CHAPTER I

INTRODUCTION

Air-conditioning is the process of developing a system which controls the properties of air inside a space in order to meet the desired conditions whether for human comfort or other specific purposes such as food preservation or handling and providing a conducive and productive environment for equipment processes.

To meet these requirements, systems of air-conditioning are continuously being developed throughout the years. These include all-water, all-air, or combined air and water systems. Incorporated in these systems may include fan coil units, air-handling units, split-type units, packaged a/c units, or centralized units.

In choosing the best system of air-conditioning, several factors are being considered such as the type of building and the level of activities inside, outside conditions, location, and construction of the building. Heat load calculations are being performed to determine the cooling load capacity of the air-conditioning units which will be used.

I. Brief History of Plant, Firm or Establishment

The building is a proposed 13-Storey Mixed-Use Building which will be located at Paranaque City. Mixed-use buildings are often applied for urban development where different types of activities are involved. This mixed-use building includes retail shops, offices, restaurants, department stores, and residential units.

This will be the subject of the air-conditioning system design. Air-Conditioning is defined as the manipulation and controlling of cleanliness, distribution, humidity and temperature of air. At the early times, it vastly grew out of successful efforts to control indoor humidity levels. System were custom designed for each installation and were used to remove warm air and recirculates it as cool air. The design aims to provide an efficient cooling for conditioned spaces. Also, it aims to provide comfort with the best price possible.

II. Subject of the Report

The subject of the report includes the following:

- Building Layout

  This includes the presentation of the evaluation of climate conditions, building orientation, components and other factors that contribute to the cooling load of the conditioned space.

  The layout of the building is included in the appendices.

- Load Calculation

  Heating load calculations or cooling load calculations are used to identify the heating or cooling load capacity that a conditioned space needs to stay cool at summer and warm at winter. The process was developed by the Heating, Ventilating and Air Conditioning (HVAC) industries and has been used for decades to accurately design a heating and air conditioning equipment. In the ventilated space of the building, the block load maximum peak hour load calculation will be used.

  Cooling load calculations using the procedures in ASHRAE manual and guide book with the selected indoor and outdoor conditions. The calculations include:

  - External load
  - Internal load

  Also, it includes the presentation the psychrometric calculation for the selection of equipment.

- Piping Design

  The piping design layout is included in the appendices.

- A/C Equipment Selection

The design will utilize the use of chilled water type of air-conditioning system and fan coil units. Also, split-type will be used on some spaces.

- System Cost Estimation

III. Location (with Maps)

Parañaque is located at Metro Manila, Philippines (NCR). The climatic condition of a 13–storey mixed used building at Parañaque City with respect to latitude is about 14.28° North latitude on the earth surface, while it was approximately 121.01° East longitude on the earth surface. The elevation stands 12m above sea level. The summer condition is estimated to have 34 degree Celsius on dry bulb and 26 degree Celsius on wet bulb. The percent relative humidity is about 50 % RH. Daily range in the locality takes 6.5 degree Celsius. Solar haze factor is zero.

- **Vicinity Map**

The proposed 13-Storey Mixed-Use Building will be located at Aseana City in Parañaque. Nestled along the shorelines of Manila Bay and extending southwest to Roxas Blvd. with the breathtaking Manila sunset as backdrop, Aseana City is being developed to be the Philippines' premier livable city.

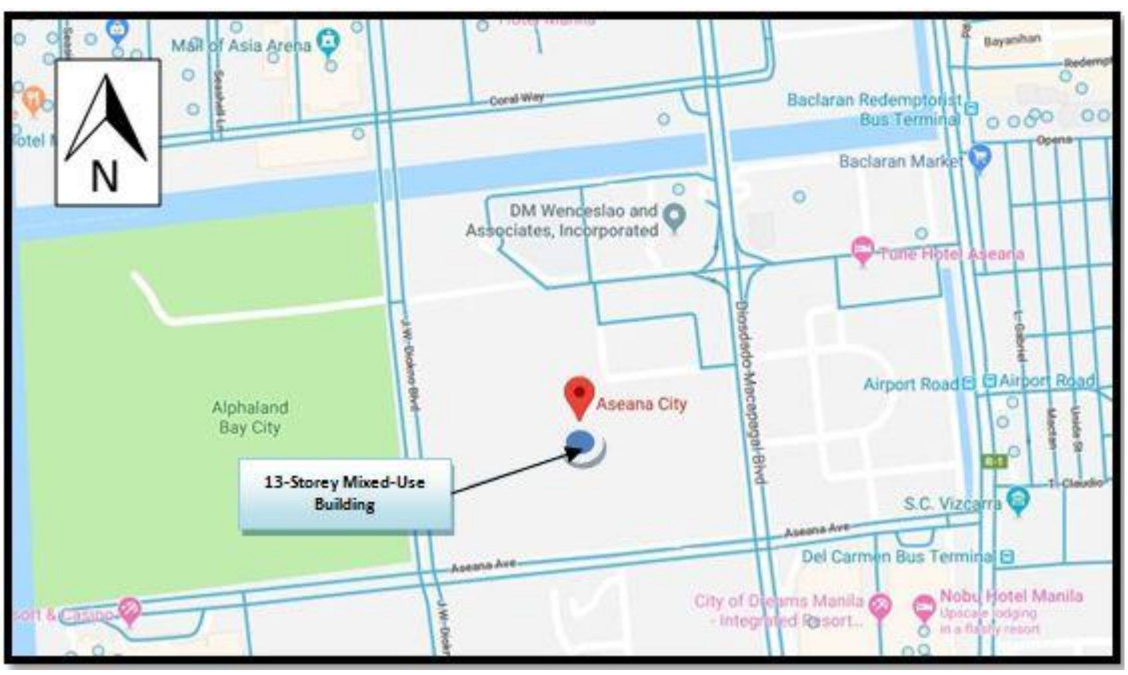


Figure 1. Building Location

CHAPTER II

REPORT PROPER

This chapter presents the details needed to carry out the equipment selection. This includes the building construction, heat and cooling load calculation, Psychrometric calculation including the psychrometric chart plotting, and piping calculation.

Heat Load Calculation

This section includes amount of heat being generated inside the conditioned space. Indicated here are the external heat load calculation coming from external walls, glass, and roof, and internal loads from infiltration, ventilation, lightings, occupants, partitions walls and doors, and miscellaneous loads.

The building has 13 floors. The mixed-used building is comprised of food shops, retail shops, department stores, offices, and residential units. The outside conditions is known to be 34 degrees Celsius dry bulb and 26 degree Celsius wet bulb while the inside condition is desired to be 25 degree Celsius dry bulb with 50% relative humidity. Daily range is 6.5 degree Celsius. The average temperature was calculated to be 30.75 degree Celsius. Design month was set to May which records the highest average temperature for the whole year. Maximum peak load was used for the calculation.

Building Components and Materials Construction

This section presents the materials used and the composition of the building walls, roofs, and partitions.

A. External Wall

The figure and table included shows the details regarding the external wall composition. This will determine the heat transfer coefficient or U value of the external walls.

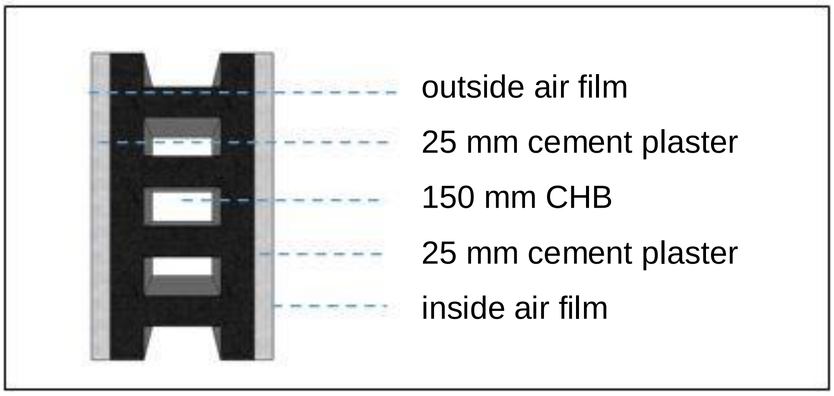


Figure 2. External Wall Composition

Table 1
Properties of Each Components of External Wall

Building Materials	$R (m^2K/W)$	ρ_S (kg/m^2)
outside air film	0.029	---
25 mm cement plaster	0.0347	39.95
150 mm CHB	0.135	147
25 mm cement plaster	0.0347	39.95
inside air film	0.12	---
Total	R_T = 0.3534 m^{2}K/W	ρ_{ST} = 226.9 Kg/m^2
	U_W = 2.8297 W/m^{2}K	**TYPE F**

Table 1 presents the building materials which composed the external wall. Included are thermal resistance value and density of each material. The calculated U value for external wall was known to be 2.8297 W/m^{2}K which falls under Type F walls.

B. Glass Load

The figure and table included shows the details regarding glass composition of the building. This will determine the heat transfer coefficient or U value of the glass.

Figure 3. Double Glaze and Single Glaze Glass

Table 2
Heat Transfer Coefficient for Double and Single Glaze Glass

Glass Type	**U(W/m^{2}K)**
Single Glaze	5.9
Double Glaze	3.5

Table 2 presents the U value for single glaze and double glaze glass for summer season. Single glaze glass has a value of 5.9 W/m^{2}K while double glaze glass has a value of 3.5 W/m^{2}K. This includes inside and outside air film resistance

C. Partition Wall

The figure and table included shows the details regarding the partition wall composition. This will determine the heat transfer coefficient or U value of the partition walls.

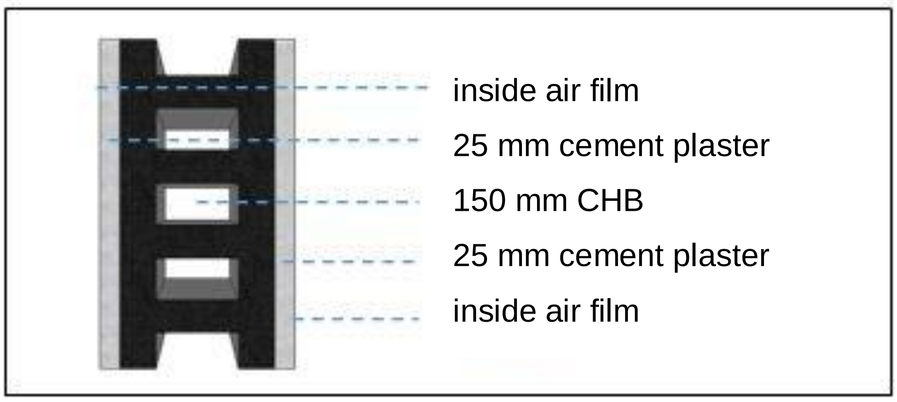


Figure 4. Partition Wall Composition

Table 3
Properties of Each Components of Partition Wall

Building Materials	**R(m^{2}K/W)**	**ρ_S (kg/m^2)**
inside air film	0.12	---
25 mm cement plaster	0.0347	39.95
150 mm CHB	0.135	147
25 mm cement plaster	0.0347	39.95
inside air film	0.12	---
Total	R_T = 0.4444 m^{2}K/W	ρ_{ST} = 226.9 Kg/m^2
	U_{PW} = 2.2502 W/m^{2}K	

Table 3 presents the building materials which composed the partition wall. Included are thermal resistance value and density of each material. The calculated U value for external wall was known to be 2.2502 W/m^{2}K.

D. External Roof

The figure and table included shows the details regarding the external roof composition. This will determine the heat transfer coefficient or U value of the external roof.

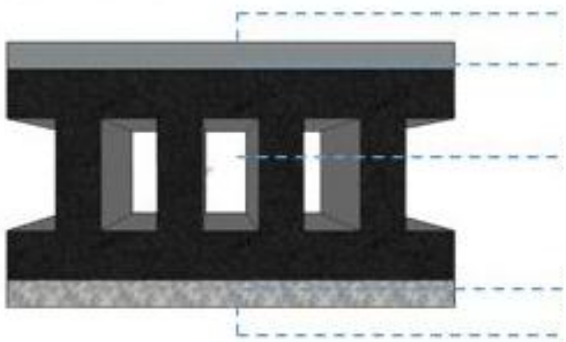


Figure 5. External Roof Composition

Table 4

Properties of each Components of External Roof

Building Materials	$R (m^2K/W)$	ρ_S (kg/m^2)
outside air film	0.044	---
25 mm granite	0.01375	42.5
200 mm concrete block, sand &gravel	0.18	196
25 mm cement plaster	0.02919	39.95
inside air film	0.12	---
Total	R_T = 0.38694 m^2K/W	ρ_{ST} = 278.45 Kg/m^2
	U_R = 2.584380007 W/m^{2}K	**TYPE 6** roof with suspended ceiling

Table 4 presents the building materials which composed the external roof. Included are thermal resistance value and density of each material. The calculated U value for external wall was known to be 2.584380007 W/m^{2}K which falls under Type 6 roof.

E. Wood Partition Door

The figure and table included shows the details regarding the wood partition door composition. This will determine the heat transfer coefficient or U value of the wood partition door.

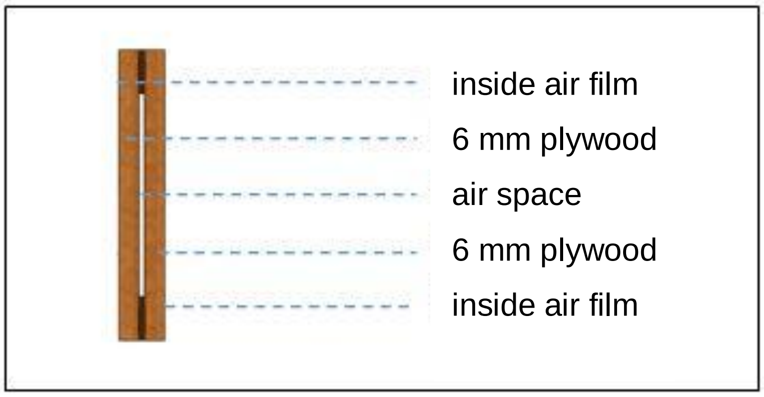


Figure 6. Wood Partition Door

Table 5
Properties of each Components of Wood Partition Door

Building Materials	$R (m^2K/W)$	ρ_S (kg/m^2)
inside air film	0.12	---
6 mm plywood	0.06	4.5
air space	0.17	---
6 mm plywood	0.06	4.5
inside air film	0.12	---
Total	$R_T = 0.53$ m^2K/W	$\rho_{ST} = 9$ Kg/m^2
	$U_{PD} = 1.8867924528$ W/m^2K	

Table 5 presents the building materials which composed the wood partition door. Included are thermal resistance value and density of each material. The calculated U value for external wall was known to be 1.8867924528 W/m^2K.

F. Partition Glass

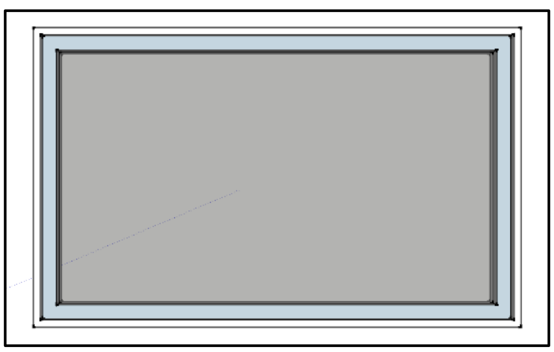


Figure 7. Partition Glass

The partition glass is classified as single glass with a heat transfer coefficient or U value of 5.9 W/m^2K. Summer condition was considered in choosing the U value of partition glass.

HEAT LOAD CALCULATION FOR GROUND FLOOR

The ground floor is composed of pizza shop, food stall, retail shop, and coffee shop.

External Loads

This section presents the summary of heat load calculations for external walls and glass loads for the ground floor.

External Wall (Ground Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

Manual computation was used to compute the area of the wall. The ground floor has a height of 2.9 m. The wall facing the North direction has a calculated area of 79.2667 m^2. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297 \frac{\mathrm{W}}{\mathrm{m}^2\mathrm{K}}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj} = (CLTD_{max} + LM)k + (25-t_i) + (29-t_{ave})$, was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted value is 13.165 °C.

Table 6. External Wall (Ground Floor)

Description	Equation $Q_W = U_W A_W CLTD_{adj}$	Results, Watts
N_{wall}	Q_W =(79.266667 m^2)(2.8297 W/m^2 °C)(13.165°C)	2993.9598
	TOTAL	**Q_{wall} = 2993.9598W**

Thus, the total heat load for external walls only came from the North side because all other sides are composed of glass walls. The total heat load for external wall has a value of 2993.9598 W.

Glass (Ground Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

Manual computation is used to compute the area of the glass facing the W, SW and SE direction with the values of 20.88 m^2, 131.515 m^2 and 41.76 m^2. The glass was known to have a thickness of 12 mm with no indoor shading. The coefficient of heat transfer that have been used has a value of $2.85\,\frac{\mathrm{W}}{\mathrm{m^2K}}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and $Q_{TH} = U_G(A_G)(\Delta T)$ were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 7. Glass (Ground Floor)

Description	Equations 1. Q_{SG} = (SHGF)(SC)(A_G)(CLF) 2. $Q_{TH} = U_G(A_G)(\Delta T)$	Results, Watts
W_{glass}	1. Q_{SG} = (678W/m^2)(0.95)(20.88 m^2)(0.82) 2. Q_{TH} = (2.85 W/m^2K)(20.88 m^2)(9°C)	1.)11208.02256 2.) 535.572
SW_{glass}	1. Q_{SG} = (363 W/m^2)(0.95)(131.515 m^2)(0.83) 2. Q_{TH} = (2.85 W/m^2K)(131.515 m^2)(9°C)	1.) 37642.94663 2.) 3373.35975
SE_{glass}	1. Q_{SG} = (285 W/m^2)(0.95)(41.76 m^2)(0.81) 2. Q_{TH} = (2.85 W/m^2K)(41.76 m^2)(9°C)	1.) 11664.75816 2.) 1071.144
	$Q_{total}=Q_{SG}+Q_{TH}$ Q_{total}=60515.72735 W + 4980.07575 W	**Q_{total}=65495.8031 W**

Thus, Q_{SG} has a total of 60515.72735 W while Q_{TH} has a value of 4980.07575 W. The total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 65495.8031 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for ground floor.

Ventilation (Ground Floor)

The table below presents the values of internal heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include pizza shop, food stall, retail shop, coffee shop, elevator lobby and hallway. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person were taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 8. Ventilation (Ground Floor)

Description	Equation (Sensible Heat) $Q_S = 1.232(Q)(to-ti)$	Results, Watts
Pizza Shop	$Q_{S.}$ = 1.232(205.32 L/s)(9°C)	2276.58816
Food Stall	Q_S = 1.232(269.04L/s)(9 °C)	2983.11552
Retail Shop	Q_S = 1.232(70.8L/s)(9°C)	785.0304
Coffee Shop	Q_S = 1.232(233.64L/s)(9 °C)	2590.60032
Elevator Lobby	Q_S = 1.232(31.86L/s)(9 °C)	353.26368
Hallway	Q_S = 1.232(230.1L/s)(9 °C)	2551.3488
	TOTAL	**$Q_{S\ ventilation}$ = 11539.94688 W**
Description	**Equation (Latent Heat) $Q_L = 3000(Q)(Wo-Wi)$**	**Results, Watts**
Pizza Shop	Q_L = 3000(205.32 L/s)(0.018- 0.01)	4927.68
Food Stall	Q_L = 3000(269.04L/s)(0.018- 0.01)	6456.96
Retail Shop	Q_L = 3000(70.8L/s)(0.018- 0.01)	1699.2
Coffee Shop	Q_L = 3000(233.64L/s)(0.018- 0.01)	5607.36
Elevator Lobby	Q_L = 3000(31.86L/s)(0.018- 0.01)	764.64
Hallway	Q_L = 3000(230.1L/s)(0.018- 0.01)	5522.4
	TOTAL	**$Q_{L\ ventilation}$ = 24978.24 W**

Thus, for the conditioned spaces on the ground floor including pizza shop, food stall, retail shop, coffee shop, elevator lobby and hallway, the calculated sensible heat load was 11539.94688 W while the latent heat load was 24978.24 W.

Infiltration (Ground Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of ground floor was 2138.409873m^3. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s. The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 132.4626116 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 9. Infiltration (Ground Floor)

Description	Equation $Q_{,S}$ = 1.232(Q)(to-ti)	Results, Watts
Ground Floor	$Q_{,S}$ = 1.232(132.4626116 L/s)(9 °C)	1468.745437
	TOTAL	**$Q_{S\ infiltration}$ = 1468.745437W**
Description	**Equation Q_L = 3000(Q)(Wo-Wi)**	**Results, Watts**
Ground Floor	Q_L = 3000(132.4626116 L/s) (0.018-0.01)	3179.102678
	TOTAL	**$Q_{L\ infiltration}$ = 3179.102678 W**

Thus, for the conditioned spaces on the ground floor including pizza shop, food stall, retail shop, coffee shop, elevator lobby and hallway, the calculated sensible heat load was 1468.745437 W while the latent heat load was 3179.102678 W.

Lighting Load (Ground Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 10. Lighting Load (Ground Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Pizza Shop	In Cafeteria or Fast Food Dining	7	121.1790123	848.2530861
Food Stall	In Cafeteria or Fast Food Dining	7	141.154321	988.080247
Retail Shop	Sales Area	15.5	71.11111	1102.222205
Coffee Shop	In Cafeteria or Fast Food Dining	7	133.6296296	935.4074072
Elevator Lobby	For Elevator	7	31.5555556	220.8888892
Hallway	All Other Corridors	7.1	238.7530864	1695.146913
		TOTAL	**1148.4692 m^2**	**13781.63006 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $\mathrm{Q_S} = (\text{lamp power})(\mathrm{F_u})(\mathrm{F_b})(\mathrm{CLF})$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.91. The computed lighting load was 6322.678633 W.

Occupant Load (Ground Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 11. Occupant Load (Ground Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Pizza Shop	Q_S = (170)(0.441176)(58)(0.92)	4002
Food Stall	Q_S = (170)(0.441176)(76)(0.92)	5244
Retail Shop	Q_S = (185)(0.50)(20)(0.92)	1702
Coffee Shop	Q_S = (170)(0.441176)(66)(0.92)	4554
Elevator Lobby	Q_S = (150)(0.50)(9)(0.92)	621
Hallway	Q_S = (150)(0.50)(9)(0.92)	6383.65
	TOTAL	**$Q_{s, occupant}$ = 22506.65W**

Table 11. Occupant Load (Ground Floor)

Description	Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)	Results, Watts
Pizza Shop	Q_L = (170)(0.55882)(56)(1)	5510
Food Stall	Q_L = (170)(0.55882)(76)(1)	7220
Retail Shop	Q_L = (185)(0.50)(20)(1)	1850
Coffee Shop	Q_L = (170)(0.55882)(66)(1)	6270
Elevator Lobby	Q_L = (150)(0.50)(9)(1)	675
Hallway	Q_L = (305)(0.65)(65)(1)	12886.25
	TOTAL	**$Q_{L, occupant}$ = 34411.25 W**

Thus, for the conditioned spaces on the ground floor including pizza shop, food stall, retail shop, coffee shop, elevator lobby and hallway, the calculated sensible heat load was 22506.65 W while the latent heat load was 34411.25 W for occupant heat load.

Partitions (Ground Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

Manual computation was used to compute the area of the concrete wall, elevator door and wooden door with the obtained value of 186.3222 m^2, 13.2 m^2 and 15.4 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall, elevator door and wooden door has a value of $2.2502\frac{\mathrm{w}}{\mathrm{m^2K}}$, $2.43309\frac{\mathrm{w}}{\mathrm{m^2K}}$ and $1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C

Table 12. Partitions (Ground Floor)

Description	Equation $Q_{partition}$=(U)(A)(ΔT)	Results, Watts
Concrete Wall	**Q=**$(2.2502\frac{\mathrm{w}}{\mathrm{m^2K}})(186.3222\mathrm{m^2})(6\ °C)$	2515.5735
Elevator Door	**Q=**$(2.43309\frac{\mathrm{w}}{\mathrm{m^2K}})(13.2\mathrm{m^2})(6\ °C)$	192.700728
Wood Door	**Q=**$(1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}})(15.4\mathrm{m^2})(6\ °C)$	179.7945205
	TOTAL	**2888.068792 W**

Thus, using the formula Q =(U)(A)(ΔT),the resulting partition heat load was 2888.068792 W.

Miscellaneous (Ground Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the ground floor.

For miscellaneous load, the ground floor consists of 3 ovens, 7 cash registers, 5 blenders,3 freezers, 3 coffee makers, 3 drink chillers, 2 steamers, 3 microwaves and 2 stoves. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 13. Miscellaneous (Ground Floor)

Description	Equation Q = (equipment electrical rating) (no. of units) (F_u)(CLF)	Results, Watts
Oven	$Q_{oven} = (1200)(3)\left(\frac{12}{24}\right)(1)$	1800
Cash Register	$Q_{Cash\ Register} = (46.5)(7)\left(\frac{12}{24}\right)(1)$	162.75
Blender	$Q_{Blender} = (400)(5)\left(\frac{8}{24}\right)(1)$	666.6667
Freezer	$Q_{Freezer} = (540)(3)\left(\frac{24}{24}\right)(1)$	1620
Coffee maker	$Q_{Coffee\ maker} = (800)(3)\left(\frac{8}{24}\right)(1)$	800
Drink Chiller	$Q_{Drinks\ Chiller} = (200)(3)\left(\frac{24}{24}\right)(1)$	600
Steamer	$Q_{Steamer} = (800)(2)\left(\frac{12}{24}\right)(1)$	800
Microwave	$Q_{Microwave} = (800)(3)\left(\frac{2}{24}\right)(1)(1)$	66.6667
Stove	$Q_{Stove} = (1100)(2)\left(\frac{8}{24}\right)(1)(1)$	733.3333
	TOTAL	**Q = 7249.416 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 7249.416 W.

Summary of Heat Load Calculation for Ground Floor

The table includes the summary of the heat load calculation for ground floor. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 14. Summary of Heat Load Calculation for Ground Floor

HEAT SOURCES		**Q_S (W)**	**Q_L (W)**
External Loads	External Wall	2952.921173	0
	Glass Load	65495.8031	0
Infiltration Load		1468.745437	3179.102678
Ventilation Load		11539.94688	24978.24
Internal Loads	Lighting Load	6322.678633	0
	Occupant Load	22506.65	34411.25
	Partition Load	2888.068792	0
	Miscellaneous Load	7249.4167	0
TOTAL		120424.2307	62568.59268
OVERALL TOTAL		**182992.8234 W**	

The calculation resulted to a sensible heat load of 120424.2307 W, latent heat load of 62568.59268 W with a total of 182992.8234 W.

HEAT LOAD CALCULATION FOR MEZZANINE FLOOR

The mezzanine floor is composed of retail shops and administration office.

External Loads

This section presents the summary of heat load calculations for external walls and glass loads for the mezzanine floor.

External Wall (Mezzanine Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

Manual computation was used to compute the area of the wall. The mezzanine floor has a height of 2.3 m. The wall facing the North direction has a calculated area of 23 m^2. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297\frac{\mathrm{W}}{\mathrm{m^2K}}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj}$ = ($CLTD_{max}$ + LM)k + (25-t_i) + (29-t_{ave}), was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted value is 13.165 °C.

