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JUDUL: DESIGN AN AIR CONDITIONING SYSTEM FOR UMP MOSQUE

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DESIGN AN AIR CONDITIONING SYSTEM FOR UMP MOSQUE

MOHD HILMI BIN TAJUD HASSAN

A report submitted in partial fulfillment of requirements
for the award of degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

MAY 2009

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I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledge. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedicated to my beloved:

Father,

Mother,

Younger sisters,

Younger brother

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ABSTRACT

This project is carried out to design a suitable air conditioning system for UMP Mosque. The architectural drawing of UMP mosque is studied first to choose the best air conditioner to be installed in UMP Mosque. Tropical country such as Malaysia is hot and humid. Taking UMP Mosque as an example, during Friday Prayer there is about 1300 Muslims perform Friday Prayer inside UMP Mosque. This situation makes the Muslims feel not comfortable with this condition. Therefore an air conditioning system should be installed in the UMP Mosque to provide comfort to the occupants. The objective of this project is to calculate the heat gains in UMP Mosque. The purpose of calculating the heat gain is to determine the total cooling load required. Another objective is to design a suitable air conditioning system for UMP Mosque. Designing the ductwork, determination of duct size, selection of suitable space to locate the air handling unit (AHU) is done in the design of the air conditioning system. The highest heat gain in UMP Mosque is at 4.00 pm on the daily basis. The total heat gain at 4.00 pm hour is 171.8 kW. However, the peak heat gain of 781.4 kW occurs during Friday prayer. Thus, the value of total heat gain during Friday Prayer is used to design the air conditioning system for UMP Mosque. The AHUs used are unitary system and each AHU connected with one duct.

ABSTRAK

Projek ini dijalankan adalah untuk merencana sistem penyaman udara yang sesuai untuk Masjid UMP. Lukisan arsitektural Masjid UMP dikaji terlebih dahulu untuk memilih penyaman udara yang terbaik untuk dipasang dalam Masjid UMP. Negara beriklim khatulistiwa seperti Malaysia merupakan negara yang panas dan lembap. Sebagai contoh semasa sembahyang Jumaat dilakukan di Masjid UMP, kira-kira 1300 orang Islam menunaikan sembahyang Jumaat di dalam Masjid UMP.Situasi ini menyebabkan keadaan tidak selesa. Oleh itu, sistem penyaman udara perlu dipasang di dalam Masjid UMP untuk memberi keselesaan kepada orang yang berada di dalam masjid. Objektif projek ini dijalankan adalah untuk mengira jumlah haba gandaan yang terdapat di dalam Masjid UMP. Tujuan pengiraan gandaan haba di Masjid UMP adalah untuk mendapatkan jumlah beban penyejukan yang diperlukan. Objektif yang kedua ialah merencana system penyaman udara yang sesuai untuk Masjid UMP. Merencana sistem saluran, menentukan saiz saluran, memilih ruang yang sesuai untuk menempatkan unit pengelolaan udara (AHU), dijalankan dalam merencana system penyaman udara. Haba gandaan yang paling tinggi dalam Masjid UMP adalah pada jam 4 petang setiap hari. Jumlah haba gandaan pada jam 4 petang ialah 171.8 kW. Walaubagaimanapun, haba gandaan puncak pada ukuran 781.4 kW berlaku semasa sembahyang Jumaat. Oleh itu, jumlah haba gandaan semasa sembahyang Jumaat digunakan untuk merencana system penyaman udara untuk Masjid UMP. AHU yang digunakan adalah system unitari dan setiap AHU menghubungkan satu saluran.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Air conditioning system is system of treating air in an internal environment to establish and maintain required standards of temperature, humidity, cleanliness and motion. Air conditioning system application engineering is as much as an art as it is a science. Science has evaluated all the factors required to determine a heating or cooling load through years of experimentation, tests and analysis. It is in the application of these factors in determining the building or space load that much care and judgement must be exercised. [3]

This project is carried out to design a suitable air conditioning system for UMP Mosque. Actually, there are many types of air conditioning system. Every type has their own concept and operation. To choose the suitable air conditioning for UMP Mosque, there are lots of thing to be study and analyze. In this project, the architectural drawing of UMP Mosque must be studied to choose the best air conditioner to be installed in UMP Mosque. The knowledge about what kind of materials that had been used to build the mosque for every structure is needed. To make this project is carried out smoothly, the understanding in Thermodynamics knowledge is required.

1.2 PROBLEM STATEMENT

Malaysia is a tropical country. Tropical country is a hot and wet country. Nowadays maximum temperature at Malaysia is about 33^{o}C where this situation gives uncomfortable condition to peoples especially in a closed space with a large number of peoples. Taking UMP Mosque as an example, during Friday Prayer there is about 1300 Muslims perform Friday Prayer inside UMP Mosque. This situation makes the indoor UMP Mosque become hot and the Muslims feel not comfortable with this condition. Therefore an air conditioning system should be installed in the UMP Mosque to provide comfort to the occupants.

1.3 OBJECTIVES OF PROJECT

The objectives of this project are:-

i. to calculate the heat gains in the mosque.
ii. to design a suitable air conditioning system for UMP mosque.

1.4 SCOPES OF PROJECT

i. Literature study and understanding about air conditioning system
ii. Determination of the building material in order to determine the overall heat transfer coefficient, U
iii. Choose the type of air conditioning system
iv. Design ductwork and determines the size of duct.
v. Design air handling unit (AHU) and find the suitable place to locate the AHU.

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the literatures that related to air conditioning system. It included the process involve and the function of components in air conditioning system. This chapter also discusses the specification of UMP Mosque

2.2 REFRIGERATION CYCLES

Refrigeration is the transfer of heat from a lower temperature region to a higher temperature region. Devices that produce refrigeration are called refrigerators, and the cycles on which they operate are called refrigeration cycles. Refrigerators are cyclic devices, and the working fluids used in the refrigeration cycles are called refrigerants.

Vapor-compression refrigeration cycle in which the refrigerant is vaporized and condensed alternately and is compressed in the vapor phase. The vapor-compression refrigeration cycle is the most widely used cycle for refrigerators, air conditioning systems, and heat pumps. **Figure 2.1** shows the vapor-compression refrigeration cycle and its T-s diagram. It consists of four processes:

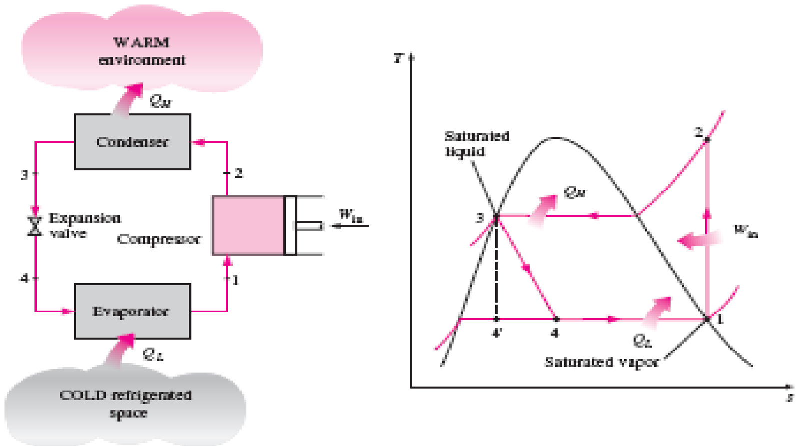


Figure 2.1: Vapor-compression refrigeration cycle T-s diagram

1-2 Isentropic compression in a compressor

2-3 Constant-pressure heat rejection in a condenser

3-4 Throttling in an expansion device

4-1 Constant-pressure heat absorption in an evaporator

In an ideal vapor-compression refrigeration cycle, the refrigerant enters the compressor at state 1 as saturated vapor and is compressed isentropically to the condenser pressure. The temperature of the refrigerant increases during this isentropic compression process to well above the temperature of the surrounding medium. The refrigerant then enters the condenser as superheated vapor at state 2 and leaves as saturated liquid at state 3 as a result of heat rejection to the surroundings.

The temperature of the refrigerant at this state is still above the temperature of the surroundings. The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant drops below the temperature of the refrigerated space during this process. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space.

The refrigerant leaves the evaporator as saturated vapor and reenters the compressor, completing the cycle. The area under the process curve on a *T-s* diagram represents the heat transfer for internally reversible processes. The area under the process curve 4-1 represents the heat absorbed by the refrigerant in the evaporator and the area under the process curve 2-3 represents the heat rejected in the condenser.

The ideal vapor-compression refrigeration cycle is not an internally reversible cycle since it involves an irreversible (throttling) process. This process is maintained in the cycle to make it a more realistic model for the actual vapor-compression refrigeration cycle. If the throttling device were replaced by an isentropic turbine, the refrigerant would enter the evaporator at state 4’ instead of state 4. As a result, the refrigeration capacity would increase (by the area under process curve 4’-4 in above figure) and the net work input would decrease (by the amount of work output of the turbine). [1]

2.2.1. Components in refrigeration system. [2]

i. Evaporator/cooling coil - Absorb heat from refrigerated space through a medium which is called refrigerant. **Figure 2.2** shows the evaporator.

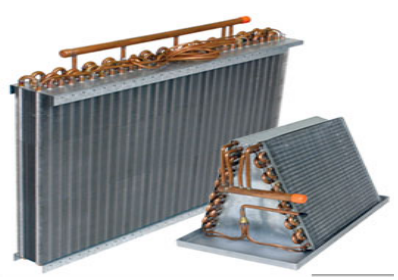


Figure 2.2: Evaporator

ii. Condenser - Remove heat from the refrigerated space to surrounding. Absorbed heat from evaporator are send to the condenser through refrigerant to be removed to the surrounding. Below in **Figure 2.3** shows the condenser.

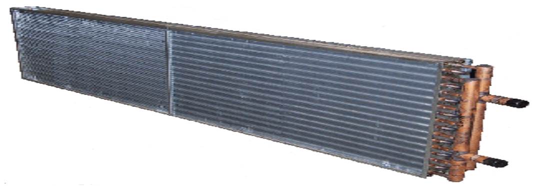


Figure 2.3: Condenser

iii. Compressor - Push the refrigerant in one cycle continuously. **Figure 2.4** shows the compressor.

Figure 2.4: Compressor

iv. Expansion valve - Cause the pressure of refrigerant drops. The refrigerant wills fashing and because of that the temperature decrease. The expansion valve is shown in **Figure 2.5.**

Figure 2.5: Expansion Valve

2.3 HEAT GAINS AND COOLING LOAD

The air inside a building receives heat from a number of sources. The heat that received from the sources is called heat gain. Heat gain is defined as the amount of heat introduced to a space from all heat producing sources, such as building occupants, lights, appliances, and from the environment, mainly solar energy. [14] If the temperatures are to be maintained at a comfortable level, the heat must be removed. The amount of heat that must be removed is called cooling load. Cooling load is defined as the amount of heat that must be removed from a building to maintain a comfortable temperature for its occupants. [15] Cooling load also can be defined as amount of heat gain that should be removed from a building to maintain a comfortable temperature for its occupants. The cooling load must be determined because it is important thing for selection of proper size air conditioning and distribution system. Unit for heat gain and cooling load are kW.

The cooling load is not always equal to the amount of heat received at a given time. This difference is because of the heat storage and time lag effects. Only a portion of heats building air immediately and others part (solar radiation process) heats the building. This is the heat storage effect. **Figure 2.6** shows the time lag effect.

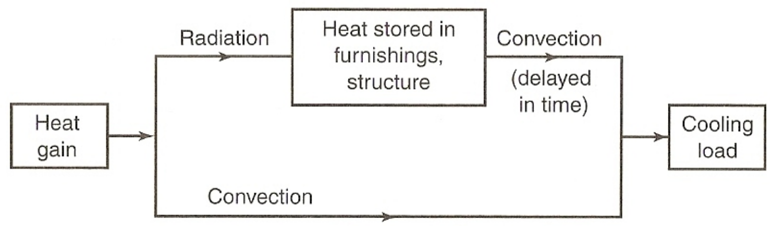


Figure 2.6: Time lag effect

The building cooling load is the rate at which heat must be removed from the building air to maintain it at the design temperature. The heat storage effect and time lag effect cause the cooling load to often be different in value from the entering heat (instantaneous heat gain). **Figure 2.7** shows an example. During the time of day at which the instantaneous heat gain is the highest (the afternoon), the cooling loads is less than instantaneous heat gain. This is because some of this heat is stored in the building and is not heating the room air. Later on in the day, the stored heat plus some of the new entering heat is released to room air, so the cooling load becomes greater than the instantaneous heat gain. [3]

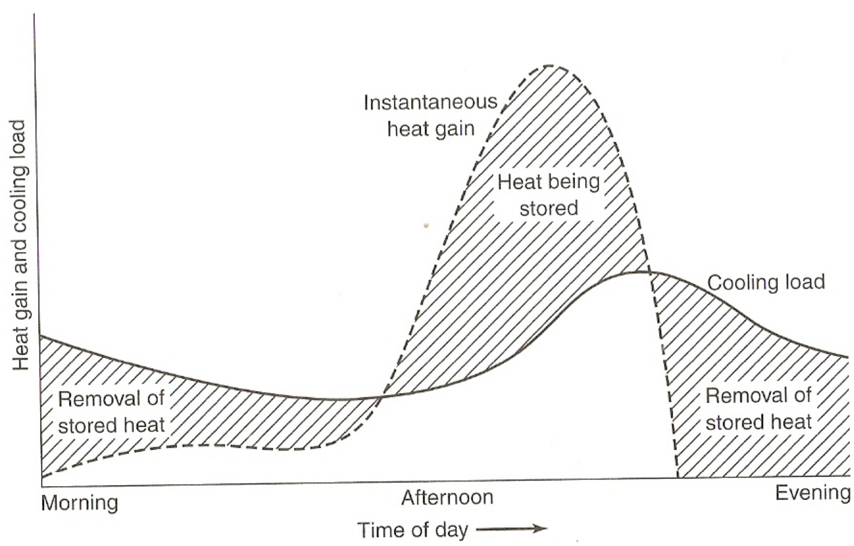


Figure 2.7: Heat gain and cooling load against time of day

The heat gain components that contribute to the building cooling load:-

i. People
ii. Heat from the structure of building that received from the sun.
iii. Air from outside the building
iv. Equipment such as computer.

2.4 SENSIBLE AND LATENT HEAT

There are two types of heat available. There are sensible heat and latent heat. Sensible heat is heat which is a substance absorbs, and while its temperature goes up, the substance does not change state. Overall sensible heat gain is total of from [3]

i. Heat transmitted through structures such as wall, door and roof.
ii. Occupants body heat
iii. Equipments
iv. Ventilation processes
v. Solar heat gain through glass

Latent heat is heat which is absorbed or given off by a substance when changing its state. Overall latent heat gain is total of from

i. Ventilation process
ii. Occupants
iii. Equipments

2.5 TYPES OF AIR CONDITIONING SYSTEM

Air conditioning systems can be classified in a number of ways such as [3]:

i. The cooling medium

- All-air systems: These systems use only air for cooling or heating.
- All-water (hydronic) systems: These systems use only water for cooling or heating.
- Air-water combination systems: These systems use both water and air for cooling and heating.

ii. Unitary or Central systems.

- A unitary system uses packaged equipment. That is most of the system components (fans, coils, refrigeration equipment) are furnished as an assembled package from the manufacturer.
- A central or built up system is one where the components are furnished separately and installed and assembled by the contractor.

iii. Single zones and multiple zones systems

- A single zone system can be satisfactory air condition only one zone in a building
- A multiple zone system can satisfactorily air condition a number of different zone.

2.5.1 All-Air systems

All-air systems transfer cooled or heated air from a central plant via ducting, distributing air through a series of diffusers to the room. It normally comprises the cheapest equipment cost, but is not necessarily easy or cheap to install in a building due to the size of ducting required and the cost to install. [3]

2.5.2 Air Handling Unit (AHU)

Figure 2.8: Air Handling Unit (AHU)

An air handling unit (AHU), cools or heats air that is then distributed to one or a group of rooms that constitute a single zone. The figure of air handling unit is shown in **Figure 2.8**. Air handling unit (AHU) consists of the cooling coils, fan, filters, air mixing section, and dampers and all these in a casing. [3]. The AHU can be classified as unitary system or central system.

2.5.3 Equipment installed in the Air Conditioning System [3]

i. Supply air fan:- Necessary to distribute air through unit, ductwork, and air distribution devices to the rooms. **Figure 2.9** shows fan that used in the air handling unit.

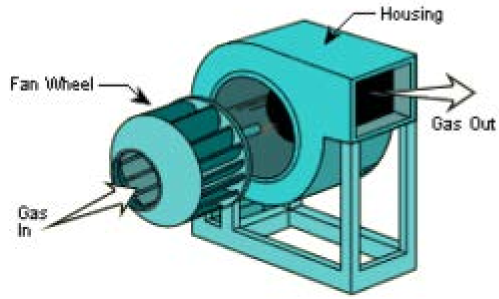


Figure 2.9: Supply air fan

ii. Cooling coils:- Cools and dehumidifies the air in summer. **Figure 2.10** shows the picture of cooling coils.

