the area of each surface.

Table 5- Storage mass shop 212

	Area m^2	**Per Unit mass (**$\frac{kg}{m^2}$**)**	**Mass** (kg)
East Wall	104	225.62	23,464.48
North Wall	90	203.8	18,342
South Wall	90	388	34,920
Floor	390	418	163,020
Ceiling	390	92	35,880

The storage mass of room 213 can then be calculated as:

$$(Storage\ mass)_{212} = \frac{Mass_{East\ wall} + 0.5(Mass_{South\ wall} + Mass_{North\ Wall} + Mass_{Floor} + Mass_{ceiling})}{Area_{213}}$$

$$= \frac{23{,}464.48 + 0.5(34{,}920 + 18{,}342 + 163{,}020 + 34{,}880)}{390}$$

$$= 382\left(\frac{kg}{m^2}\right)$$

<u>3.9.2. Storage mass calculation room 213</u>

The assumptions in 2.5.1 also hold here.

3.9.2.1. *East Wall - Brick Veneer with plaster and marble.*

- Mass per unit area of Brick Veneer = 184 $\frac{kg}{m^2}$
- Mass per unit area of 9mm Plaster = 9.9 $\frac{kg}{m^2}$
- Mass per unit area of 12mm marble = $(\frac{12}{1000} m \times 2643 \frac{kg}{m^3})$ = 31.716 $\frac{kg}{m^2}$

$$Mass_{East\ Wall} = 184 + 9.9 + 31.716 = 225.62 \frac{kg}{m^2}$$

3.9.2.2. West wall - Brick veneer with plaster

- Mass per unit area of Brick Veneer = 184 $\frac{kg}{m^2}$
- Mass per unit area of 9mm Plaster = 9.9 $\frac{kg}{m^2}$

$$Mass_{West\,Wall} = 184 + 9.9 + 9.9 = 203.8\ \frac{kg}{m^2}$$

3.9.2.3. North wall - Double brick with plaster on both side

- Mass per unit area of Double brick = 346 $\frac{kg}{m^2}$
- Mass per unit area of 15mm Plaster = 21 $\frac{kg}{m^2}$

$$Mass_{North\,Wall} = 346 + 21 + 21 = 388\ \frac{kg}{m^2}$$

3.9.2.4. South Wall – Crushed Rock aggregate, plaster both sides

- Mass per unit area of crushed Rock aggregate = 240 $\frac{kg}{m^2}$
- Mass per unit area of 15mm Plaster = 21 $\frac{kg}{m^2}$

$$Mass_{South\,Wall} = 240 + 21 + 21 = 282\ \frac{kg}{m^2}$$

3.9.2.5. Floor - 150mm concrete slab covered with carpet

- Mass per unit area of floor = 418 $\frac{kg}{m^2}$

$$Mass_{Floor} = 418\frac{kg}{m^2}$$

3.9.2.6. Ceiling - 100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking.

- Mass per unit area of wood roof = 62 $\frac{kg}{m^2}$
- Mass per unit area of 12mm Plaster = 24 $\frac{kg}{m^2}$
- Mass per unit area of Mineral fibre = 6 $\frac{kg}{m^2}$

$$Mass_{Ceiling} = 62 + 24 + 6 = 92\ \frac{kg}{m^2}$$

The above mass per unit areas can then be multiplied by the area of each surface.

Table 6- Storage mass shop 213

	Area m^2	**Per Unit mass** ($\frac{kg}{m^2}$)	**Mass** (kg)
East Wall	116	225.62	26,171.92
West Wall	90	203.8	18,342
North Wall	90	388	34,920
South Wall	64	282	18,048
Floor	436	418	182,248

Ceiling	436	92	40,112

The storage mass of room 213 can then be calculated as:

$$(Storage\ mass)_{213} = \frac{Mass_{East\ wall} + Mass_{South\ wall} + 0.5(Mass_{West\ wall} + Mass_{North\ Wall} + Mass_{Floor} + Mass_{ceiling})}{Area_{213}}$$

$$= \frac{26{,}171.92 + 18{,}048 + 0.5(18{,}342 + 34{,}920 + 182{,}248 + 40{,}112)}{436}$$

$$= 417.5(\frac{kg}{m^2})$$

4. External loads – Solar Transmission

4.1. Surfaces experiencing solar transmission loads

All external surfaces undergo solar transmission loads. The extent of the solar transmission loads depends on the angle of the surface and its orientation. For the purposes of calculations, the following surfaces are determined to be external.

- Shop 212 and 213 East wall
- Shop 212 and 213 ceiling/roof
- Shop 213 South wall

It is assumed that the glazing on the west walls of shop 212 and 213 are fully shaded and experience no wind, thus they are deemed to be partitions and will be discussed further in Section 4.

4.2. Modified temperature difference

The modified temperature difference in relation to solar determines the effective heat transfer through an external surface due to Solar radiation. As Solar radiation hits an external surface it begins to heat the outer most portion of that surface. This increases the temperature of the outer layer creating a convection heat transfer from the surface back to the ambient air. Similarly, conduction heat transfer takes place through the external surface, eventually reaching the inside surface. As both convection and conduction is occurring simultaneously, and often in both directions, the external panel takes time to heat up and eventually transfer heat into the air conditioned space. In order to calculate this rate, a modified temperature difference is used.

Given the location of this project, the modified temperature difference due to solar is lower than the temperature difference between internal and external surfaces. This difference ranges from 0.5℃ to 2℃ depending on the external wall in question.