Table 15. External Wall (Mezzanine Floor)

Description	**Equation** $Q_W = U_W A_W CLTD_{adj}$	**Results, Watts**
N_{wall}	Q_W =(23 m^2)(2.8297 W/m^2 °C)(13.165°C)	889.851247
	TOTAL	**Q_{wall} = 889.851247 W**

Thus, the total heat load for external walls only came from the North side because all other sides are composed of glass walls. The total heat load for external wall has a value of 889.851247W.

Glass (Mezzanine Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

Manual computation is used to compute the area of the glass facing the W, SW and SE direction with the values of 16.56 m^2, 104.305 m^2 and 33.12 m^2. The glass was known to have a thickness of 12 mm with no indoor shading. The coefficient of heat transfer that have been used has a value of $2.85 \frac{\mathrm{W}}{\mathrm{m^2K}}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and $Q_{TH} = U_G(A_G)(\Delta T)$ were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 16. Glass (Mezzanine Floor)

Description	**Equations** **1. Q_{SG} = (SHGF)(SC)(A_G)(CLF)** **2. $Q_{TH} = U_G(A_G)(\Delta T)$**	**Results, Watts**
W_{glass}	1. Q_{SG} = (678W/m^2)(0.95)(16.56 m^2)(0.82) 2. Q_{TH} = (2.85 W/m^2K)(16.56 m^2)(9°C)	1.) 8746.36272 2.) 424.764
SW_{glass}	1. Q_{SG} = (363 W/m^2)(0.95)(104.305 m^2)(0.83) 2. Q_{TH} = (2.85 W/m^2K)(104.305 m^2)(9°C)	1.) 29624.33925 2.) 2654.775
SE_{glass}	1. Q_{SG} = (285 W/m^2)(0.95)(33.12 m^2)(0.81) 2. Q_{TH} = (2.85 W/m^2K)(33.12 m^2)(9°C)	1.) 9251.35992 2.) 859.528
	$Q_{total}=Q_{SG}+Q_{TH}$ Q_{total}=47622.06189 W + 3939.067 W	**Q_{total} = 51561.12889 W**

Thus, Q_{SG} has a total of 47622.06189 W while Q_{TH} has a value of 3939.067W. The total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 51561.12889 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for mezzanine floor.

Ventilation (Mezzanine Floor)

The table below presents the values of internl heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include administration office, retail shops, elevator lobby and hallway. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person was taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 17. Ventilation (Mezzanine Floor)

Description	Equation (Sensible Heat) $Q_S = 1.232(Q)(to\text{-}ti)$	Results, Watts
Admin Office	$Q_{S.} = 1.232(3.952L/s)(9°C)$	43.82
Office 2	$Q_S = 1.232(3.952L/s)(9\ °C)$	43.82
Retail Shop 1	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 2	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 3	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 4	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 5	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 6	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 7	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Retail Shop 8	$Q_S = 1.232(68.93L/s)(9°C)$	764.30
Elevator Lobby	$Q_S = 1.232(2.736L/s)(9\ °C)$	30.34
Hallway	$Q_S = 1.232(22.698768L/s)(9\ °C)$	251.68
	TOTAL	$Q_{S\ ventilation}$ **= 6484.02698 W**
Description	**Equation (Latent Heat) $Q_L = 3000(Q)(Wo\text{-}Wi)$**	**Results, Watts**

Table 17. Ventilation (Mezzanine Floor)

Admin Office	$Q_{S.}$ = 3000(3.952L/s)(0.018-0.01)	94.848
Office 2	$Q_{S.}$ = 3000(3.952L/s)(0.018-0.01)	94.848
Retail Shop 1	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 2	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 3	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 4	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 5	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 6	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 7	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Retail Shop 8	$Q_{S.}$ = 3000(68.93L/s)(0.018-0.01)	1654.32
Elevator Lobby	$Q_{S.}$ = 3000(2.736L/s)(0.018-0.01)	65.664
Hallway	$Q_{S.}$ = 3000(22.698768L/s)(0.018-0.01)	544.7704
TOTAL		**$Q_{L\ ventilation}$ = 14034.69043 W**

Thus, for the conditioned spaces on the mezzanine floor including administration office, retail shops, elevator lobby and hallway, the calculated sensible heat load was 6484.02698 W while the latent heat load was 14034.69043 W.

Infiltration (Mezzanine Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of mezzanine floor was $1305.697248\ \mathrm{m}^3$. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s. The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 80.88069063 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 18. Infiltration (Mezzanine Floor)

Description	Equation $Q_{,S} = 1.232(Q)(to-ti)$	Results, Watts
Mezzanine Floor	$Q_{,S}$ = 1.232(80.88069063 L/s)(9 °C)	896.8050977
		$Q_{S\ infiltration}$ = 896.8050977 W
Description	**Equation $Q_L = 3000(Q)(Wo-Wi)$**	**Results, Watts**
Mezzanine Floor	Q_L = 3000(80.88069063 L/s)(0.018-0.01)	1941.136575
	TOTAL	**$Q_{L\ infiltration}$ = 1941.136575 W**

Thus, for the conditioned spaces on the mezzanine floor including administration office, retail shops, elevator lobby and hallway, the calculated sensible heat load was 896.8050977 W while the latent heat load was 1941.136575 W.

Lighting Load (Mezzanine Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 19. Lighting Load (Mezzanine Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Office 2	Office Enclosed	12	8.8889	106.6668
Admin Office	Office Enclosed	12	48.25	579
Retail Shop 1	Sales Area	15.5	57.07407407	884.6481481
Retail Shop 2	Sales Area	15.5	60.14814815	932.2962963

Table 19. Lighting Load (Mezzanine Floor)

Retail Shop 3	Sales Area	15.5	73.28395062	1135.901235
Retail Shop 4	Sales Area	15.5	36.2962963	562.5925927
Retail Shop 5	Sales Area	15.5	37.33333333	578.666666
Retail Shop 6	Sales Area	15.5	36.2962963	562.5925927
Retail Shop 7	Sales Area	15.5	36.74074074	569.4814815
Retail Shop 8	Sales Area	15.5	67.16049383	1040.987654
Elevator Lobby	For Elevator	7	31.55555556	220.888889
Hallway	All Other Corridors	7.1	74.66666667	530.1333334
TOTAL			**567.6944556 m²**	**7703.855689 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $Q_S = (\text{lamp power})(F_u)(F_b)(CLF)$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.91. The computed lighting load was 8412.610412 W.

Occupant Load (Mezzanine Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 20. Occupant Load (Mezzanine Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Admin Office	Q_S = (12)(150)(0.56)(0.92)	75.9
Office 2	Q_S = (1)(150)(0.55)(0.92)	910.8
Retail Shop 1	Q_S = (16)(185)(0.50) (0.92)	1361.6
Retail Shop 2	Q_S = (17)(185)(0.50) (0.92)	1446.7
Retail Shop 3	Q_S = (20) (185)(0.50) (0.92)	1702
Retail Shop 4	Q_S = (10) (185)(0.50) (0.92)	851
Retail Shop 5	Q_S = (11) (185)(0.50) (0.92)	936.1
Retail Shop 6	Q_S = (10) (185)(0.50) (0.92)	851
Retail Shop 7	Q_S = (10) (185)(0.50) (0.92)	851
Retail Shop 8	Q_S = (19) (185)(0.50) (0.92)	1616.9

Table 20. Occupant Load (Mezzanine Floor)

Elevator Lobby	Q_S = (9)(150)(0.50)(0.92)	621
Hallway	Q_S = (21)(305)(0.35)(0.92)	2062.41
TOTAL		**$Q_{s, occupant}$ = 13286.41 W**
Description	**Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)**	**Results, Watts**
Admin Office	Q_S = (12)(150)(0.45)(1)	67.5
Office 2	Q_S = (1)(150)(0.45)(1)	810
Retail Shop 1	Q_S = (16)(185)(0.50) (1)	1480
Retail Shop 2	Q_S = (17) (185)(0.50) (1)	1572.5
Retail Shop 3	Q_S = (20) (185)(0.50) (1)	1850
Retail Shop 4	Q_S = (10) (185)(0.50) (1)	925
Retail Shop 5	Q_S = (11) (185)(0.50) (1)	1017.5
Retail Shop 6	Q_S = (10) (185)(0.50) (1)	925
Retail Shop 7	Q_S = (10) (185)(0.50) (1)	925
Retail Shop 8	Q_S = (19) (185)(0.50) (1)	1757.5
Elevator Lobby	Q_S = (9) (185)(0.50) (1)	675
Hallway	Q_S = (21) (185)(0.50) (1)	4163.25
TOTAL		**$Q_{L, occupant}$ = 16168.25 W**

Thus, for the conditioned spaces on the mezzanine floor including administration office, retail shops, elevator lobby and hallway, the calculated sensible heat load was 13286.41 W while the latent heat load was 16168.25 W for occupant heat load.

Partitions (Mezzanine Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

Manual computation was used to compute the area of the concrete wall, glass wall, glass door, elevator door, and wooden door with the obtained value of 138.15 m^2, 10.25 m^2, 8.8 m^2, 13.2 m^2 and 4.4 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall, glass wall, glass door, elevator door, and wooden door has a value of $2.2502\frac{\mathrm{w}}{\mathrm{m^2K}}$, $5.9\frac{\mathrm{w}}{\mathrm{m^2K}}$, $5.9\frac{\mathrm{w}}{\mathrm{m^2K}}$, $2.43009\frac{\mathrm{w}}{\mathrm{m^2K}}$, and $1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C

Table 21. Partitions (Mezzanine Floor)

Description	Equation $Q_{partition}$=(U)(A)(ΔT)	Results, Watts
Concrete Wall	**Q=**(2.2502$\frac{\mathrm{w}}{\mathrm{m^2K}}$)(138.15m^2)(6 °C)	1865.19078
Glass Wall	**Q=**(5.9$\frac{\mathrm{w}}{\mathrm{m^2K}}$)(10.25m^2)(6 °C)	362.85
Glass Door	**Q=**(5.9$\frac{\mathrm{w}}{\mathrm{m^2K}}$)(8.8m^2)(6 °C)	311.52
Wood Door	**Q=**(1.945828144$\frac{\mathrm{w}}{\mathrm{m^2K}}$)(4.4m^2)(6 °C)	51.369863
Elevator Door	**Q=**(2.43009$\frac{\mathrm{w}}{\mathrm{m^2K}}$)(13.2m^2)(6 °C)	192.7007299
	TOTAL	**2783.631373 W**

Thus, using the formula Q =(U)(A)(ΔT),the resulting partition heat load was 2783.631373 W.

Miscellaneous (Mezzanine Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the mezzanine floor.

For miscellaneous load, the mezzanine floor consists of 3 computers, 2 multi-functional printers, 8 cash registers, and 1 projector. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 22. Miscellaneous (Mezzanine Floor)

Description	Equation Q = (equipment electrical rating) (no. of units) (F_u)(CLF)	Results, Watts
Computer	$Q_{computer} = (250)(3)\left(\frac{12}{24}\right)(1)$	375
Multi-functional Printer	$Q_{multifunction\quad printer} = (500)(2)\left(\frac{12}{24}\right)(1)$	500

Table 22. Miscellaneous (Mezzanine Floor)

Cash Register	$Q_{cash\ register} = (46.5)(8)\left(\frac{12}{24}\right)(1)$	186
Projector	$Q_{projector} = (300)(1)\left(\frac{12}{24}\right)(1)$	150
	TOTAL	**1211 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 1211W.

Summary of Heat Load Calculation for Mezzanine Floor

The table includes the summary of the heat load calculation for mezzanine floor. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 23. Summary of Heat Load Calculation for Mezzanine Floor

HEAT SOURCES		**Q_S (W)**	**Q_L (W)**
External Loads	External Wall	889.851247	0
	Glass Load	51561.12889	0
Infiltration Load		896.8050977	1941.136575
Ventilation Load		6484.02698W	14034.69043
Internal Loads	Lighting Load	8412.610412	0
	Occupant Load	13286.41	16168.25
	Partition Load	2783.631373	0
	Miscellaneous Load	1211	0
TOTAL		85525.464	32144.07701
OVERALL TOTAL		**117669.541W**	

The calculation resulted to a sensible heat load of 85525.464W, latent heat load of 32144.07701 W with a total of 117669.541 W.

HEAT LOAD CALCULATION FOR 6TH AND 7TH FLOOR

The 6th and 7th floor are composed of department stores.

External Loads

This section presents the summary of heat load calculations for external walls and glass loads for the 6th and 7th floors.

External Wall (6th and 7th Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

Manual computation was used to compute the area of the wall. The 6th and 7th floor has a height of 3 m. The wall facing the N, W, SW, NW, and NE directions has a calculated area of 53.54 m^2, 5.93 m^2, 1.8 m^2, 6 m^2, and 38.4 m^2 respectively. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297\frac{\mathrm{w}}{\mathrm{m^2K}}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj} = (CLTD_{max} + LM)k + (25-t_i) + (29-t_{ave})$, was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted values for N, W, SW, NW, and NE walls are 13.165 °C, 26.0875 °C, 22.1725 °C, 22.495 °C, and 15.745 °C respectively.

Table 24. External Wall (6th and 7th Floor)

Description	**Equation** $Q_W = U_W A_W CLTD_{adj}$	**Results, Watts**
N_{wall}	Q_W =(53.54 m^2)(2.8297 W/m^2 °C)(13.165°C)	1994.525647
W_{wall}	Q_W =(5.93 m^2)(2.8297 W/m^2 °C)(26.0875°C)	437.9972265
SW_{wall}	Q_W =(1.8 m^2)(2.8297 W/m^2 °C)(22.1725°C)	112.9347419
NW_{wall}	Q_W =(6 m^2)(2.8297 W/m^2 °C)(22.495°C)	381.924609
NE_{wall}	Q_W =(38.4 m^2)(2.8297 W/m^2 °C)(15.745°C)	1710.859258
	TOTAL	**Q_{wall} = 4638.241728 W**

The total heat load for external wall has a value of 4638.241728 W.

Glass (6th and 7th Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

The 6th and 7th floors both contain glass which are single glaze and double glaze, regular sheet, with dark roller shades. The single glaze glass has a heat transfer coefficient of $5.9\ \frac{w}{m^2K}$ while the double glaze glass has a value of $3.2\ \frac{w}{m^2K}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and $Q_{TH} = U_G(A_G)(\Delta T)$ were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 25. Glass (6th and 7th Floor)

Single Glaze

Description	**Equations** **1. Q_{SG} = (SHGF)(SC)(A_G)(CLF)** **2. $Q_{TH} = U_G(A_G)(\Delta T)$**	**Results, Watts**
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.59)(3.6 m^2)(0.83) 2. Q_{TH} = (5.9 W/m^{2}K)(3.6 m^2)(9°C)	1.) 639.93996 2.) 191.16
W_{glass}	1. Q_{SG} = (678 W/m^2)(0.59)(5.4 m^2)(0.82) 2. Q_{TH} = (5.9 W/m^{2}K)(5.4 m^2)(9°C)	1.) 1771.28856 2.) 286.74
N_{glass}	1. Q_{SG} = (164 W/m^2)(0.59)(26.76 m^2)(0.91) 2. Q_{TH} = (5.9 W/m^{2}K)(26.76 m^2)(9°C)	1.) 2356.260816 2.) 1420.956
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.59)(9.6 m^2)(0.76) 2. Q_{TH} = (5.9 W/m^{2}K)(9.6 m^2)(9°C)	1.) 2565.56544 2.) 509.76

Double Glaze

Description	**Equations** **1. Q_{SG} = (SHGF)(SC)(A_G)(CLF)** **2. $Q_{TH} = U_G(A_G)(\Delta T)$**	**Results, Watts**
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.6)(136.05 m^2)(0.83) 2. Q_{TH} = (3.2 W/m^{2}K)(136.05 m^2)(9°C)	1.) 24594.3027 2.) 3918.24
S_{glass}	1. Q_{SG} = (129 W/m^2)(0.6)(19.11 m^2)(0.82) 2. Q_{TH} = (3.2 W/m^{2}K)(19.11 m^2)(9°C)	1.) 1212.87348 2.) 550.368
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.6)(31.2 m^2)(0.76) 2. Q_{TH} = (3.2 W/m^{2}K)(31.2 m^2)(9°C)	1.) 8479.4112 2.) 898.56
SE_{glass}	1. Q_{SG} = (363 W/m^2)(0.6)(91.2 m^2)(0.81) 2. Q_{TH} = (3.2 W/m^{2}K)(91.2 m^2)(9°C)	1.) 16089.3216 2.) 2626.56
	TOTAL	**Q_{total} = 68126.0989 W**

Thus, the total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 68126.0989 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for 6th and 7th floors.

Ventilation (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include department store, fitting room, storage, and elevator lobby. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person were taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 26. Ventilation (6th and 7th Floor)

Description	**Equation (Sensible Heat)** **Q_S = 1.232(Q)(to-ti)**	**Results, Watts**
Department Store	$Q_{S.}$ = 1.232(874.38L/s)(9°C)	9695.125
Fitting Room	Q_S = 1.232(70.67L/s)(9 °C)	783.589
Storage	Q_S = 1.232(74.81L/s)(9°C)	829.4933
Elevator Lobby	Q_S = 1.232(31.86L/s)(9°C)	353.2637
	TOTAL	**$Q_{S\ ventilation}$ = 11661.47136 W**
Description	**Equation (Latent Heat)** **Q_L = 3000(Q)(Wo-Wi)**	**Results, Watts**
Department Store	$Q_{S.}$ = 3000(874.38L/s)(0.018-0.01)	20985.12
Fitting Room	$Q_{S.}$ = 3000(70.67L/s)(0.018-0.01)	1696.08
Storage	$Q_{S.}$ = 3000(74.81L/s)(0.018-0.01)	1795.44
Elevator Lobby	$Q_{S.}$ = 3000(31.86L/s)(0.018-0.01)	764.64
	TOTAL	**$Q_{L\ ventilation}$ = 25241.28 W**

Thus, for the conditioned spaces on the 6th and 7th floor including department store, fitting room, storage, and elevator lobby the calculated sensible heat load was 11661.47136 W while the latent heat load was 25241.28W.

Infiltration (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of each floor was $1388.7608055\ \mathrm{m}^3$. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s. The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 258.07080498 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 27. Infiltration (6th and 7th Floor)

Description	**Equation** **$Q_{,S}$ = 1.232(Q)(to-ti)**	**Results, Watts**
6th and 7th Floor	$Q_{,S}$ = 1.232(258.07080498 L/s)(9 °C)	2861.569416
	TOTAL	**$Q_{S\ infiltration}$ = 2861.569416 W**
Description	**Equation** **Q_L = 3000(Q)(Wo-Wi)**	**Results, Watts**
6th and 7th Floor	Q_L = 3000(258.07080498 L/s) (0.018-0.01)	6193.873195
	TOTAL	**$Q_{L\ infiltration}$ = 6193.873195W**

Thus, for the conditioned spaces on the 6th and 7th floor including department store, fitting room, storage, and elevator lobby, the calculated sensible heat load was 2861.569416 W while the latent heat load was 6193.873195 W.

Lighting Load (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 28. Lighting Load (6th and 7th Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Department Store	Sales Area	15.5	1118.711426	17340.0271
Fitting Room	Dressing/ Fitting Room	7.7	115.8518519	892.0592596
Storage	All other Storage Rooms	6.8	122.641972	833.9654096
Elevator Lobby	For Elevator	7	31.5555556	220.8888892
		TOTAL	**1388.760806 m^2**	**19286.94066 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $Q_S = (\text{lamp power})(F_u)(F_b)(CLF)$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.91. The computed lighting load was 21061.3392 W.

Occupant Load (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 29. Occupant Load (6th and 7th Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Department Store	Q_S = (247)(185)(0.50(0.92)	21019.7
Fitting Room	Q_S = (18)(185)(0.50)(0.92)	1531.8
Storage	Q_S = (3)(185)(0.50) (0.92)	255.3
Elevator Lobby	Q_S = (9)(150)(0.50) (0.92)	621
	TOTAL	**$Q_{s,\ occupant}$ = 23427.8 W**
Description	**Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)**	**Results, Watts**
Department Store	Q_S = (247)(185)(0.50)(1)	22847.5
Fitting Room	Q_S = (18)(185)(0.50)(1)	1665
Storage	Q_S = (3)(185)(0.50) (1)	277.5
Elevator Lobby	Q_S = (9) (185)(0.50) (1)	675
	TOTAL	**$Q_{L,\ occupant}$ = 25465 W**

Thus, for the conditioned spaces on the 6th and 7th floor including department store, fitting room, storage, and elevator lobby, the calculated sensible heat load was 23427.8 W while the latent heat load was 25465 W for occupant heat load.

Partitions (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

Manual computation was used to compute the area of the concrete wall, wood door, and elevator door with the obtained value of 193.1998 m^2, 17.6 m^2, and 13.2 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall, wood door, and elevator door has a value of $2.2502\frac{\mathrm{W}}{\mathrm{m^2K}}$, $1.945828144\frac{\mathrm{W}}{\mathrm{m^2K}}$, and $2.43009\frac{\mathrm{W}}{\mathrm{m^2K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C.

Table 30. Partitions (6th and 7th Floor)

Description	Equation $Q_{partition}$=(U)(A)(ΔT)	Results, Watts
Concrete Wall	**Q=**$(2.2502\frac{W}{m^2K})(193.1998m^2)(6\ °C)$	2608.42914
Wood Door	**Q=**$(1.945828144\frac{W}{m^2K})(17.6m^2)(6\ °C)$	205.479452
Elevator Door	**Q=**$(2.43009\frac{W}{m^2K})(13.2m^2)(6\ °C)$	192.7007299
	TOTAL	**3006.60939 W**

Thus, using the formula Q =(U)(A)(ΔT),the resulting partition heat load was 3006.60939 W.

Miscellaneous (6th and 7th Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

For miscellaneous load, the 6th and 7th floor consists of 10 cash registers. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 31. Miscellaneous (6th and 7th Floor)

Description	Equation Q = (equipment electrical rating) (no. of units) (F_u)(CLF)	Results, Watts
Cash Register	$Q_{cash\ \mathrm{regiater}} = (46.5)(10)\left(\frac{12}{24}\right)(1)$	232.5
	TOTAL	**232.5 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 232.5W.

Summary of Heat Load Calculation for 6th and 7th Floor

The table includes the summary of the heat load calculation for 6th and 7th floors. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 32. Summary of Heat Load Calculation for 6th and 7th Floor

HEAT SOURCES		Q_S (W)	Q_L (W)
External Loads	External Wall	4638.241728	0
	Glass Load	57018.67795	0
Infiltration Load		2861.569416	6193.873195
Ventilation Load		11661.47136	25241.28
Internal Loads	Lighting Load	21061.3392	0
	Occupant Load	23427.8	25465
	Partition Load	3006.609398	0
	Miscellaneous Load	232.5	0
TOTAL		123907.2091	56900.1532
OVERALL TOTAL		**180807.3623 W**	

The calculation resulted to a sensible heat load of 123907.2091 W, latent heat load of 56900.1532 W with a total of 180807.3623 W.

HEAT LOAD CALCULATION FOR 8TH AND 9TH FLOOR

The 8th and 9th floor are composed of office areas.

External Loads

This section presents the summary of heat load calculations for external walls and glass loads for the 8th and 9th floors.

External Wall (8th and 9th Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

Manual computation was used to compute the area of the wall. The 8th and 9th floor has a height of 3 m. The wall facing the N, W, SW, NW, and NE directions has a calculated area of 46.21 m^2, 5.93 m^2, 1.8 m^2, 6 m^2, and 38.4 m^2 respectively. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297\frac{\mathrm{w}}{\mathrm{m^2K}}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj}$ = ($CLTD_{max}$ + LM)k + (25-t_i) + (29-t_{ave}), was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted values for N, W, SW, NW, and NE walls are 13.165 °C, 26.0875 °C, 22.1725 °C, 22.495 °C, and 15.745 °C respectively.

Table 33. External Wall (8th and 9th Floor)

Description	Equation $Q_W = U_W A_W CLTD_{adj}$	Results, Watts
N_{wall}	Q_W =(46.21m^2)(2.8297 W/m^2 °C)(13.165°C)	1721.33821
W_{wall}	Q_W =(5.93 m^2)(2.8297 W/m^2 °C)(26.0875°C)	437.9972265
SW_{wall}	Q_W =(1.8 m^2)(2.8297 W/m^2 °C)(22.1725°C)	112.9347419
NW_{wall}	Q_W =(6 m^2)(2.8297 W/m^2 °C)(22.495°C)	381.924609
NE_{wall}	Q_W =(38.4 m^2)(2.8297 W/m^2 °C)(15.745°C)	1710.859258
	TOTAL	**Q_{wall} = 4365.054053 W**

The total heat load for external wall has a value of 4365.054053 W.

Glass (8th and 9th Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

The 8th and 9th floors both contain glasses which are single glaze and double glaze, regular sheet, with dark roller shades. The single glaze glass has a heat transfer coefficient of $5.9\ \frac{w}{m^2K}$ while the double glaze glass has a value of $3.2\ \frac{w}{m^2K}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and Q_{TH} = U_G(A_G)(ΔT) were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 34. Glass (8th and 9th Floor)

Single Glaze

Description	Equations 1. $Q_{SG} = (SHGF)(SC)(A_G)(CLF)$ 2. $Q_{TH} = U_G(A_G)(\Delta T)$	Results, Watts
SW_{glass}	1. $Q_{SG} = (363 W/m^2)(0.59)(3.6\ m^2)(0.83)$ 2. $Q_{TH} = (5.9\ W/m^2K)(3.6\ m^2)(9°C)$	1.) 639.93996 2.) 191.16
W_{glass}	1. $Q_{SG} = (678\ W/m^2)(0.59)(5.4\ m^2)(0.82)$ 2. $Q_{TH} = (5.9\ W/m^2K)(5.4\ m^2)(9°C)$	1.) 1771.28856 2.) 286.74
N_{glass}	1. $Q_{SG} = (164\ W/m^2)(0.59)(26.76\ m^2)(0.89)$ 2. $Q_{TH} = (5.9\ W/m^2K)(26.76\ m^2)(9°C)$	1.) 2304.474864 2.) 1420.956
NE_{glass}	1. $Q_{SG} = (596\ W/m^2)(0.59)(9.6\ m^2)(0.76)$ 2. $Q_{TH} = (5.9\ W/m^2K)(9.6\ m^2)(9°C)$	1.) 2565.56544 2.) 509.76

Double Glaze

Description	Equations 1. $Q_{SG} = (SHGF)(SC)(A_G)(CLF)$ 2. $Q_{TH} = U_G(A_G)(\Delta T)$	Results, Watts
SW_{glass}	1. $Q_{SG} = (363 W/m^2)(0.6)(132.67\ m^2)(0.83)$ 2. $Q_{TH} = (3.2\ W/m^2K)(132.67\ m^2)(9°C)$	1.) 23982.69003 2.) 3820.8
S_{glass}	1. $Q_{SG} = (129\ W/m^2)(0.6)(19.11\ m^2)(0.83)$ 2. $Q_{TH} = (3.2\ W/m^2K)(19.11\ m^2)(9°C)$	1.) 1227.66462 2.) 550.368
NE_{glass}	1. $Q_{SG} = (596\ W/m^2)(0.6)(31.2\ m^2)(0.76)$ 2. $Q_{TH} = (3.2\ W/m^2K)(31.2\ m^2)(9°C)$	1.) 8479.4112 2.) 898.56
SE_{glass}	1. $Q_{SG} = (363\ W/m^2)(0.6)(88\ m^2)(0.81)$ 2. $Q_{TH} = (3.2\ W/m^2K)(88\ m^2)(9°C)$	1.) 15524.784 2.) 2534.4
	TOTAL	**Q_{total} = 66707.82277 W**

Thus, the total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 66707.82277 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for 8th and 9th floors.