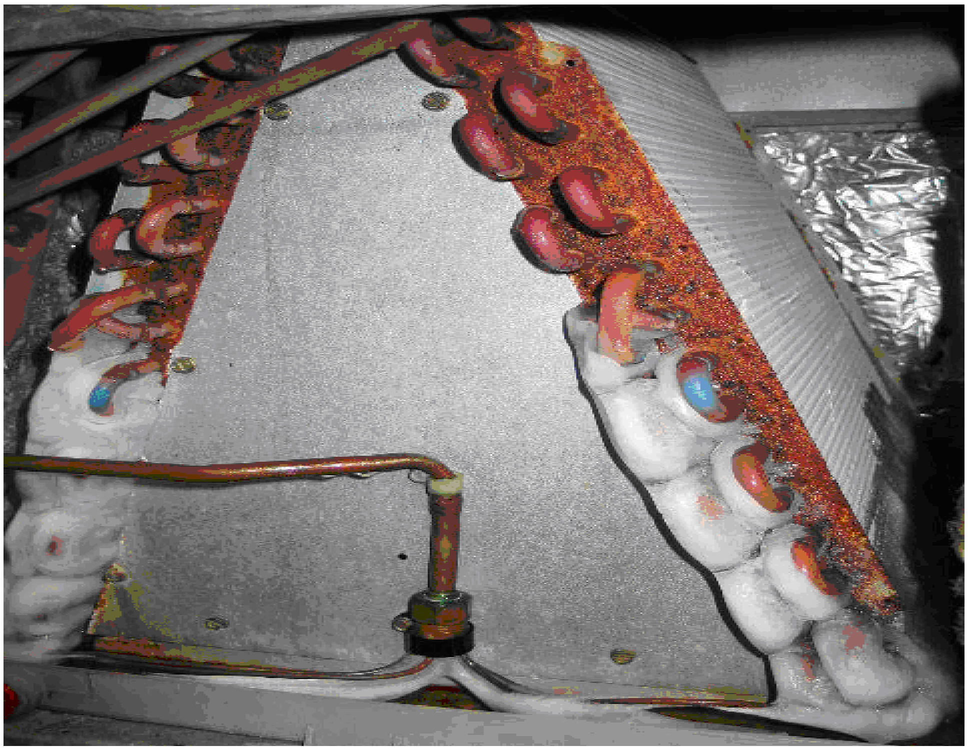


Figure 2.10: Cooling coils

iii. Duct:- Ducts are used in air conditioning system to deliver and remove air. A duct system is often called ductwork. Planning, sizing, optimizing, detailing, and finding the pressure loss through a duct system is called duct design. The most commonly used material for air conditioning system is galvanized steel sheet metal. Molded glass fiber ducts also come into use. To avoid corrosion, more material that is corrosion-resistance such as stainless steel, copper, and aluminium is used to make duct. [3] The picture of duct is shown in **Figure 2.11**

Figure 2.11: Duct

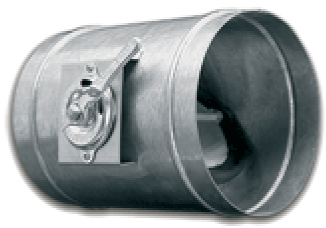
iv. Return air fans:- Takes the air from the rooms and distributes it through return air ducts back to the air conditioning unit or to the outdoors.

v. Filter:- Required to clean the air. **Figure 2.12** shows the picture of air filter.

Figure 2.12: Filter

vi. Dampers:

- a device that are arranged so that 100% outside air can be drawn into the unit and exhausted.
- to vary proportion of outside and return duct air.
- **Figure 2.13** shows the picture of dampers in air mixing section. **Figure 2.14** shows the arrangement of dampers in air mixing section.



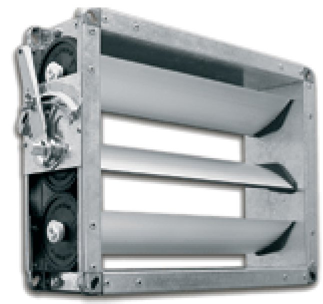


Figure 2.13: Circular air damper and rectangular air damper

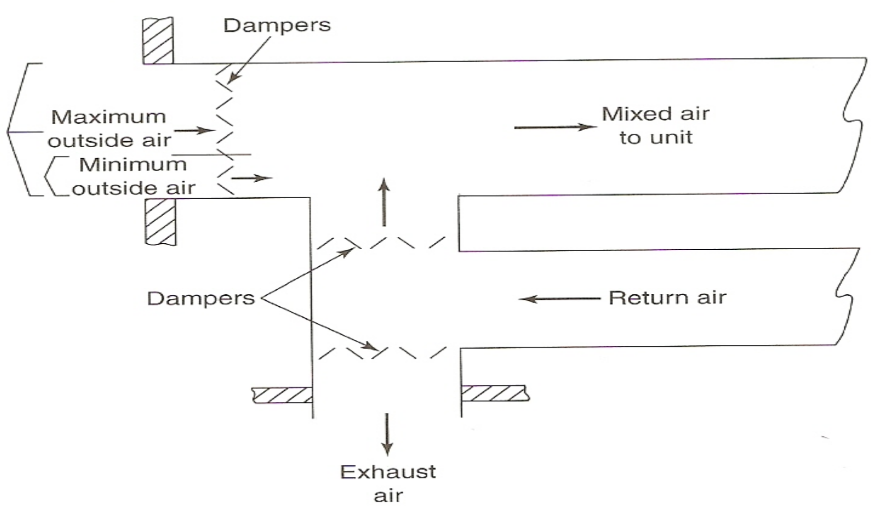


Figure 2.14: Arrangement of dampers in air mixing section

2.6 UMP MOSQUE SPECIFICATION

Table 2.1 shows the UMP Mosque specification. The specification was obtained from the architectural drawing of UMP Mosque. **Figure 2.15** shows the basic drawing of UMP Mosque. The maximum dimension of indoor UMP Mosque is 36m x 35m.

Table 2.1: UMP Mosque Specification

Structure	Material
Roof	i. Color bond metal sheet roofing ii. 50mm thick fibre wool insulation iii. One layer aluminium foil
Wall	115mm brickwall with 19mm thick cement plastering both sides
Door	Timber solid door
Window / Glass	i. Aluminium frame colour glass ii. Natural aluminium frame glass louvered window

.

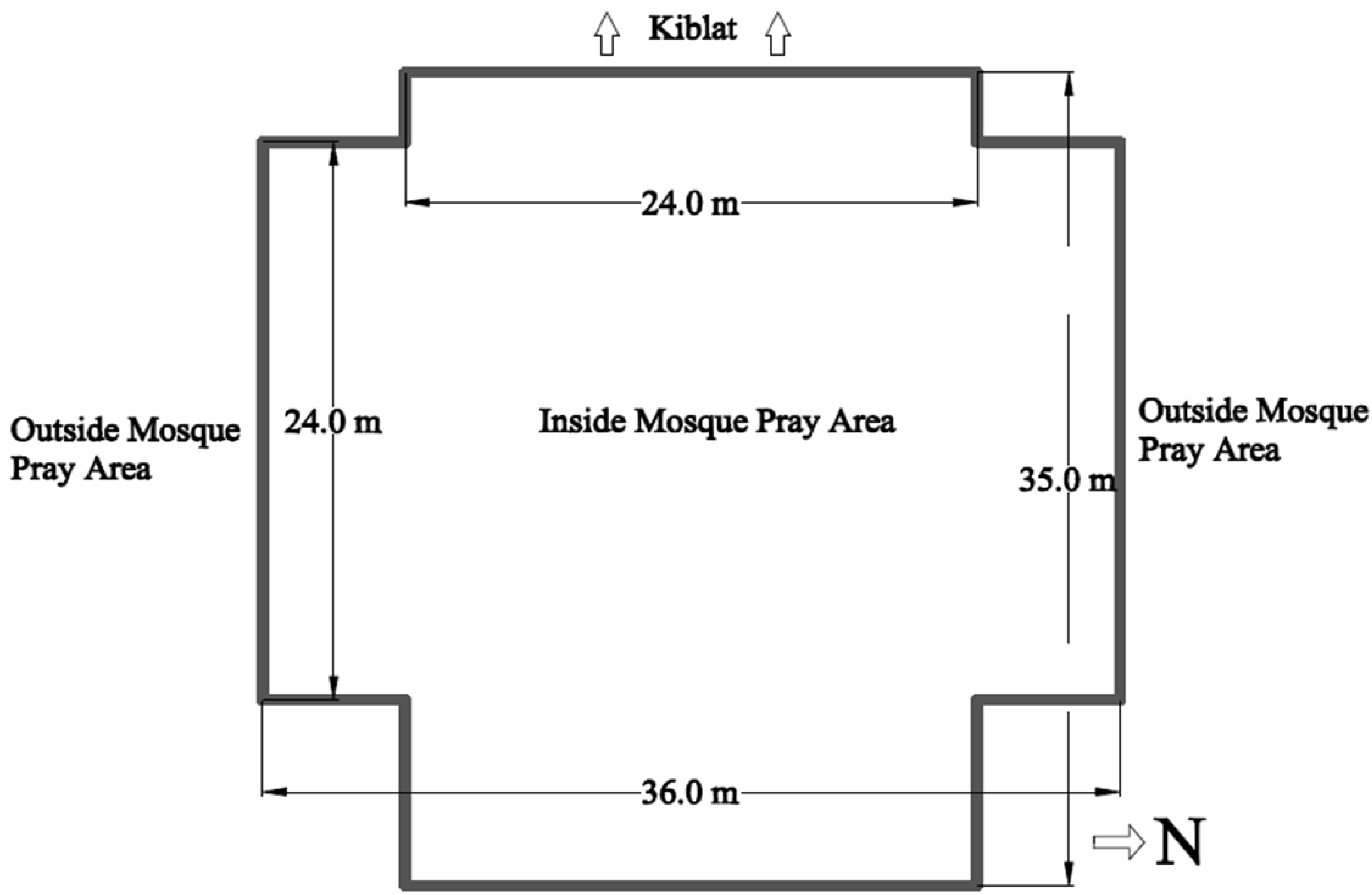


Figure 2.15: Basic drawing of indoor UMP Mosque

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the procedure to design an air conditioning system for UMP Mosque. A flowchart about the procedure to design an air conditioning system for UMP Mosque is shown in **Figure 3.1**. The flowchart shown facilitates readers to understand the flow of the project. From the flowchart, there are six processes to accomplish the project. All the processes are discussed in the next section.

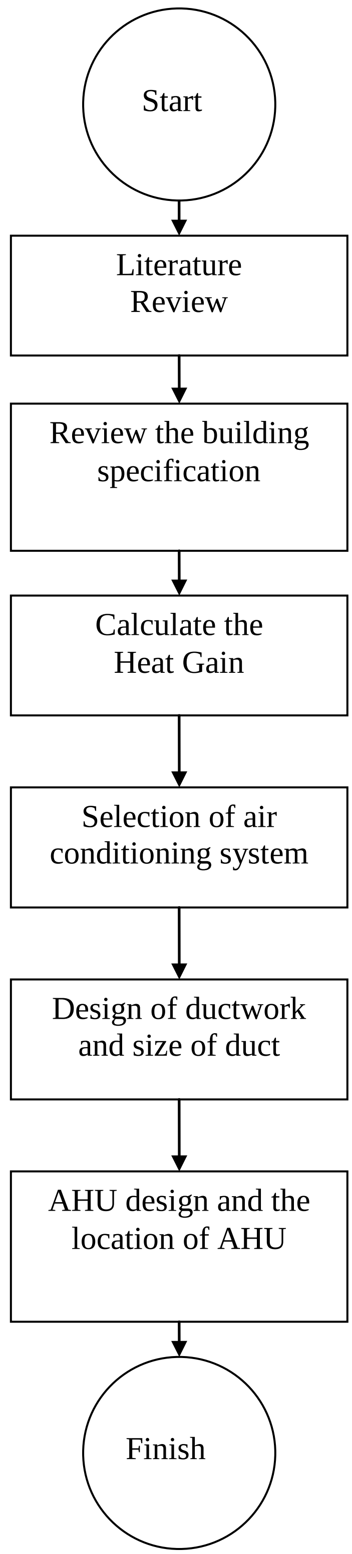


Figure 3.1: Flowchart of the project

3.2 LITERATURE REVIEW

In literature review part, all things that related to air conditioning system and UMP mosque must be studied. Refrigeration cycle, cooling load, types of air conditioning system must be understood so that all the procedure to design air conditioning system will undergo smoothly.

3.3 REVIEW BUILDING SPECIFICATION

Reviewing the specification of UMP mosque is done to know the measurement of the dimension and area of structures in UMP mosque. Other than that is to know the building material to determine the overall heat transfer coefficient, U. The U-value is used to calculate heat gain.

3.4 CALCULATE THE HEAT GAIN

Calculating the heat gain is very important in designing the air conditioning system. It tells the amounts of heat available in UMP Mosque at a time. The heat gain is calculated to determine the total cooling load required to remove the heat in the UMP Mosque.

3.5 SELECTION OF AIR CONDITIONING SYSTEM

After calculate the heat gain, the suitable type of air conditioning system can be chosen. This can be done by compare all the types of air conditioning system. All the advantages and disadvantages of each type are discussed. Finally, the type of air conditioning system that meets the capacity and environment of UMP Mosque will be chosen.

3.6 DESIGN OF DUCTWORK AND SIZE OF DUCT

The duct is going to be arranged so that the conditioned air could be distributed efficiently. The duct sizes will be determined based on calculation of the heat gains and the arrangement of duct.

3.7 AHU DESIGN AND THE LOCATION OF AHU

AHU is chosen based on the cooling load required. So, AHU that will be used for UMP Mosque must have the cooling capacity higher than the heat available in UMP Mosque. AHUs in this project will be located in rooms. The rooms sizes are depend on the size of AHU. The rooms will be built at the outside of UMP Mosque.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter shows the calculations to determine the heat gain available in UMP Mosque and the calculation to determine the size of ducts that are match and suitable with the heat gain and the environment in the UMP Mosque. The purpose of heat gain calculation is to determine the amount of cooling load required to remove heat in UMP Mosque to comfort the occupants. This chapter also discusses the suitable air conditioning system for UMP Mosque.

4.2 HEAT GAIN CALCULATION

Calculate the heat gain is the first step to design an air conditioning system. The heat gain is calculated to get the value of cooling load that required to remove heat that available in the UMP Mosque in order to comfort the occupants. The method used to calculate heat gain in this project is CLTD/SCL/CLF method. [9] The heat gain calculation is divided into three processes. The processes are heat gain caused by solar radiation process, heat gain caused by conduction process through exterior structures, and heat gain caused by internal heat gains. All processes use different formula. [3]

4.2.1 Heat gain Caused by Solar Radiation Process

Solar radiation process is a process that receives heat directly from the sun through glasses. From this process, the month that has highest heat gain can be determined. This can be done by choosing the largest area of glass in UMP Mosque and know which side it located. After that, refer table in **Appendix A1** and choose the highest maximum solar heat gain factor, SHGF. [10] For UMP Mosque, the largest area of glass is at West side. The highest value of maximum solar heat gain factor, SHGF is in March. Thus, the design day for this project is in March 21^{st}.

The parameters that are needed to calculate the heat gain caused by solar radiation are maximum solar heat gain factor, SHGF, shading coefficient, SC, heat gain factor, CLF and area, A. The CLF value can be taken from table in **Appendix A2**. The formula used to calculate heat gain caused by solar radiation is shown below. [3]

$$\text{Heat Gain, } Q = SHGF \times A \times SC \times CLF \tag{4.1}$$

Where SHGF = maximum solar heat gain factor

SC = shading coefficient

CLF = cooling load factor

A = area of the glass

4.2.2 Heat gain Caused By Conduction Process through Exterior Structures.

Conduction process through exterior structures is a process where heat is transferred from outside to inside of UMP Mosque through exterior structures. The exterior structures that involve in this process are roof, wall, glass and door. The properties of the structures that needed to calculate the heat gain are overall heat transfer coefficient, U, the area, A and corrected heat gain temperature different, CLTDc. The formula used to calculate the heat gain caused by exterior structure is shown on the next page. [3]

$$\text{Heat gain, } Q = U \times A \times CLTDc \tag{4.2}$$

Where; U = overall heat transfer coefficient ($W/m^2.^oC$)

A = area of the structure (m^2)

CLTDc = corrected cooling load temperature different

4.2.2.1 Overall Heat Transfer Coefficient, U ($W/m^2.^oC$)

The value of overall heat transfer coefficient, U for certain types of structures is difficult to be found. So, the best way is find the resistance, R for every layer of the structure. The formula to determine the U-value from R-value is shown below. [10]

$$\text{Overall Heat Transfer Coefficient, } U = 1/\sum R \tag{4.3}$$

Where $\sum R$ is summation of all layer resistance, R

Below is the calculation to determine the U-value for every structure.

i. Roof structure.

The roof is made from metal sheet type with layers of insulation and without ceiling. The elements layers are as follows: [11, 12]

a) Outside moving air
b) Aluminium foil +50mm fibrewool insulation
c) Metal sheet
d) Inside still air

Table 4.1: Roof total resistance, R

Element layer	R(m^2. $^oC/W$)
a) Outside moving air	0.044
b) Aluminium foil +50 mm fibrewool insulation	1.333
c) Metal sheet	0.11
d) Inside still air	0.13
Total	= 1.62

By using equation (4.3),

U =1/ (1.62)

=0.617 W/m^2.^oC

Overall heat transfer coefficient, U for roof is 0.617 W/m^2.^oC.

ii. Wall structure.