4.3. Glazing heat load

Equation 3-Cooling load due to Glazing heat load

$$
\begin{aligned}
Cooling\ load\ &= Peak\ solar\ at\ design\ time\ \times window\ area \times storage\ load\ factor \\
&\quad \times k1 \times k2 \times k3 \times k4 \times k5 \times k6
\end{aligned}
$$

$$
\begin{aligned}
&where \\
&k1 = sash\ correction\ factor \\
&k2 = haze\ correction\ factor \\
&k3 = altitude\ correction\ factor \\
&k4 = dewpoint\ correction\ factor \\
&k5 = glass\ factor \\
&k6 = solar\ factor
\end{aligned}
$$

Each component associated with Glazing heat load is detailed below

4.3.1.1. *Peak solar at design time*

This is the peak solar time experienced at the design time, for the respective orientation and Latitude of the glazing.

Table 7- Solar Heat Gain

Shop and Orientation	**Solar Heat Gain** $(\frac{W}{m^2})$
Shop 212 East Glazing	44
Shop 213 East Glazing	44
Shop 213 South Glazing	44

4.3.1.2. *Window Area*

This is the area of the glazing.

Table 8- Area of Windows

Shop and Orientation	**Area** (m^2)
Shop 212 East Glazing	52
Shop 213 East Glazing	58
Shop 213 South Glazing	26

4.3.1.3. *Storage Load Factor*

This is the amount of heat/energy stored by the surfaces of the room due to solar radiation.

From table 9[7] we assume the Mass per unit floor area is 500 $\frac{kg}{m^2}$ for both shop 212 and 213 and that the shopping centre operates within a 16-hour cycle. Taking our design condition of 3pm, and assuming that the glass is bare and without shading we obtain the following Storage Load Factors

Table 9- Storage Load Factor for Orientation

Orientation	**Sun Time (bare glass)**
East	0.25
South	0.80

4.3.1.4. *Sash Correction Factor*

Takes into account the heat transfer through the Sash of the glazing. As we have a Steel Sash surrounding all Glazing, we apply a 1.17 correction factor

4.3.1.5. *Haze Correction Factor*

Haze can determine the amount of Solar radiation that makes it way to the building as haze is able to defuse, and this lower the peak Solar radiation seen by the building.

It is assumed that haze is minimal and no correction factor need be applied.

[7] DA09

4.3.1.6. Altitude Correction Factor

Altitude determines the distance from the Sun and the amount of Solar radiation received. Altitude correction need only be applied once the altitude reaches 1000m or above.

As Temperate Town is below 1,000m no correction factor is applied.

4.3.1.7. Dewpoint Correction Factor

The dewpoint of the air effects the amount of Solar radiation received as the moisture content is able to diffuse/reduce the radiation that makes its way to the external surface of the building.

Correction factors of $\pm$ 13% must be applied per every 10°C above/below respectively.

Temperate town has a Due Point of 18.5°C during our design condition. This gives the following correction.

$$1 + \frac{18.5 - 20}{10} \times 0.13 = 98.05\%$$

4.3.1.8. Glass Factor

The type of glass influences the amount of Solar radiation diffused between the external layer of the glazing and the internal layer of the glazing. This decreases the amount of solar transmitted through the glass.

All glazing for this project is 6mm reference glass which gives a Glass Factor of 1.00[8]

4.3.1.9. Solar Factor

Solar Factor takes into account any external shading devices. This reduces the solar load introduced in to the room.

As per the design parameters, no internal shading devices have been accounted for.

4.4. External solar transmission calculation

4.4.1. Solar transmission due to Glazing heat load

From section 3.3 the cooling load due to glazing can be calculated as follows.

$$Cooling\ load\ correction\ factors\ for\ all\ rooms = 1.17 \times 1 \times 1 \times 0.9805 \times 1 \times 1 = \ 1.147$$

4.4.1.1. Shop 212 East Glazing

$$Cooling\ load\ = 1.147 \times 44 \times 52 \times 0.25 = 656.084 \text{ W}$$

4.4.1.2. Shop 213 East Glazing

$$Cooling\ load\ = 1.147 \times 44 \times 58 \times 0.25 = 731.786 \text{ W}$$

4.4.1.3. Shop 213 South Glazing

$$Cooling\ load\ = 1.147 \times 44 \times 26 \times 0.8 = 1{,}049.7344 \text{ W}$$

[8] DA09 Table 15 – page 46

4.4.2. Solar transmission due to temperature difference

Solar transmission due to temperature difference is calculated using the following formula.

$$\Delta t_e = 0.55 \frac{\sigma_s}{\sigma_m} + \left(1 - 0.78 \frac{\sigma_s}{\sigma_m}\right) \Delta t_{es}$$

$$where$$
$$\Delta t_e = equilivant\ temperature\ difference\ for\ month\ and\ latitude\ desired$$
$$\sigma_s \ = maximum\ solar\ heat\ gain\ for\ glass\ are\ month\ and\ latitude\ desired$$
$$\sigma_m \ = maximuim\ solar\ heat\ gain\ at\ January, 40°\ South\ Latitude$$
$$\Delta t_{es} = \ equlivant\ temperature\ difference\ at\ January, 40°\ South\ Latitude$$
$$0.55\ is\ the\ figure\ used\ for\ light\ colour\ surfaces$$

A correction factor of -1 must be made as the daily temperature difference experience by building is 9℃ whilst the reference is calculated at 10℃

