Prediction of Cooling Load of a Glazed Building under Malaysia Weather Conditions

By

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Dissertation submitted in partial fulfilment of
the requirements for the
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Universiti Teknologi PETRONAS,
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Perak

CERTIFICATEION OF APPROVAL

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Approved by,

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January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Omar Ahmed Salem Basyoal

ABSTRACT

Air conditioning systems in the buildings are essential for the occupants comfort. Good estimation of the cooling load result in a better design of the HVAC system. Moreover, direct solar radiation into the office for buildings that face the east affects the occupants comfort leading to less productivity and might cause illness. This project is aimed to predict the cooling load for a glazed building (Block 16, lecturers' offices at UTP) under Malaysia weather conditions using cooling load temperature difference (CLTD) method and Hourly Analysis Program. Cooling capacity estimations undertake many variables in order to have optimum air conditioning unit and satisfy the occupant's needs. Some of these parameters are occupant gains, gains of heat via infiltration, lightening and ventilation and gains through windows and doors. The cooling load results have been compared against the cooling capacity of the system. The project studied the effect of tinted film on glazed wall and the temperature set point. The results show that there is 17.8% overdesign on the cooling capacity of the air handling unit compared to Hourly Analysis Program results. While 20% overdesign on the supplied cooling load compared to CLTD method results. There is great effect of temperature set point on the cooling load. Increasing just one degree Celsius from 24ºC to 25ºC can decrease the cooling load by 7.23% of the current one. A tinted film which decrease the heat transfer coefficient by 30% can cause reducing the cooling load of the space by 3.36%.

ACKNOWLEDGEMENT

First and foremost, I would like to thank my Almighty Allah who blessed me with life and guided me to the knowledge path and made easy for me. It is my great honor to express my appreciation and gratitude to my supervisor Dr. Aklilu Tesfamichael Baheta for his assistance, encouragement, assistance and guidance in my research and related issues. I am highly appreciate his earnest opinion and help in matters concerning this project.

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Lastly, I would like to express my love and sincere thankfulness to my dear parents who sacrifice everything for me and their continuous supplications. My deepest heart gratitude goes to my siblings and their families. I dedicate this work to them and I highly appreciate their encouragement and endless support and advice.

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NOMENCLATURE

CLTD	**Cooling Load Temperature Difference**
HAP	**Hourly Analysis Program**
ASHRAE	**American Society for Heating, Refrigeration and Airconditioning Engineers**
HVAC	**Heating, Ventilation and Air Conditioning**
UTP	**Universiti Teknologi PETRONAS**
AHU	**Air Handling Unit**
BTU	**British Thermal Unit**
DB	**Dry Bulb**
WB	**Wet Bulb**
RH	**Relative Humidity**
Δ	**Delta (difference)**
U	**Coefficient of heat transfer**

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Air conditioning is the process of changing the properties of the air such as the humidity and temperature into more preferred conditions to satisfy the needs of the occupant of the building or office. The air conditioner is a device that lowers the temperature mainly by refrigeration cycle.

Environmental impact of the energy consumption is very critical issue nowadays. According to the International Energy Agency Buildings consume about 40% of the total primary energy consumption and around 32% of the overall final energy consumption [1,2]. The large buildings and complexes, which are air conditioned nearly 60% of the total energy is used for the cooling purposes. There are many crucial factors to reduce the energy consumption like good estimation of the heating and cooling load and proper sizing & control of the HVAC system [2]. HVAC systems design handbook defines "Heating, ventilating and air conditioning (HVAC) as the simultaneous control of temperature, humidity, radiant energy, and air motion & quality within a space for the purpose of satisfying the requirements of comfort or a process."

The initial idea that a person can think of in order to design proper sizing is to select a large system to retain the indoors in the preferred circumstances at all times and under extreme environments. However this fundamental is not practical for this system as it will increase the initial & operating costs and the system will be overweight which require more space. The sizing and selection of the air handling unit is based on the cooling load which is the heat gain from the indoor outdoor. Basic factors that influence the cooling loads are the outdoor temperature, solar radiation and humidity and such things which known as the external climates[3]. Similar, Local weather environments are vital factors for the energy performance.

Over estimating cooling load or under estimating it as well is a major problem in air conditioning systems. It disturbs the human comfort which the system set up for as it can cause receiving more cool or feel hot. Energy consumption influence the environment and cause many effects. Nearly 72% of the energy in this world is consumed by industry, infrastructure, commercial and residential buildings [4,5]. Consequently, about 60 % of the air conditioned large buildings energy goes to the cooling aims and FIGURE 1.1 shows the energy consumption in Malaysia. Reducing the energy consumption is very vital in order to save our environment and at the same time will save costs. Consuming energy in buildings which relies upon the circumstances of the weather and the efficiency of the air conditioning systems also variate with them, proper designing of air conditioning applications which put into consideration of the suitable weather situations will lead to enhance comfort and better performance energy buildings. Ultimately, a good estimation of the cooling load is the key to a proper design of HVAC system and necessary for air handling unit selection. Moreover, direct solar radiation into the office for buildings that faces the east effects the occupants comfort leading to less productivity and might cause illness.