The wall of UMP Mosque is consists of a number of element layers. The element layers are as follows: [10]

a) Outside moving air
b) 2x 19mm cement plaster
c) 115mm brick wall
d) Inside still air

Table 4.2: Wall total Resistance, R

Element layer	R(m^2. ^oC/W)	Mass(kg/ m^2)
Outside moving air	0.044	-
19 mm cement plaster	0.026	35.5
115 mm brick wall	2.86	197.6
19 mm cement plaster	0.026	35.5
Inside still air	0.13	-
	Total= 3.086	Total= 286.6

By using equation (4.3),

U =1/ (3.086)

=0.324 W/m^2.^oC

= 0.0685 Btu/Hr/ (ft^2.F)

Mass (kg/ m^2) = 286.6 kg/ m^2

=55 Ib/ft^2

The mass value is determined to find the category of UMP Mosque wall. By referring **Appendix A3**, the UMP Mosque wall is best in group E.

iii. Glass structure

The glass structure in UMP Mosque is clear single glass type .The overall heat transfer coefficient, U for glass is 6.1 W/m^2. ^oC. [7]

iv. Door structure

The type of door in UMP Mosque is timber door. The overall heat transfer, U for timber door is 0.9 W/m^2. ^oC. [8]

0.9 W/m^2. ^oC = 0.158 Btu/Hr/(ft^2.F)

By referring **Appendix A3**, the UMP Mosque door is best in group D.

4.2.2.2 Corrected Cooling Load Temperature Different, CLTDc

The cooling load temperature different, CLTD can directly taken from table in **Appendix A4** for roof, **Appendix A5** for wall and door and **Appendix A6** for glass but the value from the table is not accurate. This is because the tables are based on the following condition;

1. Indoor temperature is 25.6 ^oC or 78 F
2. Outdoor average temperature on the design day is 29.4 ^oC or 85 F
3. Date is July 21st
4. Location is 40^{o}N latitude.

For this project, the condition is;

1. Indoor temperature is 23 ^oC or 73.4 F
2. Outdoor average temperature on the design day is 33.3 ^oC or 91.94 F
3. Date is March 21st
4. Location is 4^{o}N latitude.

So, the CLTD value must be corrected first. The formula used to determine the corrected cooling load temperature different, CLTDc is shown below. [3]

$$CLTDc = CLTD + LM + (25.5 - Tr) + (Ta - 29.4) \quad (4.4)$$

Where Tr = Indoor temperature. The value is 23 ^oC.

Ta is average temperature. Ta is determined by using below formula,

$$Ta = To - DR/2 \quad (4.5)$$

Where DR =Daily range. The value is 11.1 ^oC

To = Outdoor temperature. The value is 33.3^oC.

$$Ta = To - DR/2$$
$$= 33.3\ ^oC - 11.1\ ^oC/2$$
$$= 27.75\ ^oC$$

LM is Latitude Month. LM value is taken from table in **Appendix A7**. Below is the calculation to determine the LM value for latitude 4^{o}N for north exposure.

Latitude 0^{o}N, LM = -3 F

=-1.67 ^{o}C

Latitude 8 ^{o}N, LM = -3 F

=-1.67^{o}C

Since the desired latitude was 4 ^{o}N, interpolation needs to be carried out.

Latitude 4^{o}N LM for North

$$(4-0)/(8-0) = (LM + 1.67)/(-1.67 + 1.67)$$

$$LM = -1.67^oC$$

The step to determine the value of latitude 4 ^{o}N for west, east and south are same as the above step.

Table 4.3: LM value at Latitude 4 ^{o}N

Exposure	Latitude 0^{o}N, LM	Latitude 8 ^{o}N LM	Latitude 4 ^{o}N LM
North	-1.67	-1.67	-1.67
South	-4.44	-2.22	-3.33
East	-0.56	-0.56	-0.56
West	-0.56	-0.56	-0.56

For roof and glass structure, the LM value is different with wall structure. This is because the exposure for roof is horizontal. The LM value for roof at latitude 4 ^{o}N is 0^{o}C. For glass structure, the LM values do not need to be added. [3]

4.2.3 Heat gain Caused by Internal Heat Gain.

There are many things that release heat in UMP Mosque such as computer, lights and many more. Peoples also release heat. Ventilation process also brings heat inside the UMP Mosque.

i. Lights

Usually lights in UMP Mosque are used only at night. There are 132 lights in UMP Mosque. For this project, the calculation of heat gain caused by lights is only at 7.00 pm. The formula that going to be used to calculate the heat gain caused by the lights is

$$Q = n \times W \times BF \times CLF \quad (4.6)$$

Where; n is the number of lights, 132 lights

W is lighting capacity 40 Watt

BF is ballast factor, 1.25

CLF is cooling load factor for lighting, 1.0 [3]

ii. Peoples

The maximum number of people that can enter the conditioned space at UMP Mosque is 1300 peoples. Usually this maximum number can be reached during the Friday Prayer. For the other time, assuming that only 5 peoples in the mosque and 150 peoples during performing the 5 Fardhu Prayer. The formula used to calculate heat gains caused by peoples is

$$Qs = q_s \times n \times CLF \quad (4.7)$$

Where Qs is sensible heat gain (loads)

q_s is sensible heat gain per person

n is number of person

CLF is cooling load factor for people

$$Ql = q_l \times n \times CLF \tag{4.8}$$

Where Ql is latent heat gain (loads)

q_l is latent heat gain per person

n is number of person

CLF is cooling load factor for people

Total heat gain,Q caused by people is Qs + Ql. The value of ql and qs are taken from table in **Appendix A8.** The value of CLF is 1.0. [3]

iii. Equipment in UMP Mosque

There is only one equipment that release heat to the surrounding of the UMP Mosque. The equipment is computer. There are two computers in UMP Mosque. To determine the heat gain caused by those computers, below equation will be used.

$$Q = q \times n \tag{4.9}$$

Where q is heat gain per equipment

N is number of equipment

The value of q is taken from **Appendix A9**. [3]

iv. Ventilation

Ventilating is the process of "changing" or replacing air in any space to control temperature or remove moisture, odors, smoke, heat, dust and airborne bacteria. Ventilation includes both the exchange of air to the outside as well as circulation of air within the building.[16] To determine the heat gain from ventilation process, the Psychrometrics chart is used to find the outdoor and inside humidity ratio. The Psychrometrics chart is shown in **Appendix A10**. The formula used to determine heat gains from ventilation process are shown on the next page.

.

$$Qs = 1.1 \times CFM \times TC \times n \quad (4.10)$$

Where Qs is sensible heat gains from ventilation air, W

CFM is air ventilation rate

TC is temperature different between outdoor and inside air, ^{o}C

n is number of people

$$Ql = 0.68 \times CFM \times (Wo' - Wi') \times n \quad (4.11)$$

Where; Ql is sensible heat gains from ventilation air, W

Wo' is outdoor humidity ratio, gr w. /kg d.a

Wi' is inside humidity ratio, gr w. /kg d.a

n is number of people

The value of CFM is recommended to be 15. [3] The total heat gain is Q = Qs + Ql.

v. Duct Heat Gain

The duct will be located below the roof of UMP Mosque and therefore the duct heat gain must be included which is refer to supply air (SA) duct gain. An estimation of 5% of sensible load is taken. [3]

vi. Fan Heat Gain

A draw – through fan arrangement will be used. This refers to SA fan gain. The value is 5%. The return air fan which refers to return air (RA) fan gain is included because the temperature rises due to the return air fan heat. The value for RA fan gain is estimated to be 2.5% of sensible load. [3]

4.3 PEAK LOAD TIME

Peak load time is a time where the highest heat gains occur in UMP Mosque. The peak load time is determined by calculate the heat gain caused by solar radiation and conduction process through the structure of UMP Mosque excluding the internal heat gains. This project only considers time from 8.00 am until 7.00 pm. To find the peak load time possibilities, only UMP Mosque building structures are involved. Only the largest area of structure for every type is chosen. For solar radiation process, choose the highest CLF from table in **Appendix A2** for shading and without shading glass. While for conduction process, choose the highest CLTD from table in **Appendix A4, A5** and **A6**. Below in **Table 4.4** is the table which contains the possibilities of peak load time for UMP Mosque. [10]

Table 4.4: Peak Load Time Possibilities

Process	Building Structure	Peak Load Time Possibilities						
		12.00 pm	1.00 pm	2.00 pm	3.00 pm	4.00 pm	5.00 pm	7.00 pm
Radiation	Shading Glass							
	Without Shading Glass							
Conduction	Roof							
	Glass							
	Wall							

After this, only time 12.00 pm until 7.00 pm will be considered to determine the highest heat gain because the peak load time is in the range. The heat gain will be calculated for every hour from 12.00 pm until 7.00 pm. All the calculation solved by using Microsoft Excel software. **Table 4.5** below shows the result.

Table 4.5: Peak Load Time

Solar Time	Structure	12:00 PM	1.00 pm	2.00 pm	3.00 pm	4.00 pm	5.00 pm	6.00 pm	7.00 pm
Process									
Solar Radiation		15.56	20.41	28.31	35.03	38.65	38.41	29.65	10.91
Conduction	Wall	1.74	2.06	2.31	2.67	3.02	3.44	3.70	3.86
	Roof	28.04	30.75	31.14	30.37	27.66	23.41	17.99	12.19
	Glass	5.56	7.14	7.66	8.20	8.20	7.66	7.14	6.09
	Door	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08
Total Cooling Load(kW)		50.93	60.39	69.46	76.32	77.58	73.00	58.56	33.13

From the result, the highest heat gain occurs at 4.00 pm. Thus, the peak load time is at 4.00 pm for daily basis.

4.3.1 Calculation at Peak Load Time

Below are samples of calculation for every process.

i. Roof Structure.

Roof information

- Roof Area, A = 1128 m^2.
- Overall Heat Transfer Coefficient for roof, U = 0.617 $W/m^2 . {}^oC$.
- CLTD at 4.00 pm, CLTD = 70 F = 38.89 ^oC

$$CLTDc = 38.89 + 0 + (25.5 - 23) + (27.75 - 29.4)$$

$$= 39.74\ ^oC$$

$$\text{Heat gain, } Q = 0.617 \times 1128 \times 39.74\ ^oC$$

$$= 27.7\ kW$$

ii. Wall Structure.

Wall information

- North exposure area, A = 121.24 m^2
- Overall Heat Transfer for wall, U =0.324 $W/m^2.\,^oC$.
- CLTD at 4.00 pm. CLTD = 17 F = 9.4 ^oC

$$CLTDc = 9.4 + (-1.67) + (25.5 - 23) + (27.75 - 29.4)$$
$$= 8.58\,^oC$$
$$\text{Heat gain, } Q = 0.324 \times 121.24 \times 8.58$$
$$= 0.34 \text{ kW}$$

iii. Glass

Glass information

- Total Glass Area of all exposure, A= 155.7 m^2
- Overall Heat Transfer for wall, U =6.1 $W/m^2.\,^oC$
- CLTD at 4.00 pm. CLTD = 14 F = 7.78 ^oC
- Note for glass LM is not included

$$CLTDc = 7.78 + (25.5 - 23) + (27.75 - 29.4)$$
$$= 8.63\,^oC$$
$$\text{Heat gain, } Q = 6.1 \times 155.7 \times 8.63$$
$$= 8.2 \text{ kW}$$

iv. Door

Door information

- North exposure area, A = 7.22 m^2
- Overall Heat Transfer for door, U =0.9 $W/m^2.\,^oC$
- CLTD at 4.00 pm CLTD = 13 F = 7.22 ^oC

CLTDc = 7.22 + (-1.67) + (25.5 – 23) + (27.75 – 29.4)

= 6.4 ^{o}C

Heat gain, Q = 0.9 x 7.22 x 6.4

= 0.027 kW

v. Solar Radiation

With Shading

- North exposure
- Area, A = 30.42 m^2
- Shading Coefficient, SC = 0.94
- Solar Heat Gain Factor, SHGF = 34 (Btu/Hr)/ ft^2 = 107.23 W/ m^2
- Cooling Load Factor, CLF = 0.79

Heat gain,Q = 107.23 x 30.42 x 0.94 x 0.79

= 2.4 kW

Without Shading

- West Exposure
- Area, A = 45.67 m^2
- Shading Coefficient, SC = 0.94
- Solar Heat Gain Factor, SHGF = 237 (Btu/Hr)/ ft^2 = 747.46 W/ m^2

- Heat gain Factor, CLF = 0.87

Heat gain, Q = 747.46 x 45.67 x 0.94 x 0.87

= 27.9 kW

Painted Glass

– North Exposure

– Area, A = 14 m^2

– Shading Coefficient, SC = 0.5

– Solar Heat Gain Factor, SHGF = 34 (Btu/Hr)/ ft^2 = 107.23 W/ m^2

– Heat gain Factor, CLF = 0.79

Heat gain, Q = 107.23 x 14 x 0.5 x 0.79

= 0.6 kW

vi. Peoples

Sensible heat gain, Qs = 73.27 x 150 x 1.0

= 11 kW

Latent heat gain, Ql= 58.62 x 150

= 8.8 kW

Total heat gain caused by peoples, Q = 11 + 8.8

= 19.8 kW

vii. Equipment in UMP Mosque

Heat gain, Q = q x n

= 996.48 x 2

= 2 kW

viii. Ventilation

Sensible heat gain, Qs = 1.1 x 15 x (50.54) x 150

= 125086.5 Btu/Hr

= 36.7 kW

Latent heat gain, Ql = 0.68 x 15 x (115 – 61) x 150

= 82620 Btu/Hr

= 24.2 kW

Total heat gain caused by ventilation process, Q = 36650.35 + 24207.66

= 60.9 kW

The total heat gain at 4.00 pm hour is 171.8 kW. Actually the largest amount of heat gain occur during Muslims perform Friday Prayer which is at 1.00 pm on Friday. The total heat gain at 1.00 pm on Friday is 781.4 kW. This happen because at that time, there are about 1300 peoples in the UMP Mosque. This number of peoples causes the amount of heat in UMP Mosque much greater. Thus at 1.00 pm on Friday is the peak load time.

4.4 ANALYSIS FROM HEAT GAIN CALCULATION.

From the heat gain calculation, analysis can be carried out. For this project, the first analysis is the comparison heat gain caused by solar radiation process and conduction process for every structure at peak load time which is at 4.00 pm. Solar radiation process is divided into 3 categories. The categories are solar radiation through without shading glasses, through with shading glasses and through painted glasses. **Figure 4.1** shows the pie chart of solar radiation process at 4.00 pm.

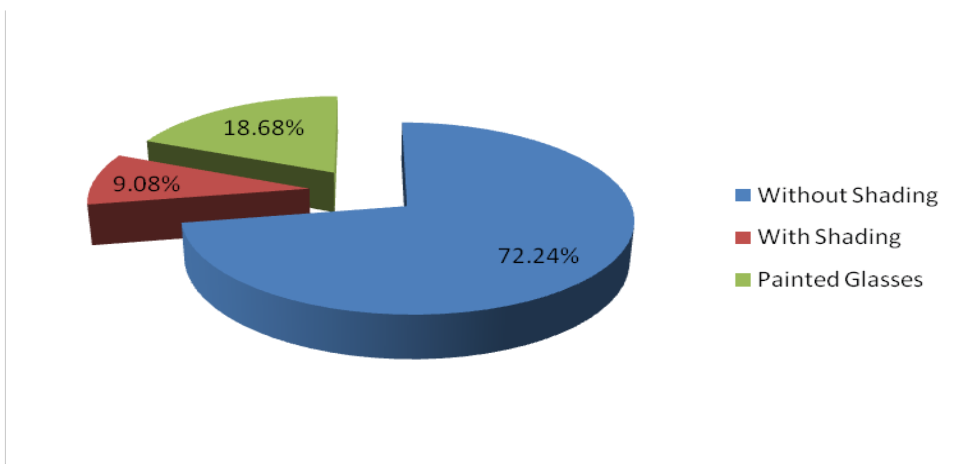


Figure 4.1: Heat Gain Contribution through Solar Radiation

From the pie chart above, the highest heat gain in solar radiation process is caused by the without shading glasses. It makes sense because the without shading glasses have large total of area compared to without shading and painted glasses. With shading glasses have the lowest heat gain because it receive small amount of light from the sun. This happen because the glasses are shaded with the roof of UMP Mosque. The heat gain caused by the painted glasses is greater than with shading glasses heat gain although the area of the painted glasses and the shading coefficient, SC are smaller than with shading glasses. This happen because the painted glasses receive more heat and light from the sun.

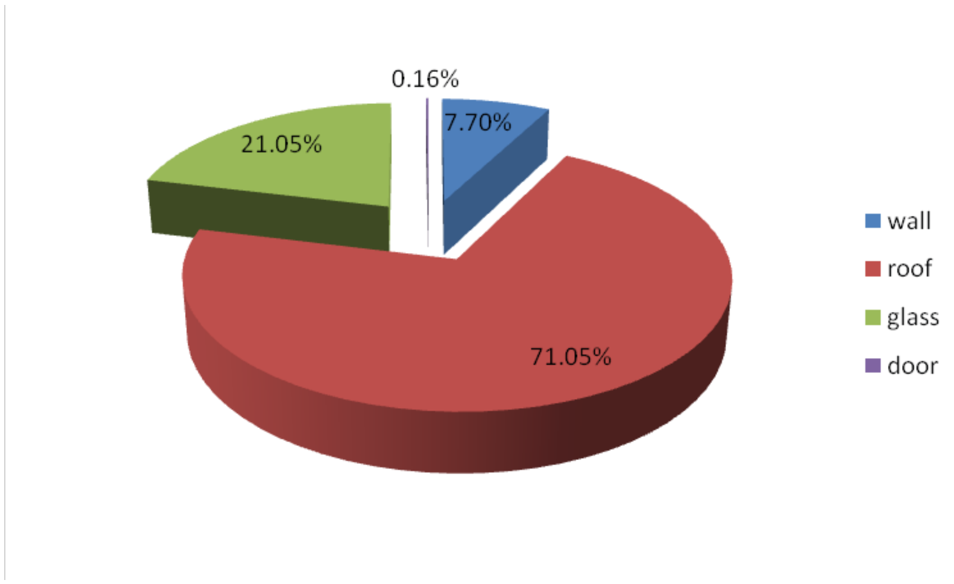


Figure 4.2: Heat Gain Contribution through Conduction

Figure 4.2 shows pie chart of conduction process happen in UMP Mosque at 4.00 pm. From the chart, the roof structure gives the highest heat gain followed by glass, wall and door. It makes sense because the area of the roof is the largest compared to three other structures. While the door structure gives the lowest heat gains because the door's area is the smallest. The total area of wall structure and glass are more less the same size. But the glass structure cause more heat gain than wall because it has greater value of overall heat transfer coefficient, U.