The equivalent temperature is dependent on the mass of the external wall not including any windows. From 2.9 and 3.3 the mass of the external walls can be calculated as follows

Table 10- Mass of external walls

Shop and Orientation	**Mass ($\frac{kg}{m^2}$)**
Shop 212 East Wall	226
Shop 212 Roof	92
Shop 213 East Wall	226
Shop 213 South Wall	282
Shop 213 Roof	92

Calculation of the above yields the following

Table 11- Equivalent Temperature

Shop and Orientation	**Equivalent temperature** (Δt_e)
Shop 212 East Wall	7.8
Shop 213 East Wall	7.8
Shop 213 South Wall	5.7
Roof	12.62

$$heat\ gain\ through\ walls = Area\ \times UValue\ \times\ \Delta t_e$$

Equation 4- Solar transmission

By applying Δt_e to the external walls in shops 212 and 213 we get the following results.

Table 12- Shop 212 - Solar Heat Gain

Shop 212				
Surface	Area (m^2)	Adjusted U-Value $\frac{w}{m^2℃}$	Δt_e	Heat Gain (W)
East Wall	104	0.4065	7.8	330
Roof	390	0.29	12.62	1,425.6

Total				1,755.6

Table 13- Shop 213 - Solar Heat Gain

Shop 213				
Surface	Area (m^2)	Adjusted U-Value $\frac{w}{m^2℃}$	Δt_e	Heat Gain (W)
East Wall	116	0.4065	7.8	368
South Wall	64	0.4348	5.7	159
Roof	436	0.29	12.62	1,593.8
Total				2,120.8

5. External Loads – Summer Partitions

5.1. Partition and external surface difference

Partitions are walls that separate or divide internal rooms whereas external surfaces separate rooms from ambient conditions. The heat load calculation differs between them by the value of one half. This is due to the assumption that the unconditioned space between the two partitions is at a temperature midway between the temperatures of the two rooms.

5.2. Partitions Shop 212

For all partitions, the following formula can be used to calculated the cooling load

$$cooling\ load = 0.5\ \times \text{area}\ \times UValue\ \times (outside\ temperature - inside\ temperature)$$

Equation 5- Internal heat transfer

5.2.1.1. West wall and door

Reference 6mm plate glass - $5.89\frac{w}{m^2℃}$ Summer, $6.42\frac{w}{m^2℃}$ Winter

Area of $156m^2$

External conditions of West wall and door are the courtyard conditions of 33℃

$$cooling\ load = 0.5\ \times 156\ \times 5.89\ \times (33 - 24) = 4{,}134.78\ \text{W}$$

5.2.1.2. South wall

Double brick with plaster on both side – U-value of Double brick wall with one side of plaster = $2.01\frac{w}{m^2℃}$, additional layer of plaster R-value = $0.041\frac{m^2℃}{w}$

External conditions of the South wall are the temperature of Shop 213 - 24℃

$$cooling\ load = 0 \text{ as no difference between the outside and inside temperature}$$

5.2.1.3. North Wall

Brick veneer with plaster. U-value of Brick Veneer wall with plaster = $2.2\frac{w}{m^2℃}$.

External conditions of North wall are the temperature of Shop 212 - 24℃

$$cooling\ load = 0 \text{ as no difference between the outside and inside temperature}$$

5.2.1.4. Floor

150mm concrete slab covered with carpet. U-Value Summer = U-value = $0.895\frac{w}{m^2℃}$.

External conditions of Floor are the combined temperatures of Shop MM15 and M02. MM15 is at 24℃, M02 is at 22℃

$225m^2$ of the floor is above M02 and $165m^2$of the floor is above M02. Only the floor above M02 is calculated as there is no temperature difference between shop 212 and shop MM15.

$$cooling\ load = 0.5\ \times 165\ \times 0.895\ \times (22 - 24) =\ -147.68\ W$$

The above calculations yield the following table

Table 14- Shop 212 - Summer Partitions Load

Shop 212	
Surface	Cooling load (W)
West wall and door	4,134.78
Floor	-147.68
Total	3990.1

5.3. Partitions Shop 213

5.3.1.1. West wall and door

Reference 6mm plate glass - 5.89$\frac{w}{m^2℃}$ Summer, 6.42$\frac{w}{m^2℃}$ Winter

Area of $84m^2$

External conditions of West wall and door are the courtyard conditions of 33℃

$$cooling\ load = 0.5\ \times 84\ \times 5.89\ \times (33 - 24) = 2{,}226.42\ \text{W}$$

5.3.1.2. West wall

Brick veneer with plaster. U-value of Brick Veneer wall with plaster = 2.2$\frac{w}{m^2℃}$.

External conditions of the West wall are the temperature of Shop 213 - 24℃

$cooling\ load = 0$ as no difference between the outside and inside temperature

5.3.1.3. North wall

Double brick with plaster on both side – U-value of Double brick wall with one side of plaster = 2.01$\frac{w}{m^2℃}$, additional layer of plaster R-value = 0.041$\frac{m^2℃}{w}$

External conditions of the North wall are the temperature of Shop 212 - 24℃

$cooling\ load = 0$ as no difference between the outside and inside temperature

5.3.1.4. Floor

150mm concrete slab covered with carpet. U-Value Summer = U-value = 0.895$\frac{w}{m^2℃}$.