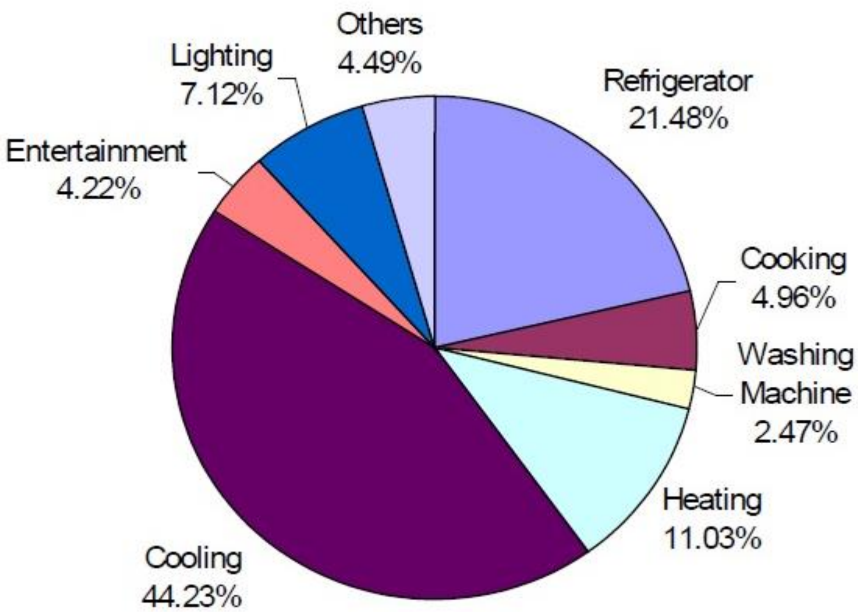

FIGURE 1.1 Average electricity consumption breakdown in Malaysia

1.2 Problem Statement

Assessment was done about the comfort of the occupants at block 16, lecturers' offices. Majority especially female occupants are feeling overcooled. Hence in order to get the comfortable level to cool the office rooms, cooling load prediction is required. Some lecturers whose offices directly facing the east affected by the sun radiation in the morning and disturbing them in their work causing them to avoid being in the office at those times which reduce the performance of the lecturers.

1.3 Objectives of The Project

The objectives of the project are:

- Estimate the cooling load of the building
- Compare the results with the installed capacity
- Recommend solution to reduce the solar gain

1.4 Scope of The Project

The scope of this project is a glazed building which is the left wing of the lecturers' offices at Level 3 Block 16 at Universiti Teknologi PETRONAS and under Malaysia weather conditions. The basic data including the climate condition and building location & structure are to be taken. Load components to be calculated from external and internal heat gains including the sensible & latent heat gains. Hourly Analysis Program (HAP) and Cooling Load Temperature Method (CLTD) is to be used in the calculation and referring to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards.

CHAPTER 2

LITERATURE REVIEW

Sandip [5] predicted the cooling load for multi-story building in India. He used the CLTD method in his calculation for different weather conditions. Cooling load gains estimated through Microsoft Office Excel program. ASHRAE standard used as a reference to compare the results, CARRIER software was used also. His study indicates that extra 9 % of cooling was needed in summer against that in monsoon weather conditions as in Roukerla, India. CLTD method results are as the following: in summer, a total of 168.03 tons of cooling load is required the four-story building whereas 153.53 tons of cooling load for monsoon. His results with CARRIER program are 183.72 tons in the summer and 177.11 tons for monsoon clime condition.

Yonas [6] investigated the cooling load and air handling unit for Hibrit Boat in Ethiopia. The study was for large room and two rooms of the boat. The larger room needs around 171,322 BTU/hour of an air conditioning capacity. Nonetheless, it requires 7 units of 24,000 BTU/hour capacity air conditioners. The other two passenger rooms require capacity of 27,245BTU/hour.

Hani [7] investigated the thermal load of a building in Rabigh city of Saudi Arabia weather condition. Manual calculation had been done and then compared with the results of HAP 4.2 program. A total of 107.1 tons of cooling load was predicted for the three floors. He found that the installed A/C units with capacities of 58, 70 and 45 the ground floor, first floor and for the second floor respectively. In case of the comparison of the expected cooling load values from HAP 4.5 with the installed A/C equipment, it is drawn that the installed ones are oversized.

Kulkarni et al. [8] studied the effect of different type of windows glazing and the reduction in heat gains when providing insulation on the roof and interior & external walls. DesignBuilder program was used to predict the cooling loads. They found that 90% of heat gain reduction for double reflective colored glazing compared to single glass one. Similarly, a reduction of solar heat gain of about 60% when applying false roof.

Fouda et al. [9] developed mathematically a new method with the help of advance computer languages for calculating the thermal loads values and cyclical heating demands for buildings. They found that this method gives accurate and reasonable results under different weather conditions.

Shariah et al. [10] studied the effect of absorptance of exterior surfaces in thermal loads for a building in Amman, Jordan. TRNSYS program have been used in this project of heavy and light concrete materials. The results show that thermal loads decreased by 32% for non-insulated building whereas reduction of 26% for insulated building when absorptance change from one to zero. They found that there a great impact of absorptance in the flat roof rather in the side walls.

Mui [11] investigated example weather year and occupant load profile. Monte Carlo sampling techniques is used to get occupant thermal loads profile with its time variation. The proposed approach can be implemented in various location with proper parameter selection.

- Occupants Comfort and Cooling Load

The occupants comfort is the prime goal of the air condition system in a building to make them feel comfortable and satisfied with the thermal environment in their space. It is greatly differ from a person to another. It is difficult to measure in terms of temperature or other factors except of the complaints of the occupants themselves. In reality, we cannot get fully comfort of all people in a zone as it differs from male to female and distinguishers such as the age and clothing. Thus in air conditioning system design the comfort condition is met as at least eighty percent of the people are thermally satisfied.

Cooling load of a space is the rate of heat energy that required to be removed from the space air to keep it at the desired (designed) condition in temperature and humidity.

In cooling it is more complex than heating as the heat gain is not the as the cooling load due to the storage factor in furnishings and walls (time delay). The heat gain does not affect the system immediately however it takes time. As shown in FIGURE 2.1, it is not recommended to design the cooling capacity of the system depending on the peak heat gains as it will lead to overdesign of the system. Indeed, the required cooling load is lower than the heat gain by certain factors such as storage in roof, partitions and floor carpets.