The second analysis that carried out in this project is comparison of total heat gain caused by solar radiation process and conduction process for every structure at every hour. The graph in **Figure 4.3** shows the total heat gains for every structure at every hour.

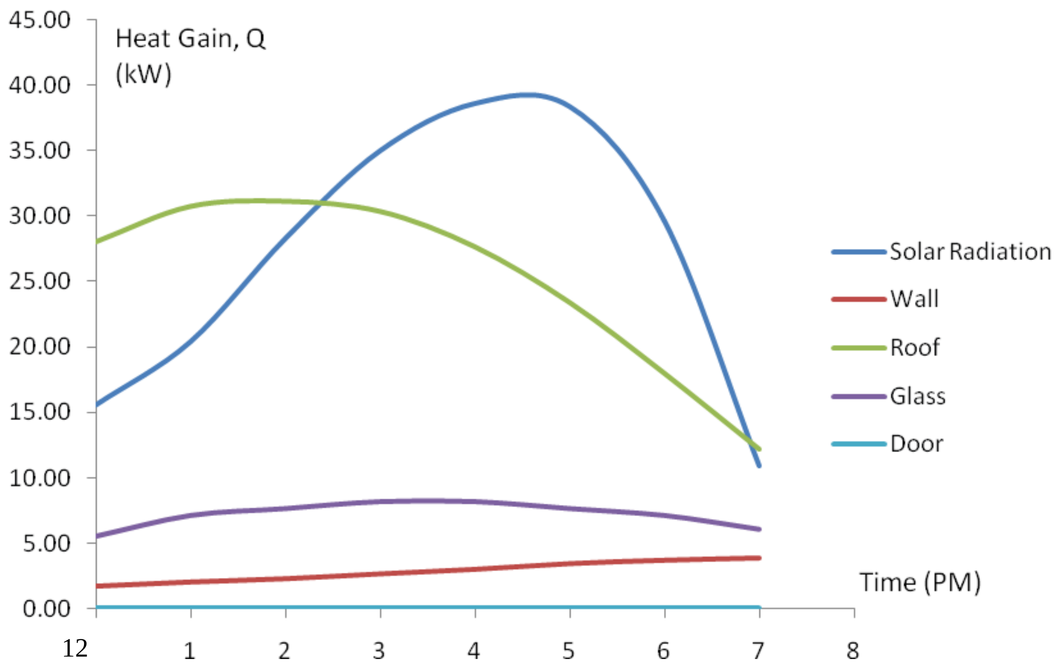


Figure 4.3: Heat Gain for Building Structure

From the graph, the highest heat gain at 12.00 pm is caused by the conduction process through the roof of UMP Mosque. It is followed by solar radiation process through glasses, conduction process through glasses, conduction process through wall and lastly conduction process through door. The heat gain caused by roof still the highest until 3.00 pm where at that time solar radiation process through glasses contributes the highest heat gain. At peak load time which is at 4.00 pm, the solar radiation process contributes most of the heat gain in UMP Mosque. The solar radiation process through glasses maintain as the highest heat gain contributor until 7.00 pm. So, it can be conclude that the main heat gain contributor in the afternoon is heat gain caused by roof and heat gain caused by solar radiation is the main contributor in the evening and also at peak load time. The other heat gain contributor such as conduction process through wall, door and glasses just contribute small amount of heat gain.

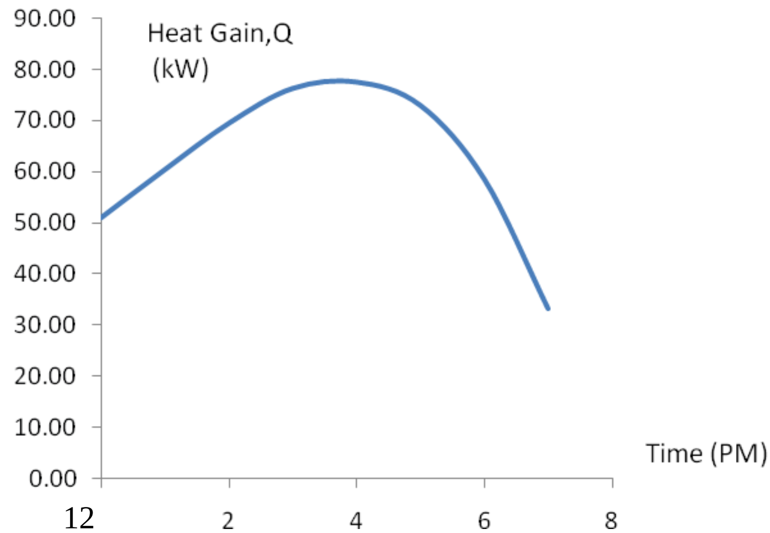


Figure 4.4: Total External Heat Gain

Figure 4.4 above shows graph of external heat gain against time. The external heat gain is a combination of heat gain caused by solar radiation process and conduction process excluding internal heat gain. From the graph, the highest heat gain occurs at 4.00 pm. This time is call peak load time. At the beginning of the graph, the heat gain is increasing until at 4.00 pm. The heat gain then decreasing because the sun is immersing.

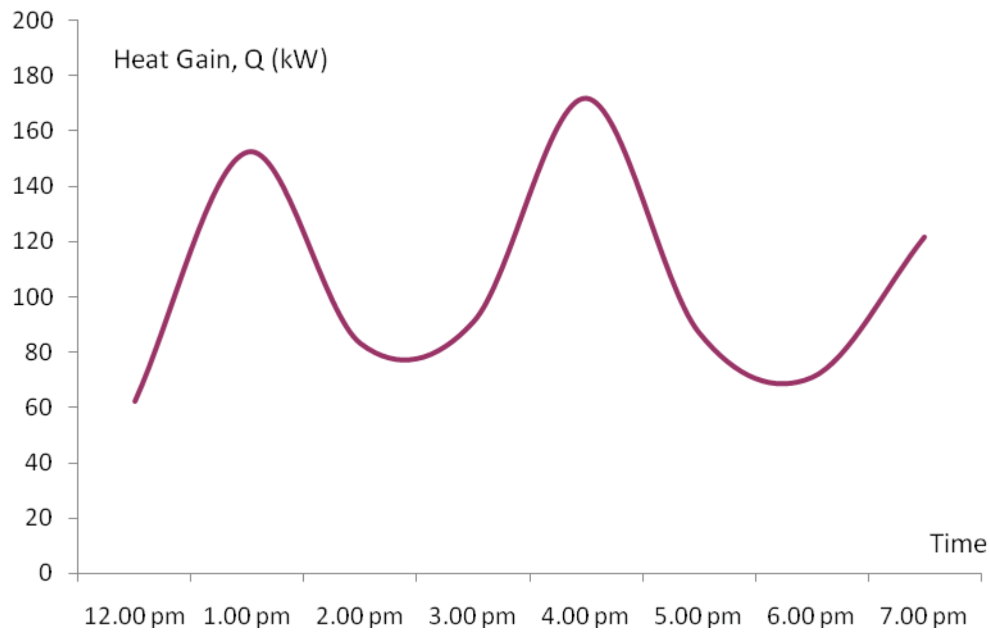


Figure 4.5: Overall heat gain on Saturday to Thursday

The next analysis is comparison of overall heat gain at 12.00 pm to 7.00 pm on Saturday to Thursday. Graph above in **Figure 4.5** shows the heat gain at 12.00 pm to 7.00 pm. From the graph, starting from 12.00 pm, the heat gain increase when time at 1.00 pm then decrease at 2.00 pm. The heat gain increase again at 4.00 pm.The heat gain at 4.00 pm is greater than at 1.00 pm. Then, the heat gain decrease again untill 6.00 pm. At 7.00 pm, the heat gain increase again. The heat gain always increase at 1.00 pm, 4.00 pm and 7.00 pm. This happen because those times are time where the Muslim and Muslimah perform Fardhu prayer and the number of them is assumed about 150 peoples.

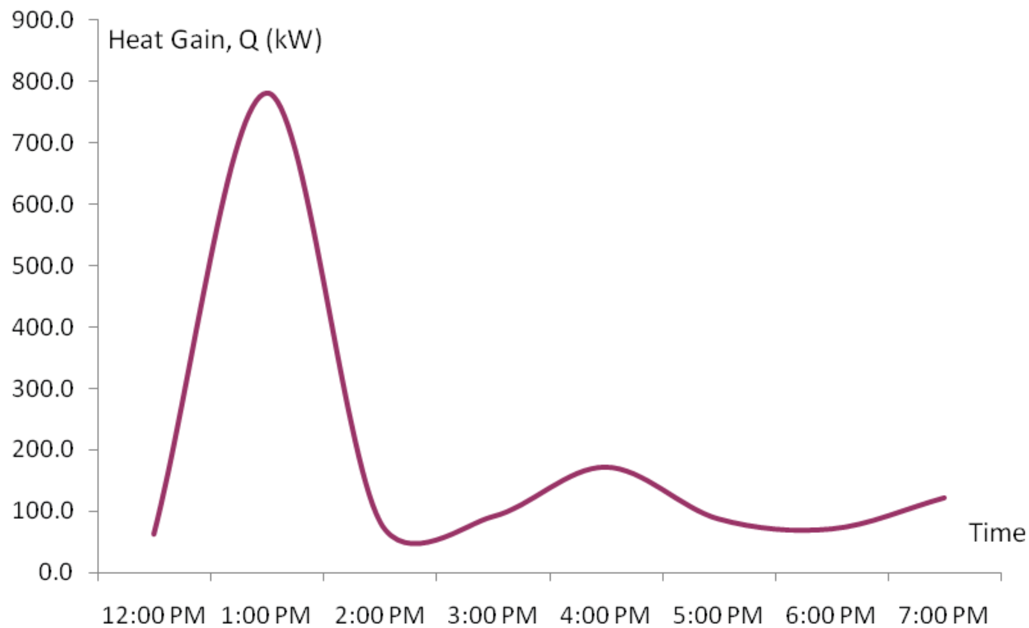


Figure 4.6: Overall Heat gain on Friday

The final analysis for this project is comparison of overall heat gain at 12.00 pm to 7.00 pm on Friday. **Figure 4.6** shows the graph of overall heat gain against time that occur on Friday. The graph is quite same with the graph in **Figure 4.5**. The only different is the heat gain at 1.00 pm. The heat gain at that time is 781.4 kW. The heat gain at 1.00 pm on Friday is the highest and it is greater than the peak load time for daily basis which is at 4.00 pm. At 1.00 pm on Friday, the Muslims perform Friday Prayer. There are about 1300 Muslims perform the Friday Prayer inside UMP Mosque excluding the Muslims who pray outside of UMP Mosque. The number of peoples cause the heat gain very high.Thus, this value of heat gain is taken as the cooling load in order to design the air conditioning system for UMP Mosque.

4.5 SYSTEM SELECTED.

For this project, an all-air single zone system is used. There will be five air handling unit (AHU) that can be operated separately. The AHUs are unitary system. The name of the AHU used in this project is High Static Ducted Split that is shown in **Figure 4.7**. [13] Each AHU is connected with one duct. The conditioned air distributed into conditioned space through ducts.

Figure 4.7: High Static Ducted Split AHU

4.6 DUCT DESIGN

To determine the duct sizes, the total supply air quantity needs to be calculated first. The formula used is shown below. [3]

$$\text{Total Supply Air} = \text{BSCL} / (1.1 \times \text{TC}) \quad (4.12)$$

Where BSCL is Building Sensible Cooling Load

TC is Temperature Different

BSCL calculated for UMP Mosque is 173.4 kW = 592.05 kBtu/Hr, temperature in conditioned space which is inside the UMP Mosque is 23^{o}C = 73.4 F and assume that temperature at cooling coil air handling unit is 53.4 F = 11.9 ^{o}C.. The total supply air for UMP Mosque is calculated and shown on the next page.

$$\text{Total Supply Air} = 592048.1 / (1.1 \times (73.4 - 53.4))$$
$$= 26911.28 \text{ CFM} \approx 27000 \text{ CFM}$$
$$= 45722.51 \text{ m}^3/\text{hr}$$

The total supply air for UMP Mosque is 26911 CFM. The total supply air is rounded up to 27000 CFM. The total supply air is distributed into UMP Mosque through ducts. Based on the design of ductwork system for this project in **Figure 4.8** below there will be 2 types of duct. The types are doubled duct and single duct. **Figure 4.9** shows duct for section AB. The sizes of duct depend on the amount of supply air distributed to the duct.

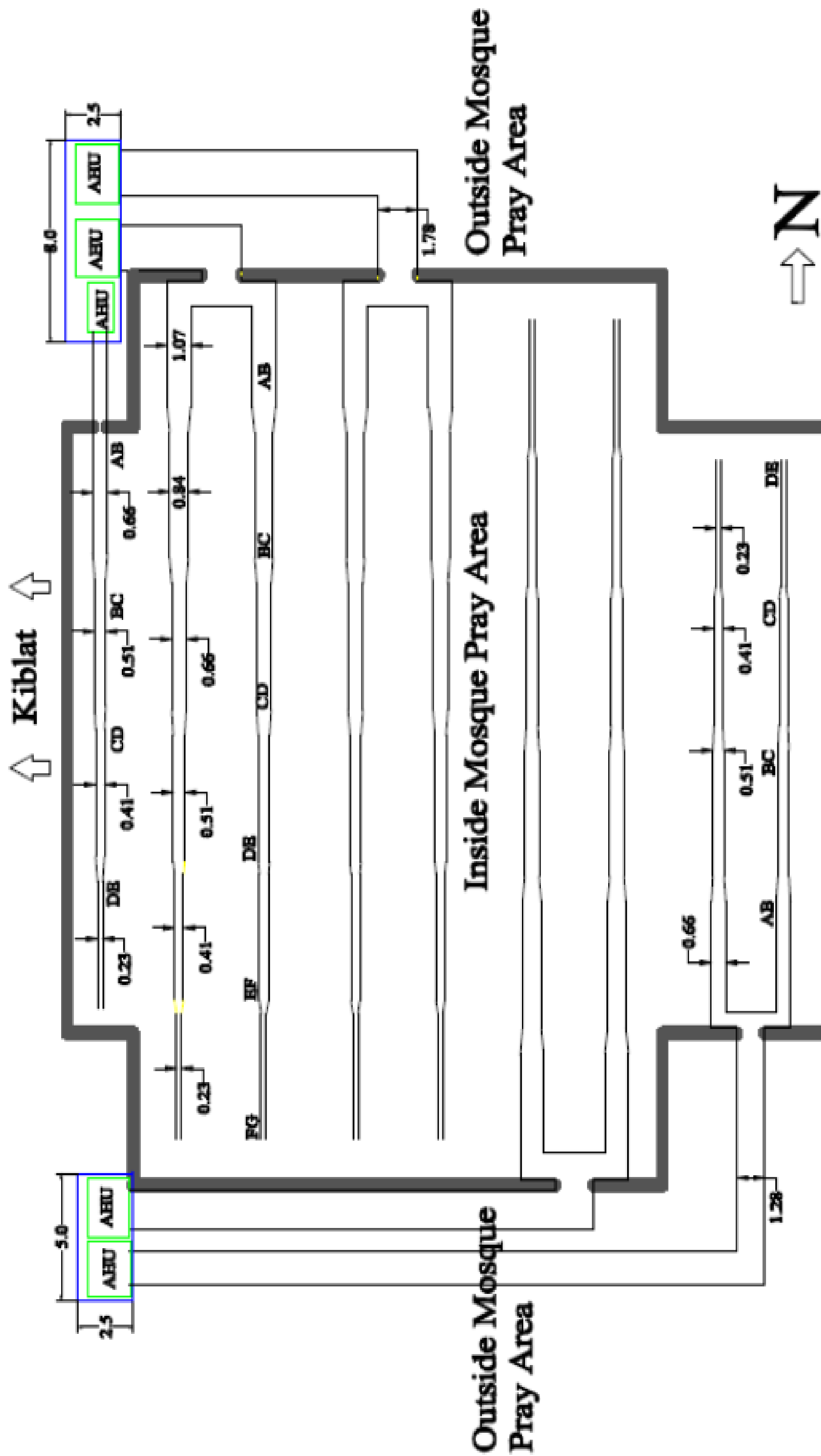


Figure 4.8: Design of Ductwork

There is just one single duct and four doubled duct. Three of the doubled ducts which are at the middle of UMP Mosque have same duct size. The method chosen to calculate the duct size is equal friction method. [3].With this method, the same value friction loss rate per length of duct is used to size each section of duct in the system. The friction loss rate is chosen to result in an economical balance between duct cost and energy cost. For example, a higher friction loss results in smaller ducts but higher fan operating costs. In this project, the friction loss rate chosen is 0.1 in w. /100 ft of duct. [3].The value is chosen because this value usually used for low velocity system. Below in **Table 4.6, 4.7, 4.8** are the summary of calculation to determine the duct size for each types of duct.