External conditions of Floor are the temperature of M02 - 22℃

Area of $436m^2$

$$cooling\ load = 0.5 \times 436 \times 0.895 \times (22 - 24) = -390.22\ W$$

Table 15- Shop 213 - Summer Partitions Load

Shop 213	
Surface	Cooling load (W)
West wall and door (glass)	2.226.42
Floor	-390.22
Total	1,836.2

6. External Loads – Winter

6.1. External cooling and heating load differences

When calculating external heating loads, the design time at 6am means that there is no Solar radiation as the Sun is yet to rise, whereas when calculating cooling loads, Solar transmission has a significant effect on the final cooling load. Cooling calculations use a modified temperature difference due to radiation on the outside of the building, whereas cooling design has is influence directly by the actual external temperature.

During winter design conditions heat is transferring from the building to its surroundings, whereas, during cooling design the heat is transferring from external conditions into the building. The difference in wind also contributes to many walls having differing U-values between Summer and Winter.

6.2. Winter conditions calculation

When calculating Winter conditions both Partitions and External walls need to be accounted for.

6.2.1. Partitions

6.2.1.1. Partitions Shop 212

6.2.1.1.1. West wall and door

Reference 6mm plate glass - 5.89$\frac{w}{m^2℃}$ Summer, 6.42$\frac{w}{m^2℃}$ Winter

Area of 156m^2

External conditions of West wall and door are the courtyard conditions of 2.1℃

$$cooling\ load = 0.5\ \times 156\ \times 6.42\ \times (2.1 - 21) = -9{,}464.36\ \text{W}$$

6.2.1.1.2. South wall

Double brick with plaster on both side – U-value of Double brick wall with one side of plaster = 2.01$\frac{w}{m^2℃}$, additional layer of plaster R-value = 0.041$\frac{m^2℃}{w}$

External conditions of the South wall are the temperature of Shop 213 - 24℃

$$cooling\ load = 0 \text{ as no difference between the outside and inside temperature}$$

6.2.1.1.3. North Wall

Brick veneer with plaster. U-value of Brick Veneer wall with plaster = 2.2$\frac{w}{m^2℃}$.

External conditions of North wall are the temperature of Shop 212 - 24℃

$cooling\ load = 0$ as no difference between the outside and inside temperature

6.2.1.1.4. Floor

150mm concrete slab covered with carpet. U-Value Summer = U-value = $0.895\frac{w}{m^2°C}$.

External conditions of Floor are the combined temperatures of Shop MM15 and M02. MM15 is at 24℃, M02 is at 20℃

$225m^2$ of the floor is above M02 and $165m^2$of the floor is above M02. Only the floor above M02 is calculated as there is no temperature difference between shop 212 and shop MM15.

$$cooling\ load = 0.5\ \times 165\ \times 0.895\ \times (20 - 21) =\ -73.84\ W$$

The above calculations yield the following table

6.2.1.2. Partitions Shop 213

6.2.1.2.1. West wall and door

Reference 6mm plate glass - $5.89\frac{w}{m^2°C}$ Summer, $6.42\frac{w}{m^2°C}$ Winter

Area of $84m^2$

External conditions of West wall and door are the courtyard conditions of 2.1℃

$$cooling\ load = 0.5\ \times 84\ \times 6.42\ \times (2.1 - 21) = -5{,}096.2\ \text{W}$$

6.2.1.2.2. West wall

Brick veneer with plaster. U-value of Brick Veneer wall with plaster = $2.2\frac{w}{m^2°C}$.

External conditions of the West wall are the temperature of Shop 213 - 24℃

$cooling\ load = 0$ as no difference between the outside and inside temperature

6.2.1.2.3. North wall

Double brick with plaster on both side – U-value of Double brick wall with one side of plaster = $2.01\frac{w}{m^2°C}$, additional layer of plaster R-value = $0.041\frac{m^2°C}{w}$

External conditions of the North wall are the temperature of Shop 212 - 24℃

$cooling\ load = 0$ as no difference between the outside and inside temperature

6.2.1.2.4. Floor

150mm concrete slab covered with carpet. U-Value Summer = U-value = $0.895\frac{w}{m^2°C}$.

External conditions of Floor are the temperature of M02 - 20℃

Area of $436m^2$

$$cooling\ load = 0.5\ \times 436\ \times 0.895\ \times (20 - 21) =\ -195.11\ W$$

6.2.2. External Panels

Heat transfer takes place between the external panels of each shop and the ambient conditions. The following formula can be used to estimate this heat transfer.

$$cooling\ load = \text{area}\ \times UValue\ \times (outside\ temperature - inside\ temperature$$

6.2.2.1. Shop 212

6.2.2.1.1. East Wall

Brick Veneer with plaster and marble - $0.407\,\frac{w}{m^2℃}$

Area of $104m^2$

External conditions of East wall are 2.1℃

$$cooling\ load = 104\ \times 0.407\ \times (2.1 - 21) = -799\ \text{W}$$

6.2.2.1.2. East Windows

Reference 6mm plate glass - $6.42\frac{w}{m^2℃}$ Winter

Area of $52m^2$

External conditions of East windows are 2.1℃

$$cooling\ load = 52\ \times 6.42\ \times (2.1 - 21) = -6{,}039.58\ \text{W}$$

6.2.2.1.3. Ceiling

100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking – $0.322\ \frac{w}{m^2℃}$ heat flow up.