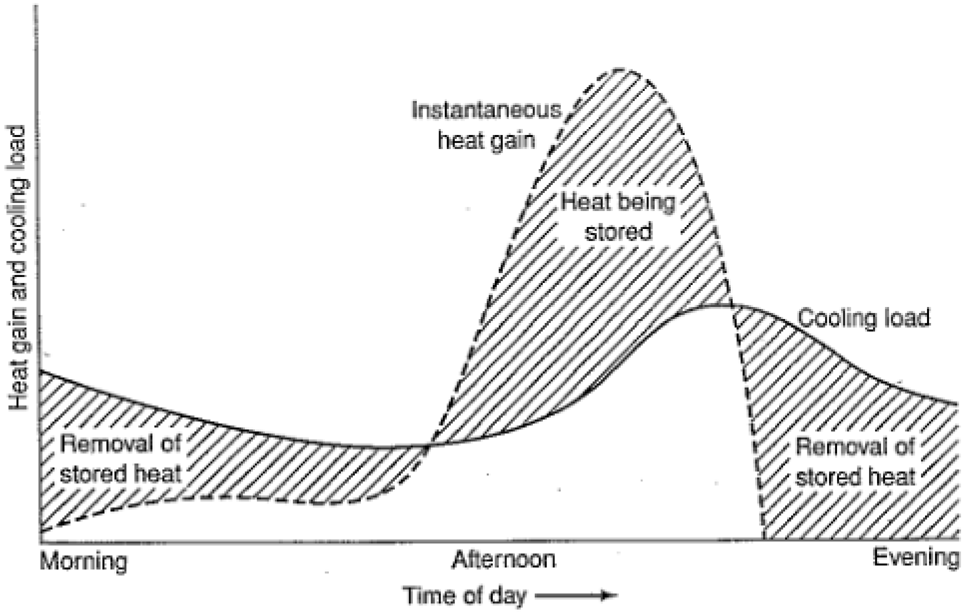

FIGURE 2.1 Heat gain and cooling load difference [12]

- Cooling Load Components

Thermal energy is directly correlated with the temperature. Higher temperature of the matter, means it has greater thermal energy. Heat transferred from the higher temperature (hot) medium to the lower one (cold). There are three ways for transferring the heat which are conduction, convection and radiation as illustrated in FIGURE 2.2. The conduction occurs through solid or stationary fluid. Convection when the fluid passes over a hot surface while radiation does not require a medium to transfer.

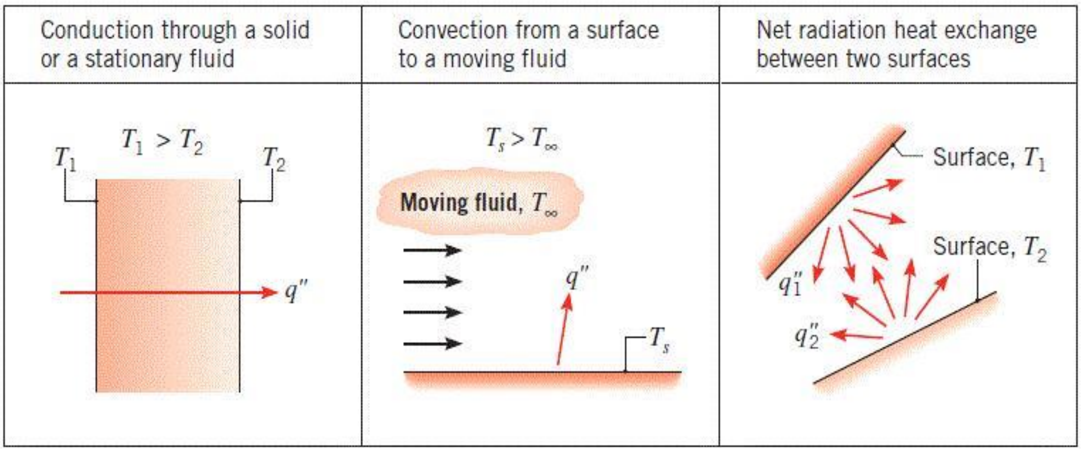

FIGURE 2.2 Heat transfer modes [13]

There are external and internal cooling load sources which the building gets the heat from. They requires the air conditioning system to remove them and make the space temperature and humidity as designed and required for the comfort of the occupants of that space. The illustration of those sources is shown in FIGURE 2.3.

The external sources of heat to the building are direct sun radiation through fenestration which through the glazed wall or window glass. Additionally, heat gains from the top roof or ceiling, floor and the partition walls by conduction and it depends on the type of materials and the structure of the building whether it is conducting the heat or acting as insulation. Glass has a large potential of conducting the heat, thus it contributes the most. Internal source of heat in the space include the lighting and electrical equipment which differs mostly with the wattage of the equipment. Moreover, infiltration through the door and window cracks or any air leakage in the space.

Ventilation of the air is also contribute to the heat gains in a particular place. Lastly, the number of occupants also generate heat to the space such as through respiration and it differs largely with the type of activity whether seated, light work or heavy work like in gymnasium.