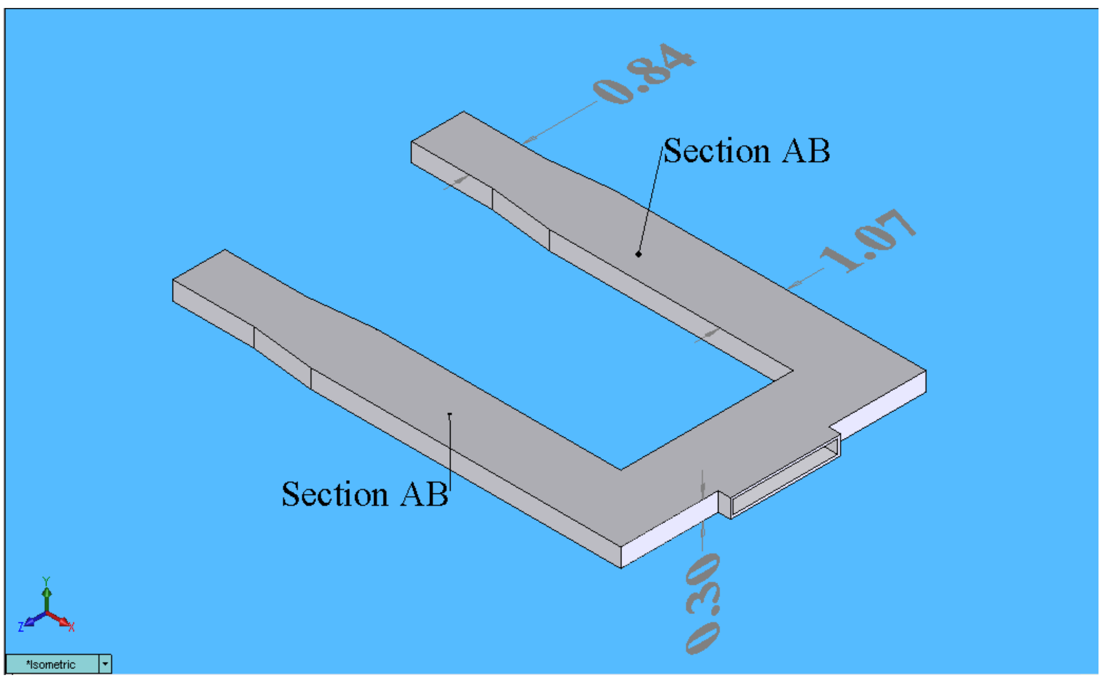


Figure 4.9: Duct for section AB

At the middle of UMP Mosque, there are three ducts. The types of the ducts are doubled duct. The total amount of flow rate for each duct transferred from AHU is 6750 CFM. The duct from AHU is single duct. The capacity of AHU for duct that located at the middle of UMP Mosque is 175.85 kW. The size of the AHU is 1.9 m height, 2.3 m wide and 1.9 m depth. [13] The size of duct that is connected to AHU is 1.78 m wide and 0.30 m depth. The single duct from AHU then doubled become two single duct when enter the conditioned space in UMP Mosque. Thus, each of the single duct from the doubled duct has 3375 CFM. The duct is divided into six sections. Each section has one diffuser. Each diffuser distributes 562.5 CFM. Each section has different velocity and size of duct. The friction loss rate and flow rate effects the duct size. The size of duct and velocity for each section can be determined from graph in **Appendix A11** and **Appendix A12**. Graph in **Appendix A11** is used to find the diameter of round duct. To find the duct size in rectangular shape, graph in **Appendix A12** is used. This graph only can be used if the friction loss rate is same for all section of duct. [3]

Table 4.6: At the middle single duct size

Section	Flow rate, CFM	Velocity, FPM	Friction loss rate	Eq. Diameter, in	Duct Size in rectangular shape, in	Duct Size, m
AB	3375	1300	0.1	23	42 x 12	1.07 x 0.30
BC	2812.5	1200	0.1	21	33 x 12	0.84 x 0.30
CD	2250	1150	0.1	19	26 x 12	0.66 x 0.30
DE	1687.5	1100	0.1	17	20 x12	0.51 x 0.30
EF	1125	1000	0.1	15	16 x 12	0.41 x 0.30
FG	562.5	850	0.1	11	9 x 12	0.23 x 0.30

Table 4.7: Front Single Duct Size

Section	Flow rate, CFM	Velocity, FPM	Friction loss rate	Eq. Diameter, in	Duct Size in rectangular shape, in	Duct Size, m
AB	2250	1150	0.1	19	26 x 12	0.66 x 0.30
BC	1687.5	1100	0.1	17	20 x 12	0.51 x 0.30
CD	1125	1000	0.1	15	16 x 12	0.41 x 0.30
DE	562.5	850	0.1	11	9 x 12	0.23 x 0.30

Table 4.8: Back Single Duct Size

Section	Flow rate, CFM	Velocity, FPM	Friction loss rate	Eq. Diameter, in	Duct Size in rectangular shape, in	Duct Size, m
AB	2250	1150	0.1	19	26 x 12	0.66 x 0.30
BC	1687.5	1100	0.1	17	20 x 12	0.51 x 0.30
CD	1125	1000	0.1	15	16 x 12	0.41 x 0.30
DE	562.5	850	0.1	11	9 x 12	0.23 x 0.30

At the front of UMP Mosque, there is only one duct. The capacity of AHU for front duct is 73.27 kW. The size of the AHU is 1.3 m height, 1.9 m wide and 1.2 m depth. [13] The type of the duct is single duct. The flow rate received from AHU is 2250 CFM. The duct is only divided into four sections.

For at the back duct, there is only one doubled duct. The capacity of AHU for back duct is 102.58 kW. The size of the AHU is 1.6 m height, 2.2 m wide and 1.9 m depth. [13] The flow rate received from AHU is 4500 CFM. The duct then doubled become two single duct. Each single duct has 2250 CFM. There are four sections for back duct.

4.7 LOCATION OF AIR HANDLING UNIT (AHU)

For this project, AHUs will be located in a room. There are two rooms. The rooms are located in front of outside praying area that is at North-West and South-West side. The size of the rooms depends on the size of the AHU. The size of the room on the North-West side is 2 m height, 8 m wide and 2.5 m depth. For South-West side, the room size is 2 m height, 5 m wide and 2.5 m depth. Room at North-West side has three AHUs and room at South-West has two AHUs. **Figure 4.10** and **4.11** below show the proposed location of the rooms.

Figure 4.10: Location of AHU room at South-West side

Figure 4.11: Location of AHU room at North-West side

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In this project, an air conditioning system is designed for UMP Mosque. Both objectives are successfully achieved. The heat gain calculation is done by using CLTD/SCL/CLF method. The heat gain is calculated to determine the total cooling load required to remove the heat in UMP Mosque. The highest heat gain occurs at 4 pm on March 21st.for daily basis However, the highest heat gain actually occurs during Friday Prayer due to high number of occupants. Thus, the time during Friday Prayer is chosen as peak load time.

The second objective which is design a suitable air conditioning system for UMP Mosque is achieved. The air conditioning system is designed based on the highest heat gain calculated. The system chosen for this project is an all air single zone system. The AHU is selected from the models that are available in the market. Ductwork system is also being designed to complete the air conditioning system for the mosque.

5.2 RECOMMENDATION FOR FURTHER WORK

There are several recommendation for further work for this project. For the first recommendation, simulate the diffuser flow using appropriate software such as Cosmos Flow and Fluent software. This process is to ensure that every area in UMP Mosque is equally distributed with conditioned air flow.

For the second recommendation, calculate heat gain in UMP Mosque by using another method. There are many method can be used to calculate the heat gain in building such as the Heat Balance Method(ASHRAE 2001), the Admittance Method, The radiant times series(ASHRAE 2001) and VDI methods (1996). Each method has their advantages and disadvantages.

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APPENDIX A1: Maximum Solar Heat Gain Factor, SHGF (BTU/hr.ft^2)

20° N. Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Ja	29	29	48	138	201	243	253	233	214	232
Fe	31	31	88	173	226	244	238	201	174	263
M	34	49	132	200	237	236	206	152	115	284
Apr.	38	92	166	213	228	208	158	91	58	287
May	47	123	184	217	217	184	124	54	42	283
June	(59)	135	189	216	210	173	108	45	42	279
Jul	48	124	182	213	212	179	119	53	43	278
Au	40	91	162	206	220	200	152	88	57	280
Se	36	46	127	191	225	225	199	148	114	275
Oct.	32	32	87	167	217	236	231	196	170	258
Nov.	29	29	48	136	197	239	249	229	211	230
Dec	27	27	35	122	187	238	254	241	226	217

24° N. Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan	27	27	41	128	190	240	253	241	227	214
Feb	30	30	80	165	220	244	243	213	192	249
Mar	34	45	124	195	234	237	214	168	137	275
Apr.	37	88	159	209	228	212	169	107	75	283
May	43	117	178	214	218	190	132	67	46	282
June	55	127	184	214	212	179	117	55	43	279
July	45	116	176	210	213	185	129	65	46	278
Aug	38	87	156	203	220	204	162	103	72	277
Sep	35	42	119	185	222	225	206	163	134	266
Oct.	31	31	79	159	211	237	235	207	187	244
Nov.	27	27	42	126	187	236	249	237	224	213
Dec	26	26	29	112	180	234	247	247	237	199

28° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	25	25	35	117	183	235	251	247	238	196
Feb.	29	29	72	157	213	244	246	224	207	234
Mar.	33	41	116	189	231	237	221	182	157	265
Apr.	36	84	151	205	228	216	178	124	94	278
May	40	115	172	211	219	195	144	83	58	280
June	51	125	178	211	213	184	128	68	49	278
July	41	114	170	208	215	190	140	80	57	276
Aug.	38	83	149	199	220	207	172	120	91	272
Sep.	34	38	111	179	219	226	213	177	154	256
Oct.	30	30	71	151	204	236	238	217	202	229
Nov.	26	26	35	115	181	232	247	243	235	195
Dec.	24	24	24	99	172	227	248	251	246	179

32° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	24	24	29	105	175	229	249	250	246	176
Feb.	27	27	65	149	205	242	248	232	221	217
Mar.	32	37	107	183	227	237	227	195	176	252
Apr.	36	80	146	200	227	219	187	141	115	271
May	38	111	170	208	220	199	155	99	74	277
June	44	122	176	208	214	189	139	83	60	276
July	40	111	167	204	215	194	150	96	72	273
Aug.	37	79	141	195	219	210	181	136	111	265
Sep.	33	35	103	173	215	227	218	189	171	244
Oct.	28	28	63	143	195	234	239	225	215	213
Nov.	24	24	29	103	173	225	245	246	243	175
Dec.	22	22	22	84	162	218	246	252	252	158

36° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	22	22	24	90	166	219	247	252	252	155
Feb.	26	26	57	139	195	239	248	239	232	199
Mar.	30	33	99	176	223	238	232	206	192	238
Apr.	35	76	144	196	225	221	196	156	135	262
May	38	107	168	204	220	204	165	116	93	272
June	47	118	175	205	215	194	150	99	77	273
July	39	107	165	201	216	199	161	113	90	268
Aug.	36	75	138	190	218	212	189	151	131	257
Sep.	31	31	95	167	210	228	223	200	187	230
Oct.	27	27	56	133	187	230	239	231	225	195
Nov.	22	22	24	87	163	215	243	248	248	154
Dec.	20	20	20	69	151	204	241	253	254	136

40° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	20	20	20	74	154	205	241	252	254	133
Feb.	24	24	50	129	186	234	246	244	241	180
Mar.	29	29	93	169	218	238	236	216	206	223
Apr.	34	71	140	190	224	223	203	170	154	252
May	37	102	165	202	220	208	175	133	113	265
June	48	113	172	205	216	199	161	116	95	267
July	38	102	163	198	216	203	170	129	109	262
Aug.	35	71	135	185	216	214	196	165	149	247
Sep.	30	30	87	160	203	227	226	209	200	215
Oct.	25	25	49	123	180	225	238	236	234	177
Nov.	20	20	20	73	151	201	237	248	250	132
Dec.	18	18	18	60	135	188	232	249	253	113

44° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	17	17	17	64	138	189	232	248	252	109
Feb.	22	22	43	117	178	227	246	248	247	160
Mar.	27	27	87	162	211	236	238	224	218	206
Apr.	33	66	136	185	221	224	210	183	171	240
May	36	96	162	201	219	211	183	148	132	257
June	47	108	169	205	215	203	171	132	115	261
July	37	96	159	198	215	206	179	144	128	254
Aug.	34	66	132	180	214	215	202	177	165	236
Sep.	28	28	80	152	198	226	227	216	211	199
Oct.	23	23	42	111	171	217	237	240	239	157
Nov.	18	18	18	64	135	186	227	244	248	109
Dec.	15	15	15	49	115	175	217	240	246	89

48° N. Lat

	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	15	15	15	53	118	175	216	239	245	85
Feb.	20	20	36	103	168	216	242	249	250	138
Mar.	26	26	80	154	204	234	239	232	228	188
Apr.	31	61	132	180	219	225	215	194	186	226
May	35	97	158	200	218	214	192	163	150	247
June	46	110	165	204	215	206	180	148	134	252
July	37	96	156	196	214	209	187	158	146	244
Aug.	33	61	128	174	211	216	208	188	180	223
Sep.	27	27	72	144	191	223	228	223	220	182
Oct.	21	21	35	96	161	207	233	241	242	136
Nov.	15	15	15	52	115	172	212	234	240	85
Dec.	13	13	13	36	91	156	195	225	233	65

APPENDIX A2: Cooling Load Factor, CLF

Dir.	Room Mass	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
		Solar Time																							
N	L	.00	.00	.00	.00	.01	.64	.73	.74	.81	.88	.95	.98	.98	.94	.88	.79	.79	.55	.31	.12	.04	.02	.01	.00
	M	.03	.02	.02	.02	.02	.64	.69	.69	.77	.84	.91	.94	.95	.91	.86	.79	.79	.56	.32	.16	.10	.07	.05	.04
	H	.10	.09	.08	.07	.07	.62	.64	.64	.71	.77	.83	.87	.88	.85	.81	.75	.76	.55	.34	.22	.17	.15	.13	.11
NE	L	.00	.00	.00	.00	.01	.51	.83	.88	.72	.47	.33	.27	.24	.23	.20	.18	.14	.09	.03	.01	.00	.00	.00	.00
	M	.01	.01	.00	.00	.01	.50	.78	.82	.67	.44	.32	.28	.26	.24	.22	.19	.15	.11	.05	.03	.02	.02	.01	.01
	H	.03	.03	.03	.02	.03	.47	.71	.72	.59	.40	.30	.27	.26	.25	.23	.20	.17	.13	.08	.06	.05	.05	.04	.04
E	L	.00	.00	.00	.00	.00	.42	.76	.91	.90	.75	.51	.30	.22	.18	.16	.13	.11	.07	.02	.01	.00	.00	.00	.00
	M	.01	.01	.00	.00	.01	.41	.72	.86	.84	.71	.48	.30	.24	.21	.18	.16	.13	.09	.04	.03	.02	.01	.01	.01
	H	.03	.03	.03	.02	.02	.39	.66	.76	.74	.63	.43	.29	.24	.22	.20	.18	.15	.12	.08	.06	.05	.05	.04	.04
SE	L	.00	.00	.00	.00	.00	.27	.58	.81	.93	.93	.81	.59	.37	.27	.21	.18	.14	.09	.03	.01	.00	.00	.00	.00
	M	.01	.01	.01	.00	.01	.26	.55	.77	.88	.87	.76	.56	.37	.29	.24	.20	.16	.11	.05	.04	.03	.02	.02	.01
	H	.04	.04	.03	.03	.03	.26	.51	.69	.78	.78	.68	.51	.35	.29	.25	.22	.19	.15	.09	.08	.07	.06	.05	.05
S	L	.00	.00	.00	.00	.00	.07	.15	.23	.39	.62	.82	.94	.93	.80	.59	.38	.26	.16	.06	.02	.01	.00	.00	.00
	M	.01	.01	.01	.01	.01	.07	.14	.22	.38	.59	.78	.88	.88	.76	.57	.38	.28	.18	.09	.06	.04	.03	.02	.02
	H	.05	.05	.04	.04	.03	.09	.15	.21	.35	.54	.70	.79	.79	.69	.52	.37	.29	.21	.13	.10	.09	.08	.07	.06
SW	L	.00	.00	.00	.00	.00	.04	.09	.13	.16	.19	.23	.39	.62	.82	.94	.94	.81	.54	.19	.07	.03	.01	.00	.00
	M	.02	.02	.01	.01	.01	.05	.09	.13	.16	.19	.22	.38	.60	.78	.89	.89	.77	.52	.20	.10	.07	.05	.04	.03
	H	.07	.06	.05	.05	.04	.07	.11	.14	.16	.18	.21	.35	.55	.71	.80	.79	.69	.48	.20	.14	.11	.10	.08	.07
W	L	.00	.00	.00	.00	.00	.03	.07	.10	.13	.15	.16	.18	.31	.55	.78	.92	.93	.73	.25	.10	.04	.01	.01	.00
	M	.02	.02	.01	.01	.01	.04	.07	.10	.13	.14	.16	.17	.30	.53	.74	.87	.88	.69	.24	.12	.07	.05	.04	.03
	H	.06	.06	.05	.04	.04	.06	.09	.11	.13	.15	.16	.17	.28	.49	.67	.78	.79	.62	.23	.14	.11	.09	.08	.07
NW	L	.00	.00	.00	.00	.00	.04	.09	.14	.17	.20	.22	.23	.24	.31	.53	.78	.92	.81	.28	.10	.04	.02	.01	.00
	M	.02	.02	.01	.01	.01	.05	.10	.13	.17	.19	.21	.22	.23	.30	.52	.75	.88	.77	.26	.12	.07	.05	.04	.03
	H	.06	.05	.05	.04	.04	.07	.11	.14	.17	.19	.20	.21	.22	.28	.48	.68	.79	.69	.23	.14	.10	.09	.08	.07
Hor.	L	.00	.00	.00	.00	.00	.08	.25	.45	.64	.80	.91	.97	.97	.91	.80	.64	.44	.23	.08	.03	.01	.00	.00	.00
	M	.02	.02	.01	.01	.01	.08	.24	.43	.60	.75	.86	.92	.92	.87	.77	.63	.45	.26	.12	.07	.05	.04	.03	.02
	H	.07	.06	.05	.05	.04	.11	.25	.41	.56	.68	.77	.83	.83	.80	.71	.59	.44	.28	.17	.13	.11	.10	.09	.08