Area of $390m^2$

External conditions of Ceiling are 2.1℃

$$cooling\ load = 390\ \times 0.322\ \times (2.1 - 21) = -2{,}373.46\ \text{W}$$

6.2.2.2. Shop 213

6.2.2.2.1. East Wall

Brick Veneer with plaster and marble - 0.407 $\frac{w}{m^2℃}$

Area of $116m^2$

External conditions of East wall are 2.1℃

$$cooling\ load = 116\ \times 0.407\ \times (2.1 - 21) = -891.22 \text{ W}$$

6.2.2.2.2. East Windows

Reference 6mm plate glass - 6.42$\frac{w}{m^2℃}$ Winter

Area of $58m^2$

External conditions of East windows are 2.1℃

$$cooling\ load = 58\ \times 6.42\ \times (2.1 - 21) = -7{,}037.6 \text{ W}$$

6.2.2.2.3. South Wall

Crushed Rock aggregate, plaster both sides – 0.435$\frac{w}{m^2℃}$

Area of $64m^2$

External conditions of South windows are 2.1℃

$$cooling\ load = 64\ \times .435\ \times (2.1 - 21) = -525.91 \text{ W}$$

6.2.2.2.4. South Windows

Reference 6mm plate glass - 6.42$\frac{w}{m^2℃}$ Winter

Area of $26m^2$

External conditions of South windows are 2.1℃

$$cooling\ load = 26\ \times 6.42\ \times (2.1 - 21) = -3{,}154.79 \text{ W}$$

6.2.2.2.5. Ceiling

100mm rafters with plaster below. Fibreglass insulation topped by wooden roof deck and covered by metal decking – 0.322 $\frac{w}{m^2℃}$ heat flow up.

Area of $436m^2$

External conditions of Ceiling are 2.1℃

$$cooling\ load = 436\ \times 0.322\ \times (2.1 - 21) = -2{,}653.41\ \text{W}$$

6.3. Summary of Winter External loads

Table 16- Shop 212 - Winter Partitions Load

Shop 212 Partitions	
Surface	Cooling load (W)
West wall and door	-9,464.36
Floor	-73.84
Total	-9,538.2

Table 17- Shop 212 - Winter External Panel Load

Shop 212 External Panels	
Surface	Cooling load (W)
East Wall	-799
East Windows	-6,039.58
Ceiling	-2,373.46
Total	-9,212.04

Table 18- Shop 213 - Winter Partitions Load

Shop 213 Partitions	
Surface	Cooling load (W)
West wall and door (glass)	-5,096.2
Floor	-195.11
Total	-5,291.31

Table 19- Shop 213 - Winter External Panel Load

Shop 213 External Panels	
Surface	Cooling load (W)
East Wall	-891.22
East Windows	-7,037.6
South Wall	-525.91
South Windows	-3,154.79
Ceiling	-2,653.41
Total	-14,262.92

Table 20- Summary Winter External Loads

Shop 212 and 213 Summary	
Shop	Cooling Load (W)
212	-18,750.21

213	-19,584.23

7. Internal Loads – Summer

7.1. Main forms of internal loading

The main forms of internal loading are the occupants, the equipment within the room and lighting within the room. In order to calculate the internal load of the room the number of occupants must be known as well as their intended activities. The equipment inside the room needs to be investigated and the heat load from the equipment calculated. Similarly, the lighting loads and times need to be calculated where the types of lights used are known a swell as the area of lighting. Lastly, infiltration must be accounted for to ensure an accurate result.

7.2. Summer internal load calculation

7.2.1. People

Table 21- Occupancy Activity Summer

Shop	Occupancy	Activities	DA09
Shop 212	35	Seated, very light work	T-45
	45	Standing, Walking Slowly	T-45
Shop 213	80	Sedentary Work – Restaurant	T-45
	5	Standing, Walking Slowly	T-45
	5	Light bench work	T-45

Sensible and latent heat load per person can be calculated through the knowledge of the ambient temp and DA09.

Table 22- People Load Summer

Shop	Sensible Heat Load (W)	Latent Heat Load (W)
Shop 212	5,600	4,450
Shop 213	7,145	7,375

7.2.2. Equipment

For Summer it is assumed that all equipment is operating at peak capacity during our design conditions.

Table 23-Shop 212- Equipment Load Summer

Shop 212

Equipment	Quantity	Sensible Heat per unit	Latent heat per unit	Reference
Desktop Computer	20	97	0	AHRAE 18.12 (Table 8)
Laptop Computer	15	29	0	AHRAE 18.12 (Table 8)
Colour A3 Laser Printer	1	130	0	AHRAE 18.12 (Table 9)
Large Plotter	1	250	250	AHRAE 18.12 (Table 9)
Small steam kettle	1	88	0	AHRAE 18.12 (Table 5B)
Toaster	2	469	293	AHRAE 18.12 (Table 5A)
Microwave oven	1	400	30	AHRAE 18.12 (Table 10)
Freezer	2	322	0	AHRAE 18.12 (Table 5A)
Coffee Maker	2	1050	322	AHRAE 18.12 (Table 10)
Total		6,925	1,510	

Table 24- Shop 213 - Equipment Load Summer

Shop 213				
Equipment	Quantity	Sensible Heat per unit	Latent heat per unit	Reference
Barbeque	6	57	31	ASHRAE 2007
Blender	2	85.5	0	DA09 Table 48 for 2000w Motor
Coffee Heater	1	2500	11	ASHRAE 18.8 Table 10
Dishwasher	1	580	818	ASHRAE 18.8 Table 12
Display Case	2	352	0	AHRAE 18.8 Table 5A
Food Warmer	8	264	762	AHRAE 18.8 Table 5A
Griddle/grill	4	1319	0	AHRAE 18.8 Table 5A
Ice Maker	2	77	0	DA09 Table 48 for 2000w Motor
Microwave Oven	1	400	0	AHRAE 18.8 Table 5A