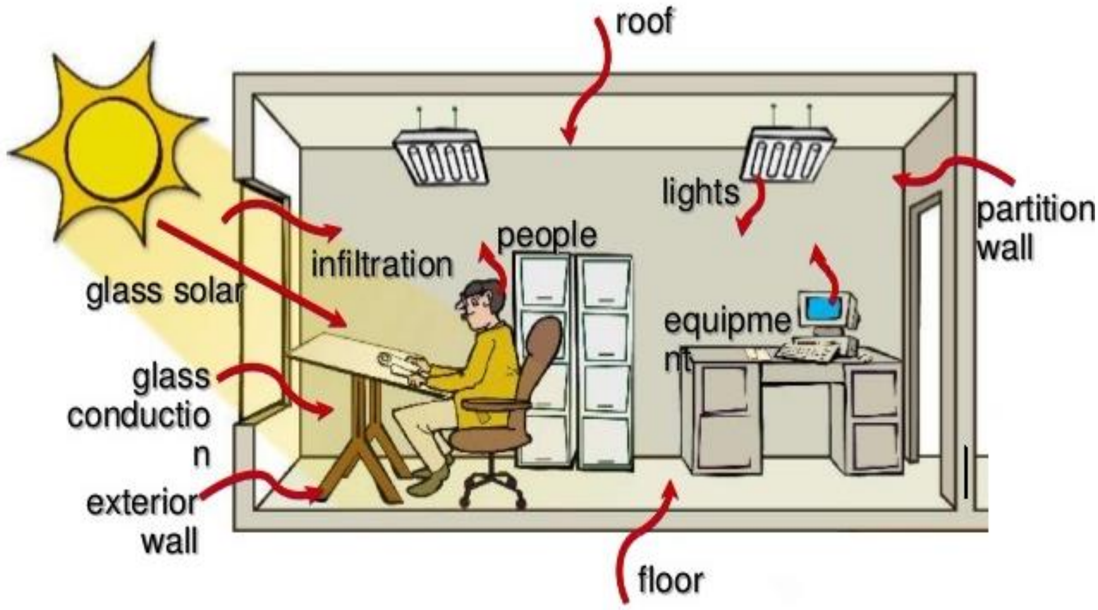

FIGURE 2.3 Illustration of the components of the cooling load [14]

The zone peak cooling load is the maximum space cooling load in a load profile for those spaces in a zone with regards to the orientation, the internal load characteristics, and the outdoor design conditions for summer and winter. For a space cooling load with several components, such as solar gain through fenestration, heat transfer conduction through roofs, or internal load from occupants, electrical equipment and lighting, the zone peak load is always the maximum sum of these zone cooling load components at a given time.

- ❖ Cooling Load Prediction Methods

Heat Balance Method where all energy balanced in the space or zone. This method considered as fundamental for other cooling load estimation. It is a transient method where at different times, the surface temperature could be determined. This method is a tedious since it involves solving many equations at the same time simultaneously and iterative operations which should be done by computer programs. Heat transfer function method is simplified method of heat balance method. Its drawback that it is hard to understand and difficult to use. There are certain programs uses this method such as carrier hourly analysis program which was used in this project. The other method is the Radiant Time Series which divide the heat gains into convective and radiant one to get the hourly cooling load. It uses the basis of steady response factors.

Cooling Load Temperature Difference (CLTD) is simplified way of Transfer Function Method that developed by ASHRAE for manual calculation. It is approximate

- Cooling Load Temperature Difference

CLTD approach is regarded as a realistically accurate approximation heat gain through a building envelope. It is a developed way improved by the American Society of Heating and Air condition Engineers (ASHRAE) as an alternative and simplified way to the difficult and massive calculation in other methods like transfer function method. It is developed under Latitude of 40ºN. So there are factors for different latitudes and date.

- Hourly Analysis Program

HAP program is used widely in the engineering consultation and for the design of the heating, ventilation and air-conditioning system. HAP program logo is illustrated in the FIGURE 2.5. It is a powerful tool to predict cooling load, design HAVAC system, equipment sizing and simulation for energy analysis of the building. It was developed by Carrier in the United States and it uses the Transfer Function Method which the CLTD is the simplified method. It follows the American Society of Heating, Ventilation and Air conditioning standards. Thus it means HAP results are more accurate than the CLTD method as it involves calculation of complex and lengthy equations. It can be used for various applications from small to large projects with different types of air conditioning units and equipment and it is very user friendly. It can be learnt easily. However, it requires knowledge in the field and understanding the standards of the air-conditioning.

FIGURE 2.4 Hourly Analysis Program logo

- ❖ Glazed Wall and Thermal Performance

There are two heat gain components through fenestration on windows and glazed walls which are the solar radiation and conduction as in FIGURE 2.5. Solar radiation is always positive where it has two parts direct and diffused ones.

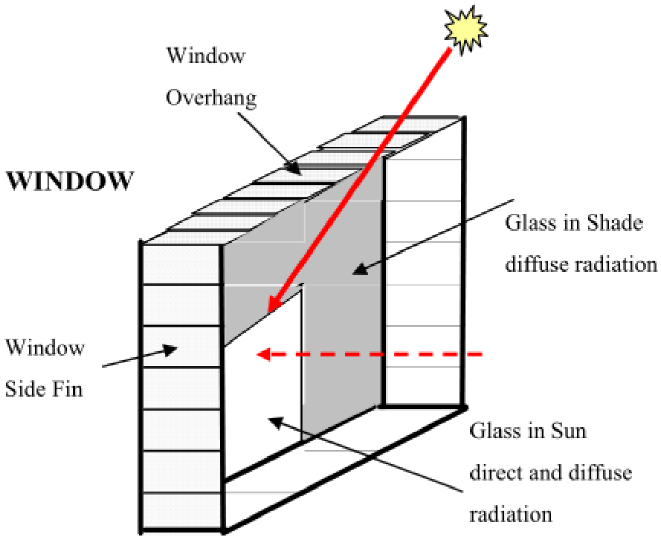

FIGURE 2.5 Heat gain components via glass [15]

The heat transfer by conduction on glazed walls happens due to the temperature difference between room temperature and outside one. Positive conduction heat gain through glass occurred when the temperature of the outside environment is greater than the space internal temperature.