Values for nominal 15 ft by 15 ft by 10 ft high space, with ceiling, and 50% or less glass in exposed surface at listed orientation.
L = Lightweight construction, such as 1 in. wood floor, Group G wall.
M = Mediumweight construction, such as 2 to 4 in. concrete floor, Group E wall.
H = Heavyweight construction, such as 6 to 8 in. concrete floor, Group C wall.
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APPENDIX A3: Wall Construction Group Description

Group No.	Description of Construction	Weight (lb/ft²)	*U*-Value (BTU/h•ft²•°F)
4-in. Face brick + (brick)			
C	Air space + 4-in. face brick	83	0.358
D	4-in. common brick	90	0.415
C	1-in. insulation or air space + 4-in. common brick	90	0.174–0.301
B	2-in. insulation + 4-in. common brick	88	0.111
B	8-in. common brick	130	0.302
A	Insulation or air space + 8-in. common brick	130	0.154–0.243
4-in. Face brick + (heavyweight concrete)			
C	Air space + 2-in. concrete	94	0.350
B	2-in. insulation + 4-in. concrete	97	0.116
A	Air space or insulation + 8-in. or more concrete	143–190	0.110–0.112
4-in. Face brick + (light or heavyweight concrete block)			
E	4-in. block	62	0.319
D	Air space or insulation + 4-in. block	62	0.153–0.246
D	8-in. block	70	0.274
C	Air space or 1-in. insulation + 6-in. or 8-in. block	73–89	0.221–0.275
B	2-in. insulation + 8-in. block	89	0.096–0.107
4-in. Face brick + (clay tile)			
D	4-in. tile	71	0.381
D	Air space + 4-in. tile	71	0.281
C	Insulation + 4-in. tile	71	0.169
C	8-in. tile	96	0.275
B	Air space or 1-in. insulation + 8-in. tile	96	0.142–0.221
A	2-in. insulation + 8-in. tile	97	0.097
Heavyweight concrete wall + (finish)			
E	4-in. concrete	63	0.585
D	4-in. concrete + 1-in. or 2-in. insulation	63	0.119–0.200
C	2-in. insulation + 4-in. concrete	63	0.119
C	8-in. concrete	109	0.490
B	8-in. concrete + 1-in. or 2-in. insulation	110	0.115–0.187
A	2-in. insulation + 8-in. concrete	110	0.115
B	12-in. concrete	156	0.421
A	12-in. concrete + insulation	156	0.113
Light and heavyweight concrete block + (finish)			
F	4-in. block + air space/insulation	29	0.161–0.263
E	2-in. insulation + 4-in. block	29–37	0.105–0.114
E	8-in. block	47–51	0.294–0.402
D	8-in. block + air space/insulation	41–57	0.149–0.173
Clay tile + (finish)			
F	4-in. tile	39	0.419
F	4-in. tile + air space	39	0.303
E	4-in. tile + 1-in. insulation	39	0.175
D	2-in. insulation + 4-in. tile	40	0.110
D	8-in. tile	63	0.296
C	8-in. tile + air space/1-in. insulation	63	0.151–0.231
B	2-in. insulation + 8-in. tile	63	0.099
Metal curtain wall			
G	With/without air space + 1- to 3-in. insulation	5–6	0.091–0.230
Frame wall			
G	1-in. to 3-in. insulation	16	0.081–0.178

APPENDIX A4: Cooling Load Temperature Different, CLTD for Roof (^oF)

Description of Construction	Weight, lb/ft²	U-value, BTU/h•ft²•°F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	of Maximum CLTD	Minimum CLTD	Maximum CLTD	Difference CLTD
Without Suspended Ceiling																														
Steel sheet with 1-in. (or 2-in.) insulation	7 (8)	0.213 (0.124)	1	−2	−3	−3	−5	−3	6	19	34	49	61	71	78	79	77	70	59	45	30	18	12	8	5	3	14	−5	79	84
1-in. wood with 1-in. insulation	8	0.170	6	3	0	−1	−3	−3	−2	4	14	27	39	52	62	70	74	74	70	62	51	38	28	20	14	9	16	−3	74	77
4-in. lightweight concrete	18	0.213	9	5	2	0	−2	−3	−3	1	9	20	32	44	55	64	70	73	71	66	57	45	34	25	18	13	16	−3	73	76
2-in. heavyweight concrete with 1-in. (or 2-in.) insulation	29 (0.122)	0.206	12	8	5	3	0	−1	−1	3	11	20	30	41	51	59	65	66	66	62	54	45	36	29	22	17	16	−1	67	68
1-in. wood with 2-in. insulation	9	0.109	3	0	−3	−4	−5	−7	−6	−3	5	16	27	39	49	57	63	64	62	57	48	37	26	18	11	7	16	−7	64	71
6-in. lightweight concrete	24	0.158	22	17	13	9	6	3	1	1	3	7	15	23	33	43	51	58	62	64	62	57	50	42	35	28	18	1	64	63
2.5-in. wood with 1-in. ins.	13	0.130	29	24	20	16	13	10	7	6	6	9	13	20	27	34	42	48	53	55	56	54	49	44	39	34	19	6	56	50
8-in. lightweight concrete	31	0.126	35	30	26	22	18	14	11	9	7	7	9	13	19	25	33	39	46	50	53	54	53	49	45	40	20	7	54	47
4-in. heavyweight concrete with 1-in. (or 2-in.) insulation	52 (52)	0.200 (0.120)	25	22	18	15	12	9	8	8	10	14	20	26	33	40	46	50	53	53	52	48	43	38	34	30	18	8	53	45
2.5-in. wood with 2-in. ins.	13	0.093	30	26	23	19	16	13	10	9	8	9	13	17	23	29	36	41	46	49	51	50	47	43	39	35	19	8	51	43
Roof terrace system	75	0.106	34	31	28	25	22	19	16	14	13	13	15	18	22	26	31	36	40	44	45	46	45	43	40	37	20	13	46	33
6-in. heavyweight concrete with 1-in. (or 2-in.) insulation	75 (75)	0.192 (0.117)	31	28	25	22	20	17	15	14	14	16	18	22	26	31	36	40	43	45	45	44	42	40	37	34	19	14	45	31
4-in. wood with 1-in. (or 2-in) insulation	17 (18)	0.106 (0.078)	38	36	33	30	28	25	22	20	18	17	16	17	18	21	24	28	32	36	39	41	43	43	42	40	22	16	43	27

APPENDIX A5: Cooling Load Temperature Different, CLTD for wall (^{o}F)

North Latitude Wall Facing	Solar Time, h 0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Maximum CLTD	Minimum CLTD	Maximum CLTD	Difference CLTD
Group A Walls																												
N	14	14	14	13	13	13	12	12	11	11	10	10	10	10	10	10	11	11	12	12	13	13	14	14	2	10	14	4
NE	19	19	19	18	17	17	16	15	15	15	15	15	16	16	17	18	18	18	19	19	20	20	20	20	22	15	20	5
E	24	24	23	23	22	21	20	19	19	18	19	19	20	21	22	23	24	24	25	25	25	25	25	25	22	18	25	7
SE	24	23	23	22	21	20	20	19	18	18	18	18	18	19	20	21	22	23	23	24	24	24	24	24	22	18	24	6
S	20	20	19	19	18	18	17	16	16	15	14	14	14	14	14	15	16	17	18	19	19	20	20	20	23	14	20	6
SW	25	25	25	24	24	23	22	21	20	19	19	18	17	17	17	17	18	19	20	22	23	24	25	25	24	17	25	8
W	27	27	26	26	25	24	24	23	22	21	20	19	19	18	18	18	18	19	20	22	23	25	26	26	1	18	27	9
NW	21	21	21	20	20	19	19	18	17	16	16	15	15	14	14	14	15	15	16	17	18	19	20	21	1	14	21	7
Group B Walls																												
N	15	14	14	13	12	11	11	10	9	9	9	8	9	9	9	10	11	12	13	14	14	15	15	15	24	8	15	7
NE	19	18	17	16	15	14	13	12	12	13	14	15	16	17	18	19	19	20	20	21	21	21	20	20	21	12	21	9
E	23	22	21	20	18	17	16	15	15	15	17	19	21	22	24	25	26	26	27	27	26	26	25	24	20	15	27	12
SE	23	22	21	20	18	17	16	15	14	14	15	16	18	20	21	23	24	25	26	26	26	26	25	24	21	14	26	12
S	21	20	19	18	17	15	14	13	12	11	11	11	11	12	14	15	17	19	20	21	22	22	22	21	23	11	22	11
SW	27	26	25	24	22	21	19	18	16	15	14	14	13	13	14	15	17	20	22	25	27	28	28	28	24	13	28	15
W	29	28	27	26	24	23	21	19	18	17	16	15	14	14	14	15	17	19	22	25	27	29	29	30	24	14	30	16
NW	23	22	21	20	19	18	17	15	14	13	12	12	12	11	12	12	13	15	17	19	21	22	23	23	24	11	23	9
Group C Walls																												
N	15	14	13	12	11	10	9	8	8	7	7	8	8	9	10	12	13	14	15	16	17	17	17	16	22	7	17	10
NE	19	17	16	14	13	11	10	10	11	13	15	17	19	20	21	22	22	23	23	23	23	22	21	20	20	10	23	13
E	22	21	19	17	15	14	12	12	14	16	19	22	25	27	29	29	30	30	30	29	28	27	26	24	18	12	30	18
SE	22	21	19	17	15	14	12	12	12	13	16	19	22	24	26	28	29	29	29	29	28	27	26	24	19	12	29	17
S	21	19	18	16	15	13	12	10	9	9	9	10	11	14	17	20	22	24	25	26	25	25	24	22	20	9	26	17
SW	29	27	25	22	20	18	16	15	13	12	11	11	11	13	15	18	22	26	29	32	33	33	32	31	22	11	33	22
W	31	29	27	25	22	20	18	16	14	13	12	12	12	13	14	16	20	24	29	32	35	35	35	33	22	12	35	23
NW	25	23	21	20	18	16	14	13	11	10	10	10	10	11	12	13	15	18	22	25	27	27	27	26	22	10	27	17
Group D Walls																												
N	15	13	12	10	9	7	6	6	6	6	6	7	8	10	12	13	15	17	18	19	19	19	18	16	21	6	19	13
NE	17	15	13	11	10	8	7	8	10	14	17	20	22	23	23	24	24	25	25	24	23	22	20	18	19	7	25	18
E	19	17	15	13	11	9	8	9	12	17	22	27	30	32	33	33	32	32	31	30	28	26	24	22	16	8	33	25
SE	20	17	15	13	11	10	8	8	10	13	17	22	26	29	31	32	32	32	31	30	28	26	24	22	17	8	32	24
S	19	17	15	13	11	9	8	7	6	6	7	9	12	16	20	24	27	29	29	29	27	26	24	22	19	6	29	23
SW	28	25	22	19	16	14	12	10	9	8	8	8	10	12	16	21	27	32	36	38	38	37	34	31	21	8	38	30
W	31	27	24	21	18	15	13	11	10	9	9	9	10	11	14	18	24	30	36	40	41	40	38	34	21	9	41	32
NW	25	22	19	17	14	12	10	9	8	7	7	8	9	10	12	14	18	22	27	31	32	32	30	27	22	7	32	25
Group E Walls																												
N	12	10	8	7	5	4	3	4	5	6	7	9	11	13	15	17	19	20	21	23	20	18	16	14	20	3	22	19
NE	13	11	9	7	6	4	5	9	15	20	24	25	25	26	26	26	26	26	25	24	22	19	17	15	16	4	26	22
E	14	12	10	8	6	5	6	11	18	26	33	36	38	37	36	34	33	32	30	28	25	22	20	17	13	5	38	33
SE	15	12	10	8	7	5	5	8	12	19	25	31	35	37	37	36	34	33	31	28	26	23	20	17	15	5	37	32
S	15	12	10	8	7	5	4	3	4	5	9	13	19	24	29	32	34	33	31	29	26	23	20	17	17	3	34	31
SW	22	18	15	12	10	8	6	5	5	6	7	9	12	18	24	32	38	43	45	44	40	35	30	26	19	5	45	40
W	25	21	17	14	11	9	7	6	6	6	7	9	11	14	20	27	36	43	49	49	45	40	34	29	20	6	49	43
NW	20	17	14	11	9	7	6	5	5	5	6	8	10	13	16	20	26	32	37	38	36	32	28	24	20	5	38	33
Group F Walls																												
N	8	6	5	3	2	1	2	4	6	7	9	11	14	17	19	21	22	23	24	23	20	16	13	11	19	1	23	23
NE	9	7	5	3	2	1	5	14	23	28	30	29	28	27	27	27	27	26	24	22	19	16	13	11	11	1	30	29
E	10	7	6	4	3	2	6	17	28	38	44	45	43	39	36	34	32	30	27	24	21	17	15	12	12	2	45	43
SE	10	7	6	4	3	2	4	10	19	28	36	41	43	42	39	36	34	31	28	25	21	18	15	12	13	2	43	41
S	10	8	6	4	3	2	1	1	3	7	13	20	27	34	38	39	38	35	31	26	22	18	15	12	16	1	39	38
SW	15	11	9	6	5	3	2	2	4	5	8	11	17	26	35	44	50	53	52	45	37	28	23	18	18	2	53	48
W	17	13	10	7	5	4	3	3	4	6	8	11	14	20	28	39	49	57	60	54	43	34	27	21	19	3	60	57
NW	14	10	8	6	4	3	2	2	3	5	8	10	13	15	21	27	35	42	46	43	35	28	22	18	19	2	46	44
Group G Walls																												
N	3	2	1	0	−1	2	7	8	9	12	15	18	21	23	24	24	25	26	22	15	11	9	7	5	18	−1	26	27
NE	3	2	1	0	−1	9	27	36	39	35	30	26	26	27	27	26	25	22	18	14	11	9	7	5	9	−1	39	40
E	4	2	1	0	−1	11	31	47	54	55	50	40	33	31	30	29	27	24	19	15	12	10	8	6	10	−1	55	56
SE	4	2	1	0	−1	5	18	32	42	49	51	48	42	36	32	30	27	24	19	15	12	10	8	6	11	−1	51	52
S	4	2	1	0	−1	0	1	5	12	22	31	39	45	46	43	37	31	25	20	15	12	10	8	5	14	−1	46	47
SW	5	4	3	1	0	0	2	5	8	12	16	26	38	50	59	63	61	52	37	24	17	13	10	8	16	0	63	63
W	6	5	3	2	1	1	2	5	8	11	15	19	27	41	56	67	72	67	48	29	20	15	11	8	17	1	72	71
NW	5	3	2	1	0	0	2	5	8	11	15	18	21	27	37	47	55	55	41	25	17	13	10	7	18	0	55	55

APPENDIX A6: Cooling Load Temperature Different, CLTD for Glass (^oF)

Solar time, h	CLTD °F	Solar time, h	CLTD °F
0100	1	1300	12
0200	0	1400	13
0300	−1	1500	14
0400	−2	1600	14
0500	−2	1700	13
0600	−2	1800	12
0700	−2	1900	10
0800	0	2000	8
0900	2	2100	6
1000	4	2200	4
1100	7	2300	3
1200	9	2400	2

APPENDIX A7: CLTD Correction for Latitude and Month, LM (^oF)