Mixer	1	85.5	0	DA09 Table 48 for 2000w Motor
Steam Kettle	1	30	0	ASHRAE 18.8 Table 5B
Waffle Iron	2	352	0	ASHRAE 18.8 Table 5A
Broiler	1	387	0	ASHRAE 18.8 Table 5A
Fryer	2	147	0	ASHRAE 18.8 Table 5A
Oven	4	2286	0	ASHRAE 18.8 Table 5A
Freezer	4	322	0	ASHRAE 18.8 Table 5A
Water Cooler	2	350	0	ASHRAE 18.8 Table 10
Hot Water urn	1	1500	700	DA09 Table 46
Total		26,371.5	7,811	

7.2.3. Lighting

Both shop 212 and 213 have a 30 $\frac{W}{m^2}$ lighting load. To calculate the effect of the lighting on the room load the following formula can be used.

$$cooling\ load = storage\ load\ factor\ \times lighting\ load \times floor\ area$$

Equation 6 - cooling load lighting

Table 25 - Lighting Load Summer

Shop	Storage Load Factor	Lighting load $\frac{W}{m^2}$	Floor area (m^2	Cooling load (W)
212	0.97	30	390	11,349
213	0.97	30	436	12,687.6

7.2.4. Infiltration

As our building is air conditioned we are able to neglect the stack effect [9]. Thus, we only look at infiltration due to wind forces.

$$Q_{Sensible} = \frac{1.2 \times AC \times Volume\ \times \Delta T}{3600}$$

[9] DA09 page 94

$$Q_{Latent} = \frac{2.9 \times AC \times Volume \ \times \Delta\omega}{3600}$$

Using the design conditions and Psychometric charts, the following moisture content and temperature difference can be found.

Table 26 - Moisture Content Summer

	Dry Bulb Temperature (℃)	Moisture Content ($\frac{g}{kg\ air}$)
Internal	24	10.3
External	33	13

Infiltration due to wind forces can be estimated[10] as shown below using these assumptions

- Room exposure is neither exposed or sheltered
- Dry construction is used
- The shops have 1 – 2 adjacent external walls
- All windows are gasketed
- The degree of fenestration is below 25% as the windows are sealed
- Partitioning has no effect as it is minor.

Table 27- Infiltration Calculation

Parameter	Condition	Ch/h
Exposure	Half sheltered and half exposed	0.25
Construction	Dry	0.5
Location of windows	1 wall or 2 adjacent walls	0
Type of windows	Gasketed	0
Degree of fenestration	Less 25%	0
Partitioning	Nil	0
Total		0.75

The volume for each shop is:

Shop 212 volume – 390m^2 x 6m = 2,340 m^3

Shop 213 volume – 436m^2 x 6m = 2,616 m^3

Using the above formulas and tables, the total infiltration can be calculated as shown below

Table 28- Infiltration Results

Shop	$Q_{Sensible}$ **(W)**	Q_{Latent} **(W)**
212	5,265	3,817
213	5,886	4,267

[10] DA09 Table 24

7.3. Summary of Summer Internal Loads

Table 29- Summary of Summer internal loads

Shop	**People (W)**	**Equipment (W)**	**Lighting (W)**	**Infiltration (W)**	**Total**
212 Sensible	5,600	6,925	11,349	5,265	29,139
212 Latent	4,450	1,510	0	3,817	9,777
213 Sensible	7,175	26,371.5	12,687.6	5,886	52,120
213 Latent	7,375	7,811	0	4,267	19,453
Total	24,600	42,618	24,037	19,235	110,489

8. Internal Loads – Winter

8.1. Internal cooling and heating load differences

Heating loads are calculated at 6am as per the design condition of this project. This time aligns with the coolest part of the day with the least number of internal heating loads placed on the building. Thus, differences exist between the calculation of Summer cooling loads and Winter heating loads.

During Winter, there are less people inside each room at the design time compared to Summer. Similarly, there is less equipment being used and generally, less lights being switched on.

8.2. Winter internal load calculation

For Winter it is assumed that neither shop 212 or 213 are in full operating conditions at the design time of 6am. Lower levels of occupancy, equipment loads and lighting loads occur. Each specific assumption will be listed in the relevant sections below.

8.2.1. People

It is assumed that two staff members are required to setup shop 212 and it is assumed that the kitchen staff is in shop 213 preparing for the day. This leads to the following Occupancy.

Table 30- Occupancy Activity Winter

Shop	Occupancy	Activities	DA09
Shop 212	2	Light bench work	T-45
Shop 213	5	Light bench work	T-45

Sensible and latent heat load per person can be calculated through the knowledge of the ambient temp and DA09.

Table 31- People Load Winter

Shop	Sensible Heat Load (W)	Latent Heat Load (W)
Shop 212	215	205
Shop 213	537.5	512.5

8.2.2. Equipment

For Winter it is assumed that the majority of equipment is switched off, with obvious exceptions of Freezers, kettles/coffee makers and toasters. Freezers must be operating 24/7 and it is likely morning staff may have a kettle/coffee marker and/or toaster operating. It is also assumed that that kitchen staff are not cooking during their prep time this early in the morning.