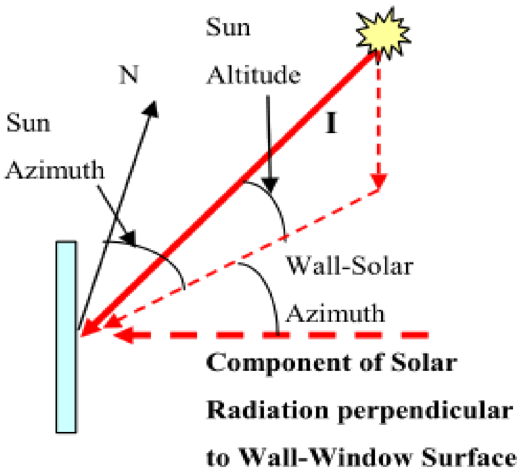

FIGURE 2.6 Building orientation and solar radiation

Negative conduction or heat loss is happened when the inside temperature is lower. Solar Cooling Load factor for glass is differ with the tilt angle and the azimuth as in FIGURE 2.6. ASHRAE provides the Solar Cooling Load factors in tables for different conditions such as the floor furnishings. According to the glass characteristics, when the sun rays hit the glass part of the radiation is transmitted through the glass, some absorbed and another portion is reflected back. Unlike thick materials or walls, the absorbed part by glazed wall is small and the large portion transmitted or reflect relative to the glass specifications. The transmitted radiation is not directly heating the space. It stored or absorbed initially in the interior particles and the furnishings then the heat is released by conduction or convection.

Tinted film on glazing contribute to cost saving as it reduce the energy requirement for cooling load. In the United States in the year of 1990, twenty million US dollars has been paid for the offset of heat gains through fenestration. Moreover, it reduce the glare and heat from the direct sun radiation. Similarly, it protects the occupants from the harmful ultra violet rays. It is a better choice than replacing the window or the glazed wall as it is economically cheaper and requires less time to install. Additionally, tinting helps to protect the interior things in the room such as the furnishings. The main factors that affect the performance of the glazing is the heat transfer coefficient, solar heat gain and the visibility transmittance of the glass. Number of glass layers and color has an effect as well. For better performance tinting and coatings are recommended.

CHAPTER 3
METHODOLOGY

3.1 Overview

This project is based on several milestones, the first is getting the building data and system design conditions. Then predicting the cooling load for both internal and external gains using CLTD method. Next is getting the result of the Hourly Analysis Program (HAP) and comparing the results against the air handling unit cooling capacity to analyze if there is any overdesign of the system. Then studying the effect of the different set point temperatures and the tinted film on glass.

3.2 Project Flowchart

The following flowchart FIGURE 3.1 describes the flow of the project

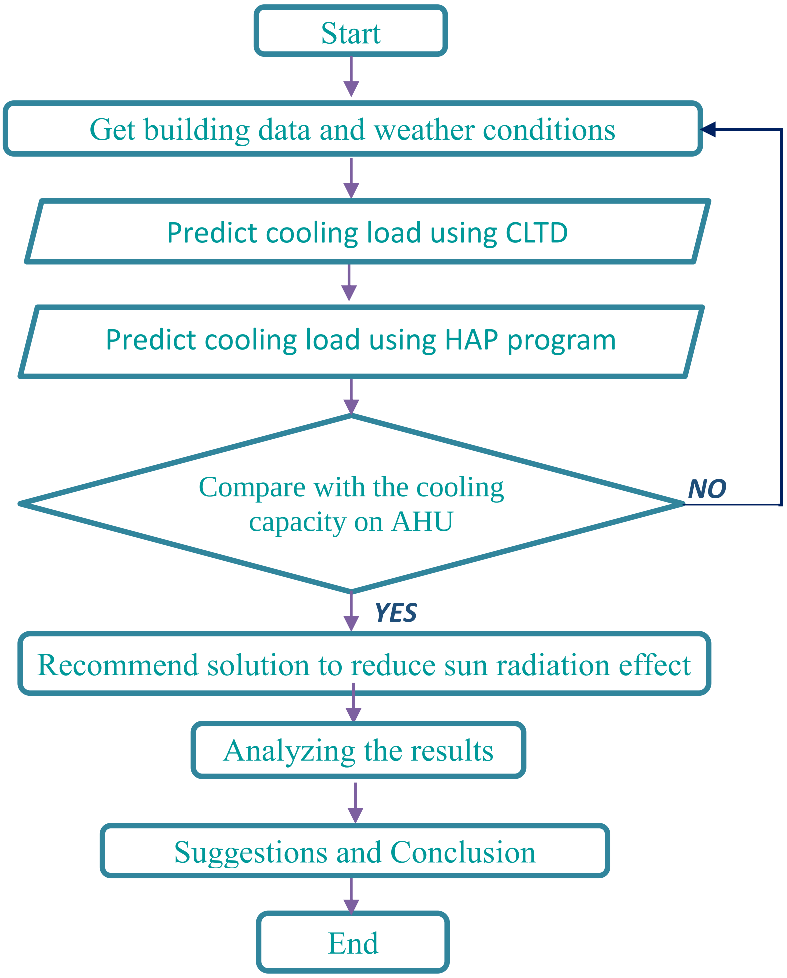

FIGURE 3.1 Project flow chart

3.3 Cooling Load Predicting Procedures

According to the flow chart in FIGURE 3.2 where the cooling load prediction procedures explained, there are a necessary data we need to get in advance of predicting the cooling load to have a proper design of HVAC system and selection of the air handling unit. For instance, building location, orientation & structures, climate condition and the materials used in the building. For a better result and good accuracy, it is required to have a precise and exact information. The Malaysian weather condition was studied in this project. Moreover, cooling load has two components which are the external and internal heat gains.