Ventilation (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include office areas. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person were taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 35. Ventilation (8th and 9th Floor)

Description	Equation (Sensible Heat) $Q_S = 1.232(Q)(to\text{-}ti)$	Results, Watts
Office 1	$Q_{S.}$ = 1.232(64.9059L/s)(9°C)	719.6766
Office 2	Q_S = 1.232(65.2587L/s)(9 °C)	723.5885
Office 3	Q_S = 1.232(67.5105L/s)(9°C)	748.5564
Office 4	Q_S = 1.232(54.0445L/s)(9°C)	599.2454
Office 5	Q_S = 1.232(61.9409L/s)(9°C)	686.8007
Office 6	Q_S = 1.232(35.4742L/s)(9°C)	393.3379
	TOTAL	**$Q_{S\ ventilation}$ = 3871.205554 W**
Description	**Equation (Latent Heat) $Q_L = 3000(Q)(Wo\text{-}Wi)$**	**Results, Watts**
Office 1	$Q_{S.}$ = 3000(64.9059L/s)(0.018-0.01)	1557.742
Office 2	$Q_{S.}$ = 3000(65.2587L/s)(0.018-0.01)	1566.209
Office 3	$Q_{S.}$ = 3000(67.5105L/s)(0.018-0.01)	1620.252
Office 4	$Q_{S.}$ = 3000(54.0445L/s)(0.018-0.01)	1297.068
Office 5	$Q_{S.}$ = 3000(61.9409L/s)(0.018-0.01)	1486.582
Office 6	$Q_{S.}$ = 3000(35.4742L/s)(0.018-0.01)	851.3808
	TOTAL	**$Q_{L\ ventilation}$ = 8379.2328 W**

Thus, for the conditioned spaces on the 8th and 9th floor including office areas, the calculated sensible heat load was 3871.205554 W while the latent heat load was 8379.2328 W.

Infiltration (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of each floor was $3445.407513\ \mathrm{m}^3$. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s. The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 213.4238543 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 36. Infiltration (8th and 9th Floor)

Description	**Equation** **$Q_{,S}$ = 1.232(Q)(to-ti)**	**Results, Watts**
8th and 9th Floor	$Q_{,S}$ = 1.232(213.4238543 L/s)(9 °C)	2366.443696
		$Q_{S\ infiltration}$ = 2366.443696 W
Description	**Equation** **Q_L = 3000(Q)(Wo-Wi)**	**Results, Watts**
8th and 9th Floor	Q_L = 3000(213.4238543 L/s) (0.018-0.01)	5122.172505
	TOTAL	**$Q_{L\ infiltration}$ = 5122.172505 W**

Thus, for the conditioned spaces on the 8th and 9th floor including office areas, the calculated sensible heat load was 2366.443696 W while the latent heat load was 5122.172505 W.

Lighting Load (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 37. Lighting Load (8th and 9th Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Office 1	Office Enclosed	12	213.5062	2562.074074
Office 2	Office Enclosed	12	214.6667	2576.0004
Office 3	Office Enclosed	12	222.0741	2664.8889
Office 4	Office Enclosed	12	177.7778	2133.3334
Office 5	Office Enclosed	12	203.7531	2445.0370
Office 6	Office Enclosed	12	116.6914	1400.2963
TOTAL			**1148.4692 m^2**	**13781.63006 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $Q_S = (\text{lamp power})(F_u)(F_b)(CLF)$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.94. The computed lighting load was 15545.6787 W.

Occupant Load (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 38. Occupant Load (8th and 9th Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Office 1	Q_S = (13)(150)(0.55)(0.92)	986.7
Office 2	Q_S = (13)(150)(0.55)(0.92)	986.7
Office 3	Q_S = (14)(150)(0.55)(0.92)	1062.6
Office 4	Q_S = (11)(150)(0.55)(0.92)	834.9
Office 5	Q_S = (13)(150)(0.55)(0.92)	986.7
Office 6	Q_S = (8)(150)(0.55)(0.92)	607.2
	TOTAL	**$Q_{s,\ occupant}$ = 5464.8 W**
Description	**Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)**	**Results, Watts**
Office 1	Q_S = (13)(150)(0.45)(1)	877.5
Office 2	Q_S = (13)(150)(0.45)(1)	877.5
Office 3	Q_S = (14)(150)(0.45)(1)	945
Office 4	Q_S = (11)(150)(0.45)(1)	742.5
Office 5	Q_S = (13)(150)(0.45)(1)	877.5
Office 6	Q_S = (8)(150)(0.45)(1)	540
	TOTAL	**$Q_{L,\ occupant}$ = 4860 W**

Thus, for the conditioned spaces on the 8th and 9th floor including office areas, the calculated sensible heat load was 5464.8 W while the latent heat load was 4860 W for occupant heat load.

Partitions (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 6th and 7th floor.

Manual computation was used to compute the area of the concrete wall, wood door, and glass partition with the obtained value of 406 m^2, 26.4 m^2, and 39.6 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall, wood door, and glass partition has a value of $2.2502 \frac{W}{m^2K}$,

$1.945828144 \frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}}$, and $5.9 \frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C

Table 39. Partitions (8th and 9th Floor)

Description	**Equation** $\mathbf{Q_{partition}=(U)(A)(\Delta T)}$	**Results, Watts**
Concrete Wall	**Q=**$(2.2502\frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}})(406\mathrm{m}^2)(6\ °\mathrm{C})$	5481.4872
Wood Door	**Q=**$(1.945828144\frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}})(26.4\mathrm{m}^2)(6\ °\mathrm{C})$	308.219178
Glass Partition	**Q=**$(5.9\frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}})(39.6\mathrm{m}^2)(6\ °\mathrm{C})$	1401.84
	TOTAL	**7191.546378 W**

Thus, using the formula Q =(U)(A)(ΔT),the resulting partition heat load was 7191.546378 W.

Miscellaneous (8th and 9th Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 8th and 9th floor.

For miscellaneous load, the 8th and 9th floor consists of 72 computers and 12 multi-functional printers. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 40. Miscellaneous (8th and 9th Floor)

Description	**Equation** **Q = (equipment electrical rating) (no. of units)** $\mathbf{(F_u)(CLF)}$	**Results, Watts**
Computer	$Q_{cash\ \mathrm{regiater}} = (46.5)(10)\left(\frac{12}{24}\right)(1)$	2088
Multi-functional Printer	$Q_{multifunction\quad printer} = (540)(12)\left(\frac{12}{24}\right)(1)$	3240
	TOTAL	**5328 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 5328W.

Summary of Heat Load Calculation for 8th and 9th Floor

The table includes the summary of the heat load calculation for 8th and 9th floor. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 41. Summary of Heat Load Calculation for 8th and 9th Floor

HEAT SOURCES		**Q_S (W)**	**Q_L (W)**
External Loads	External Wall	4365.054053	0
	Glass Load	66707.82277	0
Infiltration Load		2366.443696	5122.172505
Ventilation Load		3871.205554	8379.2328
Internal Loads	Lighting Load	15545.6787	0
	Occupant Load	5464.8	4860
	Partition Load	7191.546378	0
	Miscellaneous Load	5328	0
TOTAL		110840.5512	18361.40531
OVERALL TOTAL		**129201.9565 W**	

The calculation resulted to a sensible heat load of 110840.5512 W, latent heat load of 18361.40531 W with a total of 129201.9565 W.

HEAT LOAD CALCULATION FOR 10TH TO 12TH FLOOR

The 10th to 12th floors are composed of residential units.

External Loads

This section presents the summary of heat load calculations for external walls and glass loads for the10th to 12th floor.

External Wall (10th to 12th Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10th to 12th floor.

Manual computation was used to compute the area of the wall. The 8th and 9th floor has a height of 3 m. The wall facing the N, W, SW, NW, and NE directions has a calculated area of 35.54 m^2, 5.93 m^2, 1.8 m^2, 6 m^2, and 38.4 m^2 respectively. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297\frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj}$ = ($CLTD_{max}$ + LM)k + (25-t_i) + (29-t_{ave}), was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted values for N, W, SW, NW, and NE walls are 13.165 °C, 26.0875 °C, 22.1725 °C, 22.495 °C, and 15.745 °C respectively.

Table 42. External Wall (10th to 12th Floor)

Description	**Equation** $Q_W = U_W A_W CLTD_{adj}$	**Results, Watts**
N_{wall}	Q_W =(35.54m^2)(2.8297 W/m^2 °C)(13.165°C)	1323.971638
W_{wall}	Q_W =(5.93 m^2)(2.8297 W/m^2 °C)(26.0875°C)	437.9972265
SW_{wall}	Q_W =(1.8 m^2)(2.8297 W/m^2 °C)(22.1725°C)	112.9347419
NW_{wall}	Q_W =(6 m^2)(2.8297 W/m^2 °C)(22.495°C)	381.924609
NE_{wall}	Q_W =(38.4 m^2)(2.8297 W/m^2 °C)(15.745°C)	1710.859258
	TOTAL	**Q_{wall} = 3967.687473 W**

The total heat load for external wall has a value of 3967.687473 W.

Glass (10th to 12th Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10th to 12th floor.

The 10th to 12th floors contain glasses which are single glaze and double glaze, regular sheet, with dark roller shades. The single glaze glass has a heat transfer coefficient of $5.9\ \frac{w}{m^2K}$ while the double glaze glass has a value of $3.2\ \frac{w}{m^2K}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and Q_{TH} = U_G(A_G)(ΔT) were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 43. Glass (10th to 12th Floor)

Single Glaze

Description	Equations 1. $Q_{SG} = (SHGF)(SC)(A_G)(CLF)$ 2. $Q_{TH} = U_G(A_G)(\Delta T)$	Results, Watts
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.59)(3.6 m^2)(0.83) 2. Q_{TH} = (5.9 W/m^{2}K)(3.6 m^2)(9°C)	1.) 639.93996 2.) 191.16
W_{glass}	1. Q_{SG} = (678 W/m^2)(0.59)(5.4 m^2)(0.82) 2. Q_{TH} = (5.9 W/m^{2}K)(5.4 m^2)(9°C)	1.) 1771.28856 2.) 286.74
N_{glass}	1. Q_{SG} = (164 W/m^2)(0.59)(22.92 m^2)(0.89) 2. Q_{TH} = (5.9 W/m^{2}K)(22.92 m^2)(9°C)	1.) 1973.78788 2.) 1217.052
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.59)(9.6 m^2)(0.76) 2. Q_{TH} = (5.9 W/m^{2}K)(9.6 m^2)(9°C)	1.) 2565.56544 2.) 509.76

Double Glaze

Description	Equations 1. $Q_{SG} = (SHGF)(SC)(A_G)(CLF)$ 2. $Q_{TH} = U_G(A_G)(\Delta T)$	Results, Watts
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.6)(102 m^2)(0.83) 2. Q_{TH} = (3.2 W/m^{2}K)(102 m^2)(9°C)	1.) 18438.948 2.) 2937.6
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.6)(26 m^2)(0.76) 2. Q_{TH} = (3.2 W/m^{2}K)(26 m^2)(9°C)	1.) 7066.176 2.) 748.8
SE_{glass}	1. Q_{SG} = (363 W/m^2)(0.6)(88.6667 m^2)(0.83) 2. Q_{TH} = (3.2 W/m^{2}K)(88.6667 m^2)(9°C)	1.) 16028.63403 2.) 2553.61
	TOTAL	**Q_{total} = 56928.32187 W**

Thus, the total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 56928.32187 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for 10th to 12th floor.

Ventilation (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10th to 12th floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include residential areas. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person were taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 44. Ventilation (10th to 12th Floor)

Description	Equation (Sensible Heat) $Q_S = 1.232(Q)(to\text{-}ti)$	Results, Watts
Room 1	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 2	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 3	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 4	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 5	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 6	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 7	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 8	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
	TOTAL	**$Q_{S\ ventilation}$ = 665.28 W**
Description	**Equation (Latent Heat) $Q_L = 3000(Q)(Wo\text{-}Wi)$**	**Results, Watts**
Room 1	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 2	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 3	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 4	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 5	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 6	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 7	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 8	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
	TOTAL	**$Q_{L\ ventilation}$ = 1440 W**

Thus, for the conditioned spaces on the 10th to 12th floor including office areas, the calculated sensible heat load was 665.28 W while the latent heat load was 1440 W.

Infiltration (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10^{th} to 12th floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of each floor was $3445.407513\ \mathrm{m}^3$. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s. The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 168.1218107 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 45. Infiltration (10th to 12th Floor)

Description	**Equation** **$Q_{,S}$ = 1.232(Q)(to-ti)**	**Results, Watts**
10^{th} to 12^{th} Floor	$Q_{,S}$ = 1.232(168.1218107L/s)(9 °C)	1864.134637
	TOTAL	**$Q_{S\ infiltration}$ = 1864.134637 W**
Description	**Equation** **Q_L = 3000(Q)(Wo-Wi)**	**Results, Watts**
10^{th} to 12^{th} Floor	Q_L = 3000(168.1218107L/s) (0.018-0.01)	4034.923457
	TOTAL	**$Q_{L\ infiltration}$ = 4034.923457 W**

Thus, for the conditioned spaces on the 1oth to 12th floor including residential areas, the calculated sensible heat load was 1864.134637 W while the latent heat load was 4034.923457 W.

Lighting Load (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 1oth to 12th floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 46. Lighting Load (10th to 12th Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Room 1	Living Quarters	4.2	110.1234568	462.5185186
Room 2	Living Quarters	4.2	108.2469136	454.6370371
Room 3	Living Quarters	4.2	108.2469136	454.6370371
Room 4	Living Quarters	4.2	140.345679	589.4518518
Room 5	Living Quarters	4.2	101.1851852	424.9777778
Room 6	Living Quarters	4.2	104.8395062	440.325926
Room 7	Living Quarters	4.2	134.1975309	563.6296298
Room 8	Living Quarters	4.2	97.50617284	409.5259259
		TOTAL	**904.6913581 m^2**	**3799.703704 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $Q_S = (\text{lamp power})(F_u)(F_b)(CLF)$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.94. The computed lighting load was 4286.065778 W.

Occupant Load (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10^{th} to 12^{th} floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 47. Occupant Load (10th to 12th Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Room 1	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 2	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 2	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 4	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 5	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 6	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 7	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 8	Q_S = (3)(70)(0.75)(0.92)	144.9
	TOTAL	**$Q_{s, occupant}$ = 1159.2 W**
Description	**Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)**	**Results, Watts**
Room 1	Q_S = (3)(70)(0.25)(1)	52.5
Room 2	Q_S = (3)(70)(0.25)(1)	52.5
Room 2	Q_S = (3)(70)(0.25)(1)	52.5
Room 4	Q_S = (3)(70)(0.25)(1)	52.5
Room 5	Q_S = (3)(70)(0.25)(1)	52.5
Room 6	Q_S = (3)(70)(0.25)(1)	52.5
Room 7	Q_S = (3)(70)(0.25)(1)	52.5
Room 8	Q_S = (3)(70)(0.25)(1)	52.5
	TOTAL	**$Q_{L, occupant}$ = 420 W**

Thus, for the conditioned spaces on the 10th to 12th floor including residential areas, the calculated sensible heat load was 1159.2 W while the latent heat load was 420 W for occupant heat load.

Partitions (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10th to 12th floor.

Manual computation was used to compute the area of the concrete wall, and wood door with the obtained value of 646.7519 m^2, and 52.5 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall and wood door has a value of $2.2502\frac{\mathrm{w}}{\mathrm{m^2K}}$ and $1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C

Table 48. Partitions (10th to 12th Floor)

Description	Equation $Q_{partition}$=(U)(A)(ΔT)	Results, Watts
Concrete Wall	**Q=**$(2.2502\frac{\mathrm{w}}{\mathrm{m^2K}})(646.7519m^2)(6\ °C)$	8371.926102
Wood Door	**Q=**$(1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}})(52.5m^2)(6\ °C)$	612.9337536
	TOTAL	**9344.859856 W**

Thus, using the formula Q =(U)(A)(ΔT),the resulting partition heat load was 9344.859856 W.

Miscellaneous (10th to 12th Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 10^{th} to 12^{th} floor.

For miscellaneous load, the 10^{th} to 12^{th} floor consists of 8 televisions, 8 refrigerators, and 8 stoves. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 49. Miscellaneous (10th to 12th Floor)

Description	Equation Q = (equipment electrical rating) (no. of units) (F_u)(CLF)	Results, Watts
Television	$Q_{television} = (50)(8)\left(\frac{12}{24}\right)(1)$	200
Refrogerator	$Q_{refrigirator} = (430)(8)\left(\frac{24}{24}\right)(1)$	3440
Stove	$Q_{stove} = (1930)(8)\left(\frac{2}{24}\right)(1)$	1286.6667
	TOTAL	**4926.666667 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 4926.66667 W.

Summary of Heat Load Calculation for 10th to 12th Floor

The table includes the summary of the heat load calculation for 10th to 12th floor. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 50. Summary of Heat Load Calculation for 10th to 12th Floor

HEAT SOURCES		Q_S (W)	Q_L (W)
External Loads	External Wall	3967.687473	0
	Glass Load	56928.32187	0
Infiltration Load		1864.134637	4034.923457
Ventilation Load		6652.8	1440
Internal Loads	Lighting Load	4286.065778	0
	Occupant Load	1159.2	420
	Partition Load	9344.859856	0
	Miscellaneous Load	4926.666667	0
TOTAL		89129.73628	5894.923457
OVERALL TOTAL		**95024.65974**	

The calculation resulted to a sensible heat load of 89129.73628 W, latent heat load of 5894.923457 W with a total of 95024.65974 W.

HEATING LOAD CALCULATION FOR 13TH FLOOR

The 13th floor is composed of residential units.

External Loads

This section presents the summary of heat load calculations for external walls, external roof, and glass loads for the 13th floor.

External Wall (13th Floor)

The table below presents the values of external heat load which comprises the wall heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

Manual computation was used to compute the area of the wall. The 13th floor has a height of 3 m. The wall facing the N, W, SW, NW, and NE directions has a calculated area of 23.8867 m^2, 5.93 m^2, 1.8 m^2, 6 m^2, and 38.4 m^2 respectively. The external wall is composed of outside and inside airfilm, 25 mm cement plaster and 150 mm CHB. Having determined the thermal resistivity of each component of the wall, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.8297 \frac{W}{m^2 K}$. The wall was classified as Type F wall. The specific formula $CLTD_{adj}$ = $(CLTD_{max}$ + LM)k + (25-t_i) + (29-t_{ave}), was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The wall is medium colored. The resulted values for N, W, SW, NW, and NE walls are 13.165 °C, 26.0875 °C, 22.1725 °C, 22.495 °C, and 15.745 °C respectively.

Table 51. External Wall (13th Floor)

Description	Equation $Q_W = U_W A_W CLTD_{adj}$	Results, Watts
N_{wall}	Q_W =(23.8867m^2)(2.8297 W/m^2 °C)(13.165°C)	889.851247
W_{wall}	Q_W =(5.93 m^2)(2.8297 W/m^2 °C)(26.0875°C)	437.9972265
SW_{wall}	Q_W =(1.8 m^2)(2.8297 W/m^2 °C)(22.1725°C)	112.9347419
NW_{wall}	Q_W =(6 m^2)(2.8297 W/m^2 °C)(22.495°C)	381.924609
NE_{wall}	Q_W =(38.4 m^2)(2.8297 W/m^2 °C)(15.745°C)	1710.859258
	TOTAL	**Q_{wall} = 3533.567082 W**

The total heat load for external wall has a value of 3533.567082 W.

Roof (13th Floor)

The table below presents the values of external heat load which comprises the roof heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

To solve for the roof heat load, manual computation was used and the area of the conditioned space must be known. The calculated area was 807.1851853 m^2. The roof is composed of outside and inside airfilm, 25 mm granite, 25 mm cement plaster, and 200 mm CHB. Having determined the thermal resistivity of each component of the roof, the coefficient of heat transfer can be calculated by taking the inverse of the total thermal resistivity. The coefficient of heat transfer that have been used has a value of $2.58\frac{\mathrm{w}}{\mathrm{m}^2\mathrm{K}}$. The roofl was classified as Type 6 roof with suspended ceiling. The specific formula $CLTD_{adj}$ = [($CLTD_{max}$ + LM)k + (25-t_i) + (29-t_{ave})](f), was applied by using the values of Stocker Jones to compute the $CLTD_{adj}$. The roof is medium colored. The resulted value for $CLTD_{adj}$ was 15.25^{o}C.

Table 52. Roof (13th Floor)

Description	**Equation** $\mathbf{Q_W = U_W A_W CLTD_{adj}}$	**Results, Watts**
Roof	Q_W =(807.1851853m^2)(2.58 W/m^2 °C)(15.25°C)	31758.70112
	TOTAL	$\mathbf{Q_{wall}}$ **= 31758.70112 W**

The total heat load for the roof has a value of 31758.70112 W.

Glass (13th Floor)

The table below presents the values of external heat load which comprises the glass heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

The 13th floor contains glasses which are single glaze and double glaze, regular sheet, with dark roller shades. The single glaze glass has a heat transfer coefficient of $5.9\ \frac{w}{m^2K}$ while the double glaze glass has a value of $3.2\ \frac{w}{m^2K}$. The specific formula Q_{SG} = (SHGF)(SC)(A)(CLF) and Q_{TH} = U_G(A_G)(ΔT) were applied by using the values of Stocker Jones to compute the Q_{SG}. By subtracting the outside Dry bulb Temperature, 34 °C, to inside Dry Bulb Temperature, 25 °C, the temperature difference was obtained resulting to 9 °C.

Table 53. Glass (13th Floor)

Single Glaze

Description	**Equations** **1.** $\mathbf{Q_{SG}}$ **= (SHGF)(SC)($\mathbf{A_G}$)(CLF)** **2.** $\mathbf{Q_{TH}}$ **=** $\mathbf{U_G(A_G)(\Delta T)}$	**Results, Watts**
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.59)(3.6 m^2)(0.83) 2. Q_{TH} = (5.9 W/m^{2}K)(3.6 m^2)(9°C)	1.) 639.93996 2.) 191.16
W_{glass}	1. Q_{SG} = (678 W/m^2)(0.59)(5.4 m^2)(0.82) 2. Q_{TH} = (5.9 W/m^{2}K)(5.4 m^2)(9°C)	1.) 1771.28856 2.) 286.74

Table 53. Glass (13th Floor)

N_{glass}	1. Q_{SG} = (164 W/m^2)(0.59)(19.08 m^2)(0.89) 2. Q_{TH} = (5.9 W/m^{2}K)(19.08 m^2)(9°C)	1.) 1643.10091 2.) 1013.148
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.59)(9.6 m^2)(0.76) 2. Q_{TH} = (5.9 W/m^{2}K)(9.6 m^2)(9°C)	1.) 2565.56544 2.) 509.76

Double Glaze

Description	Equations 1. Q_{SG} = (SHGF)(SC)(A_G)(CLF) 2. Q_{TH} = U_G(A_G)(ΔT)	Results, Watts
SW_{glass}	1. Q_{SG} = (363W/m^2)(0.6)(102 m^2)(0.83) 2. Q_{TH} = (3.2 W/m^{2}K)(102 m^2)(9°C)	1.) 18438.948 2.) 2937.6
NE_{glass}	1. Q_{SG} = (596 W/m^2)(0.6)(26 m^2)(0.76) 2. Q_{TH} = (3.2 W/m^{2}K)(26 m^2)(9°C)	1.) 7066.176 2.) 748.8
SE_{glass}	1. Q_{SG} = (363 W/m^2)(0.6)(88.6667 m^2)(0.83) 2. Q_{TH} = (3.2 W/m^{2}K)(88.6667 m^2)(9°C)	1.) 16028.63403 2.) 2553.61
	TOTAL	**Q_{total} = 56394.461 W**

Thus, the total glass heat load was obtained by adding Q_{SG} and Q_{TH} which results to 56394.461 W.

Internal Loads

This section presents the summary of heat load calculations for ventilation, infiltration, lightings, occupants, partitions, and miscellaneous loads for 13th floor.

Ventilation (13th Floor)

The table below presents the values of internal heat load which comprises the ventilation calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

To solve for the ventilation rate, the number of occupants present inside the conditioned space must be initially determined. The conditioned spaces include residential areas. The ventilation rate can be solved through the formula Q = (outdoor air requirements per person)(no. of person). The values of the minimum outdoor air rate per person were taken from Stocker Jones. Also the outside and inside temperature and humidity ratio was also determined.

Table 54. Ventilation (13th Floor)

Description	Equation (Sensible Heat) $Q_S = 1.232(Q)(to\text{-}ti)$	Results, Watts
Room 1	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 2	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 3	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 4	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 5	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 6	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
Room 7	$Q_{S.} = 1.232(7.5L/s)(9°C)$	83.16
	TOTAL	**$Q_{S\ ventilation}$ = 582.12 W**
Description	**Equation (Latent Heat) $Q_L = 3000(Q)(Wo\text{-}Wi)$**	**Results, Watts**
Room 1	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 2	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 3	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 4	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 5	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 6	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
Room 7	$Q_{S.} = 3000(7.5L/s)(0.018\text{-}0.01)$	180
	TOTAL	**$Q_{L\ ventilation}$ = 1260 W**

Thus, for the conditioned spaces on the 13th floor including office areas, the calculated sensible heat load was 582.12 W while the latent heat load was 1260 W.

Infiltration (13th Floor)

The table below presents the values of internal heat load which comprises the infiltration calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

To solve for the ventilation rate, the volume of the conditioned space must be initially determined, the computed total volume of each floor was $2421.555556\ \mathrm{m}^3$. The infiltration rate can be solved through the formula Q = (no. of air changes/ hr)(volume of the conditioned space); where No. of air changes = a + bV + c(t_o-t_i). The assumed air velocity inside the space was 1m/s.

The building was assumed to be classified under tight construction. The no. of air changes has a computed value of 0.223 changes/hour while the Q has a computed value of 150.0019196 L/s. The values used in solving no. of air changes are from the tables of Stocker Jones. Also, the outside and inside temperature and humidity ratio was also determined using the psychrometric chart.

Table 55. Infiltration (13th Floor)

Description	**Equation** $Q_{,S} = 1.232(Q)(to\text{-}ti)$	**Results, Watts**
13th Floor	$Q_{,S} = 1.232(150.0019196 L/s)(9\ °C)$	1663.221218
	TOTAL	$Q_{S\ infiltration}$ **= 1663.221218 W**
Description	**Equation** $Q_L = 3000(Q)(Wo\text{-}Wi)$	**Results, Watts**
13th Floor	$Q_L = 3000(150.0019196 L/s)(0.018-0.01)$	3600.045926
	TOTAL	$Q_{L\ infiltration}$ **= 3600.045926 W**

Thus, for the conditioned spaces on the 13th floor including residential areas, the calculated sensible heat load was 1663.221218 W while the latent heat load was 3600.045926 W.

Lighting Load (13th Floor)

The table below presents the values of internal heat load which comprises the lighting load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

For the calculation of the lighting load, the lighting power densities were determined as well as the area of each conditioned spaces. These parameters were taken to solve for the total power rating of the lamps on a certain space. The lighting power densities were based on the type of conditioned space presented by ASHRAE 2017 on Table 2: Lighting Power Densities Using Space by Space Method. The lamps used were fluorescent lamps with Fixture X type.