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	HOR
0	Dec	−3	−5	−5	−5	−2	0	3	6	9	−1
	Jan/Nov	−3	−5	−4	−4	−1	0	2	4	7	−1
	Feb/Oct	−3	−2	−2	−2	−1	−1	0	−1	0	0
	Mar/Sept	−3	0	1	−1	−1	−3	−3	−5	−8	0
	Apr/Aug	5	4	3	0	−2	−5	−6	−8	−8	−2
	May/Jul	10	7	5	0	−3	−7	−8	−9	−8	−4
	Jun	12	9	5	0	−3	−7	−9	−10	−8	−5
8	Dec	−4	−6	−6	−6	−3	0	4	8	12	[illegible]
	Jan/Nov	−3	−5	−6	−5	−2	0	3	6	10	−4
	Feb/Oct	−3	−4	−3	−3	−1	−1	1	2	4	−1
	Mar/Sept	−3	−2	−1	−1	−1	−2	−2	−3	−4	0
	Apr/Aug	2	2	2	0	−1	−4	−5	−7	−7	−1
	May/Jul	7	5	4	0	−2	−5	−7	−9	−7	−2
	Jun	9	6	4	0	−2	−6	−8	−9	−7	−2
16	Dec	−4	−6	−8	−8	−4	−1	4	9	13	−9
	Jan/Nov	−4	−6	−7	−7	−4	−1	4	8	12	−7
	Feb/Oct	−3	−5	−5	−4	−2	0	2	5	7	−4
	Mar/Sept	−3	−3	−2	−2	−1	−1	0	0	0	−1
	Apr/Aug	−1	0	−1	−1	−1	−3	−3	−5	−6	0
	May/Jul	4	3	3	0	−1	−4	−5	−7	−7	0
	Jun	6	4	4	1	−1	-4	−6	−8	0	−7
24	Dec	−5	−7	−9	−10	−7	−3	3	9	13	−13
	Jan/Nov	−4	−6	−8	−9	−6	−3	9	3	13	−11
	Feb/Oct	−4	−5	−6	−6	−3	−1	3	7	10	−7
	Mar/Sept	−3	−4	−3	−3	−1	−1	1	2	4	−3
	Apr/Aug	−2	−1	0	−1	−1	−2	−1	−2	−3	0
	May/Jul	1	2	2	0	0	−3	−3	−5	−6	1
	Jun	3	3	3	1	0	−3	−4	−6	−6	1
32	Dec	−5	−7	−10	−11	−8	−5	2	9	12	−17
	Jan/Nov	−5	−7	−9	−11	−8	−15	−4	2	9	12
	Feb/Oct	−4	−6	−7	−8	−4	−2	4	8	11	−10
	Mar/Sept	−3	−4	−4	−4	−2	−1	3	5	7	−5
	Apr/Aug	−2	−2	−1	−2	0	−1	0	1	1	−1
	May/Jul	1	1	1	0	0	−1	−1	−3	−3	1
	Jun	1	2	2	1	0	−2	−2	−4	−4	2
40	Dec	−6	−8	−10	−13	−10	−7	0	7	10	−21
	Jan/Nov	−5	−7	−10	−12	−9	−6	1	8	11	−19
	Feb/Oct	−5	−7	−8	−9	−6	−3	3	8	12	−14
	Mar/Sept	−4	−5	−5	−6	−3	−1	4	7	10	−8
	Apr/Aug	−2	−3	−2	−2	0	0	2	3	4	−3
	May/Jul	0	0	0	0	0	0	0	0	1	1
	Jun	1	1	1	0	1	0	0	−1	−1	2
48	Dec	−6	−8	−11	−14	−13	−10	−3	2	6	−25
	Jan/Nov	−6	−8	−11	−13	−11	−8	−1	5	8	−24
	Feb/Oct	−5	−7	−10	−11	−8	−5	1	8	11	−18
	Mar/Sept	−4	−6	−6	−7	−4	−1	4	8	11	−11
	Apr/Aug	−3	−3	−3	−3	−1	0	4	6	7	−5
	May/Jul	0	−1	0	0	1	1	3	3	4	0
	Jun	1	1	2	1	2	1	2	2	3	2

APPENDIX A8: Rates of Heat Gain from Occupants

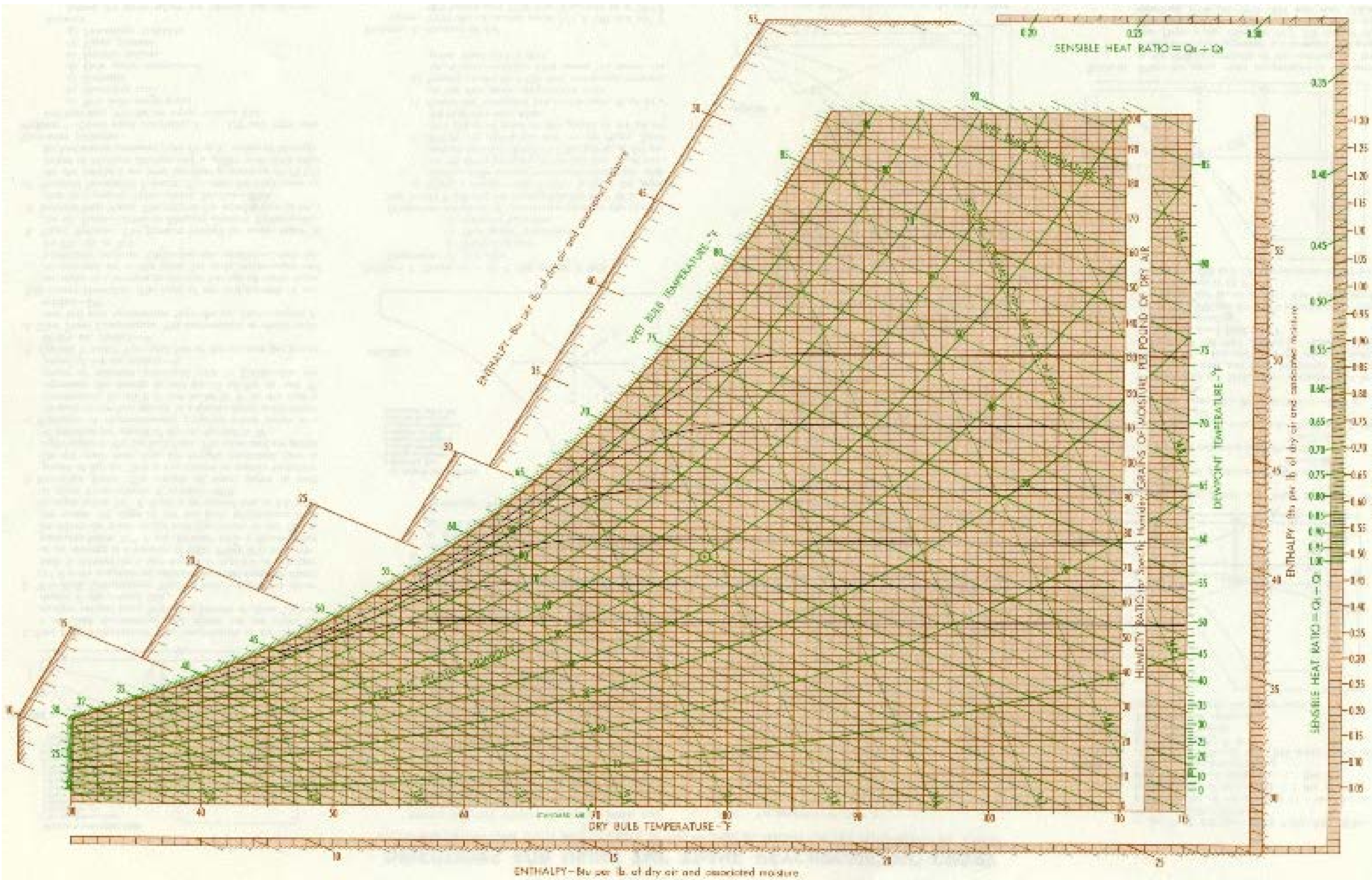
Degree of Activity	Typical Applications	Total Heat Adults, Male, Btu/h	Total Heat Adjusted,[d] Btu/h	Sensible Heat, Btu/h	Latent Heat Btu/h
Seated at theater	Theater—Matinee	390	330	225	105
Seated at theater	Theater—Evening	390	350	245	105
Seated, very light work	Offices, hotels, apartments	450	400	245	155
Moderately active office work	Offices, hotels, apartments	475	450	250	200
Standing, light work; walking	Department store, retail store	550	450	250	200
Walking; standing	Drug store, bank	550	500	250	250
Sedentary work	Restaurant[e]	490	550	275	275
Light bench work	Factory	800	750	275	475
Moderate dancing	Dance hall	900	850	305	545
Walking 3 mph; light machine work	Factory	1000	1000	375	625
Bowling[f]	Bowling alley	1500	1450	580	870
Heavy work	Factory	1500	1450	580	870
Heavy machine work; lifting	Factory	1600	1600	635	965
Athletics	Gymnasium	2000	1800	710	1090

APPENDIX A9: Recommended Rate of Heat Gain for Equipment, (BTU/hr)

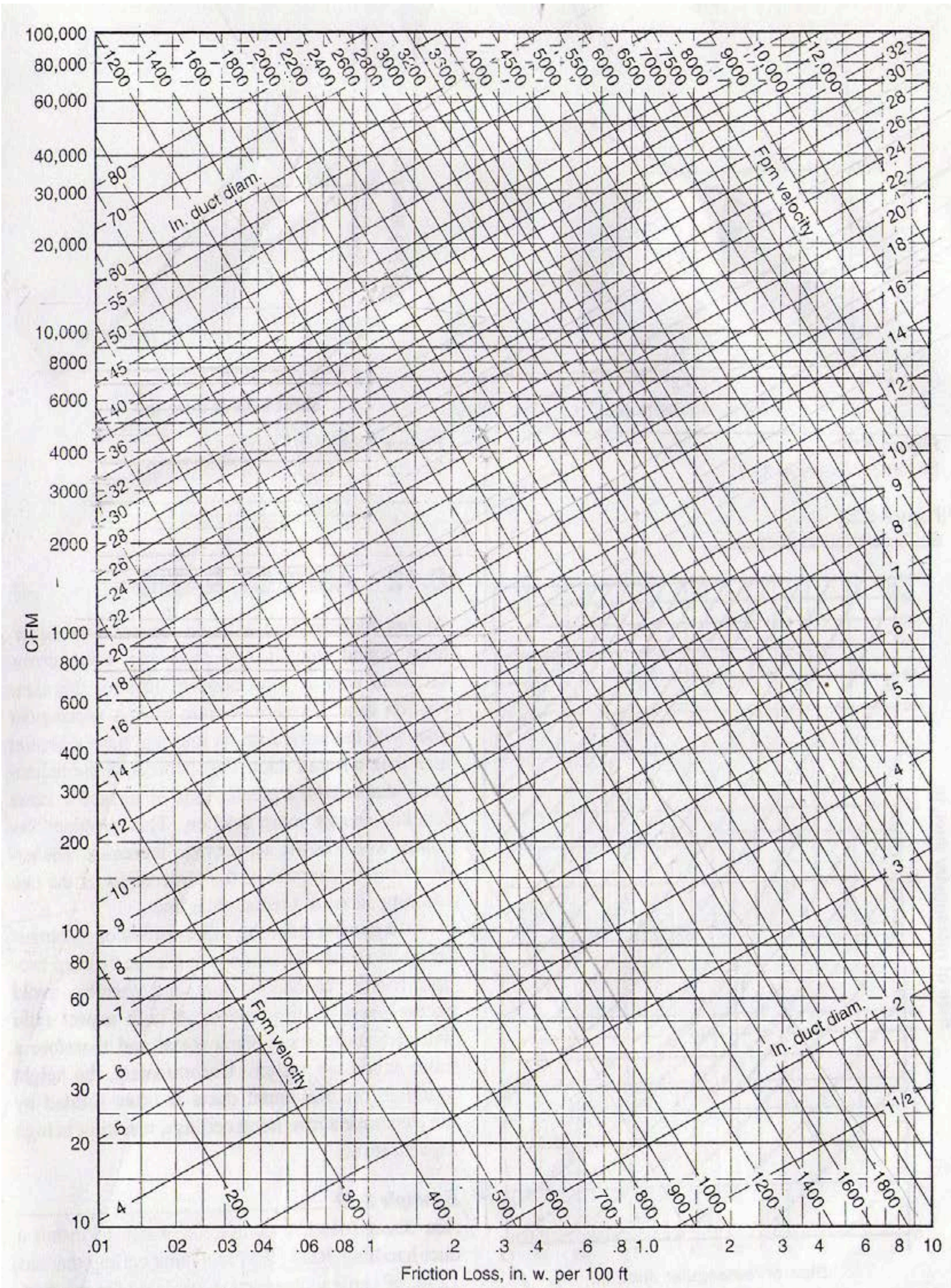
Appliance	Size	Recommended Rate of Heat Gain, BTU/hr			
		Without Hood			With Hood
		Sens.	Latent	Total	Sensible
Restaurant, electric blender, per quart of capacity	1 to 4 qt	1000	520	1520	480
Coffee brewer	12 cups/2 brnrs	3750	1910	5660	1810
Coffee heater, per warming burner	1 to 2 brnrs	230	110	340	110
Display case (refrigerated), per ft^3 of interior	6 to 67 ft^3	62	0	62	0
Hot plate (high-speed double burner)		7810	5430	13,240	6240
Ice maker (large)	220 lb/day	9320	0	9320	0
Microwave oven (heavy-duty commercial)	0.7 ft^3	8970	0	8970	0
Toaster (large pop-up)	10 slice	9590	8500	18,080	5800

Appliance	Size		Recommended Rate of Heat Gain, BTU/hr
Computer Devices			
Communication/transmission			5600–9600
Disk drives/mass storage			3400–22,400
Microcomputer/word processor	16–640 kbytes		300–1800
Minicomputer			7500–15,000
Printer (laser)	8 pages/min		1000
Printer (line, high-speed)	5000 or more pages/min		2500–13,000
Tape drives			3500–15,000
Terminal			270–600
Copiers/Typesetters			
Blue print			3900–42,700
Copiers (large)	30–67 copies/min		1700–6600
Copiers	6–30 copies/min		460–1700
Miscellaneous			
Cash register			160
Cold food/beverage			1960–3280
Coffee maker	10 cup	sensible	3580
		latent	1540
Microwave oven	1 ft^3		1360
Paper shredder			680–8250
Water cooler	8 gal/hr		6000

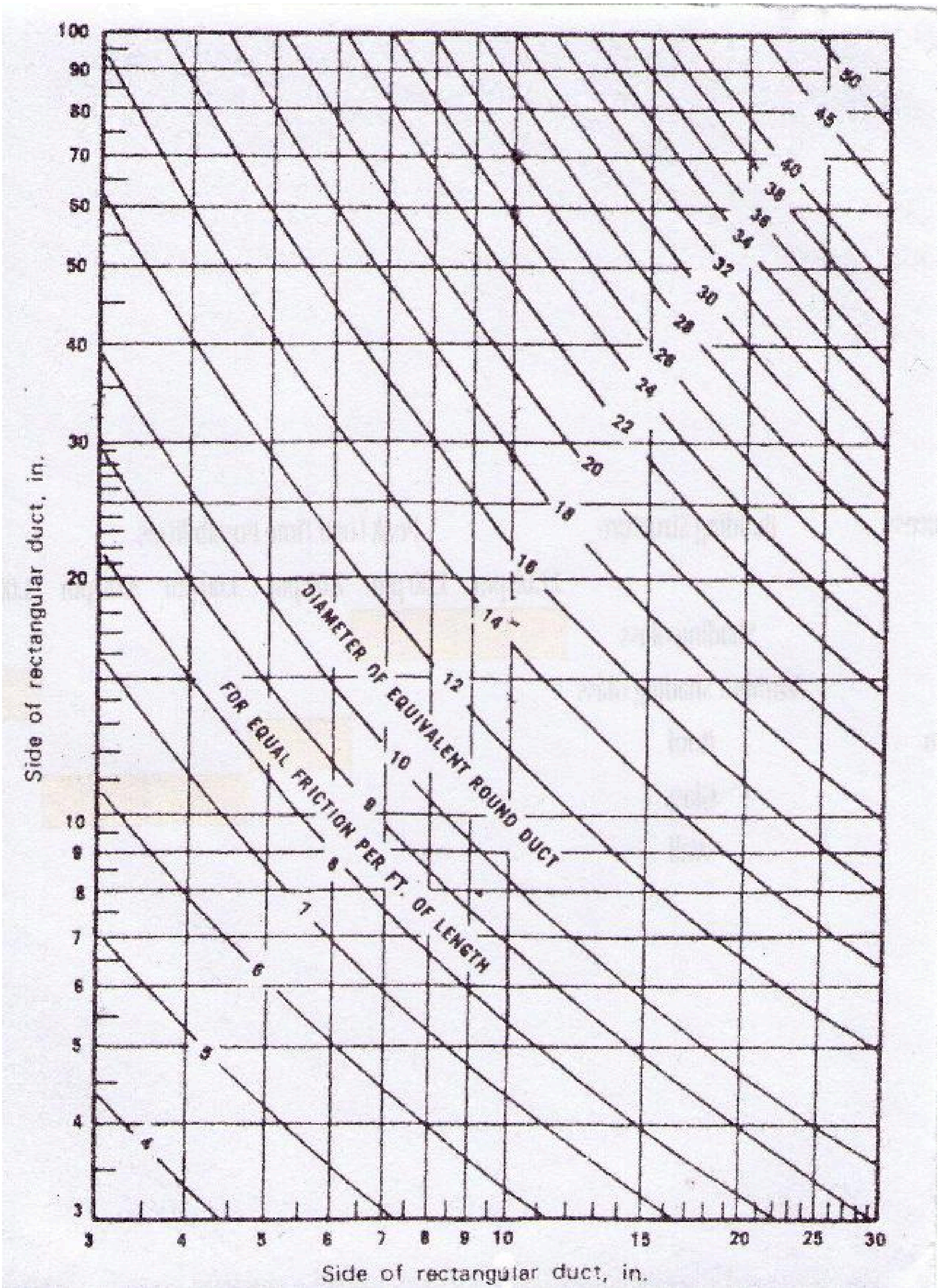
APPENDIX A10: Psycometric Chart



APPENDIX A11: Chart Used To Determine the Size of Round Duct



APPENDIX A12: Chart Used To Determine the Size of Rectangular Duct



APPENDIX B1: Total Cooling Load Required at 12.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	5	5.85	5556.15
Wall		N		0.324		121.24	5	4.18	164.20
		S				123.27	7.2	4.72	188.51
		W				225.45	5	5.29	386.41
		E				152.69	20	20.29	1003.78
Roof		Hor		0.617		1128	39.44	40.29	28040.87
Door		North		0.9		4.75	3.89	3.07	13.12
		South				3.39	5	2.52	7.69