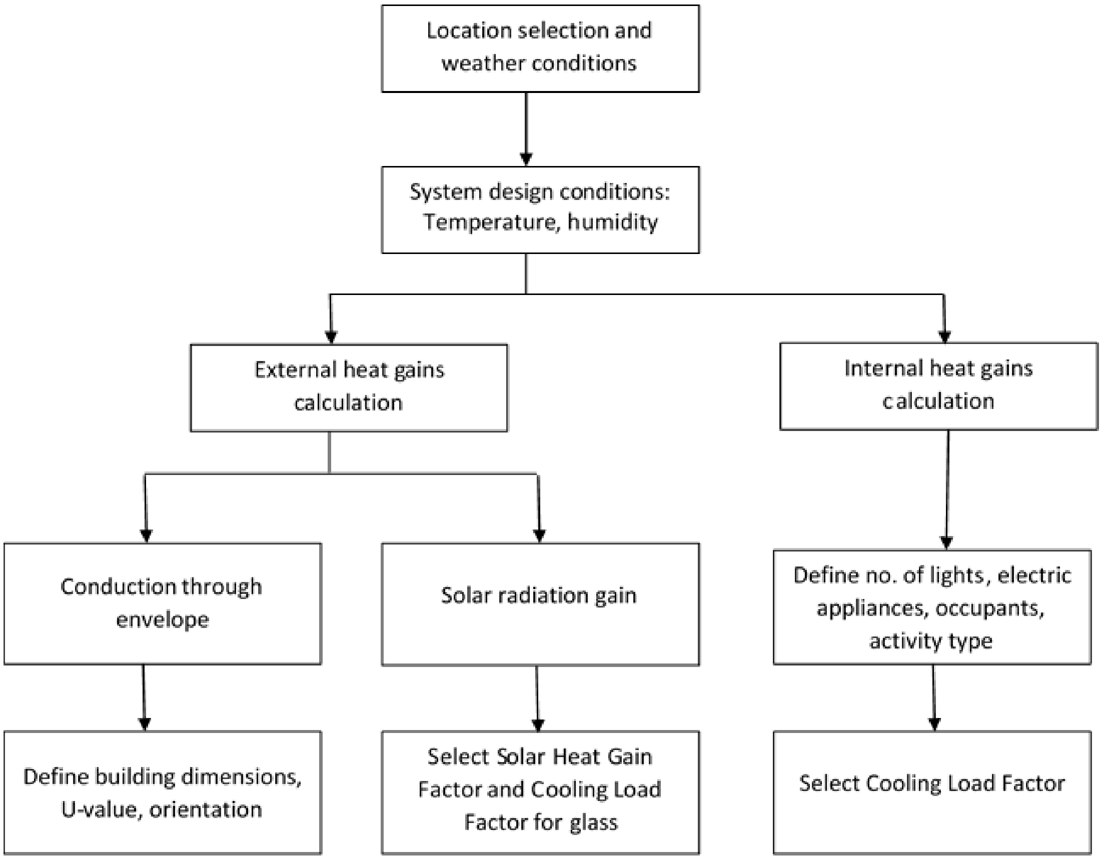

FIGURE 3.2 Cooling load prediction flow

❖ Building Location

The project selected location is Block 16, Universiti Teknologi PETRONAS, Seri Iskandar, Tronoh, Malaysia as illustrated in FIGURE 3.3. It has a longitude of 101 degree east, latitude of 4.4 degree north and elevation of 32 m above sea level.

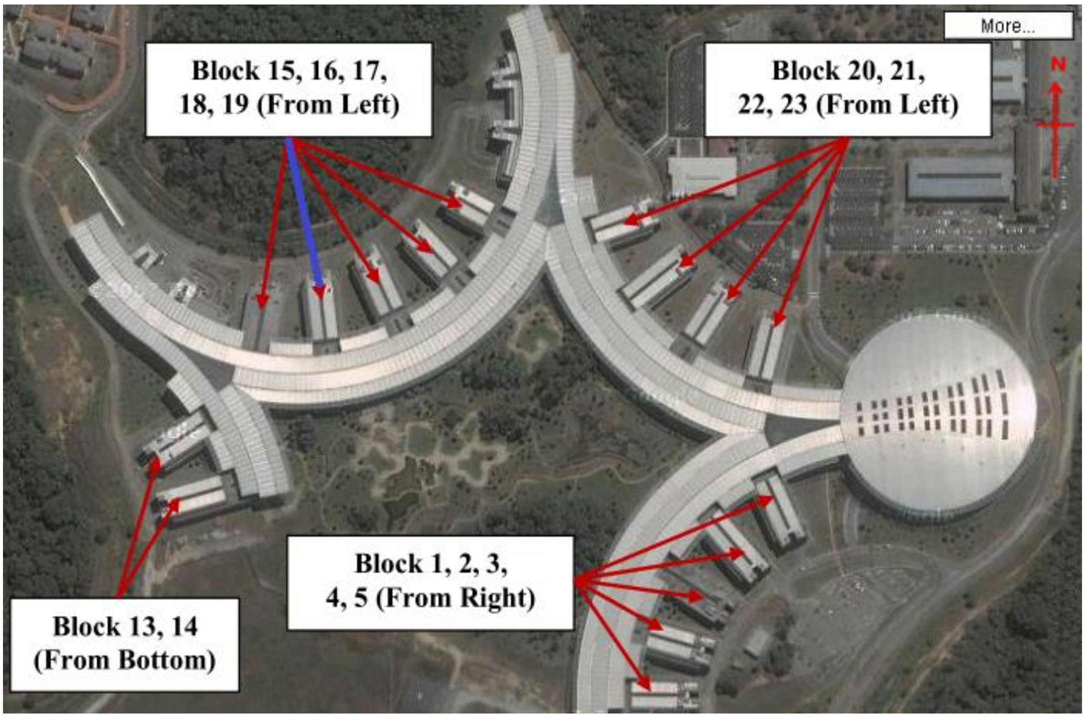

FIGURE 3.3 Block 16 location taken using google earth [13]

Difference in the warm temperature in the exterior medium and the interior space causes transfer of the thermal potential and thus called external. Conduction through exterior parts, roof, interior partitions, ceilings and floors causes the potential transfer. Also comes from solar radiation through transparent surfaces (windows), doors, infiltration and ventilation.