Table 56. Lighting Load (13th Floor)

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Room 1	Living Quarters	4.2	110.1234568	462.5185186
Room 2	Living Quarters	4.2	108.2469136	454.6370371
Room 3	Living Quarters	4.2	108.2469136	454.6370371
Room 4	Living Quarters	4.2	140.345679	589.4518518
Room 5	Living Quarters	4.2	101.1851852	424.9777778
Room 6	Living Quarters	4.2	104.8395062	440.325926
Room 7	Living Quarters	4.2	134.1975309	563.6296298
		TOTAL	**1023.679013 m^2**	**3390.177778 W**

After determining the lamp power rating, the total lighting load was calculated using the formula, $Q_S = (\text{lamp power})(F_u)(F_b)(CLF)$. The utilization factor (F_u) was 1 and the ballast factor (F_b) was 1.2. CLF used was 0.94. The computed lighting load was 3824.120534 W.

Occupant Load (13th Floor)

The table below presents the values of internal heat load which comprises the occupant load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

Using the table of Stocker Jones, the sensible heat load capacity can be obtained while the latent heat load capacity was a constant value of 1 and the latent heat gain can be obtained by %LHG = 1 - %SHG.

Table 57. Occupant Load (13th Floor)

Description	Equation Q_S=(no. of occupant)(heat gain)(%SHG)(CLF_S)	Results, Watts
Room 1	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 2	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 2	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 4	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 5	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 6	Q_S = (3)(70)(0.75)(0.92)	144.9
Room 7	Q_S = (3)(70)(0.75)(0.92)	144.9
	TOTAL	**$Q_{s, occupant}$ = 1014.3 W**
Description	**Equation Q_L = (no. of occupant)(heat gain)(% LHG)(CLF_L)**	**Results, Watts**
Room 1	Q_S = (3)(70)(0.25)(1)	52.5

Table 57. Occupant Load (13th Floor)

Room 2	$Q_S = (3)(70)(0.25)(1)$	52.5
Room 2	$Q_S = (3)(70)(0.25)(1)$	52.5
Room 4	$Q_S = (3)(70)(0.25)(1)$	52.5
Room 5	$Q_S = (3)(70)(0.25)(1)$	52.5
Room 6	$Q_S = (3)(70)(0.25)(1)$	52.5
Room 7	$Q_S = (3)(70)(0.25)(1)$	52.5
	TOTAL	**$Q_{L,\ occupant}$ = 367.5 W**

Thus, for the conditioned spaces on the 13th floor including residential areas, the calculated sensible heat load was 1014.3 W while the latent heat load was 367.5 W for occupant heat load.

Partitions (13th Floor)

The table below presents the values of internal heat load which comprises the partition walls and partition doors heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor

Manual computation was used to compute the area of the concrete wall, and wood door with the obtained value of 517.2185186 m^2, and 48.8 m^2 respectively while the coefficient of heat transfer that have been used for concrete wall and wood door has a value of $2.2502\frac{\mathrm{w}}{\mathrm{m^2K}}$ and $1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}}$ respectively. The difference in temperature of conditioned and unconditioned space was 6 °C

Table 58. Partitions (13th Floor)

Description	**Equation** **$Q_{partition}$=(U)(A)(ΔT)**	**Results, Watts**
Concrete Wall	**Q=**$(2.2502\frac{\mathrm{w}}{\mathrm{m^2K}})(517.2185186\mathrm{m^2})(6\ °C)$	6983.070663
Wood Door	**Q=**$(1.945828144\frac{\mathrm{w}}{\mathrm{m^2K}})(48.8\mathrm{m^2})(6\ °C)$	569.7365175
	TOTAL	**7552.807181 W**

Thus, using the formula Q = (U)(A)(ΔT),the resulting partition heat load was 7552.807181 W.

Miscellaneous (13th Floor)

The table below presents the values of internal heat load which comprises the miscellaneous heat load calculation. Formulas and procedures were followed in order to obtain the required heat load for the 13th floor.

For miscellaneous load, the 13th floor consists of 7 televisions, 7 refrigerators, and 7 stoves. The number of operating hours of each appliance was known to establish the utilization factor. The power ratings were also determined.

Table 59. Miscellaneous (13th Floor)

Description	Equation Q = (equipment electrical rating) (no. of units) (F_u)(CLF)	Results, Watts
Television	$Q_{television} = (50)(7)\left(\frac{12}{24}\right)(1)$	174
Refrogerator	$Q_{refrigirator} = (430)(7)\left(\frac{24}{24}\right)(1)$	3010
Stove	$Q_{stove} = (1930)(7)\left(\frac{2}{24}\right)(1)$	1125.833
	TOTAL	**4310.8333 W**

Miscellaneous loads also contribute to increase in heat load capacity because of heating and radiation. The total miscellaneous heat load computed was 4310.833333 W.

Summary of Heat Load Calculation for 13th Floor

The table includes the summary of the heat load calculation for 13th floor. It shows the calculated sensible heat, latent heat, and overall heat load.

Table 60. Summary of Heat Load Calculation for 13th Floor

HEAT SOURCES		Q_S (W)	Q_L (W)
External Loads	External Wall	3533.567082	0
	Roof Load	31758.70112 W	0
	Glass Load	56394.461	0
Infiltration Load		1663.221218	3600.045926
Ventilation Load		582.12	1260

Table 60. Summary of Heat Load Calculation for 13th Floor

Internal Loads	Lighting Load	3824.120534	0
	Occupant Load	1014.3	367.5
	Partition Load	7552.807181	0
	Miscellaneous Load	4310.833333	0
TOTAL		110634.1315	5227.545926
OVERALL TOTAL		**115861.6774 W**	

The calculation resulted to a sensible heat load of 110634.1315 W, latent heat load of 5227.545926 W with a total of 115861.6774 W.

PSYCHROMETRIC METHOD OF EQUIPMENT SELECTION

This section is consists of the psychrometric calculations to compute the A/C capacity of specific conditioned space of the building. Equipment selection was based from the computed A/C capacity and the computed manufacturer's catalogue rating for A/C units.

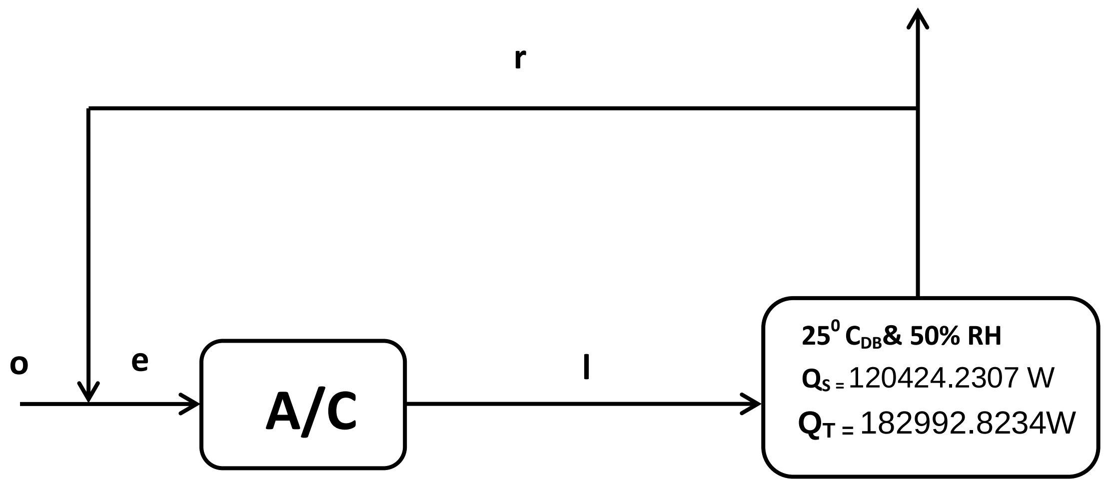
PSYCHROMETRIC CALCULATION FOR GROUND FLOOR

The table shows a brief summary of the results of ground floor heat load calculation.

Table 61. Ground Floor Heat Load Calculation

Q_S	120424.2307	**W**
Q_L	62568.59268	**W**
Q_T	182992.8234	**W**
SHF = QS/QT	0.6580817131	

The SHF for ground floor was calculated by dividing the total sensible and total latent heat for ground floor which gives a value of 0.6580817131.



Schematic Diagram of Air-conditioning for Ground Floor

Using Psychrometric Chart:

for w_o; T_{DB} = 34°C , T_{WB}=26°C

w_o= 0.018 kg/kg

for w_i; T_{DB} = 24°C , RH = 50%

w_i= 0.01 kg/kg

$$0.018\frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

Ps= $2.849765625\ kPa$

Then,

$$Vo = \frac{0.287(26 + 273)}{101.325 - 2.849765625}$$

Vo= 0.8714170679$\frac{m^3}{kg}$

$$m_o = \frac{1.04076}{0.8714170679}$$

m_o = 1.19433052 kg/s

Solving for m_a:

120.4242307= m_a (1.0062) (34-25)

m_a= **13.29802234 kg/s**

% outdoor air

% outdoor air= $\frac{1.19433052\ \text{kg/s}}{13.29802234\ kg/s}$ x 100

% outdoor air= **8.981264202 %**

Since %outdoor <10%, use %outdoor = 10%

% return air

% return air= 100- 10

% return air= **90%**

Solving for w_e, h_e, t_e:

$h_R = C_p t + W_R\, h_g$ @25^0C

$$h_R = 1.0062(25^0C) + (0.01)(2547.3)$$

$$\mathbf{h_R = 50.628\ kJ/kg}$$

$$m_o w_o + m_r w_r = m_e w_e$$

$$(0.1)m_t(0.018) + (0.9)m_t(0.01) = m_t w_e$$

$$\mathbf{W_e = 0.0108\ kg/kg}$$

$$m_o h_o + m_r h_r = m_e h_e$$

$$(0.1)m_t(80.777) + (0.9)m_t(50.628) = m_t h_e$$

$$\mathbf{h_e = 53.6429\ KJ/kg}$$

$$m_o t_o + m_r t_r = m_e t_e$$

$$(0.1)m_t(34) + (0.9)m_t(25) = m_t t_e$$

$$\mathbf{t_{e=}\ 25.9\ ^oC}$$

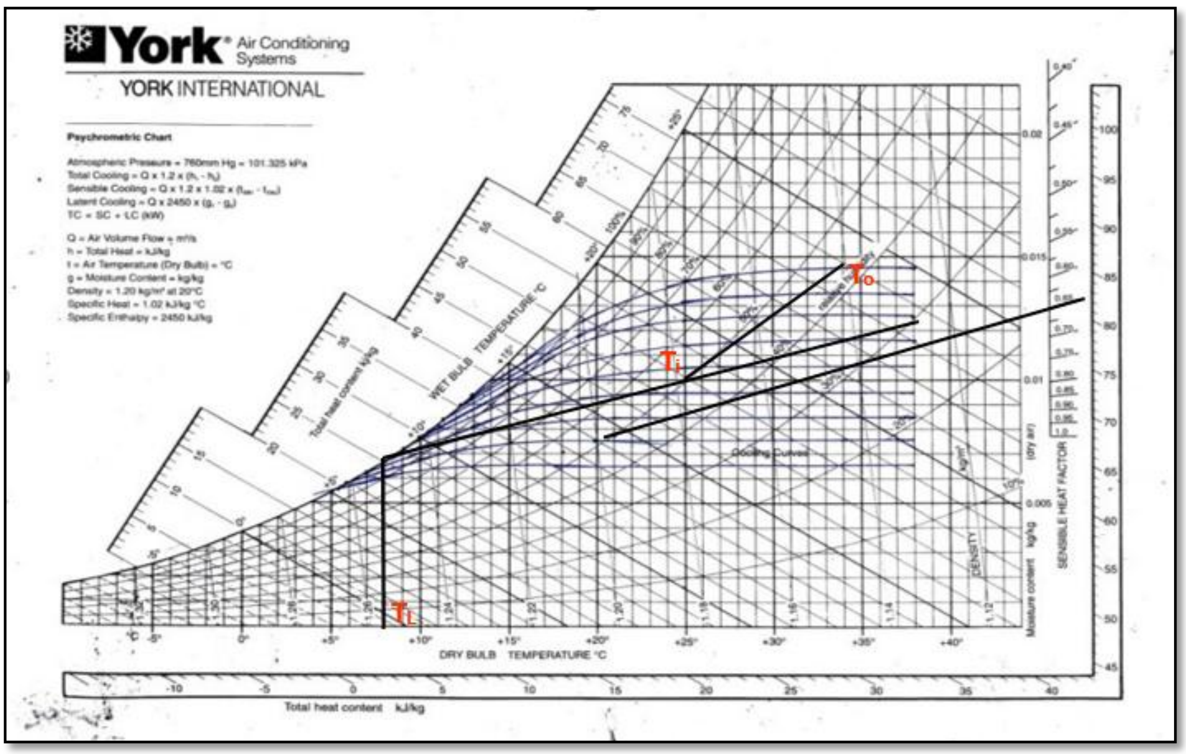


Figure 8. Ground Floor Psychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be TL = 8 °C.

For Capacity of Cooling Coil:

$$Capacity = m_e(h_e - h_L)$$

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.6580817131 = \frac{1.0062(25-8)}{50.628 - h_L}$$

h_L= 24.63517926 kJ/kg

Then substituting:

Cap of A/C = $m_e(h_e - h_L)$

$= 13.29802234\ (53.6429 - 24.63517926)$

Cap of A/C = 385.7453184 kW x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 385.7453184 kW or 109.7114102 TOR

Summary of Psychrometric Calculations for Ground Floor

This table presents the summary of the cooling load for each conditioned room for ground floor.

Table 62. Summary of Psychrometric Calculations for Ground Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Pizza Shop	121.1790	63.39209713	18.02601789
Food Stall	141.1543	73.84173428	20.99745053
Retail Shop	71.11111	37.20019091	10.57815307
Coffee Shop	133.6296	69.90535983	19.87811296
Elevator Lobby & Hallway	270.3086	141.4059362	40.2098377
	Total Q	**385.7453184 kW**	**109.7114102 TOR**

The calculated total cooling load for ground floor is 385.7453184 kW or 109.7114102 TOR.

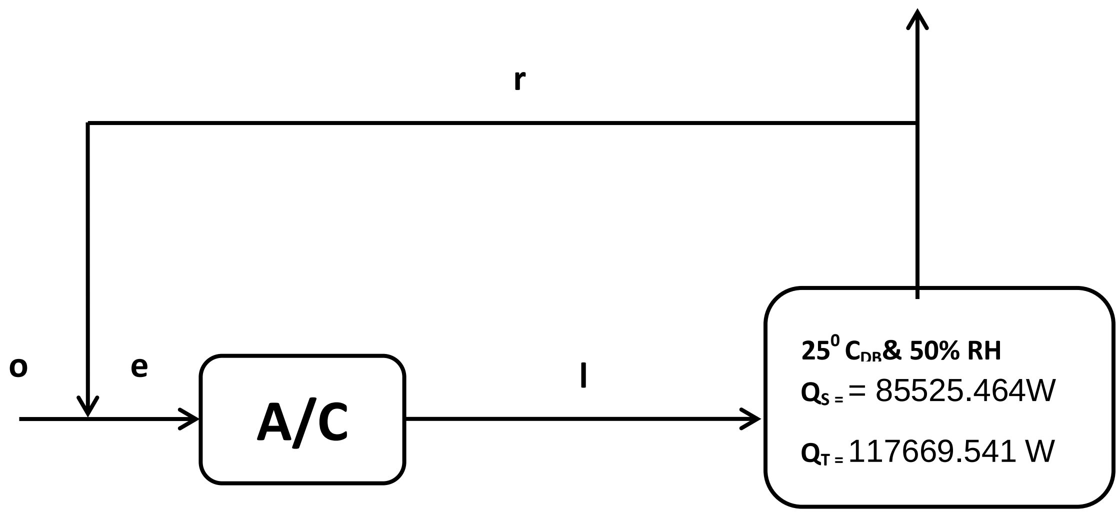
PSYCHROMETRIC CALCULATION FOR MEZZANINE FLOOR

The table shows a brief summary of the results of mezzanine floor heat load calculation.

Table 63. Mezzanine Floor Heat Load Calculation

Q_S	85525.464	**W**
Q_L	32144.07701	**W**
Q_T	117669.541	**W**
SHF = QS/QT	0.7268275483	

The SHF for mezzanine floor was calculated by dividing the total sensible and total latent heat for mezzanine floor which gives a value 0.7268275483.



Schematic Diagram of Air-conditioning for Mezzanine Floor

$W_o = 0.018\ kg/kg$

$W_i = 0.01\ kg/kg$

$$0.018\frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

Ps= $2.849765625\ kPa$

Then,

$$Vo = \frac{0.287(26 + 273)}{101.325 - 2.849765625}$$

Vo= 0.8714170679$\frac{m^3}{kg}$

$m_{o=}$ $\frac{0.584778768}{0.8714170679}$

$m_{o=}$ 0.6710664612 kg/s

Solving for m_a:

$$85.525464 = m_a (1.0062)(34-25)$$

$$m_a = 9.444274829 \text{ kg/s}$$

% outdoor air

$$\% \text{ outdoor air} = \frac{= 0.6710664612 \ \ /s}{9.444274829 \ \ kg/s} \times 100$$

$$\% \text{ outdoor air} = 7.1055372\%$$

Since %outdoor <10%, use %outdoor = 10%

% return air

$$\% \text{ return air} = 100 - 10$$

% return air= **90%**

Solving for w_e, h_e, t_e:

$$m_o w_o + m_r w_r = m_e w_e$$

$$(.1)mt(0.018) + (0.9)mt(0.01) = mtW_e$$

$$\mathbf{W_e = 0.0108 \text{ kg/kg}}$$

$h_R = C_p t + W_R h_g$ @25^0C

$$h_R = 1.0062(25^0C) + (0.01)(2547.3)$$

h_R= 50.628 **kJ/kg**

$$m_o h_o + m_r h_r = m_e h_e$$

$$(.1)mt(80.777) + (0.9)mt(50.628) = mth_e$$

$$\mathbf{h_e = 53.6429 \text{ kJ/kg}}$$

$$m_o t_o + m_r t_r = m_e t_e$$

$$(.1)mt(34) + (0.9)mt(25) = mt(t_e)$$

$$\mathbf{t_e = 25.9\ ^oC}$$

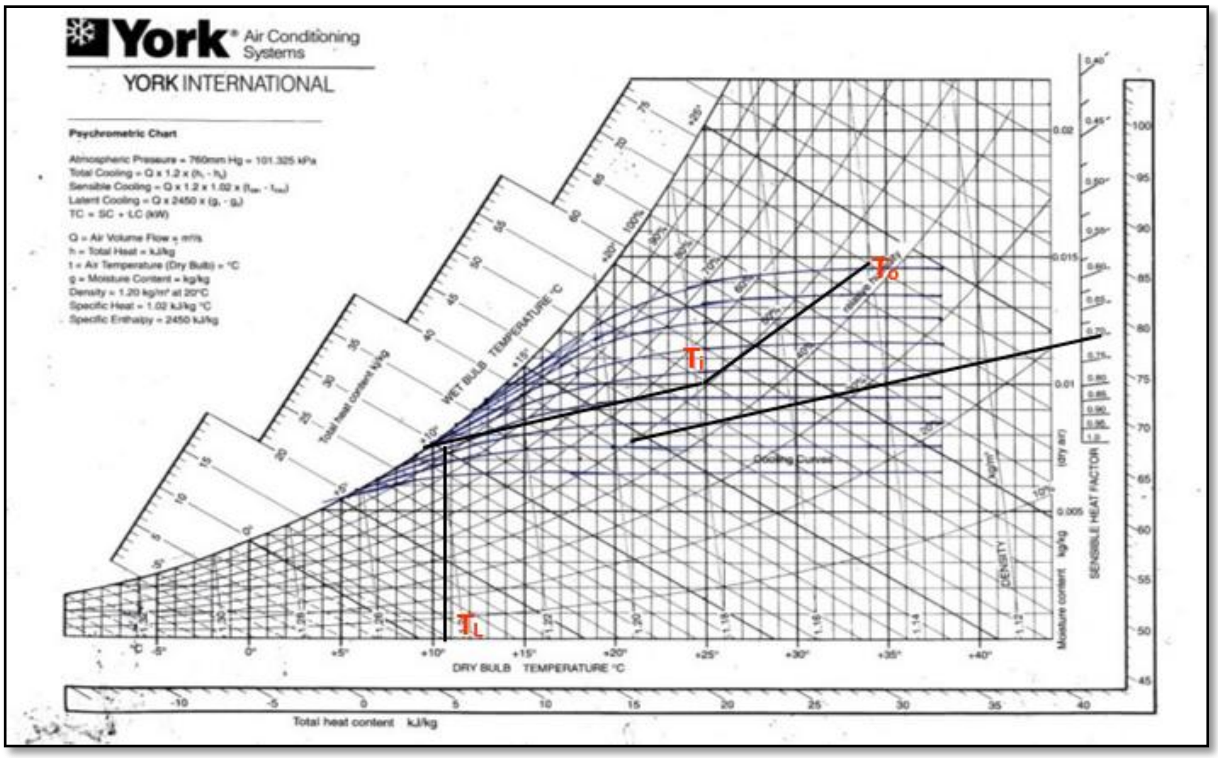


Figure 9. Mezzanine Floor Psychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be TL = 10.8 °C.

For Capacity of Cooling Coil:

$$\text{Capacity} = m_e(h_e - h_L)$$

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.7268275483 = \frac{1.0062(25 - 10.8)}{50.628 - h_L}$$

$$h_L = 30.96991187 \text{kJ/kg}$$

Then substituting:

$$\text{Cap of A/C} \quad = m_e(h_e - h_L)$$

$$= 9.444274829\,(53.6429 - 30.96991187)$$

Cap of A/C = 214.1299311 x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 214.1299311 kW or 60.90157312 TOR

Summary of Psychrometric Calculations for Mezzanine Floor

This table presents the summary of the cooling load for each conditioned room for mezzanine floor.

Table 64. Summary of Psychrometric Calculations for Mezzanine Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Office 2	8.8889	3.35282391	0.9535904182
Admin Office	48.25	18.19952454	5.176201518
Retail Shop 1	57.07407	21.52789661	6.122837489
Retail Shop 2	60.14815	22.68741344	6.452620431
Retail Shop 3	73.28395	27.64213591	7.861813398
Retail Shop 4	36.29630	13.69068052	3.893822674
Retail Shop 5	37.33333	14.08184281	4.005074746
Retail Shop 6	36.29630	13.69068052	3.893822674
Retail Shop 7	36.74074	13.85832151	3.941502135
Retail Shop 8	67.16049	25.33241566	7.204896376
Elevator Lobby & Hallway	106.2222	40.06619564	11.39539125
	Total Q	**214.1299311 kW**	**60.90157312 TOR**

The calculated total cooling load for ground floor is 214.1299311 kW or 60.90157312 TOR.

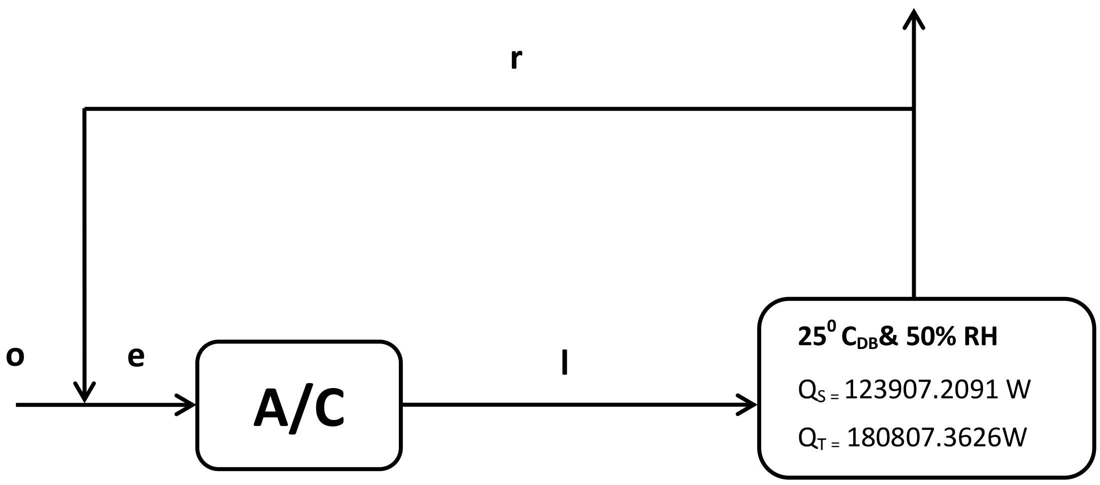
PSYCHROMETRIC CALCULATION FOR 6th and 7th FLOOR

The table shows a brief summary of the results of 6th and 7th floor heat load calculation.

Table 65. 6th and 7th Floor Heat Load Calculation

Q_S	123907.2091	**W**
Q_L	56900.1532	**W**
Q_T	180807.3623	**W**
SHF = QS/QT	0.6852995781	

The SHF for 6th and 7th floor was calculated by dividing the total sensible and total latent heat for 6th and 7th floor which gives a value 0.6852995781.