Solar	Direction	SHGF	A ,m²	SC	CLF	
Glass w shading	N	107.23	30.42	0.94	0.94	2882.25
	S	107.23	28.39	0.94	0.88	2518.21
Glass w/o shading	W	747.46	45.67	0.94	0.17	5455.01
Green Glass	N	107.23	14	0.5	0.94	705.57
	S	362.7	14	0.5	0.88	2234.23
	W	747.46	16.2	0.5	0.17	1029.25
	E	747.46	6.6	0.5	0.3	739.99

Subtotal 50925.26

				SCL,W	LCL,W	
People	SHG	n	CLF			
	73.27	5	1	366.35		
	LHG	n				
	58.62	5			293.1	
Equipment						
		q	n			
Computer		996.48	2	1992.96		
Subtotal				53284.57	293.1	
SA duct Gain	5%			2664.22		
SA fan gain (draw through)	5%			2664.22		Total CL W
Building Cooling Load				58613.01	293.1	58906.11

Ventilation		CFM	TC	gr/lb	n	Btu/hr		Watt	
	1.1	15	50.54		5	4169.55		1221.68	
	0.68	15		54	5		2754		806.92

RA Fan gain	2.50%	1465.33		
Cooling Coil Load		61300.02	1100.02	62400.04

Total Cooling Load (kW) 62.40

APPENDIX B2: Total Cooling Load Required at 1.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	6.67	7.52	7142.27
Wall		N		0.324		121.24	6.1	5.28	207.41
		S				123.27	10.6	8.12	324.31
		W				225.45	6.1	6.39	466.76
		E				152.69	21.1	21.39	1058.20
Roof		Hor		0.617		1128	43.33	44.18	30748.22
Door		North		0.9		4.75	4.44	3.62	15.48
		South				3.39	6.67	4.19	12.78

Solar	Direction	SHGF	A ,m²	SC	CLF	
Glass w shading	N	107.23	30.42	0.94	0.95	2912.91
	S	107.23	28.39	0.94	0.88	2518.21
Glass w/o shading	W	747.46	45.67	0.94	0.3	9626.49
Green Glass	N	107.23	14	0.5	0.95	713.08
	S	362.7	14	0.5	0.88	2234.23
	W	747.46	16.2	0.5	0.3	1816.33
	E	747.46	6.6	0.5	0.24	591.99

Subtotal 60388.67

	SHG	n	CLF	SCL,W	LCL,W
People	73.27	150	1	10990.5	
	LHG	n			
	58.62	150			8793

Equipment

	q	n	
Computer	996.48	2	1992.96

Subtotal 73372.13 | 8793

SA duct Gain 5% 3668.61

SA fan gain (draw through) 5% 3668.61

			Total CL W
Building Cooling Load	80709.35	8793	89502.35

Ventilation		CFM	TC	gr/lb	n	Btu/Hr		Watt	
	1.1	15	50.54		150	125086.5		36650.35	
	0.68	15		54	150		82620		24207.66

RA Fan gain 2.50% 2017.73

Cooling Coil Load	119377.43	33000.66	152378.09

Total Cooling Load(kW) 152.38

APPENDIX B3: Total Cooling Load Required at 2.00 PM

Conduction	Direction	U (W/m2. °C)	A,m² Net	CLTD,°C Table	CLTD,°C Corrected	SCL,W
Glass		6.1	155.7	7.22	8.07	7664.64
Wall	N	0.324	121.24	7.2	6.38	250.62
	S		123.27	13.3	10.82	432.15
	W		225.45	7.8	8.09	590.94
	E		152.69	20.6	20.89	1033.46
Roof	Hor	0.617	1128	43.89	44.74	31137.97
Door	North	0.9	4.75	5.56	4.74	20.26
	South		3.39	8.89	6.41	19.56

Solar	Direction	SHGF	A ,m²	SC	CLF	SCL,W
Glass w shading	N	107.23	30.42	0.94	0.91	2790.26
	S	107.23	28.39	0.94	0.76	2174.82
Glass w/o shading	W	747.46	45.67	0.94	0.53	17006.80
Green Glass	N	107.23	14	0.5	0.91	683.06
	S	362.7	14	0.5	0.76	1929.56
	W	747.46	16.2	0.5	0.53	3208.85
	E	747.46	6.6	0.5	0.21	517.99
Subtotal						69460.93

				SCL,W	LCL,W	
People	SHG: 73.27	n: 5	CLF: 1	366.35		
	LHG: 58.62	n: 5			293.1	
Equipment						
Computer	q: 996.48	n: 2		1992.96		
Subtotal				71820.24	293.1	
SA duct Gain	5%			3591.01		
SA fan gain (draw through)	5%			3591.01		Total CL W
Building Cooling Load				79002.26	293.1	79295.36

Ventilation		CFM	TC	gr/Ib	n	Btu/hr		Watt	
	1.1	15	50.54		5	4169.55		1221.68	
	0.68	15		54	5		2754		806.92

RA Fan gain	2.50%	1975.06		
Cooling Coil Load		82199.00	1100.02	83299.02
Total Cooling Load(kW)				83.30

APPENDIX B4: Total Cooling Load Required at 3.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	7.78	8.63	8196.52
Wall		N		0.324		121.24	8.3	7.48	293.83
		S				123.27	16.1	13.62	543.98
		W				225.45	11.1	11.39	831.99
		E				152.69	20	20.29	1003.78
Roof		Hor		0.617		1128	42.78	43.63	30365.43
Door		North		0.9		4.75	6.67	5.85	25.01
		South				3.39	11.11	8.63	26.33

Solar	Direction	SHGF	A ,m²	SC	CLF	SCL,W
Glass w shading	N	107.23	30.42	0.94	0.86	2636.95
	S	107.23	28.39	0.94	0.57	1631.11
Glass w/o shading	W	747.46	45.67	0.94	0.74	23745.35
Green Glass	N	107.23	14	0.5	0.86	645.52
	S	362.7	14	0.5	0.57	1447.17
	W	747.46	16.2	0.5	0.74	4480.28
	E	747.46	6.6	0.5	0.18	443.99

Subtotal 76317.24

					SCL,W	LCL,W
People	SHG	n	CLF			
	73.27	5	1		366.35	
	LHG	n				
	58.62	5				293.1
Equipment						
			q	n		
Computer			996.48	2	1992.96	
				Subtotal	78676.55	293.1
SA duct Gain	5%				3933.83	
SA fan gain (draw through)	5%				3933.83	

			Total CL W
Building Cooling Load	86544.21	293.1	86837.31

Ventilation		CFM	TC	gr/lb	n
	1.1	15	50.54		5
	0.68	15		54	5

	Btu/hr		Watt	
	4169.55		1221.68	
		2754		806.92

RA Fan gain 2.50% 2163.61

Cooling Coil Load	89929.50	1100.02	91029.52

Total Cooling Load (kW) 91.03

APPENDIX B5: Total Cooling Load Required at 4.00 PM

Conduction	Direction	U (W/m2. °C)	A,m² Net	CLTD,°C Table	CLTD,°C Corrected	SCL,W
Glass		6.1	155.7	7.78	8.63	8196.52
Wall	N	0.324	121.24	9.4	8.58	337.04
	S		123.27	17.8	15.32	611.87
	W		225.45	15	15.29	1116.87
	E		152.69	18.9	19.19	949.36
Roof	Hor	0.617	1128	38.89	39.74	27658.09
Door	North	0.9	4.75	7.22	6.4	27.36
	South		3.39	13.33	10.85	33.10

Solar	Direction	SHGF	A ,m²	SC	CLF	SCL,W
Glass w shading	N	107.23	30.42	0.94	0.79	2422.31
	S	107.23	28.39	0.94	0.38	1087.41
Glass w/o shading	W	747.46	45.67	0.94	0.87	27916.83
Green Glass	N	107.23	14	0.5	0.79	592.98
	S	362.7	14	0.5	0.38	964.78
	W	747.46	16.2	0.5	0.87	5267.35
	E	747.46	6.6	0.5	0.16	394.66

Subtotal 77576.53

				SCL,W	LCL,W	Total CL W
People	SHG 73.27	n 150	CLF 1	10990.5		
	LHG 58.62	n 150			8793	
Equipment						
Computer	q 996.48	n 2		1992.96		
Subtotal				90559.99	8793	
SA duct Gain	5%			4527.99		
SA fan gain (draw through)	5%			4527.99		
Building Cooling Load				99615.97	8793	108408.97

Ventilation		CFM	TC	gr/lb	n	Btu/Hr		Watt	
	1.1	15	50.54		150	125086.5		36650.35	
	0.68	15		54	150		82620		24207.66

RA Fan gain	2.50%	2490.39		
Cooling Coil Load		138756.71	33000.66	171757.37

Total Cooling Load (kW) 171.76

APPENDIX B6: Total Cooling Load Required at 5.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	7.22	8.07	7664.64
Wall		N		0.324		121.24	10.6	9.78	384.18
		S				123.27	18.9	16.42	655.81
		W				225.45	20	20.29	1482.10
		E				152.69	18.3	18.59	919.68
Roof		Hor		0.617		1128	32.78	33.63	23405.67
Door		North		0.9		4.75	8.33	7.51	32.11
		South				3.39	15	12.52	38.20

Solar	Direction	SHGF	A ,m²	SC	CLF	SCL,W
Glass w shading	N	107.23	30.42	0.94	0.79	2422.31
	S	107.23	28.39	0.94	0.28	801.25
Glass w/o shading	W	747.46	45.67	0.94	0.88	28237.71
Green Glass	N	107.23	14	0.5	0.79	592.98
	S	362.7	14	0.5	0.28	710.89
	W	747.46	16.2	0.5	0.88	5327.89
	E	747.46	6.6	0.5	0.13	320.66
					Subtotal	72996.08

					SCL,W	LCL,W
People	SHG	n	CLF			
	73.27	5	1		366.35	
	LHG	n				
	58.62	5				293.1
Equipment						
			q	n		
Computer			996.48	2	1992.96	
				Subtotal	75355.39	293.1
SA duct Gain	5%				3767.77	
SA fan gain (draw through)	5%				3767.77	

				Total CL W
Building Cooling Load		82890.93	293.1	83184.03

Ventilation		CFM	TC	gr/lb	n	Btu/hr		Watt	
	1.1	15	50.54		5	4169.55		1221.68	
	0.68	15		54	5		2754		806.92

RA Fan gain	2.50%	2072.27		
Cooling Coil Load		86184.88	1100.02	87284.90
Total Cooling Load (kW)				87.28

APPENDIX B7: Total Cooling Load Required at 6.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	6.67	7.52	7142.27
Wall		N		0.324		121.24	11.1	10.28	403.82
		S				123.27	18.3	15.82	631.84
		W				225.45	23.89	24.18	1766.25
		E				152.69	17.78	18.07	893.95
Roof		Hor		0.617		1128	25	25.85	17990.98
Door		North		0.9		4.75	9.44	8.62	36.85
		South				3.39	16.1	13.62	41.55

Solar	Direction	SHGF	A ,m²	SC	CLF	
Glass w shading	N	107.23	30.42	0.94	0.56	1717.08
	S	107.23	28.39	0.94	0.18	515.09
Glass w/o shading	W	747.46	45.67	0.94	0.69	22140.93
Green Glass	N	107.23	14	0.5	0.56	420.34
	S	362.7	14	0.5	0.18	457.00
	W	747.46	16.2	0.5	0.69	4177.55
	E	747.46	6.6	0.5	0.09	222.00

Subtotal 58557.51

	SHG	n	CLF	SCL,W	LCL,W
People	73.27	5	1	366.35	
	LHG	n			
	58.62	5			293.1

Equipment

	q	n	
Computer	996.48	2	1992.96

Subtotal 60916.82 293.1

SA duct Gain 5% 3045.84

SA fan gain (draw through) 5% 3045.84

	SCL,W	LCL,W	Total CL W
Building Cooling Load	67008.50	293.1	67301.60

Ventilation		CFM	TC	gr/lb	n	Btu/hr		Watt	
	1.1	15	50.54		5	4169.55		1221.68	
	0.68	15		54	5		2754		806.92

RA Fan gain 2.50% 1675.21

Cooling Coil Load	69905.39	1100.02	71005.41

Total Cooling Load (kW) 71.01

APPENDIX B8: Total Cooling Load Required at 7.00 PM

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	5.56	6.41	6088.03
Wall		N		0.324		121.24	11.6	10.78	423.46
		S				123.27	17.2	14.72	587.91
		W				225.45	27.2	27.49	2008.03
		E				152.69	16.7	16.99	840.52
Roof		Hor		0.617		1128	16.67	17.52	12193.50
Door		North		0.9		4.75	10	9.18	39.24
		South				3.39	16.1	13.62	41.55

Solar	Direction	SHGF	A ,m²	SC	CLF	SCL,W
Glass w shading	N	107.23	30.42	0.94	0.32	981.19
	S	107.23	28.39	0.94	0.09	257.54
Glass w/o shading	W	747.46	45.67	0.94	0.24	7701.19
Green Glass	N	107.23	14	0.5	0.32	240.20
	S	362.7	14	0.5	0.09	228.50
	W	747.46	16.2	0.5	0.24	1453.06
	E	747.46	6.6	0.5	0.04	98.66

Subtotal 33182.59

	SHG	n	CLF	SCL,W	LCL,W
People	73.27	150	1	10990.5	
	LHG	n			
	58.62	150			8793

Equipment

	q	n	SCL,W
Computer	996.48	2	1992.96

Subtotal 46166.05 | 8793

SA duct Gain 5% — 2308.3

SA fan gain (draw through) 5% — 2308.3

	SCL,W	LCL,W	Total CL W
Building Cooling Load	50782.65	8793	59575.65

Ventilation		CFM	TC	gr/lb	n
	1.1	15	50.54		150
	0.68	15		54	150

Btu/Hr		Watt	
125086.5		36650.35	
	82620		24207.66

RA Fan gain 2.50% — 1269.57

Cooling Coil Load	88702.57	33000.66	121703.23

Total Cooling Load (kW) 121.70

APPENDIX B9: Total Cooling Load Required at 1.00 PM on Friday

Conduction		Direction		U (W/m2. °C)		A,m²	CLTD,°C		SCL,W
						Net	Table	Corrected	
Glass				6.1		155.7	6.67	7.52	7142.27
Wall		N		0.324		121.24	6.1	5.28	207.41
		S				123.27	10.6	8.12	324.31
		W				225.45	6.1	6.39	466.76
		E				152.69	21.1	21.39	1058.20
Roof		Hor		0.617		1128	43.33	44.18	30748.22
Door		North		0.9		4.75	4.44	3.62	15.48
		South				3.39	6.67	4.19	12.78

Solar	Direction	SHGF	A ,m²	SC	CLF	
Glass w shading	N	107.23	30.42	0.94	0.95	2912.91
	S	107.23	28.39	0.94	0.88	2518.21
Glass w/o shading	W	747.46	45.67	0.94	0.3	9626.49
Green Glass	N	107.23	14	0.5	0.95	713.08
	S	362.7	14	0.5	0.88	2234.23
	W	747.46	16.2	0.5	0.3	1816.33
	E	747.46	6.6	0.5	0.24	591.99
					Subtotal	60388.67

					SCL,W	LCL,W	Total CL W
People	SHG	n	CLF				
	73.27	1300	1		95251		
	LHG	n					
	58.62	1300				76206	
Equipment			q	n			
Computer			996.48	2	1992.96		
Subtotal					157632.63	76206	
SA duct Gain	5%				7881.63		
SA fan gain (draw through)	5%				7881.63		
Building Cooling Load					173395.89	76206	249601.89

Ventilation		CFM	TC	gr/lb	n	Btu/hr		Watt	
	1.1	15	50.54		1300	1084083		317636.32	
	0.68	15		54	1300		716040		209799.72

RA Fan gain	2.50%	4334.9		
Cooling Coil Load		495367.11	286005.72	781372.83
Total Cooling Load (kW)				781.37

APPENDIX C1: FYP 1 Gantt Chart

No.	Work Done (Week)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Understand the procedure to drive the project	■	■	■													
2	Search project utility (internet, books, thesis)		■	■	■	■	■	■	■	■	■	■					
3	Completing chapter 1			■	■	■	■										
4	Submit draft of chapter 1				■	■	■	■									
5	Completing chapter 2							■	■	■	■						
6	Submit draft of chapter 2								■	■	■	■					
7	Completing chapter 3											■	■	■			
8	Submit overall draft (chapter 1, 2 and 3)											■	■	■	■		
9	Submit proposal of the project to the panels														■		
10	Preparing slide presentation														■		
11	Presentation FYP 1															■	
12	Completing FYP 1 full report															■	■
13	Submit FYP 1 full report																■

■ - Work Progress

APPENDIX C2: FYP 2 Gantt Chart

No.	Work Done (Week)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Determines the U-value for all structures																
2	Calculating the heat gains																
3	Analysis from heat gains																
4	Designing ductwork																
5	Calculating the size of duct																
6	Finding the suitable AHU																
7	Choose the location of AHU rooms																
8	Completing chapter 4																
9	Submit draft of chapter 4																
10	Completing chapter 5																
11	Presentation FYP 2																
12	Completing FYP 2 full report																
13	Submit FYP 2 full report																

- Work Progress