Table 32- Shop 212 Equipment Load Winter

Shop 212

Equipment	Quantity	Sensible Heat per unit	Latent heat per unit	Reference
Toaster	1	469	293	AHRAE 18.12 (Table 5A)
Freezer	2	322	0	AHRAE 18.12 (Table 5A)
Small steam kettle	1	88	0	AHRAE 18.12 (Table 5B)
Total		1,201	293	

Table 33- Shop 213 Equipment Load Winter

Shop 213				
Equipment	Quantity	Sensible Heat per unit	Latent heat per unit	Reference
Steam Kettle	1	30	0	
Freezer	4	322	0	
Total		1,318	0	

8.2.3. Lighting

It is assumed that both shop 212 has half of its lighting switch on as the staff must see during setup. It is assumed that shop 213 only has one quarter of its lighting switched on as the dining area does not need to be lit.

Table 34 - Lighting Load Winter

Shop	**Storage Load Factor**	**Lighting load** $\frac{W}{m^2}$	**Floor area** (m^2)	**Equivalent Floor area** (m^2)	**Cooling load (W)**
212	0.97	30	390	195	5,674.5
213	0.97	30	436	109	3,172

8.2.4. Infiltration

Table 35 – Moisture Content Winter

	Dry Bulb Temperature (°C)	**Moisture Content** ($\frac{g}{kg\ air}$)
Internal	21	12.5
External	2.1	3.5

Using the Formulas in for $Q_{Sensible}$ and Q_{Latent} located in 6.2.4, as well as maintain those assumptions and using the Ch/h hour as it does not change, we obtain the following Infiltration numbers.

Table 36 - Infiltration Results Winter

Shop	$Q_{Sensible}$ **(W)**	Q_{Latent} **(W)**
212	-11,086	-12,724
213	-12,361	-14,225

8.3. Summary of Winter Internal Loads

Shop	People (W)	Equipment (W)	Lighting (W)	Infiltration (W)	Total
212 Sensible	215	1,201	5,674.5	-11,086	-3,996
212 Latent	205	293	0	-12,724	-12,226
213 Sensible	537.5	1,318	3,172	-12,361	-7,334
213 Latent	512.5	0	0	-14,225	-13,713
Total	1,470	2,812	8,847	-50,396	-37,268

9. Cooling and Heating Summary

Table 37 - Shop 212 - Cooling Summary

Shop 212				
	Summer		Winter	
	Sensible	Latent	Sensible	Latent
Solar Transmission	2,411.68	0	0	0
Partitions	3,990.1	0	-9,538.2	0
External Panels	0	0	-9,212.04	0
Internal	29,139	9,777	-3,996	-12,226
Total	35,540.78	9,777	-22,746.24	-12,226
Total	45,317.78		-34,972.24	

Table 38- Shop 213 - Cooling Summary

Shop 213				
	Summer		Winter	
	Sensible	Latent	Sensible	Latent
Solar Transmission	3,902.3	0	0	0
Partitions	1,836.2	0	-5,921.31	0
External Panels	0	0	-14,262.92	0
Internal	52,120	19,453	-7,334	-13,713
Total	57,858.50	19,453.	-27,518.23	-13,713.00
Total	77,311.50		-41,231.23	

10. Psychrometric Charts (Summer)

A Psychrometric chart is a chart that's allows the comparison of physical and thermal properties of air at standard atmospheric pressure. It allows the user to quickly easily compare wet bulb, dry bulb, moisture content, volume, Enthalpy, saturation temperature and relative humidity of air. It allows calculations of the size of air conditioning system required

$$SHF = \frac{Q_s}{Q_s + Q_L}$$

Equation 7 - Sensible Heat Factor

10.1. Shop 212

$$SHF = \frac{35{,}540.78}{45{,}317.78} = 0.784$$

External air requirement of $\frac{10l}{s} \times 80\ people = \frac{800l}{s}$

Mass flow rate of supply air can be calculated as

$$\dot{m}_{sa} = \frac{Q_s}{C_{p_m}(t_{rm} - t_{sa})}$$

$$C_{p_m} \approx 1.02\ \frac{kJ}{kgK}$$

$$\dot{m}_{sa} = \frac{35.54}{1.02(24 - 12)} = 2.904\ \frac{kg}{s}$$

$$\dot{m}_{oa} = \frac{\dot{\boldsymbol{V}}_{OA}}{v_{OA}} = \frac{0.8}{0.8875} = 0.9\ \frac{kg}{s}$$

$$\dot{m}_{ra} = \dot{m}_{sa} - \dot{m}_{oa} = 2.904 - 0.9 = 2.004\ \frac{kg}{s}$$

$$\frac{\dot{m}_{oa}}{\dot{m}_{sa}} = \frac{0.9}{2.904} = 0.31$$

$$n_c = \frac{w_{MA} - w_W}{w_{MA} - w_{ADP}} = \frac{11.4 - 9.3}{11.4 - w_{ADP}} = 0.85$$