Schematic Diagram of Air-conditioning for 6th and 7th Floor

$W_o = 0.018\ kg/kg$

$W_i = 0.01\ kg/kg$

$$0.018 \frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

$$\text{Ps} = 2.849765625\ kPa$$

Then,

$$Vo = \frac{0.287(26 + 273)}{101.325 - 2.849765625}$$

$$\mathbf{Vo = 0.8714170679}\ \frac{m^3}{kg}$$

$$\mathbf{m_{o}} = \frac{\mathbf{1.05172}}{\mathbf{0.8714170679}}$$

$$m_o = 1.206907735\ \text{kg/s}$$

Solving for m_a:

$$123.9072091 = m_a (1.0062)\ (34\text{-}25)$$

$$m_a = \mathbf{13.68263534\ kg/s}$$

% outdoor air

$$\%\ \text{outdoor air} = \frac{1.206907735\ \ \text{kg/s}}{\mathbf{13.68263534}\ kg/s} \times 100$$

% outdoor air= **8.820725724%**

Since %outdoor <10%, use %outdoor = 10%

% return air

% return air= 100- 10

% return air= **90%**

Solving for w_e, h_e, t_e:

$m_o w_o + m_r w_r = m_e w_e$

(.1)mt(0.018) + (0.9)mt(0.01) = mtW_e

W_e= 0.0108 kg/kg

$h_R = C_p t + W_R h_g$ @25^0C

h_R=1.0062(25^0C) + (0.01)(2547.3)

h_R= 50.628 kJ/kg

$m_o h_o + m_r h_r = m_e h_e$

(.1)mt(80.777) + (0.9)mt(50.628) = mth_e

h_e= 53.6429 KJ/kg

$m_o t_o + m_r t_r = m_e t_e$

(.1)mt(34) + (0.9)mt(25) = mtt_e

$t_{e=}$ 25.9 ºC

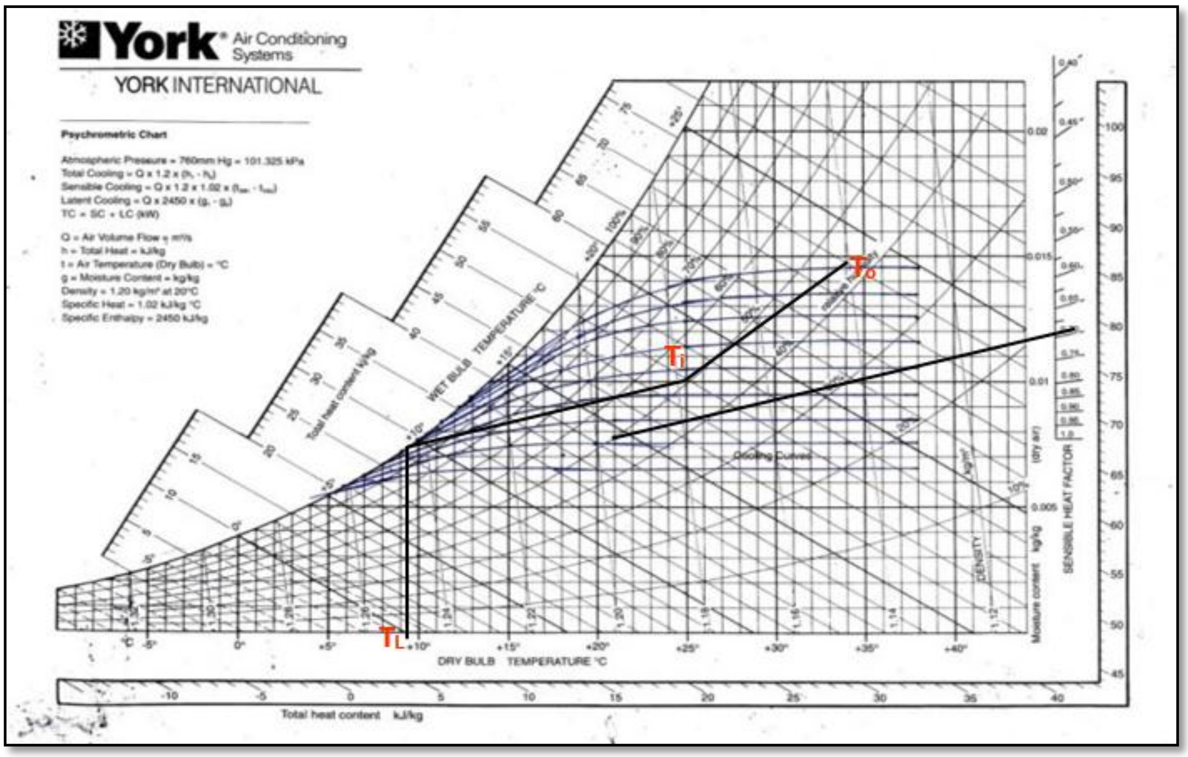


Figure 10. **.** 6th to 7thPsychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be T_L = 9.5 °C.

For Capacity of Cooling Coil:

$$Capacity = m_e(h_e - h_L)$$

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.6852995781 = \frac{1.0062(25 - 9.5)}{50.628 - h_L}$$

$$h_L = 27.86992383 \text{ kJ/kg}$$

Then substituting:

$$\text{Cap of A/C} \quad = m_e(h_e - h_L)$$

$$= 13.68263534(53.6429 - 27.86992383)$$

Cap of A/C = 352.6422346kW x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 352.6422346 kW or 100.2964262 TOR

Summary of Psychrometric Calculations for 6th and 7th Floor

This table presents the summary of the cooling load for each conditioned room for 6th and 7th floor.

Table 66. Summary of Psychrometric Calculations for 6th and 7th Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Department Store	1388.76	352.6422346	100.2964262
	Total Q	**352.6422346 kW**	**100.2964262 TOR**

The calculated total cooling load for ground floor is = 352.6422346 kW or 100.2964262 TOR.

PSYCHROMETRIC CALCULATION FOR 8th and 9th FLOOR

The table shows a brief summary of the results of 8th and 9th floor heat load calculation.

Table 67. 8th and 9th Floor Heat Load Calculation

Q_S	110840.5512	**W**
Q_L	18361.40531	**W**
Q_T	129201.9565	**W**
SHF = QS/QT	0.857886012	

The SHF for 8th and 9th floor was calculated by dividing the total sensible and total latent heat for 8th and 9th floor which gives a value 0.857886012.

r

25^0 C_{DB}& 50% RH

Q_{S} = 110840.5512W

o **e** **l**

Q_{T} = 18361.40531 W

A/C

Schematic Diagram of Air-conditioning for 8th and 9th Floor

$W_o = 0.018\ kg/kg$

$W_i = 0.01\ kg/kg$

$$0.018\frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

Ps= $2.849765625\ kPa$

Then,

$$Vo = \frac{0.287(26+273)}{101.325 - 2.849765625}$$

Vo= 0.8714170679$\frac{m^3}{kg}$

$$\mathbf{m_{o}} = \frac{\mathbf{0.3491}}{\mathbf{0.8714170679}}$$

m_o= 0.4006118458 kg/s

Solving for m_a:

110.8405512 = m_a (1.0062) (34-25)

m_a= **12.23973047 kg/s**

% outdoor air

% outdoor air= $\frac{0.4006118458\ \ kg/s}{12.23973047\ \ kg/s}$ x 100

% outdoor air= **3.27304467%**

Since %outdoor <10%, use %outdoor = 10%

% return air

% return air= 100- 10

% return air= **90%**

Solving for w_e, h_e, t_e:

$m_o w_o + m_r w_r = m_e w_e$

(.1)mt(0.018) + (0.9)mt(0.01) = mtW_e

W_e= 0.0108 kg/kg

$h_R = C_p t + W_R\, h_g$ @25^{0}C

h_R=1.0062(25^{0}C) + (0.01)(2547.3)

h_R= 50.628 kJ/kg

$$m_o h_o + m_r h_r = m_e h_e$$

$$(.1)mt(80.777) + (0.9)mt(50.628) = mth_e$$

$$\mathbf{h_e = 53.6429\ kJ/kg}$$

$$m_o t_o + m_r t_r = m_e t_e$$

$$(.1)mt(34) + (0.9)mt(25) = mt(t_e)$$

$$\mathbf{t_e = 25.9\ ^oC}$$

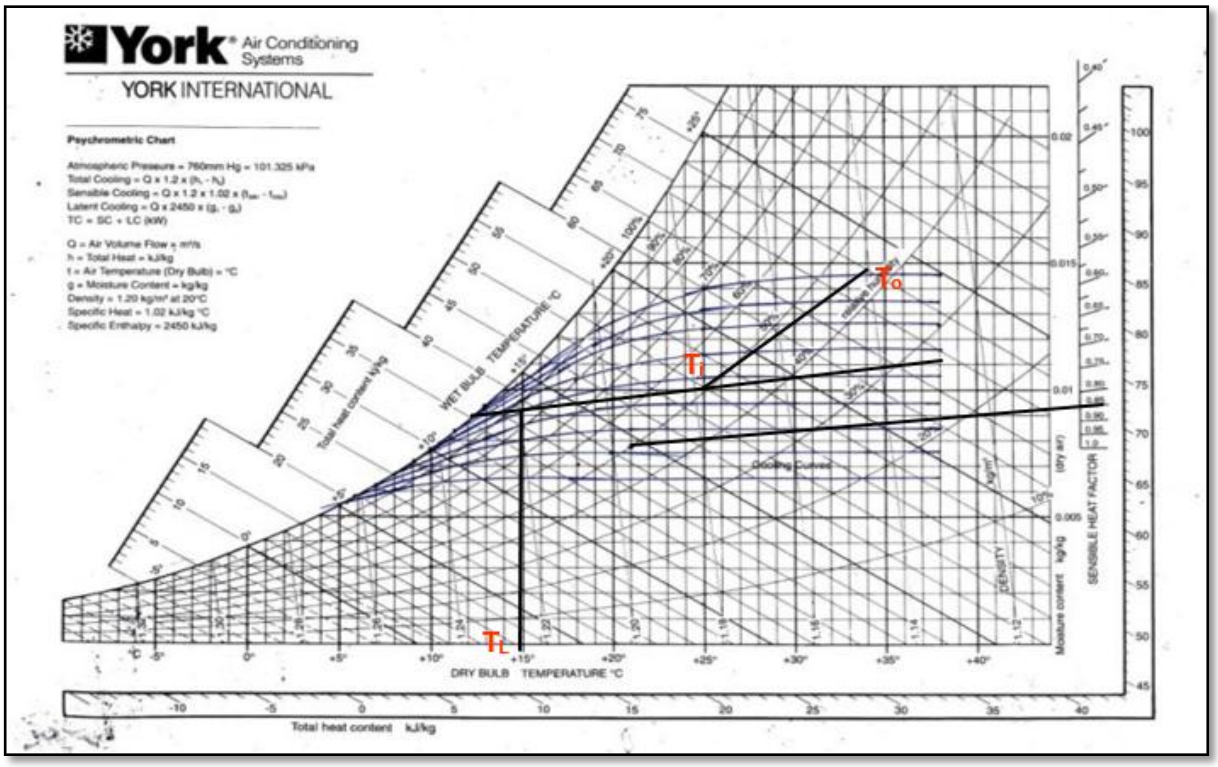


Figure 11. 8th and 9th Floor Psychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be T_L = 15 °C.

For Capacity of Cooling Coil:

$$\text{Capacity} = m_e(h_e - h_L)$$

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.857886012 = \frac{1.0062(25 - 15)}{50.628 - h_L}$$

$$h_L = 38.89916906\ \text{kJ/kg}$$

Then substituting:

$$\text{Cap of A/C} \quad = m_e(h_e - h_L)$$

$$= 12.23973047(53.6429 - 38.89916906)$$

Cap of A/C = 180.4592928 kW x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 180.4592928 kW or 51.32516861 TOR

Summary of Psychrometric Calculations for 8th and 9th Floor

This table presents the summary of the cooling load for each conditioned room for 8th and 9th floor.

Table 68. Summary of Psychrometric Calculations for 8th and 9th Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Office 1	203.7531	32.01578136	9.103927364
Office 2	214.6667	33.73064062	9.591560446
Office 3	222.07407	34.89333272	9.922180658
Office 4	177.77778	27.93427396	7.943320146
Office 5	203.7530864	32.01578136	9.103927364
Office 6	116.691358	18.33574681	5.213907018
	Total Q	**180.4592928 kW**	**51.32516861 TOR**

The calculated total cooling load for ground floor is 180.4592928 kW or 51.32516861 TOR.

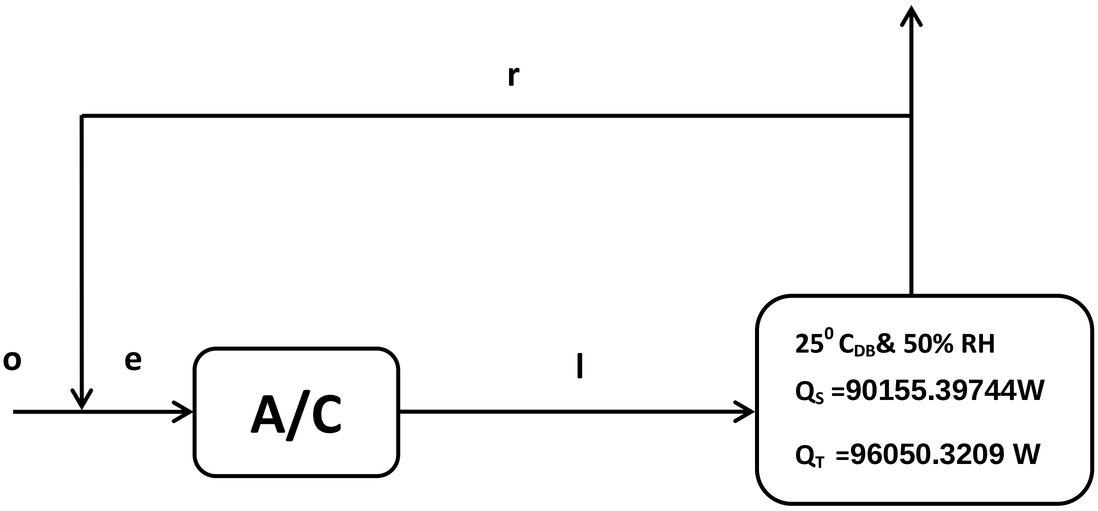
PSYCHROMETRIC CALCULATION FOR 10th to 12th FLOOR

The table shows a brief summary of the results of 10th to 12th floor heat load calculation.

Table 69. 10th to 12th Floor Heat Load Calculation

Q_S	110840.5512	**W**
Q_L	18361.40531	**W**
Q_T	129201.9565	**W**
SHF = QS/QT	0.9379642391	

The SHF for 10th to 12th floor was calculated by dividing the total sensible and total latent heat for 10th to 12th floor which gives a value 0.9379642391.



Schematic Diagram of Air-conditioning for 10th to 12th Floor

$W_o = 0.018\ kg/kg$

$W_i = 0.01\ kg/kg$

$$0.018\frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

Ps= $2.849765625\ kPa$

Then,

$$Vo = \frac{0.287(26 + 273)}{101.325 - 2.849765625}$$

$$\mathbf{Vo = 0.8714170679 \frac{m^3}{kg}}$$

$$\mathbf{m_{o} = \frac{0.06}{0.8714170679}}$$

m_{o}= 0.06885336793 kg/s

Solving for m_a:

89.12973628= m_a (1.0062) (34-25)

m_a= **9.842281883 kg/s**

% outdoor air

% outdoor air= $\frac{0.06885336793\ \text{kg}/s}{9.842281883\ kg/s}$ x 100

% outdoor air= **0.6995671202%**

Since %outdoor <10%, use %outdoor = 10%

% return air

$$\% \text{ return air} = 100 - 10$$

$$\% \text{ return air} = 90\%$$

Solving for w_e, h_e, t_e:

$$m_o w_o + m_r w_r = m_e w_e$$

$$(.1)mt(0.018) + (0.9)mt(0.01) = mtW_e$$

$$\mathbf{W_e = 0.0108\ kg/kg}$$

$$h_R = C_p t + W_R\, h_g\ @25^0C$$

$$h_R = 1.0062(25^0C) + (0.01)(2547.3)$$

$$\mathbf{h_R = 50.628\ kJ/kg}$$

$$m_o h_o + m_r h_r = m_e h_e$$

$$(.1)mt(80.777) + (0.9)mt(50.628) = mth_e$$

$$\mathbf{h_e = 53.6429\ KJ/kg}$$

$$m_o t_o + m_r t_r = m_e t_e$$

$$(.1)mt(34) + (0.9)mt(25) = mtt_e$$

$$\mathbf{t_{e=}\ 25.9\ ^oC}$$

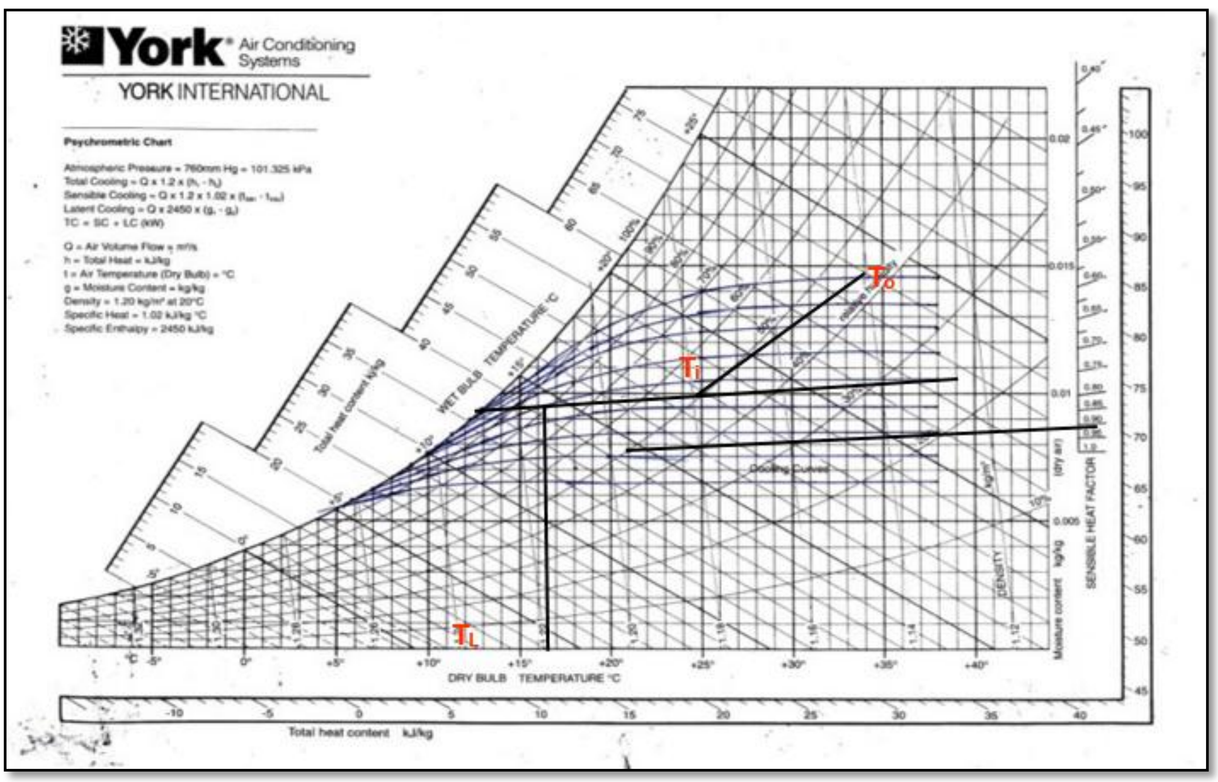


Figure 12. 10^{th} to 12^{th}Floor Psychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be T_L = 16.5 °C.

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.9379642391 = \frac{1.0062(25 - 16.5)}{50.628 - h_L}$$

h_L= 41.50963531 kJ/kg

Cap of A/C = $m_e(h_e - h_L)$

$= 9.842281883(53.6429 - 41.50963531)$

Cap of A/C = 119.4190113 kW x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 119.4190113 kW or 33.96445144 TOR

Summary of Psychrometric Calculations for 10th to 12th Floor

This table presents the summary of the cooling load for each conditioned room for 10th to 12th floors.

Table 70. Summary of Psychrometric Calculations for 10th to 12th Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Room 1	110.1234568	11.36827269	4.133496208
Room 2	108.2469136	11.12056951	4.06305995
Room 3	108.2469136	11.12056951	4.06305995
Room 4	140.345679	15.35759774	5.267890682
Room 5	101.1851852	10.18842329	3.797997188
Room 6	104.8395062	10.67079266	3.93516253
Room 7	134.1975309	14.54604386	5.037119258
Room 8	97.50617284	9.702790243	3.6136626389
	Total Q	**119.4190113 kW**	**33.96445144 TOR**

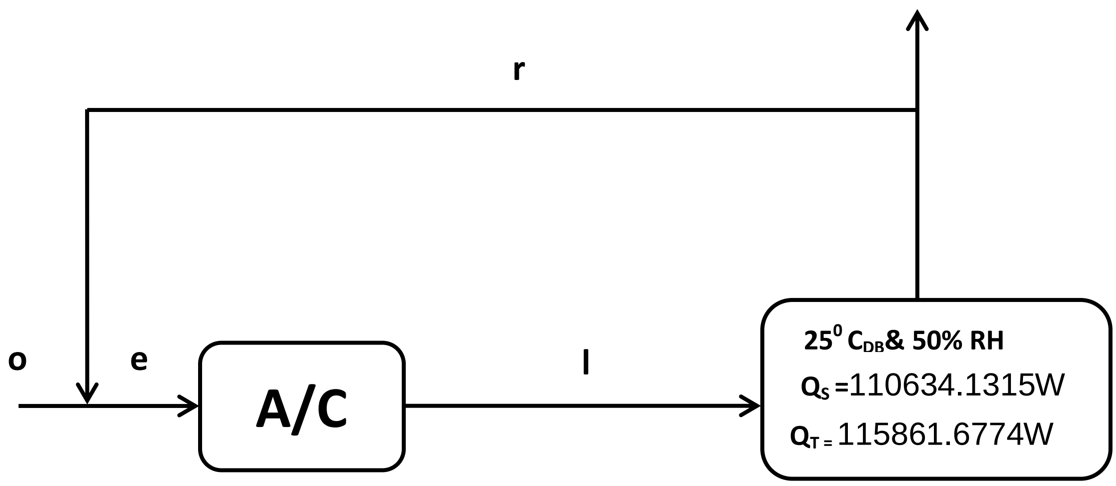
The calculated total cooling load for ground floor is 119.4190113 kW or 33.96445144 TOR.**PSYCHROMETRIC CALCULATION FOR 13th FLOOR**

The table shows a brief summary of the results of 13th floor heat load calculation.

Table 71. 13th Floor Heat Load Calculation

Q_S	110634.1315	**W**
Q_L	5227.545926	**W**
Q_T	115861.6774	**W**
SHF = QS/QT	0.9548811478	

The SHF for 13th floor was calculated by dividing the total sensible and total latent heat for 13th floor which gives a value 0.9548811478.



Schematic Diagram of Air-conditioning for 13th Floor

$W_o = 0.018\ kg/kg$

$W_i = 0.01\ kg/kg$

$$0.018\frac{kg}{kg} = \frac{0.622Ps}{101.325 - Ps}$$

Ps= $2.849765625\ kPa$

Then,

$$Vo = \frac{0.287(26 + 273)}{101.325 - 2.849765625}$$

Vo= 0.8714170679$\frac{m^3}{kg}$

m_{O}= $\frac{0.0525}{0.8714170679}$

$$m_{o=} 0.06024669694 kg/s$$

Solving for m_a:

$$110.6341315 = m_a (1.0062)(34-25)$$

$$\mathbf{m_a = 12.21693627\ kg/s}$$

% outdoor air

$$\%\ outdoor\ air = \frac{0.06024669694\ \text{kg/s}}{12.21693627\ kg/s} \times 100$$

% outdoor air= **0.4931%**

Since %outdoor <10%, use %outdoor = 10%

% return air

% return air= 100- 10

% return air= **90%**

Solving for w_e, h_e, t_e:

$$m_o w_o + m_r w_r = m_e w_e$$

$$(.1)mt(0.018) + (0.9)mt(0.01) = mtW_e$$

$$\mathbf{W_e = 0.0108\ kg/kg}$$

$h_R = C_p t + W_R h_g$ @25^0C

$$h_R = 1.0062(25^0C) + (0.01)(2547.3)$$

$$\mathbf{h_R = 50.628\ kJ/kg}$$

$$m_o h_o + m_r h_r = m_e h_e$$

$$(.1)mt(80.777) + (0.9)mt(50.628) = mth_e$$

$$\mathbf{h_e = 53.6429\ kJ/kg}$$

$$m_o t_o + m_r t_r = m_e t_e$$

$$(.1)mt(34) + (0.9)mt(25) = mt(t_e)$$

$$\mathbf{t_{e=} 25.9\ ^oC}$$

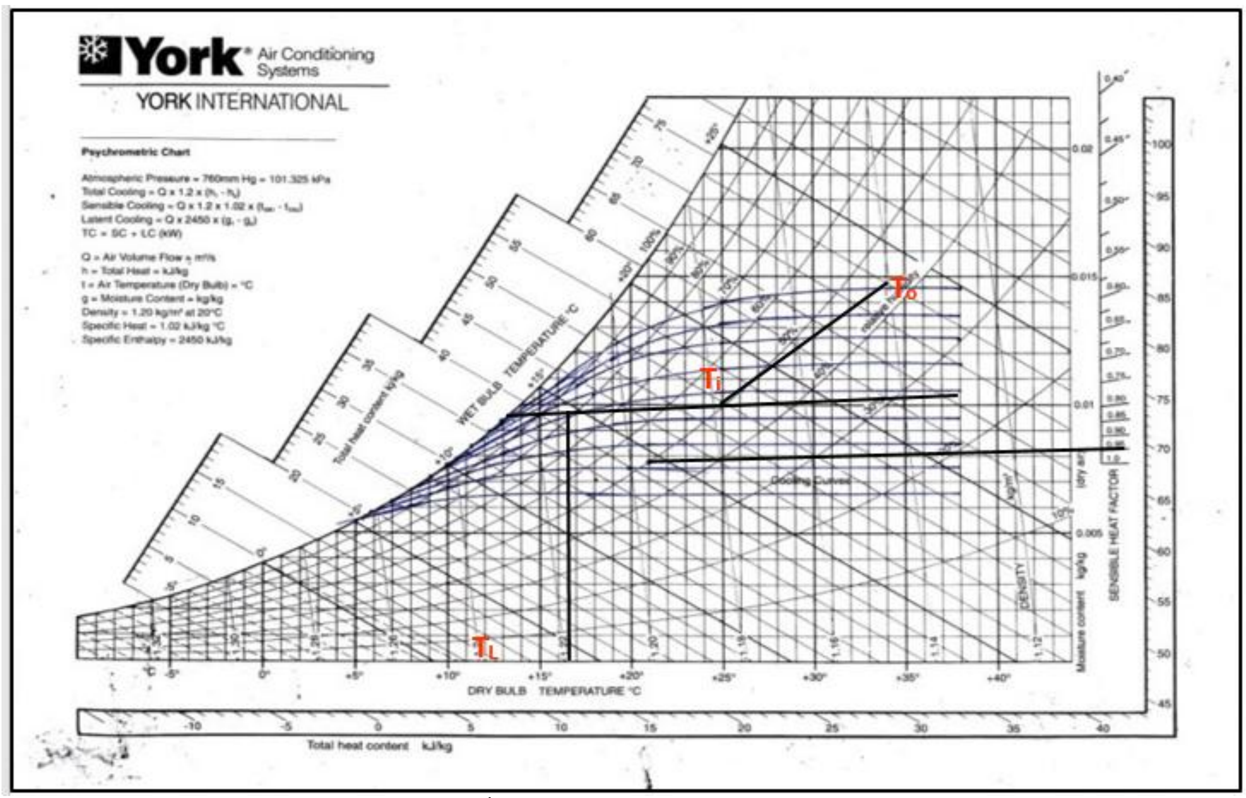


Figure 13. 13th Floor Psychrometric Chart

Plotting the acquired conditions to Psychrometric chart, leaving coil temperature will be T_L = 16.8 °C.

For Capacity of Cooling Coil:

$$\text{Capacity} = m_e(h_e - h_L)$$

Solving for h_L:

$$SHF = \frac{C_p(t_R - t_L)}{h_R - h_L}$$

$$0.9548811478 = \frac{1.0062(25 - 16.8)}{50.628 - h_L}$$

$$h_L = 41.98730161 \text{ kJ/kg}$$

Then substituting:

$$\text{Cap of A/C} = m_e(h_e - h_L)$$

$$= 12.3301964(53.6429 - 41.98730161)$$

Cap of A/C = 143.7158173 kW x $\frac{1\ TOR}{3.516\ KW}$

Cap of A/C = 143.7158173 kW or 40.87480583 TOR

Summary of Psychrometric Calculations for 13th Floor

This table presents the summary of the cooling load for each conditioned room for 13th floor.

Table 72. Summary of Psychrometric Calculations for 13th Floor

Space	Area (m^2)	Capacity of Cooling Coil (kW)	Capacity of Cooling Coil (TOR)
Room 1	110.1234568	15.32919672	5.57368339
Room 2	108.2469136	14.99518859	5.478707742
Room 3	108.2469136	14.99518859	5.478707742
Room 4	140.345679	20.7084785	7.1033324543
Room 5	101.1851852	13.73826481	5.121292045
Room 6	104.8395062	14.3887009	5.3062482
Room 7	134.1975309	19.61416375	6.792147942
	Total Q	**143.7158173 kW**	**40.87480583 TOR**

The calculated total cooling load for ground floor is 143.7158173 kW or 40.87480583 TOR.