The other form of the heat gains is the internal heat gain from occupants, lightening and electric equipment and appliances. Sensible and Latent Heat Gain:
Sensible and latent heat are not types of energy rather they describe the change in temperature. It is called a sensible capacity when there is temperature difference due to adding or removing heat to an object. On the other hand it is called latent heat when

there is no temperature change rather the phase of the object changed like from solid to liquid and so on.

Required parameters for cooling load calculation of a place:

- Areas of the wall
- Over all heat transfer coefficient (U-factor) for the envelope
- Temperature difference between inside medium and outside
- Glass transmission factors
- Lighting density and relevant factors
- Occupants and type of activities
- Enthalpy of the air inside & outside and ventilation rate

3.3.1 Sensible Heat Gain through Conduction

Using the formula (1) we can calculate the rate of heat transfer

$$Q = U \times A \times CLTD \tag{1}$$

U is the overall heat transfer coefficient (W/m^2 -ºC)

CLTD is the cooling load temperature difference (ºC)

A is the area of the surface (m^2)

- ❖ Overall heat transfer coefficient

$$\mathbf{U} = \frac{\mathbf{1}}{\frac{1}{h_i}+\frac{x1}{k1}+\cdots+\frac{x3}{k3}+\frac{1}{h_o}} \tag{2}$$

Surface area of the wall deducting the area of the windows and doors.

- ❖ Cooling load temperature difference

CLTD approach is regarded as a realistically accurate approximation heat gain through a building envelope. It is a developed way improved by the American Society of Heating and Air condition Engineers (ASHRAE) as an alternative and simplified way to the difficult and massive calculation in other methods like transfer function method. It is developed under Latitude of 40ºN. So there are factors for different latitudes.

3.3.2 Heat Gain via Glazed Wall

Heat can be transmitted by glass: $Q = U \times A \times CLTD_{glass}$

Through radiation of the sun:

Q = A × Solar Factor × Shading Coefficient × Cooling Factor (3)

Where:

Solar factor is the factor of the maximum solar gain

Shading coefficient is the shading coefficient (vary with kind)

Cooling factor is the factor of the cooling load

3.3.3 Heat Gain from Occupants

Sensible gain of the heat via inhabitants

Qs,person = qs,person × No. of occupants × Cooling Factor (4)

Where qs,person is the heat gain per occupant

Latent gain of the heat via inhabitants

Qs,person = ql,person × N ×Cooling Factor

ql,person is the heat gain per occupant

3.3.4 Heat Gain from Lighting Equipment

Qlight = Total wattage of light × Use factor × Allowance factor (5)

3.3.5 Heat Gain from Electric Equipment

Qelec,equip = Total wattage of light × Use factor × Allowance factor (6)

3.3.6 Heat Gain via Infilteration

Amount of the air (V inf) = A space of Valume × Ac /60 (m3/min) (7)

Ac is number of air fluctuation rate per hour

The gains of the heat via infiltration can be calculated using this formula:

Qs,infilterated = 20.44 × Vinfiltrated × (Toutside- Tiside) (8)

The gains of the heat via infiltration can be calculated using this formula:

$Q_{l,infilterated} = 20.44 \times V_{infiltrated} \times (W_{outsie} - W_{inside})$ (9)

W outside and W inside = specific humidity of outside and inside at conditioned space (kg/kg of dry air)

3.3.7 Heat Gain via Ventilation

The American Society of Heating, Refrigeration and Air-condition Engineers ASHRAE provides allowable rate of fresh air for every occupant for variety of conditions.

Total Loads = Total Room Sensible Heat Gain + Total Room Latent Heat Gain

Total Room Latent Heat Gain = Latent gain via infiltration + Latent heat gain via occupants + Latent gains via ventilations + Latent gains through utilities

3.4 GANTT Chart

TABLE 3.1 Gantt chart for FYPI and FYPII

No.	Activity/week	1-2	3-4	5-6	7-8	9-10	11-12	13-14
		15-16	17-18	19-20	21-22	23-24	25-26	27-28
1	Project title selection							
2	Defining the problem & the scope							
3	Review scientific researches related to the topic							
4	Extended proposal and defense presentation							
5	Identify climate conditions							
6	Identify building structure							
7	Getting building data							
8	Interim report submission							
9	Getting cooling load using CLTD method							
10	Getting cooling load using HAP program							
11	Comparing against designed capacity							
12	Pre-SEDX presentation							
	Analyzing the results							
13	Conclusion and recommendation							
14	Dissertation and technical paper submission							
14	VIVA							

3.5 Key Milestones

The project key milestones are as follows:

1. Predict cooling load using CLTD
2. Predict cooling load using HAP Program
3. Analysis and comparison of the results

CHAPTER 4

RESULTS AND DISCUSSION

❖ Climate Conditions

Ambient temperature readings have been taken on the solar research site at Universiti Teknologi Petronas with one hour interval as shown in FIGURE 4.1. In this report, heat gains are calculated for Septemper12, 2015 from 7 morning to 7 evening as it is the operating time of the air-conditioning system in UTP. The design temperature of the system is 24 ºC and 50% relative humidity which is set by the operator [16]. Ashrae standards are used in the calculation as equations, CLTD values from tables and correction factors [14].