Where

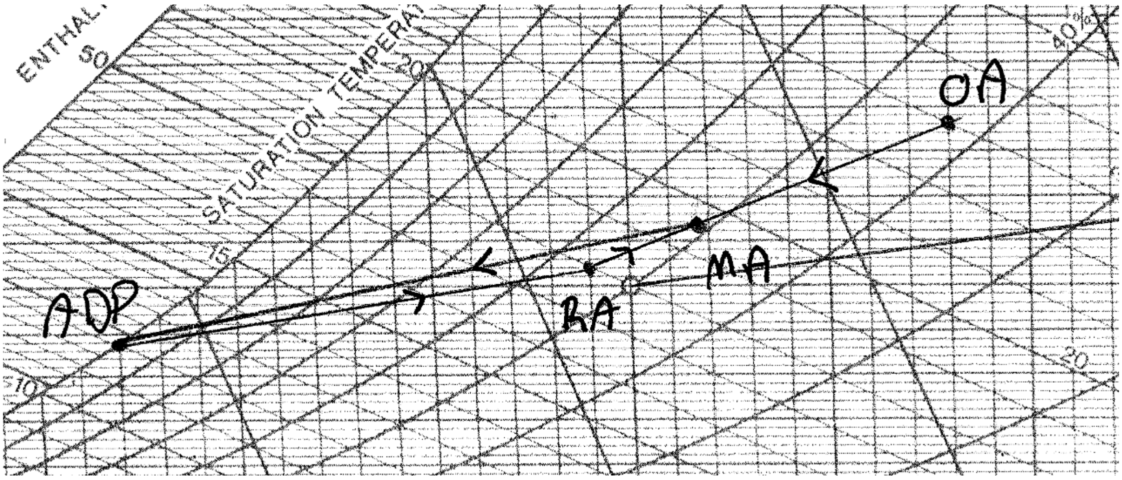
$$w_{MA} = \text{ the moisture content of the air mixing point}$$
$$w_W = \text{ the moisture content of the air leaving the coil}$$

$$w_{ADP} = \text{ the moisture content at the apparatus dew point}$$

$$w_{ADP} = 8.92 \frac{g}{kg_{dry\ air}}$$

$$\begin{aligned} Q &= \dot{m}_{sa}\,(h_{RA} - h_{ADP}) \\ &= 2.904(51 - 34.5) \\ &= 47.92\ KW \end{aligned}$$

Figure 1 - Psychrometric Chart Shop 212



10.2. Shop 213

$$SHF = \frac{57{,}858.50}{77{,}311.50} = 0.748$$

External air requirement of $\frac{10l}{s} \times 90\ people = \frac{900l}{s}$

Mass flow rate of supply air can be calculated as

$$\dot{m}_{sa} = \frac{Q_s}{C_{p_m}(t_{rm} - t_{sa})}$$

$$C_{p_m} \approx 1.02\ \frac{kJ}{kgK}$$

$$\dot{m}_{sa} = \frac{57.86}{1.02(24 - 12)} = 4.73\ \frac{kg}{s}$$

$$\dot{m}_{oa} = \frac{\dot{\boldsymbol{V}}_{OA}}{v_{OA}} = \frac{0.9}{0.8875} = 1.014\ \frac{kg}{s}$$

$$\dot{m}_{ra} = \dot{m}_{sa} - \dot{m}_{oa} = 4.73 - 1.014 = 3.716\ \frac{kg}{s}$$

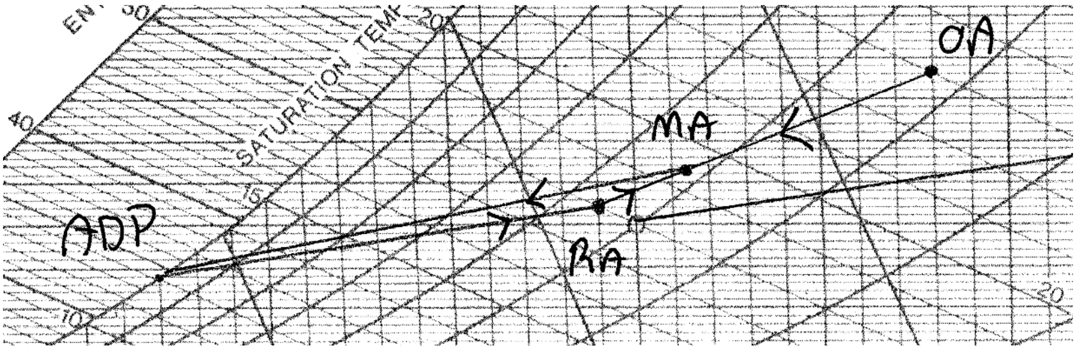
$$\frac{\dot{m}_{oa}}{\dot{m}_{sa}} = \frac{1.014}{4.73} = 0.214$$

$$n_c = \frac{w_{MA} - w_W}{w_{MA} - w_{ADP}} = \frac{11.2 - 9.2}{11.2 - w_{ADP}} = 0.85$$

$$w_{ADP} = 8.85\frac{g}{kg_{dry\ air}}$$

$$Q = \dot{m}_{sa}\,(h_{RA} - h_{ADP})$$
$$= 4.73(51 - 34)$$
$$= 80\ KW$$

Figure 2 Psychometric Chart Shop 213



11. References

DA09 – Australian Institute of Refrigeration Air Conditioning and Heating - 1994

ASHRAE Fundamentals 2009 – American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc

"U-Value." *Merriam-Webster.com*. 2016. http://www.merriam-webster.com (7 September 2016).

"R-Value." *Merriam-Webster.com*. 2016. http://www.merriam-webster.com (7 September 2016).

Spitler, J., Parker, J., McQuiston, F., *Heating, Ventilating and Air Conditioning – Analysis and Design;* sixth Edition., John Wiley and Sons Inc, 2005