PIPING CALCULATIONS

This section provides the calculation for volume flow rate of the chillers and air-conditioning units. Also, this shows the pipe run for each floor. Indicated here are the equivalent lengths for the pipe run, pressure drops, and pipe size or diameter.

Summary of Volume Flow Rate for Chillers

The table below shows the summary of the calculated volume flow rate for chiller 1 and chiller 2 in L/s. The chillers used were air-cooled chillers from Daikin catalogue with water entering at a temperature of 15 ^{o}C and a leaving temperature of 8 ^{o}C. The cooling capacity of the first chiller is 1192 kW while the second chiller has a cooling capacity of 1678 kW.

Table 73. Summary of Volume Flow Rate for Chillers

Chiller	Chiller Cooling Capacity	Volume Flow Rate (L/s)
Chiller 1	1192 kW	32.56476118
Chiller 2	1678 kW	44.60883621

Chiller 1 has a calculated volume flow rate of 44.60883621 L/s while chiller 2 has a calculated volume flow rate of 32.56476118 L/s.

Summary of Volume Flow Rate for A/C Unit Capacity

The table below shows the summary of the calculated volume flow rate in L/s for A/C units of certain cooling capacities in kW. The A/C units used were from Daikin Catalogue. Fan coil units such as ceiling cassette type, wall mounted type, and ceiling mounted type were used.

Table 74. Summary of Volume Flow Rate for A/C Unit Capacity

A/C Unit Capacity (kW)	Volume Flow Rate (L/s)
2.43	0.036763362
4.54	0.155032891
5.95	0.203181873
6.15	0.210011515
7.21	0.246208622
9.14	0.312114675
11.14	0.380411102
12.6	0.430267495
13.19	0.450414941

The results for the volume flow rate calculation for the listed A/C unit capacities were used for the piping calculation for both chiller 1 and chiller 2.

Piping Calculation for Chiller 1

This table shows the summary of manual calculation for the flow rate, pipe size, velocity inside the pipe, pressure gradient, equivalent length of the pipe run, and pressure drop of the first chiller.

Table 75. Piping Calculation for Chiller 1

Pipe Run	L/s of Specific	L/s for Table	ND (mm)	ID (mm)	Velocity (m/s)	Pressure Gradient (Pa/m)	Equivalent Length	Pressure Drop
pump-chill		32.56	125	128.2	2.52	460	102	46920
chill-a		32.56	125	128.2	2.52	460	71	32660
A-B	5.09	27.47	125	128.2	2.13	290	11.2	3248
B-C	4.78	22.69	125	128.2	1.76	220	11.2	2464
C-D	4.78	17.91	100	102.3	2.18	370	19.4112	7182.144

Table 75. Piping Calculation for Chiller 1

D-E	4.78	13.13	75	77.92	2.75	650	19.6996	12804.74
E-F	11.56	1.57	40	40.9	1.2	270	54.0503	14593.581
F-G	0.38	1.19	35	35.04	1.24	470	10.1896	4789.112
G-H	0.38	0.81	35	35.04	0.84	295	9.8	2891
H-FCU	0.43	0.38	25	26.64	0.68	260	10.2851	2674.126
							Total	**260453.406**

Chiller 1 is used to supply chilled water for the 8th floor up to the 13th floor. The calculated total pressure drop is 260453.406 Pa. The calculated pressure drop was used to solve for pump capacity of the chiller.

Piping Calculation for Chiller 2

This table shows the summary of manual calculation for the flow rate, pipe size, velocity inside the pipe, pressure gradient, equivalent length of the pipe run, and pressure drop of the second chiller.

Table 76. Piping Calculation for Chiller 2

Pipe Run	L/s of Specific	L/s for Table	ND (mm)	ID (mm)	Velocity (m/s)	Pressure Gradient (Pa/m)	Equivalent Length	Pressure Drop
pump-chill		44.61	150	154.1	2.39	330	119.1	39303
chill-a		44.61	150	154.1	2.39	460	106.9	49174
A-B	12.05	32.56	125	128.2	2.52	420	19.4383	8164.086
B-C	12.05	20.51	125	128.2	1.59	190	22.8	4332
C-D	16.31	4.2	60	62.65	1.36	310	73.8648	22898.09
D-E	0.86	3.34	60	62.65	1.08	210	8.7	1827
E-F	0.86	2.48	50	52.51	1.15	280	10.407	2913.96
F-G	0.86	1.62	40	40.9	1.23	290	11.6077	3366.233
G-H	0.81	0.81	35	35.04	0.84	300	6.8085	2042.55
H-FCU	0.38	0.43	25	26.64	0.77	370	5.5048	2036.776
							Total	**272115.4**

Chiller 2 is used to supply chilled water for the ground floor up to the 7th floor. The calculated total pressure drop is 272115.4 Pa. The calculated pressure drop was used to solve for pump capacity of the chiller.

PUMP CAPACITY CALCULATIONS

This section provides the calculation for the required pump capacity for each chiller.

Calculation for Pump Capacity

The table below indicates the summary of the calculation for pump capacity. The first and second pump has the capacity to pump water at a total dynamic height of 26.55244152 m and 27.7413 m respectively.

Table 77. Calculation for Pump Capacity

Pump	TDH (m)	Pump Capacity (kW)
Pump 1	26.55244152	11.3088
Pump 2	27.7413	16.185

The calculated pump capacities for the first and second chiller are 11.3088 kW and 16.185 kW respectively. The pumps used are centrifugal pumps.

CHAPTER III

ENGINEERING ECONOMICS ANALYSIS, OBSERVATION, COMMENTS, AND RECOMMENDATIONS

After computing the A/C capacity of the air conditioning unit for each floor level, the selection of the appropriate unit follows. The fan coil unit air conditioning system is chosen and selected in reference with the capacity.

3.1 Engineering Economic Analysis

Annual Operation Cost

AOC = Materials Cost + Maintenance Cost +Annual Energy Consumption Cost + Annual Labor Cost

A. Material Cost

The table below shows the breakdown of costs of materials or equipment of the air-conditioning system. The system includes the fan coil units, split-type units, air-cooled chillers, centrifugal pumps, and exhaust fans.

Table 78. Material and Equipment Cost

Fan Coil Units	Type	Price(PHP)	Quantity	Total(PHP)
FWK11E	Ceiling Cassette	83000	41	3403000
FWK13E	Ceiling Cassette	90000	82	7380000
FWE05E	Ceiling Mounted	18000	1	18000
FWE06E	Ceiling Mounted	24000	39	936000
FWE07E	Ceiling Mounted	25000	4	100000
FWE07D	Ceiling Mounted	29000	18	522000
FWE09D	Ceiling Mounted	37000	12	444000
FWE13D	Ceiling Mounted	53000	9	477000
FWW02L	Wall Mounted	20000	62	1240000
			TOTAL	14520000
Split Type Units	**Type**	**Price(PHP)**	**Quantity**	**Total(PHP)**
FTK535DVM	Wall Mounted	30000	1	30000
FTK560GVMG	Wall Mounted	65000	3	195000
			TOTAL	225000
Chiller Units	**Type**	**Price(PHP)**	**Quantity**	**Total(PHP)**
EWAD-C-XS/XL-C11	Air Cooled	520000	1	520000
EWAD-C-XS/XL-C17	Air Cooled	740000	1	740000
			TOTAL	1260000
Pump Units	**Type**	**Price(PHP)**	**Quantity**	**Total(PHP)**
CP 750B-N	Centrifugal Pump	5200	1	5200
CP 750A-N	Centrifugal Pump	6200	1	6200
			TOTAL	5200

Table 78. Material and Equipment Cost

Exhaust Fan Units	Type	Price(PHP)	Quantity	Total(PHP)
EDM-300S	Wall Mounted	1000	24	24000
CPE0564FHP	Wall Mounted	7000	12	84000
JVU-CPA-400-2-3	Jet Fan	7500	2	15000
			TOTAL	123000
TOTAL MATERIAL AND EQUIPMENT COST			**PhP 16 162 200**	

The total calculated material and equipment cost is PhP 16 162 200.

B. Annual Energy Consumption

The table shows the breakdown of cost for the power consumption of every air-conditioning system equipments used. The data shown are power consumption, number of units, and the total annual cost of energy. The estimated number of hours used for calculation is 12 hours of operation per day. The cost per kilowatt-hour(kWh) is known to be PhP 10.0732.

Table 79. Annual Energy Consumption Cost

Fan Coil Units	Power Consumption (kW)	Quantity	Total(kW)	kWh	Annual kWh
FWK11E	0.186	41	7.626	91.512	32944.32
FWK13E	0.227	82	18.614	223.368	80412.48
FWE05E	0.086	1	0.086	1.032	371.52
FWE06E	0.135	39	5.265	63.18	22744.8
FWE07E	0.16	4	0.64	7.68	2764.8
FWE07D	0.132	18	2.376	28.512	10264.32
FWE09D	0.24	12	2.88	34.56	12441.6
FWE13D	0.24	9	2.16	25.92	9331.2
FWW02L	0.031	62	1.922	23.064	8303.04
	TOTAL		41.569	498.828	179578.08
ANNUAL ENERGY COST			**1808925.915**		
Split Type Units	**Power Consumption (kW)**	**Quantity**	**Total(kW)**	**kWh**	**Annual kWh**
FTK535DVM	1.035	1	1.035	12.42	4471.2
FTK560GVMG	1.78	3	5.34	64.08	23068.8
	TOTAL		5.34	76.08	27388.8
ANNUAL ENERGY COST			**275892.86016**		
Chiller Units	**Power Consumption (kW)**	**Quantity**	**Total(kW)**	**kWh**	**Annual kWh**
EWAD-C-XS/XL-C11	367	1	367	4404	1585440
EWAD-C-XS/XL-C17	541	1	541	6492	2337120
	TOTAL		908	10896	3922560
ANNUAL ENERGY COST			**39512731.39**		
Pump Units	**Power Consumption (kW)**	**Quantity**	**Total(kW)**	**kWh**	**Annual kWh**

Table 79. Annual Energy Consumption Cost

CP 750B-N	11.616	1	11.616	139.392	50181.12
CP 750A-N	13.772	1	13.772	165.264	59495.04
	TOTAL		11.616	304.656	109676.16
ANNUAL ENERGY COST			**1104789.895**		
Exhaust Fan Units	**Power Consumption (kW)**	**Quantity**	**Total(kW)**	**kWh**	**Annual kWh**
EDM-300S	0.03	24	0.72	8.64	3110.4
CPE0564FHP	0.75	12	9	108	38880
JVU-CPA-400-2-3	1.5	1	1.5	18	6480
	TOTAL		20.1	241.2	48470.4
ANNUAL ENERGY COST			**488252.0333**		
TOTAL ANNUAL ENERGY COST			**PhP 43 190 592.095828**		

The estimated total cost for the annual energy consumption of the whole air-conditioning system is PhP 43 190 592.095828

C. Maintenance and Labor Cost

For large establishments, such as a 13-Storey Mixed-Use Building, the annual maintenance and labor cost is estimated to be PhP 350 000.

D. Annual Operation Cost

The annual operation cost is the sum of the total material and equipment cost, total annual energy consumption, and maintenance and labor cost. The annual operation cost has a total of PhP 59 702 792.10.

3.2 Observations

The design project has tested the students' capabilities to design an air-conditioning system by following the calculation procedure and taking into account the conditions and different building considerations such as ambient temperatures, material composition, and desired indoor conditions.

An air-conditioning system is designed for a 13-storey mixed-use building. It is located at Paranaque City. This building hosts the different needs of people to promote diversity of city life. Inside this building, variety of establishments can be found such as retail shops, restaurants, offices, department stores, and residential units.

In order to come up with the design of the system, total heat load was calculated considering the desired indoor conditions. After the heat load calculation for each floor, the total cooling capacity was the established with the aid of the psychrometric chart. It was then followed by choosing the desired a/c equipment for each designation.

The chosen system of air-conditioning is the chilled-water type. Fan coil units were used for some reasons. First reason is the flexibility of the application. It can be applied on majority of the area in the building. Types of fan coil units used were ceiling cassette type and ceiling mounted type. Cassette type was used in offices, restaurants, and department stores. On the other hand, ceiling mounted type was used on retail shops and residential areas. Another advantage is that fan coil units only require piping. This is applicable for the building because of the limited space for ducting works. Another units used were the split-type. Both floor mounted and wall mounted type were used for bedrooms of the residential units.

The piping design was based on the a/c units chosen for the system. Manual calculation was used.

3.3 Comments and Recommendations

1. Knowledge on the types of air-conditioning system and different a/c equipments must be acquired before doing the design project. This will give ideas on how the project must be done. Also, having prior knowledge on the subject makes it easy to imagine how the system will work.
2. Make sure to provide all the necessary information of the building such as its layout, schedule of doors, and windows, elevation, and orientation to make calculation more accurate and correct.
3. If possible, ask assistance on experienced people regarding the design project. Ask help regarding different design considerations, and proper choosing of a/c equipment.

APPENDICES

CATALOGUE

DAIKIN

PCXF14

Chilled Water
PRODUCT SYSTEM

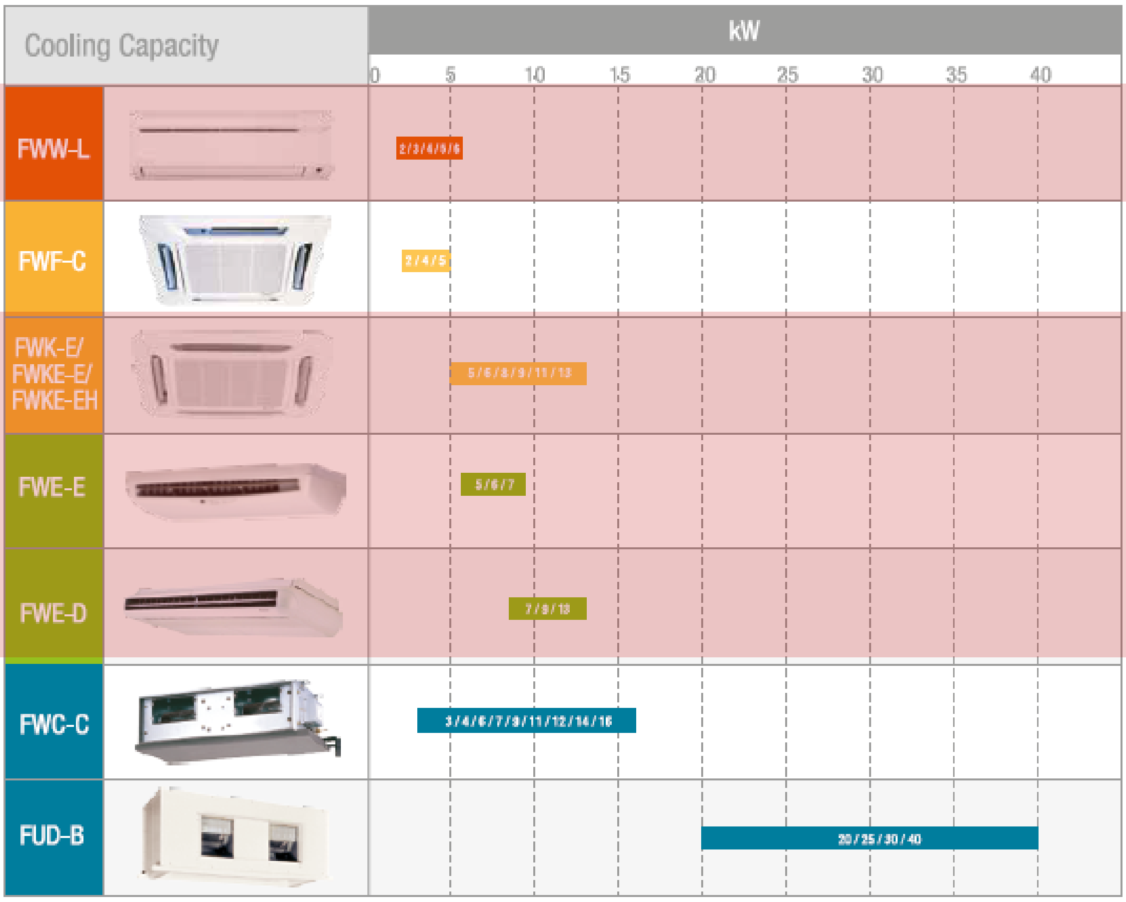
Wall Mounted

Ceiling Cassette

Ceiling Convertible

Ducted

Fan Coil Unit Product Catalogue



Wall Mounted Type


FWW-L


Wireless Remote Controller
BRC52A


Wired Remote Controller
BRC51A (Option)

- Comfortable Air Flow & Lower Sound Level
- Stylish Flat-Panel
- Indoor Quiet Mode
- Turbo Mode
- Uniform Air Distribution
- Easy Maintenance
- NIM-Able
- Sleep Function For Cool And Heat Mode
- Auto Restart With Last-State-Memory
- Valve & Valveless Control Options
- Self Diagnosis Features
- Compact & Easy To Use Wireless Remote Controller

Specification for Wall Mounted Type ~ **50HZ**

MODEL				FWW02L	FWW03L	FWW04L	FWW05L	FWW06L
NOMINAL COOLING CAPACITY			Btu/h	8300	9200	11300	15500	18000
			W	2430	2700	3310	4540	5280
NOMINAL SENSIBLE COOLING CAPACITY			Btu/h	6300	6900	9000	11700	14000
			W	1850	2020	2640	3430	4100
NOMINAL HEATING CAPACITY (ENTERING WATER TEMP. = 50°C)			Btu/h	11000	12000	15000	20500	25000
			W	3220	3520	4400	6010	7330
NOMINAL TOTAL INPUT POWER			W	31	32	42	57	72
NOMINAL RUNNING CURRENT			A	0.20	0.20	0.21	0.30	0.34
POWER SOURCE			V/Ph/Hz		220-240 / 1 / 50			
REFRIGERANT TYPE					N/A			
INDOOR UNIT	CONTROL	AIR DISCHARGE			AUTOMATIC LOUVER (UP & DOWN)			
		OPERATION			LCD WIRELESS MICRO-COMPUTER REMOTE CONTROL			
	AIR FLOW	HIGH	CFM	260	280	370	510	620
		MEDIUM	CFM	230	250	320	450	520
		LOW	CFM	200	220	260	390	460
		QUIET	CFM	180	190	240	360	440
	NOMINAL WATER FLOW RATE		USGPM	1.85	2.03	2.51	3.43	4.01
			litres/min	7.00	7.68	9.50	13.00	15.18
	HEAD LOSS (COOLING)		kPa	34.0	24.0	31.0	30.0	36.0
	HEAD LOSS (HEATING) : 50°C		kPa	29.0	20.0	25.0	27.0	33.0
	MAX. WORKING PRESSURE		kPa		1608			
	SURFACE AIR VELOCITY		m/s	0.68	0.74	0.97	0.83	1.01
	SOUND PRESSURE LEVEL (H/M/L/Q)		dBA	34 / 29 / 25 / 24	35 / 30 / 25 / 24	42 / 39 / 32 / 29	42 / 38 / 34 / 32	46 / 42 / 39 / 37
	UNIT DIMENSION	H X W X D	mm		288 X 800 X 206		310 X 1065 X 224	
	PACKING DIMENSION	H X W X D	mm		344 x 874 x 274		388 X 1136 X 314	
	UNIT WEIGHT		kg		9		14	
	CONDENSATE DRAIN SIZE		mm		19.05			
	PIPE CONNECTION		mm		12.70			
	FAN	TYPE			CROSS FLOW FAN			
		DRIVE			DIRECT			
		FAN SPEED HIGH	RPM	1030	1050	1310	1035	1250
		FAN SPEED MEDIUM	RPM	890	910	1150	920	1070
		FAN SPEED LOW	RPM	760	780	965	825	970
	FAN MOTOR	TYPE			INDUCTION			
		INDEX OF PROTECTION (IP)			IP20		IP44	
		INSULATION GRADE			E			
		RATED INPUT POWER HIGH	W	31	32	42	57	72
		RATED INPUT POWER MEDIUM	W	29	31	37	50	68
		RATED INPUT POWER LOW	W	25	29	33	43	60
		RATED RUNNING CURRENT HIGH	A	0.20	0.20	0.21	0.30	0.34
		RATED RUNNING CURRENT MEDIUM	A	0.19	0.20	0.20	0.29	0.32
		RATED RUNNING CURRENT LOW	A	0.17	0.19	0.19	0.26	0.31
		STARTING CURRENT	A	0.40	0.40	0.40	0.60	0.43
		MOTOR OUTPUT	W	18	18	18	28	30
		POLES			4			
	COIL	TUBE MATERIAL			COPPER			
		TUBE DIAMETER	mm		7.00			
		FIN MATERIAL			ALUMINIUM			
		FIN FACE AREA	m²	0.18	0.18	0.18	0.29	0.29
		FIN ROW			2			
		WATER VOLUME	litre	0.52	0.58	0.58	0.95	0.95
	AIR QUALITY	FILTER TYPE			WASHABLE SARANET FILTER			
		FILTER QUANTITY	pc		2			
	CASING		COLOUR		WHITE			

MODE	COOLING	HEATING
ENTERING AIR TEMPERATURE	27°C DB / 19°C WB	20°C DB
ENTERING WATER TEMPERATURE	7°C	50°C (2 Pipes System) 70°C (4 Pipes System)
LEAVING WATER TEMPERATURE	12°C	45°C (2 Pipes System) 60°C (4 Pipes System)

ALL SPECIFICATIONS ARE SUBJECTED TO CHANGE BY THE MANUFACTURER WITHOUT PRIOR NOTICE.

Ceiling Cassette Type (900x900)

FWK-E

Wireless Remote Controller
BRC52A

Wired Remote Controller
BRC51A

- Multi Comfort - 3 Air Swing Pattern Control
- Fresh Air Intake
- Optimum Air Discharge
- Superior Sound Level
- Branch Duct Connection
- Low Height Design
- Built In High Head Drain Pump & Water Flow Switch
- Modern & Elegant Panel
- Low water Pressure Drop
- Self Diagnosis Features
- NIM-Able
- Valve Or Valveless Control Options
- Sleep Function For Cool & Heat Mode
- Auto Restart With Last-State-Memory
- Choices Of Wired Or Wireless Remote Controller

Specification for Ceiling Cassette Type ~ **50Hz**

MODEL				FWK06E	FWK08E	FWK09E	FWK11E	FWK13E
NOMINAL COOLING CAPACITY			Btu/h	21000	25000	30000	38000	43000
			W	6150	7330	8790	11140	12600
NOMINAL SENSIBLE COOLING CAPACITY			Btu/h	16700	19200	22300	27400	31000
			W	4890	5630	6540	8030	9090
NOMINAL HEATING CAPACITY (ENTERING WATER TEMP. = 50°C)			Btu/h	28000	33600	38300	45500	52000
			W	8210	9850	11230	13340	15240
NOMINAL TOTAL INPUT POWER			W	95	126	167	186	227
NOMINAL RUNNING CURRENT			A	0.44	0.55	0.74	0.85	1.03
POWER SOURCE			V/Ph/Hz	220-240 / 1 / 50				
REFRIGERANT TYPE				N/A				
INDOOR UNIT	CONTROL	AIR DISCHARGE		4 WAY AUTOMATIC LOUVER (UP & DOWN)				
		OPERATION		LCD WIRELESS MICRO-COMPUTER REMOTE CONTROL				
	AIR FLOW	HIGH	CFM	750	860	890	1000	1140
		MEDIUM	CFM	620	700	720	840	1000
		LOW	CFM	480	540	570	680	840
		QUIET	CFM	320	380	420	540	700
	NOMINAL WATER FLOW RATE		USGPM	4.71	5.59	6.69	8.45	9.60
			litres/min	17.83	21.17	25.29	31.94	36.29
	HEAD LOSS (COOLING)		kPa	20	37	22	44	53
	HEAD LOSS (HEATING) : 50°C		kPa	19	33	19	38	47
	MAX. WORKING PRESSURE		kPa	1600				
	SURFACE AIR VELOCITY		m/s	0.91	1.04	1.14	1.03	1.17
	SOUND PRESSURE LEVEL (H/M/L/Q)		dBA	42/38/32/23	46/42/35/27	48/43/38/30	50/47/43/33	52/49/45/39
	UNIT DIMENSION - ( ) WITH PANEL	H X W X D	mm	265 X 820 X 820 (340 X 990 X 990)			300 X 820 X 820 (375 X 990 X 990)	
	PACKING DIMENSION - ( ) PANEL	H X W X D	mm	341 X 916 X 916 (125 X 1020 X 1020)			376 X 916 X 916 (125 X 1020 X 1020)	
	UNIT WEIGHT (UNIT + PANEL)		kg	26 + 4	26 + 4	28 + 4	32 + 4	32 + 4
	CONDENSATE DRAIN SIZE		mm	19.05				
	FAN	TYPE		TURBO FAN				
		DRIVE		DIRECT				
		FAN SPEED HIGH	RPM	530	600	660	710	800
		FAN SPEED MEDIUM	RPM	450	500	550	610	710
		FAN SPEED LOW	RPM	360	400	450	510	610
	FAN MOTOR	TYPE		INDUCTION				
		INDEX OF PROTECTION (IP)		IP20				
		INSULATION GRADE		B				
		RATED INPUT POWER HIGH	W	95	126	167	186	227
		RATED INPUT POWER MEDIUM	W	79	103	109	151	176
		RATED INPUT POWER LOW	W	67	89	86	118	144
		RATED RUNNING CURRENT HIGH	A	0.44	0.55	0.74	0.85	1.03
		RATED RUNNING CURRENT MEDIUM	A	0.40	0.45	0.49	0.71	0.82
		RATED RUNNING CURRENT LOW	A	0.36	0.39	0.39	0.57	0.69
		STARTING CURRENT	A	0.44	0.71	0.89	1.02	1.28
		MOTOR OUTPUT	W	30	45	65	80	110
		POLES		8				
	COIL	TUBE MATERIAL		COPPER				
		TUBE DIAMETER	mm	7.00				
		FIN MATERIAL		ALUMINIUM				
		FIN FACE AREA	m^2	0.39	0.39	0.37	0.46	0.46
		ROW		2	2	3	3	3
		WATER VOLUME	litre	1.36	1.34	1.97	2.35	2.35
	AIR QUALITY	FILTER TYPE		WASHABLE SARANET FILTER				
		FILTER QUANTITY	pc	1				
	CASING		COLOUR	LIGHT GREY				

MODE	COOLING	HEATING
ENTERING AIR TEMPERATURE	27°C DB / 19°C WB	20°C DB
ENTERING WATER TEMPERATURE	7°C	50°C (2 Pipes System) 70°C (4 Pipes System)
LEAVING WATER TEMPERATURE	12°C	45°C (2 Pipes System) 60°C (4 Pipes System)

ALL SPECIFICATIONS ARE SUBJECTED TO CHANGE BY THE MANUFACTURER WITHOUT PRIOR NOTICE.

Ceiling Convertible Type

FWE-E

Wireless Remote Controller
BRC52A

Wired Remote Controller
BRC51A

- Compact Design
- Far Air Throw
- Auto Air Swing
- Service & Maintenance At Ease
- Ceiling & Floor Installing Option
- Versatile Installation
- Room Temperature Sensing
- Saranet Filter
- Sleep Function For Cool And Heat Mode
- Auto Restart With Last-State-Memory
- Valve Or Valveless Control Options
- Self Diagnosis Features
- NIM-Able
- Choices Of Wired Or Wireless Remote Controller

Specification for Ceiling Convertible Type

MODEL				FWE05E	FWE06E	FWE07E
NOMINAL COOLING CAPACITY			Btu/h	15500	20300	21000
			W	4540	5950	6150
NOMINAL SENSIBLE COOLING CAPACITY			Btu/h	12700	15400	16150
			W	3720	4510	4730
NOMINAL HEATING CAPACITY (ENTERING WATER TEMP. = 50ºC)			Btu/h	19500	25000	28000
			W	5720	7330	8210
NOMINAL TOTAL INPUT POWER			W	86	135	160
NOMINAL RUNNING CURRENT			A	0.38	0.67	0.79
POWER SOURCE			V/Ph/Hz	220-240 / 1 / 50		
REFRIGERANT TYPE				N/A		
INDOOR UNIT	CONTROL	AIR DISCHARGE		AUTOMATIC LOUVER (UP & DOWN)		
		OPERATION		LCD WIRELESS MICRO-COMPUTER REMOTE CONTROL		
	AIR FLOW	HIGH	CFM	520	580	640
		MEDIUM	CFM	460	530	560
		LOW	CFM	406	490	460
	NOMINAL WATER FLOW RATE		USGPM	3.43	4.49	4.67
			Litres/min	13	17	17.68
	HEAD LOSS (COOLING)		kPa	27	48	57
	HEAD LOSS (HEATING) : 50˚C		kPa	24	42	50
	MAX. WORKING PRESSURE		kPa	1608		
	SURFACE AIR VELOCITY		m/s	0.87	1.01	1.08
	SOUND PRESSURE LEVEL (H/M/L)		dBA	45 / 38 / 36	46 / 43 / 39	49 / 46 / 41
	UNIT DIMENSION	H X W X D	mm	212 X 1090 X 630		
	PACKING DIMENSION	H X W X D	mm	297 X 1197 X 740		
	UNIT WEIGHT		kg	27		
	CONDENSATE DRAIN SIZE		mm	19.05		
	PIPE CONNECTION		mm	12.7 BSP FEMALE THREAD ADAPTOR		

MODE	COOLING	HEATING
ENTERING AIR TEMPRATURE	27°c DB / 19°c WB	20°c DB
ENTERING WATER TEMPRATURE	7°c	50°c (2 PIPES SYSTEM)
		70°c (4 PIPES SYSTEM)
LEAVING WATER TEMPRATURE	12°c	
		60°c (4 PIPES SYSTEM)

ALL SPECIFICATIONS ARE SUBJECTED TO CHANGE BY THE MANUFACTURER WITHOUT PRIOR NOTICE

Specification for Ceiling Convertible Type

MODEL				FWE07D	FWE09D	FWE13D
NOMINAL COOLING CAPACITY			Btu/h	24600	31200	45000
			W	7210	9140	13190
NOMINAL SENSIBLE COOLING CAPACITY			Btu/h	17700	25600	31400
			W	5190	7500	9200
NOMINAL HEATING CAPACITY (ENTERING WATER TEMP. = 50ºC)			Btu/h	28000	42300	51500
			W	8210	12400	15090
NOMINAL TOTAL INPUT POWER			W	132	240	240
NOMINAL RUNNING CURRENT			A	0.57	0.98	1.03
POWER SOURCE			V/Ph/Hz	220-240/ 1 /50		
REFRIGERANT TYPE				N/A		
INDOOR UNIT	CONTROL	AIR DISCHARGE		AUTOMATIC LOUVER (UP & DOWN)		
		OPERATION		LCD WIRELESS MICRO-COMPUTER REMOTE CONTROL		
	AIR FLOW	HIGH	CFM	697	956	1059
		MEDIUM	CFM	687	908	1023
		LOW	CFM	650	889	956
	NOMINAL WATER FLOW RATE		USGPM	5.46	6.91	9.99
			Litres/min	20.67	26.16	37.82
	HEAD LOSS (COOLING)		kPa	49	24	38
	HEAD LOSS (HEATING) : 50ºC		kPa	43	22	32
	MAX. WORKING PRESSURE		kPa	1608		
	SURFACE AIR VELOCITY		m/s	1.37	1.22	1.35
	SOUND PRESSURE LEVEL (H/M/L)		dBA	51 / 50 / 48	54 / 53 / 52	54 / 53 / 52
	UNIT DIMENSION	H X W X D	mm	249 x 1214 x 670	249 x 1714 x 670	
	PACKING DIMENSION	H X W X D	mm	354 x 1376 x 766	354 x 1876 x 766	
	UNIT WEIGHT		kg	45	70	70
	CONDENSATE DRAIN SIZE		mm	19.05		
	PIPE CONNECTION		mm	19.05 BSP FEMALE THREAD ADAPTOR		

MODE	COOLING	HEATING
ENTERING AIR TEMPRATURE	27°c DB / 19°c WB	20°c DB
ENTERING WATER TEMPRATURE	7°c	50°c (2 PIPES SYSTEM)
		70°c (4 PIPES SYSTEM)
LEAVING WATER TEMPRATURE	12°c	
		60°c (4 PIPES SYSTEM)

ALL SPECIFICATIONS ARE SUBJECTED TO CHANGE BY THE MANUFACTURER WITHOUT PRIOR NOTICE

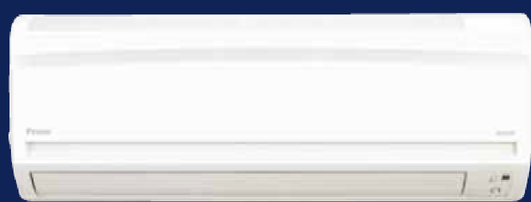
PCRSG0708C

DAIKIN

Split Type Air Conditioners

DC Inverter Power Control

Cooling Only [50 Hz] R-410A



FTKS25/35D

RKS25/35G

INVERTER

FTKS25DVM / RKS25GVMG
2.5 (1.2-3.2) kW
8,500 (4,050-10,900) Btu/h

FTKS35DVM / RKS35GVMG
3.5 (1.4-4.0) kW
11,900 (4,750-13,650) Btu/h

Specifications

FTKS25/35D

Model name	Indoor unit		FTKS25DVM	FTKS35DVM
	Outdoor unit		RKS25GVMG	RKS35GVMG
Capacity	Rated (Min.-Max.)	kW	2.5 (1.2-3.2)	3.5 (1.4-4.0)
		Btu/h	8,500 (4,050-10,900)	11,900 (4,750-13,650)
Power supply			1 phase, 230 V, 50 Hz	
Running current	Rated	A	3.9	4.8
Power consumption	Rated (Min.-Max.)	W	700 (295-1,050)	1,035 (300-1,400)
COP	Rated	W/W	3.57	3.38
Indoor unit			**FTKS25DVM**	**FTKS35DVM**
Front panel colour			White	
Airflow rate (H)		m³/min (cfm)	8.7 (307)	8.9 (314)
Fan speed			5 steps, quiet and automatic	
Sound levels (H/L/SL)		dB (A)	37/25/22	39/26/23
Dimensions (H x W x D)		mm	283 x 800 x 195	
Machine weight		kg	9	
Outdoor unit			**RKS25GVMG**	**RKS35GVMG**
Casing colour			Ivory white	
Compressor	Type		Hermetically sealed swing type	
	Motor output	W	600	
Refrigerant charge (R-410A)		kg	0.8	1.0
Sound levels (H/L)		dB (A)	46/43	47/44
Dimensions (H x W x D)		mm	550 x 765 x 285	
Machine weight		kg	32	34
Operation range		°CDB	10 to 46	
Piping connections	Liquid	mm	ø6.4	
	Gas		ø 9.5	
	Drain		ø18.0	
Max. piping length		m	25	
Max. height difference			15	

FTKS50/60G and 71H

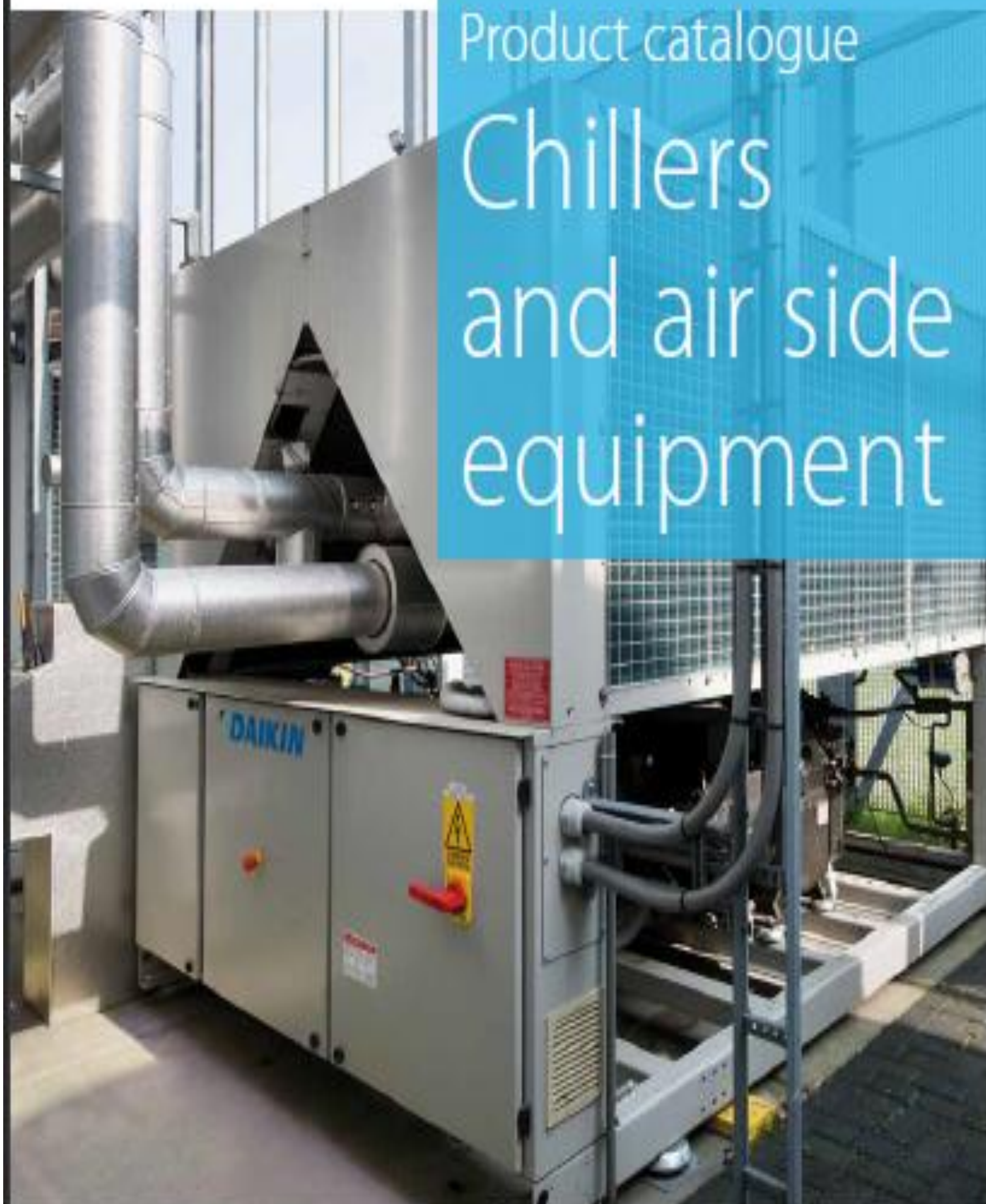
Model name	Indoor unit		FTKS50GVMG	FTKS60GVMG	FTKS71HVMG
	Outdoor unit		RKS50GVMG	RKS60GVMG	RKS71HVMG
Capacity	Rated (Min.-Max.)	kW	5.0 (1.7-6.0)	6.0 (2.3-6.7)	7.1 (2.3-8.5)
		Btu/h	17,100 (5,800-20,500)	20,500 (7,800-22,900)	24,200 (7,800-29,000)
Power supply			1 phase, 230 V, 50 Hz		
Running current	Rated	A	6.2	7.8	9.2
Power consumption	Rated (Min.-Max.)	W	1,400 (440-2,080)	1,780 (570-3,580)	2,100 (570-3,100)
COP	Rated	W/W	3.57	3.37	3.38
Indoor unit			**FTKS50GVMG**	**FTKS60GVMG**	**FTKS71HVMG**
Front panel colour			White		
Airflow rate (H)		m³/min (cfm)	14.7 (519)	17.4 (614)	21.5 (760)
Fan speed			5 steps, quiet and automatic		
Sound levels (H/L/SL)		dB (A)	43/34/31	46/37/34	
Dimensions (H x W x D)		mm	290 x 1,050 x 238		340 x 1,200 x 240
Machine weight		kg	12		17
Outdoor unit			**RKS50GVMG**	**RKS60GVMG**	**RKS71HVMG**
Casing colour			Ivory white		
Compressor	Type		Hermetically sealed swing type		
	Motor output	W	1,100	1,920	
Refrigerant charge (R-410A)		kg	1.5	1.7	2.3
Sound levels (H/L)		dB (A)	47/44	54/49	52/49
Dimensions (H x W x D)		mm	735 x 825 x 300		770 x 900 x 320
Machine weight		kg	47	55	71
Operation range		°CDB	10 to 46		
Piping connections	Liquid	mm	ø6.4		ø9.5
	Gas		ø12.7	ø15.9	
	Drain		ø18.0		
Max. piping length		m	30		
Max. height difference			20		

Measurement conditions
1. Cooling capacity is based on: indoor temp. 27 °CDB, 19 °CWB; outdoor temp. 35 °CDB; piping length 7.5 m.
2. Sound levels are based on the temperature conditions 1. above. These are anechoic conversion values. These values are normally somewhat higher during actual operation as a result of ambient conditions.

DAIKIN

Product catalogue

Chillers and air side equipment



High performance and reliability for comfort and process applications

EWAD-C-XS/XL

Air cooled screw chiller, high efficiency, standard/low sound

- Stepless single-screw compressor
- Large operation range (ambient temperature down to -18°C and up to 50°C)
- 2-3 truly independent refrigerant circuits
- DX shell and tube evaporator – one pass refrigerant side to minimize pressure drops
- Partial and total heat recovery option available
- Standard electronic expansion valve
- MicroTech III controller with superior control logic and easy interface

Cooling only				EWAD-C-XS/XL	760	830	890	990	C10	C11	C12	C13	H14	H15	C16	C17	C18	C19	C20	C21	C22
Cooling capacity	Nom.			kW	752	827	885	997	1,069	1,192	1,276	1,343	1,408	1,517	1,590	1,678	1,760	1,849	1,896	1,947	2,002
Power input	Cooling	Nom.		kW	237	256	282	311	343	367	404	416	450	483	510	541	569	598	619	648	678
Capacity control	Method				Stepless																
	Minimum capacity			%	12.5										7.0						
EER					3.17	3.22	3.14	3.20	3.12	3.25	3.15	3.23	3.13	3.14	3.12	3.10	3.09		3.06	3.00	2.95
ESEER					3.77	3.92	3.81	3.91	3.84	3.99	3.86	4.05	4.04	4.06	4.00	3.96	3.94	3.93	4.02	3.91	3.89
IPLV					4.48		4.52	4.50	4.44	4.50	4.47	4.60	4.71	4.81	4.58	4.59	4.51	4.53	4.57	4.42	4.47
Dimensions	Unit	Height		mm	2,540																
		Width		mm	2,285																
		Depth		mm	6,285	7,185		8,085		9,885					12,085	12,985	13,885	14,785			
Weight (XS)	Unit			kg	5,990	6,340	6,360	7,190	7,470	8,220	8,240	8,900			11,570	11,900	12,260	12,600			
	Operation weight			kg	6,240	6,580	6,600	7,600	7,870	8,610	8,630	9,890			12,430	12,760	13,140	13,470			
Weight (XL)	Unit			kg	6,280	6,630	6,650	7,480	7,760	8,510	8,530	9,190			12,010	12,350	12,700	13,040			
	Operation weight			kg	6,520	6,870	6,890	7,880	8,160	8,900	8,920	10,180			12,870	13,200	13,580	13,910			
Water heat exchanger	Type				Single pass shell & tube																
	Water flow rate	Cooling	Nom.	l/s	36.1	39.6	42.4	47.8	51.2	57.1	61.1	64.4	67.5	72.8	76.1	80.4	84.4	88.6	90.7	93.2	95.8
	Water pressure drop	Cooling	Nom.	kPa	81	57	64	61	69	45	51	68	77	84	62	68		74	39	41	43
	Water volume			l	251	243		403		386		979			850		871	850			
Air heat exchanger	Type				High efficiency fin and tube type																
Compressor	Type				Asymmetric single screw compressor																
	Quantity				2										3						
Fan	Type				Direct propeller																
	Quantity				12	14		16		20					24	26	28	30			
	Air flow rate	Nom.		l/s	64,131	74,819		85,508		106,885					128,262	138,950	149,639	160,327			
	Speed			rpm	900																
Sound power level (XS)	Cooling	Nom.		dBA	100	101			102		103					104					
Sound power level (XL)	Cooling	Nom.		dBA	97			98		99					100						
Sound pressure level (XS)	Cooling	Nom.		dBA	80				81	80					81						
Sound pressure level (XL)	Cooling	Nom.		dBA	76	77											78				
Operation range	Air side	Cooling	Min.~Max.	°CDB	-18~50																
	Water side	Cooling	Min.~Max.	°CDB	-8~15																
Refrigerant	Type / GWP				R-134a / 1,430																
	Circuits	Quantity			2										3						
Refrigerant charge	Per circuit			kg/TCO$_2$Eq	750/1073	810/1158		910/1301	1000/1430	1150/1645	1175/1680	1250/1788	1455/2081	1250/1788	801/1146	827/1182	1183/1478	1090/1559	1133/1621	1200/1716	
Piping connections	Evaporator water inlet/outlet (OD)				168.3mm			219.1mm				273mm									
Unit	Starting current	Max		A	618	657		923	970	1,029			1,072	1,085	1,268	1,328	1,387		1,430	1,472	1,486
	Running current	Cooling	Nom.	A	387	423	463	511	559	607	667	686	731	778	835	885	934.0	984	1,018	1,059	1,100
		Max		A	510	561	605	672	731	811	875		929	982	1,096	1,168	1,241	1,313	1,366	1,419	1,473
Power supply	Phase/Frequency/Voltage			Hz/V	3~/50/400																

CP

Centrifugal pumps

- Clean water
- Civil use
- Agricultural use
- Industrial use

PERFORMANCE RANGE

- Flow rate up to **900 l/min** (54 m^3/h)
- Head up to **106 m**

APPLICATION LIMITS

- Manometric suction lift up to **7 m**
- Liquid temperature between **-10 °C** and **+90 °C**
- Ambient temperature between **-10 °C** and **+40 °C**
- Max. working pressure **11 bar**
- Continuous service **S1**

CONSTRUCTION AND SAFETY STANDARDS

EN 60335-1	**EN 60034-1**
IEC 60335-1	**IEC 60034-1**
CEI 61-150	**CEI 2-3**

CE

CERTIFICATIONS

Company with management system certified DNV
ISO 9001: QUALITY
ISO 14001: ENVIRONMENT

INSTALLATION AND USE

Suitable for use with clean water and with liquids that are not chemically aggressive towards the materials from which the pump is made. As a result of their reliability and the fact that they are easy to use, these pumps are widely used in civil, agricultural and industrial applications such as for supplying water, in air conditioning and cooling systems, for irrigation, etc.
The pump should be installed in an enclosed environment or sheltered from inclement weather.

PATENTS - TRADE MARKS - MODELS

- Registered EU Design n. 002098434 for CP 160, CP 210, CP 750-N
- Registered Italian model n. 72753 for CP 680, CP 700

OPTIONS AVAILABLE ON REQUEST

- Special mechanical seal
- EN 10088-3 - 1.4401 (AISI 316) stainless steel pump shaft for CP 680, CP 700, 750
- Other voltages
- IP X5 class protection for CP 160

GUARANTEE

2 years subject to terms and conditions

CP 680-700-750

POS.	COMPONENT	CONSTRUCTION CHARACTERISTICS
1	**PUMP BODY**	Cast iron complete with NPT ANSI B 1.20.1 threaded ports
2	**BODY BACKPLATE**	Cast iron
3	**IMPELLER**	Brass for CP 680, CP 700 Cast iron for CP 750-N
4	**MOTOR SHAFT**	Stainless steel EN 10088-3 - 1.4104
5	**MECHANICAL SEAL**	see table below
6	**BEARINGS**	see table below
7	**CAPACITOR**	see table below
8	**ELECTRIC MOTOR**	**CPm**: single-phase 220 V - 60 Hz. **CP**: three-phase 220/380 V - 60 Hz or 220/440 V - 60 Hz. **➠ The three-phase pumps are fitted with high performance motors in class IE3 (IEC 60034-30-1)** – Insulation: class F – Protection: IP X5

5 MECHANICAL SEAL

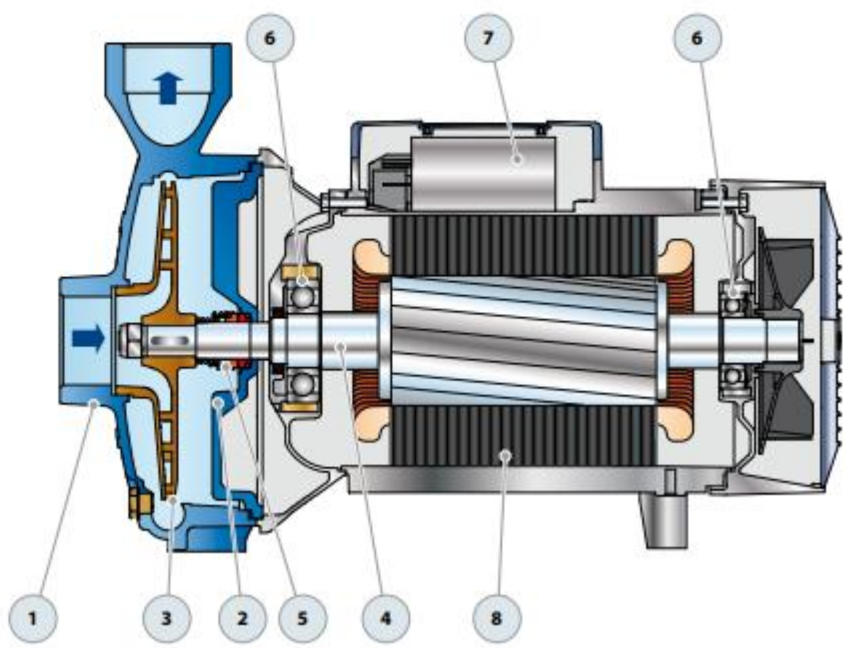
Pump Model	***Seal*** Model	***Shaft*** Diameter	*Materials* Stationary ring	*Materials* Rotational ring	*Materials* Elastomer
CP 680 **CP 700**	**FN-24**	**Ø 24** mm	Graphite	Ceramic	NBR
CP 750-N	**FN-32 NU**	**Ø 32** mm	Graphite	Ceramic	NBR

6 BEARINGS

Pump	***Model***
CP 680 **CP 700**	**6307 ZZ - C3 / 6206 ZZ - C3**
CP 750-N	**6310 ZZ - C3 / 6308 ZZ - C3**

7 CAPACITOR

Pump *Single-phase*	***Capacitance*** *(220 V)*
CPm 680C	**90** μF - 450 VL



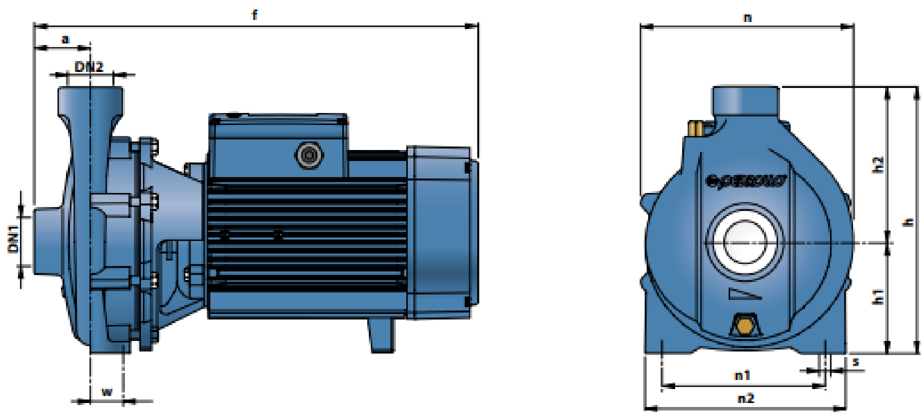
MODEL Three-phase	POWER (P2) kW	HP	▲	Q m³/h l/min	0 **0**	6 **100**	12 **200**	18 **300**	24 **400**	30 **500**	36 **600**	42 **700**	48 **800**	51 **850**	54 **900**
CP 750C-N	11	15			77.3	77.3	77.2	75.5	72.5	69.3	65.5	61.2	55.1		
CP 750B-N	15	20	IE3	**H** metres	92	92	92	90.8	88.5	85.2	81.2	77	72.3	69.5	
CP 750A-N	18.5	25			106.6	106.6	106	105	102.5	99.5	95.5	91	85.5	83	79.6

Q = Flow rate **H** = Total manometric head **HS** = Suction height

Tolerance of characteristic curves in compliance with EN ISO 9906 Grade 3B.

▲ Performance class of the three-phase motor (IEC-60034-30)

DIMENSIONS AND WEIGHT



MODEL		PORTS		DIMENSIONS mm										kg	
Single-phase	Three-phase	DN1	DN2	a	f	h	h1	h2	n	n1	n2	w	s	1~	3~
CPm 680C	**CP 680C**	**2"**	**2"**	70	505/460	328	136	192	273	190	250	40	14	**47.0**	**42.0**
–	**CP 680B**				505									–	**47.0**
–	**CP 680A**													–	**51.0**
–	**CP 700C**													–	**47.0**
–	**CP 700B**													–	**51.0**
–	**CP 700A**													–	**51.5**
–	**CP 750C-N**			65	571	392	160	232	322	230	294	45	14	–	**103.0**
–	**CP 750B-N**				666									–	**120.0**
–	**CP 750A-N**													–	**135.6**

ABSORPTION

MODEL	VOLTAGE
Single-phase	220 V
CPm 680C	**28.0** A

MODEL	VOLTAGE			
Three-phase	220 V	380 V	220 V	440 V
CP 680C	**20.5** A	**12.0** A	**18.3** A	**10.6** A
CP 680B	**25.1** A	**14.5** A	**21.8** A	**12.6** A
CP 680A	**34.6** A	**20.0** A	**32.0** A	**18.5** A
CP 700C	**27.7** A	**16.0** A	**23.5** A	**13.6** A
CP 700B	**33.8** A	**19.5** A	**28.2** A	**16.7** A
CP 700A	**34.7** A	**20.0** A	**29.8** A	**17.5** A
CP 750C-N	**41.2** A	**23.8** A	**41.2** A	**23.8** A
CP 750B-N	**52.8** A	**30.5** A	**52.0** A	**27.0** A
CP 750A-N	**62.6** A	**36.2** A	**65.0** A	**34.0** A

EXHAUST FAN

EDM Series – EDM-300S

Description

The EDM Series can be wall or ceiling mounted and is suitable for exhausting stale and moist air from homes, town houses and commercial buildings. Available in models to suit 100, 125 and 150mm duct sizes. The EDM-100 is also available in a 12V model suitable for caravans and mobiles homes.

Features

- Includes a high quality mechanical backdraft shutter that prevents outside air entering building when fan is switched off (except EDM-100S, EDM-200S and EDM-300S models)
- The EDM-100 is also available in a 12V model suitable for caravans and mobiles homes
- ‘CT-4PL’ Range - Includes 8 minute run-on timer, shutters, and 4 pin plug and lead. Model EDM-200 only.
- ‘12V’ Unit - Suitable for wet areas (IPX7): requires a low-voltage transformer. Model EDM-100S-12V only.
- All models can be used to exhaust along a short length of duct. It is essential allowances be made for pressure losses in the duct to ensure air flows will meet the requirements of the application.
- 300 model features a slim line body.
- Grille can be easily removed for cleaning.
- All models, except the EDM-100S-12V, feature a pilot lamp.
- Class B motor, IP44 rated.
- Not speed controllable.

Construction

All units have weather and impact resistant housings.

Motors

Type - shaded-pole induction motor.

Electricity supply - single-phase 230V, 50Hz

Bearings - Ball

Maximum ambient temperature - 40°C

Class II insulation, IP44 rated*.

*The EDM-100 12V has Class III insulation, IP57.

Internal Thermal Protection

Model 100 - impedance

Model 200 & 300 – fuse

Testing

Air flow to ISO5801:1997

Noise to BS848:Part 2, 1985

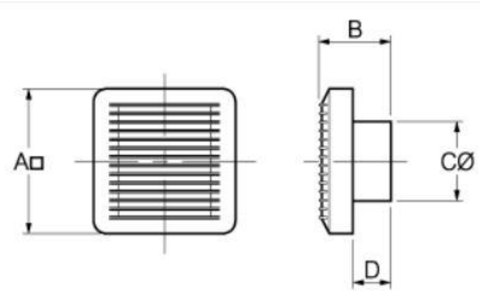
Suggested Specification

The wall/ceiling fans shall be of the EDM Series as supplied by Fantech Pty Ltd and be of the model numbers shown.

Technical Data - EDM-300S

Speed [rps]	Avg. dBA @ 3m	kWatts (Input)	Amps	Max.°C	Approx. Weight [kg]
37	41	0.03	0.21	40	1.44

Dimensions



A	B	C	D
200	129	148	104

*All dimensions in mm, unless otherwise stated

EXHAUST FAN (Parking Area)

FANTECH
Intelligent Ventilation

Compact 2000 Series – CPE0564FHP

Description

The Compact 2000 Series of square plate axial fans is a high quality, robust product with 10 sizes ranging from 250 to 800mm diameter. They are suitable for a wide range of commercial and industrial applications and can be speed controlled to better manage energy consumption.

Features

- Robust high quality construction.
- Inlet guard is incorporated as standard for models 025 to 063 and is an optional extra for models 071 and 080.
- The 040 to 063 size range in 3 phase are fitted with 2-speed star/delta motors as standard.
- Capable of operating across a wide temperature range; -20oC to 70oC.
- A flying lead with junction box and 20mm dia flexible conduit is fitted as standard to models 025 to 063.
- Can be mounted in any position.
- An extensive range of matched ancillary equipment is available

Construction

The square plate is manufactured from galvanised steel with an additional high quality polyester epoxy finish as standard. Impellers have GRP blades as standard; aluminium and nylon blades are an optional extra. Non-sparking blades can be fitted to models 071 and 080.

Motors

Type - squirrel cage induction motor.
Electricity supply - 230V single or 415V three-phase, 50Hz.
Bearings - sealed for life, ball.
Operating temperature range; -20oC to 70oC.
Maximum ambient temperature when being speed controlled is 40oC.

IP55 rating.
All three phase models in the 040 to 063 range are fitted with 2-speed star/delta motors as standard.
Models to 063 can be speed controlled using electronic or auto-transformer controllers.

Internal Thermal Protection

Manual-reset thermal protection is supplied as standard up to model 063 and as an optional extra on models 071 and 080.

Testing

Air flow tests to AS ISO5801:1997
Noise tests to BS848:Part 2, 1985

Special Note

Derate the air flow by at least 25% if the air flow direction is reversed from standard. Add the suffix “R” to fan code.

Suggested Specification

The Compact 2000 Series of square plate mounted axial fans shall be as supplied by Fantech Pty Ltd. The axial impellers shall have GRP blades Square plates shall be made from galvanised steel with a polyester epoxy finish. All models shall be fully tested to AS ISO5801:1997 for air flow and to BS848:Part 2, 1985 for noise

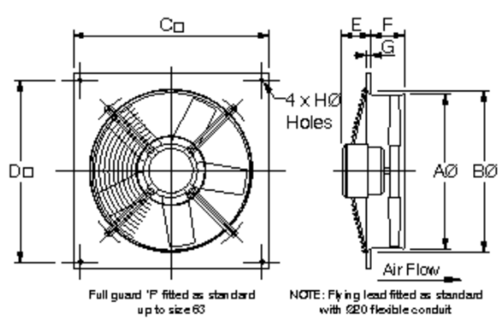
Technical Data - CPE0564FHP

Speed [rps]	Avg. dBA @ 3m	kWatts (Input)	Amps	Max.°C	Approx. Weight [kg]
22	63	0.75	4.9	70	27

Sound Data

Type	63	125	250	500	1K	2K	4K	8K
Inlet	76	74	77	78	80	77	75	66

Dimensions



A	B	C	D	E	F	G	H
575	600	725	670	145	100	15	11

*All dimensions in mm, unless otherwise stated

JET FAN

FANTECH
Intelligent Ventilation

JV Series – JVU-CPA-400-2-3

Description

The JV Series of JetVent axial fans have been designed to provide effective ventilation in most spaces that contain harmful vehicle exhaust pollutants. They can be supplied for uni-directional or truly reversible air flow and are available in 2 sizes, 315mm and 400mm diameter. Units approved to AS4429:1999 for smoke exhaust are also available.

Features

- Available with single (high) or 2 speed (high/low) motor.
- Integral aerodynamically designed silencers provide quiet operation.
- Bell mouth inlet and outlet optimises performance.
- Units can be speed controlled using Variable Speed Drives.
- Can be supplied for uni-directional or truly reversible air flow.
- Fitted with a high performance aerofoil impeller.
- Durable galvanised steel housing with light grey powder coated finish as standard.
- Integral mounting feet allows unit to be easily mounted to ceiling.
- Electrical isolator fitted on ambient temperature units.

Construction

Galvanised steel housing with integral aerodynamically designed silencers. Light grey powder coated finish is standard. Axial flow aerofoil impellers manufactured from aluminium.

Motors

Type - squirrel cage induction motor.
Electricity supply - 415V, three-phase, 50Hz.
Bearings - sealed-for-life, ball.
Single or 2-speed as nominated.
Speed controllable using frequency inverters.
Standard motors are suitable for ambient conditions up to 40°C.
Units for high temperature conditions, such as smoke-control, are available.

Internal Thermal Protection

Thermisters can be provided on all motors except where Standards prohibit their use.

Testing

Thermistors performance based on tests to BS848 Part 10,1999:
"Fans for general purpose - Performance testing of jet fans".
Noise data based on tests to BS848:Part 2, 1985. High temperature tests to AS4429:1999.

Special Note

Jet fans should be treated as an Alternative Solution within the National Construction Code (NCC)(formerly the BCA) from a fire and smoke control perspective (in addition to the ventilation requirements). Therefore the fire engineer on the project would need to add the car park ventilation design into their fire engineering report for the project and ensure that they meet the relevant BCA performance clauses. For more information please refer to the JetVent “Practical Guide for Selection and Application”

Smoke-Spill Applications

Smoke-spill models have been fully tested to meet the air performance and high temperature requirements of Standards AS/NZS1668.1:1998 and AS4429:1999.

In the case of a fire occurring, smoke-spill models will stop operating for a predetermined time to allow occupants to escape the building. After this time the fan will commence operation again.

Control Systems

There are two types of analogue control systems used with the JetVent JV Series:

- Two speed system using relays to drive contactors connected to the fans
- Variable speed system using 0 to 10 Vdc outputs to proportionally drive VSDs

Suggested Specification

The high velocity axial jet fans shall be of the JetVent JV Series as designed and manufactured by Fantech Pty Ltd. and be of the model number shown. The housing shall be of galvanised steel with a light grey powder coated finish as standard. They shall incorporate aluminium axial impellers of aerofoil design and aerodynamically engineered silencers. They shall be single or 2-speed as nominated.
Performance data shall be based on tests to BS848:Part 10,1999 for thrust and BS848:Part 2, 1985 for noise. Units for smoke-spill applications shall be tested to AS4429:1999.

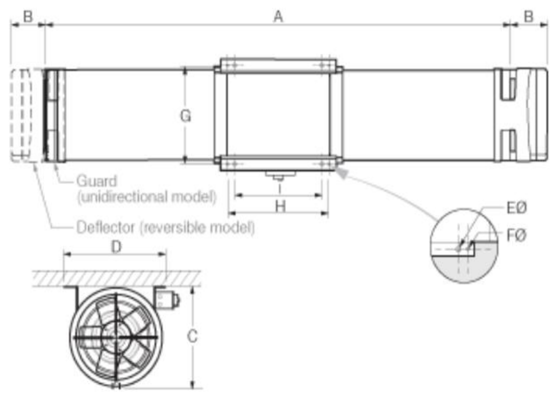
Technical Data - JVU-CPA-400-2-3

Speed [rps]	Avg. dBA @ 3m	kWatts (Input)	Amps	Max.°C	Approx. Weight [kg]
48	62	1.5	2.9	40	71

Sound Data

Type	63	125	250	500	1K	2K	4K	8K
Inlet	86	81	88	79	70	69	70	68

Dimensions



A	B	C	D	E	F	G	H
2660	145	423	471	25	13	420	360

*All dimensions in mm, unless otherwise stated

Wiring Diagram

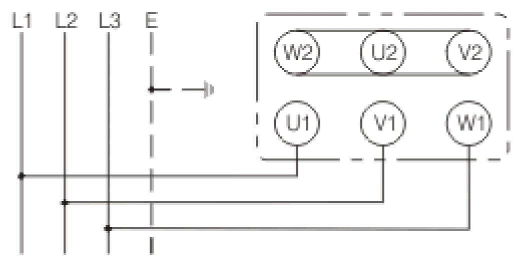


Diagram shown is for single-speed only.

Sample Manual Calculation

This section provides the specific details of how the calculations were done. For sample purposes, the data and calculations for ground floor are presented.

HEAT LOAD CALCULATION for GROUND FLOOR

Details:

Location:	14.28° N Latitude
	121.01° E Longitude
Outdoor Design:	Dry-Bulb Temperature = 34°C
	Wet-Bulb Temperature = 26°C
Daily Range:	6.5°C
Design Month:	May
Indoor Design:	Dry-Bulb Temperature = 25°C
	50 % Relative Humidity
Service Schedule:	7:00 AM - 7:00 PM
Wall Construction:	Type F
	Permanent MediumColor (Rural Area)
Temperatures:	$t_{av}= t_o – ½$ (Daily Range) = 34 – ½ (6.5)
	$\mathbf{t_{av}= 30.75°C}$
	$\Delta T = (t_o - t_i) = (34 – 25)$
	$\mathbf{\Delta T = 9°C}$

A. EXTERNAL HEAT LOADS

Assume all walls and roofs are mediumcolored. Use positive ventilation for roof construction.

1. External Wall

INFORMATION: 25 mm cement plaster, 150 mm CHB ,25 mm cement plaster

$$\boxed{\mathbf{Q_w = UA\ CLTD_{adj}}}$$

- *Area, A (m^2)*

W:	0	**0 m²**
SW:	0	**0 m²**
SE:	0	**0 m²**
N:	2.9(27.3333)	**79.266667 m²**

- *Cooling Load Temperature Difference, $CLTD_{adj}$ (^oC)*

$$\mathbf{CLTD_{adj} = (CLTD_{sel} + LM)k + (25 - t_i) + (t_{av} - 29)}$$

where: $\mathbf{t_{av} = t_o - \frac{1}{2}(daily\ range)} =$ **30.75°C**

N :	(13+2.22)(0.75) + (25-25) + (30.75-29)	**13.165 °C**

- *Heat Transfer Coefficient, U_w ($W/m^2\,K$)*

$$\mathbf{U} = \frac{1}{R_T} = \frac{1}{0.353394} = \mathbf{2.8297\frac{w}{m^2K}}$$

- *Thermal Heat Load, Q_w (W)*

N:	(79.266667)(2.8297)(13.165)	**2952.921173 W**

Q_w = 2952.921173 W

2. Glass Load

$$\boxed{\mathbf{Q_G = Q_{SG} + Q_{TH}}}$$

For Single Glaze 12 mm thick: $\boldsymbol{U = 2.85\frac{w}{m^2K}}$

- *Area, (m^2)*

W:	7.2(2.9)	**20.88 m^2**
SW:	45.35(2.9)	**131.515 m^2**
SE :	14.4(2.9)	**41.76 m^2**

- *Solar Heat Gain, Q_{SG} (W)*

$$\boxed{\mathbf{Q_{SG} = (SHGF)(SC)(A)(CLF)}}$$

W:	(678)(0.95)(20.88)(0.82)	**11208.02256 W**
SW:	(363)(0.95)(131.515)(0.83)	**37642.94663 W**
SE:	(2.85)(0.95)(41.76)(0.81)	**11664.75816 W**
	Q_{SG}=	**60515.72735 W**

- *Thermal Heat Gain, Q_{TH} (W)*

$$\boxed{\mathbf{Q_{TH} = U_g\,A_g\,\Delta T\ ;\ U = 3.2\ W/m^2\,K}}$$

W:	(2.85)(20.88)(9)	**535.572 W**
SW:	(2.85)(131.515)(9)	**3373.35975 W**
SE:	(2.85)(41.76)(9)	**1071.144 W**
	Q_{TH}=	**4980.07575 W**

3. INFILTRATION LOAD

$$\boxed{\mathbf{Q_S = 1.232Q(t_o - t_i)}}$$

$$\boxed{\mathbf{Q_L = 3000Q(\omega_o - \omega_i)}}$$

- *Volume Flow Rate of Outside Air, Q (L/s)*

Q = (number of air changes) (volume of conditioned space)

number of air changes = a + bV + c(t_o – t_i)

volume of conditioned space = (floor area)(building height)

**assuming tight construction and wind velocity, V = 1 m/s*

number of air changes = 0.15+(0.01)(1)+0.007(34-25)

number of air changes = 0.223 changes/hour

volume of conditioned space = (2.9)(737.3827149)

volume of conditioned space = 2138.409873 m^3

$$Q = \left(0.223\ {}^{\text{changes}}/_{\text{hr}}\right)(2138.409873\text{m}^3)\left(\frac{1000\ \text{L}}{1\ \text{m}^3}\right)\left(\frac{1\ \text{hr}}{3600\ \text{s}}\right)$$

Q = 132.4626116 L/s

- *Humidity Ratio (kg/kg)*

Using psychrometric chart:

ω_O@ 34°C DB & 26°C WB

ω_O= 0.018 kg/kg

ω_i@ 25°C DB & 50% RH

ω_i= 0.010 kg/kg

- *Sensible Heat Load, Q_s (W)*

$$\mathbf{Q_S = 1.232(132.4626116)(34 - 25)}$$

Qs = 1468.745437 W

- *Latent Heat Load, Q_L (W)*

$$Q_L = 3000(132.4626116)(0.018 - 0.01)$$

Q_L= 3179.102678W

4. VENTILATION LOAD

$$\boxed{Q_S = 1.232Q(t_o - t_i)}$$

$$\boxed{Q_L = 3000Q(\omega_o - \omega_i)}$$

- *Volume Flow Rate of Outside Air, Q (L/s)*

Pizza Shop

Occupants: 58 persons

for Q: (3.54 L/sec-person)(58 person) = **205.32 L/s**

Food Stall

Occupants: 76 persons

for Q: (3.54 L/sec-person)(76 person) = **269.04 L/s**

Retail Shop

Occupants: 20 persons

for Q: (3.54 L/sec-person)(20 person) = **70.8 L/s**

Coffee Shop

Occupants: 66 persons

for Q: (3.54 L/sec-person)(66 person) = **233.64L/s**

Elevator Lobby

Occupants: 9 persons

for Q: 1. (3.54 L/sec-person)(9 person) = **31.86 L/s**

Hallway

Occupants: 29 persons

for Q: (3.54 L/sec-person)(65 person) = **230.1 L/s**

Parameters Needed for Ventilation Load Calculation of Ground Floor

Space	Area (m^2)	Occupants (person)	Q (L/s)
Pizza Shop	121.20	58	205.32
Food Stall	141.15	76	269.04
Retail Shop	71.11	20	70.8
Coffee Shop	133.63	66	233.64
Elevator Lobby	31.56	9	31.86
Hallway	238.75	65	230.1
		Total	**1040.76**

- *Sensible Heat Load, Q_S (W)*

  Qs = 1.232(1040.76)(34-25)

  Qs = 11539.94688 W

- *Latent Heat Load, Q_L (W)*

  Q_L = 3000(1040.76)(0.018-0.01)

  Q_L = 24978.24 W

B. INTERNAL LOADS

1. Lighting Load

Space	Space Type	LPD (W/m^2)	Area(m^2)	Lamp Power (W)
Pizza Shop	In Cafeteria or Fast Food Dining	7	121.1790123	848.2530861
Food Stall	In Cafeteria or Fast Food Dining	7	141.154321	988.080247
Retail Shop	Sales Area	15.5	71.11111	1102.222205
Coffee Shop	In Cafeteria or Fast Food Dining	7	133.6296296	935.4074072
Elevator Lobby	For Elevator	7	31.5555556	220.8888892
Hallway	All Other Corridors	7.1	238.7530864	1695.146913
		Total	**1148.4692**	**13781.63006**

$$\boxed{\mathbf{Q_S = (lamp\ power)(F_u)(F_b)(CLF)}}$$

where: lamp power = 13781.63006W/m^2

F_u = 1

F_b = 1.2

CLF = 0.91

Q_S = (13781.63006)(1)(1.2)(0.91)

Q_S = 6322.678633 W

2. Occupant Load

$$\boxed{\mathbf{Q_S} = (\mathbf{gain\ per\ person})(\mathbf{sensible\ heat\ gain})(\mathbf{no.\ of\ people})(\mathbf{CLF})}$$

$$\boxed{\mathbf{Q_L} = (\mathbf{gain\ per\ person})(\mathbf{latent\ heat\ gain})(\mathbf{no.\ of\ people})(\mathbf{CLF})}$$

Parameters Needed for Occupant Load Calculation of Ground Floor

Space	**Gain/ Person**	**SHG**	**No. of People**	**CLF** (SHG)	**LHG**	**CLF** (LHG)
Pizza Shop	170	0.441176	58	0.92	0.55882	1
Food Stall	170	0.441176	76	0.92	0.55882	1
Retail Shop	185	0.5	20	0.92	0.5	1
Coffee Shop	170	0.441176	66	0.92	0.55882	1
Elevator Lobby	150	0.5	9	0.92	0.5	1
Hallway	305	0.35	65	0.92	0.65	1

Space	**Degree of Activity**	**Symbol**
Pizza Shop	Seated, eating	Q_1
Food Stall	Seated, eating	Q_2
Retail Shop	Retail Shop	Q_3
Coffee Shop	Seated, eating	Q_4
Elevator Lobby	Standing	Q_5
Hallway	Walking, 3km/h	Q_6

- *Sensible Heat Load, Q_s (W)*

Q_1 = (170)(0.441176)(58)(0.92)

Q_1 = 4002 W

Q_2 = (170)(0.441176)(76)(0.92)

Q_2 = 5244 W

Q_3 = (185)(0.50)(20)(0.92)

Q_3 = 1702 W

Q_4 = (170)(0.441176)(66)(0.92)

Q_4 = 4554 W

Q_5 = (150)(0.50)(9)(0.92)

Q_5 = 621 W

Q_6 = (305)(0.35)(65)(0.92)

Q_6 = 6383.65 W

$Q_S = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$

Q_S = 22506.65 W

- *Latent Heat Load, Q_L (W)*

Q_1 = (170)(0.55882)(56)(1)

Q_1 = 5510 W

Q_2 = (170)(0.55882)(76)(1)

Q_2 = 7220 W

Q_3 = (185)(0.50)(20)(1)

Q_3 = 1850 W

Q_4 = (170)(0.55882)(66)(1)

Q_4 = 6270 W

Q_5 = (150)(0.50)(9)(1)

Q_5 = 675 W

Q_6 = (305)(0.65)(65)(1)

Q_6 = 12886.25 W

$Q_L = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$

Q_L = 34411.25 W

3. **Partition Load**

INFORMATION:

Concrete:25 mm cement plaster, 150 mm CHB, 25 mm cement plaster

Elevator Door:8mm stainless steel, air space, 8 mm stainless steel

Wood Door: 6mm plywood, air space, 6 mm plywood

Glass: Single Glaze

$$\boxed{\mathbf{Q_S = U\ A\ \Delta T}}$$

Parameters Needed for Partition Load Calculation of Ground Floor

Partition	U (W/m^2K)	Area (m^2)	ΔT (K)	Q (W)
Concrete Wall	2.2502	186.3222	6	2515.5735
Elevator Door	2.43309	13.2	6	192.700728
Wood Door	1.945828144	15.4	6	179.7945205
			Total Q	**2888.068792 W**

4. Miscellaneous Loads

$$\boxed{\mathbf{Q_S} = (\mathbf{rating})(\mathbf{no.\,of\ equipments})(\frac{\mathbf{utilization}}{\mathbf{24hrs}})((\mathbf{F}_u)(\mathbf{CLF})}$$

where: $F_u = 1$

$CLF = 1$

- *Total Heat Load, Q(W)*

$$Q_{\text{oven}} = (1200)(3)\left(\frac{12}{24}\right)(1)(1) = 1800\ \text{W}$$

$$Q_{\text{Cash Register}} = (46.5)(7)\left(\frac{12}{24}\right)(1)(1) = 162.75\ \text{W}$$

$$Q_{\text{Blender}} = (400)(5)\left(\frac{8}{24}\right)(1)(1) = 666.6667\ \text{W}$$

$$Q_{\text{Freezer}} = (540)(3)\left(\frac{24}{24}\right)(1)(1) = 1620\ \text{W}$$

$$Q_{\text{Coffee maker}} = (800)(3)\left(\frac{8}{24}\right)(1)(1) = 800\ \text{W}$$

$$Q_{\text{Drinks Chiller}} = (200)(3)\left(\frac{24}{24}\right)(1)(1) = 600\ \text{W}$$

$$Q_{\text{Steamer}} = (800)(2)\left(\frac{12}{24}\right)(1)(1) = 800\ \text{W}$$

$$Q_{\text{Microwave}} = (800)(3)\left(\frac{2}{24}\right)(1)(1) = 66.6667\ \text{W}$$

$$Q_{\text{Stove}} = (1100)(2)\left(\frac{8}{24}\right)(1)(1) = 733.3333\ \text{W}$$

Q_{Total} = 7249.4167 W

Summary of Heat Load Calculation for Ground Floor

HEAT SOURCES		Q_S (W)	Q_L (W)
External Loads	External Wall	**2952.921173**	**0**
	Glass Load	**65495.8031**	**0**
Infiltration Load		**1468.745437**	**3179.102678**
Ventilation Load		**11539.94688**	**24978.24**
Internal Loads	Lighting Load	**6322.678633**	**0**
	Occupant Load	**22506.65**	**34411.25**
	Partition Load	**2888.068792**	**0**
	Miscellaneous Load	**7249.4167**	**0**
TOTAL		**120424.2307**	**62568.59268**
OVERALL TOTAL		**182992.8234 W**	

PIPING MANUAL CALCULATIONS

Volume flow rate for Chiller 1

$$m_{wc} = \frac{953.63}{4.187(15-8)} = 32.53710464\frac{Kg}{sec}$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 32.53710464(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{32.56476118}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for Chiller 2

$$m_{wc} = \frac{1306.33}{4.187(15-8)} = 44.5709509\frac{Kg}{sec}$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 44.5709509(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{44.60883621}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 13.19 kW

$$m_{wc} = \frac{13.19}{4.187(15-8)} = 0.4500324133\frac{Kg}{sec}$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.4500324133(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.4504149408}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 12.6 kW

$$m_{wc} = \frac{12.6}{4.187(15-8)} = 0.499020779\frac{Kg}{sec}2$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.499020779(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.4302674946}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 11.14 kW

$$m_{wc} = \frac{11.14}{4.187(15-8)} = 0.3800880276\frac{Kg}{sec}2$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.3800880276(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.3804111024}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 9.14 kW

$$m_{wc} = \frac{9.14}{4.187(15-8)} = 0.3118496025\frac{Kg}{sec}$$

V at 15°C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.3118496025(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.3121146747}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 7.21 kW

$$m_{wc} = \frac{7.21}{4.187(15-8)} = 0.2459995223 \frac{Kg}{sec}$$

V at 15^{o}C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.2459995223(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.2462086219}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 6.15 kW

$$m_{wc} = \frac{6.15}{4.187(15-8)} = 0.2098331571 \frac{Kg}{sec}$$

V at 15^{o}C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.2098331571(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.2100115152}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 5.95 kW

$$m_{wc} = \frac{5.95}{4.187(15-8)} = 0.2030093145 \frac{Kg}{sec}$$

V at 15^{o}C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.2030093145(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.2031818725}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 4.54 kW

$$m_{wc} = \frac{4.54}{4.187(15-8)} = 0.1549012249 \frac{Kg}{sec}$$

V at 15^{o}C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.1549012249(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.1550328909}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

Volume flow rate for 2.43 kW

$$m_{wc} = \frac{2.43}{4.187(15-8)} = 0.03673213956 \frac{Kg}{sec}$$

V at 15^{o}C = 0.00100085 m^3/kg

$$\boldsymbol{Q} = 0.03673213956(0.00100085)\left(\frac{1000L}{m^3}\right) = \mathbf{0.03676336188}\ \frac{\boldsymbol{L}}{\boldsymbol{s}}$$

PUMP CAPACITY MANUAL CALCULATION

Computation for Pump @ Chiller 1

- **Solving for TDH**
  TDH = Pressure Drop x 2

  = (130226.703)(2)

TDH = 260453.406 Pa (assuming no pressure drop @ chiller of air pressure)

TDH = $\frac{260.453406}{999.90001\ x\ (\frac{9.81}{1000})}$

TDH = 26.55244152 m

- **Solving for Power of Pump**

  $\eta = \frac{Q\Delta P}{BP}$

  BP = $\frac{(260.453406\text{kPA})(0.03256476118)}{0.75}$

  BP =11.3088 kW (Centrifugal Pump)

Computation for Pump @ Chiller 2

- **Solving for TDH**

  TDH = Pressure Drop x 2 (assuming no pressure drop @ chiller of air pressure)

  = (136057.693)(2)

TDH = 272.115386kPa

TDH = $\frac{272.115386}{999.90001\ x\ (\frac{9.81}{1000})}$

TDH = 27.7413 m

- **Solving for Power of Pump**

  $\eta = \frac{Q\Delta P}{BP}$

  BP = $\frac{(272.115386\text{kPA})(0.04460883621)}{0.75}$

  BP =16.1850 kW (Centrifugal)