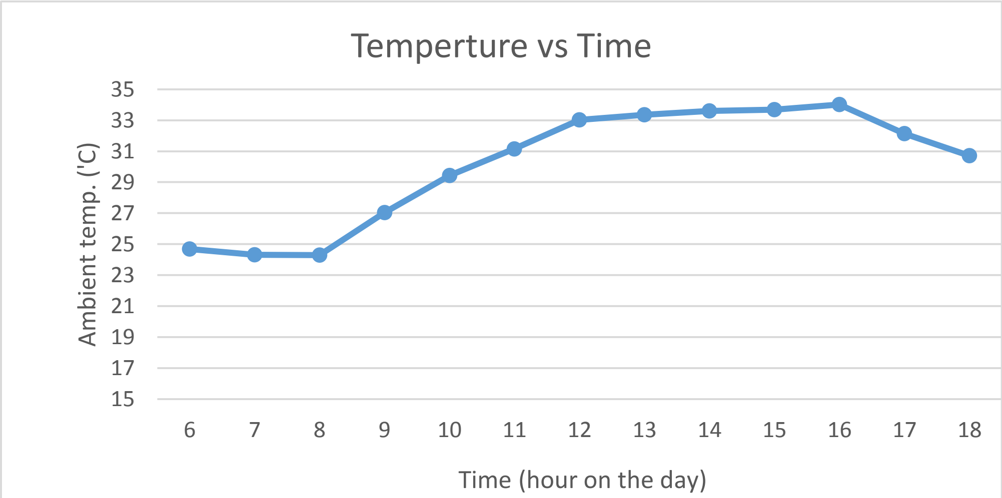

FIGURE 4.1 Ambient temperature versus time during the day

- Sensible Heat Gain through the roof

$Q = U \times A \times (CLTD)$

U = overall heat transfer coefficient ($W/m^2/^0C$)

CLTD = Cooling Load Temperature Difference

- Overall heat transfer coefficient

Overall U-value for composite of different materials as illustrated in FIGURE 4.2 can be calculated using the formula

$$U = \{ \frac{1}{h_i} + \frac{x_1}{k_1} + \ldots + \frac{1}{h_o} \}^{-1}$$

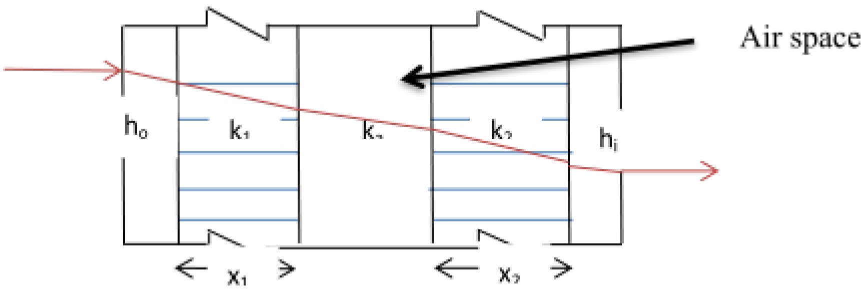

FIGURE 4.2 Convection and conduction via composite wall

The conductance for each material is shown in TABLE 4.1. Surface combined heat transfer coefficient [13] for outdoor is $h_0 = 25$ $W/m^2/^oC$ while for indoor one is $h_i = 7.69$ W/m^2 ^oC as recommended by ASHRAE.

Table 4.1 Properties of the construction materials [17]

Building Structure	**Specification (thinkness – Conductance)**
Roof	Alumunium (1mm-846 KJ/hmK), rockwool (25mm-0.162KJ/hmK), Alumunium foil (1mm-846 KJ/hmK), common concrete (10mm-7.56 KJ/hmK)
Floor	Concrete slab (100mm-4.07KJ/hmK), common concrete (550mm-7.56 KJ/hmK)
Window	Otiwhite glass (12mm-3.24 KJ/hmK)
External Wall	Steel (5mm-54 KJ/hmK), air gap (0.047 hm^2K/KJ), Steel (11mm-54 KJ/hmK)
Internal Wall	Plasterboard (25mm-0.576 KJ/hmK), air gap (92mm- 0.047 hm^2K/KJ), plasterboard (25mm-0.576 KJ/hmK),

❖ Calculation of overall U-value:

$$\mathbf{U_{glass}} = \frac{1}{\frac{1}{25}+\frac{3.24\times10^{3}}{0.012*3600}+\frac{1}{7.7}} = 5.459\ \text{W/m}^2.^{\circ}\text{C}$$

$$\mathbf{U_{roof}} = \frac{1}{\frac{1}{25}+\frac{2*0.001*3600}{846*1000}+\frac{0.025*3600}{0.162*1000}+\frac{0.01*3600}{7.56*1000}+\frac{1}{7.7}} = 1.369\ \text{W/m}^2.^{\circ}\text{C}$$

$$\mathbf{U_{partition}} = \frac{1}{\frac{1}{0.012}+\frac{0.14}{0.02}} = 0.011\ \text{W/m}^2.^{\circ}\text{C}$$

❖ Surface area of the wall

Example of the room four orientations and dimensions are shown in FIGURE 4.3.

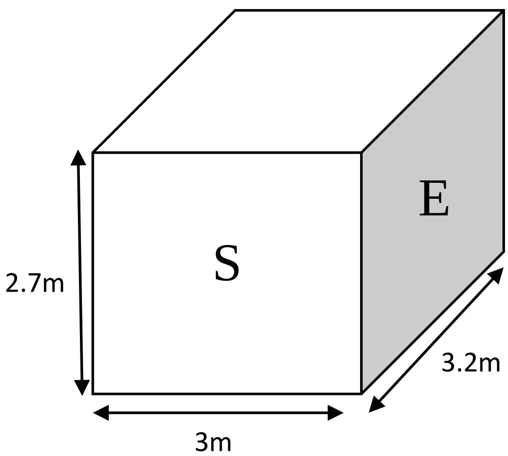

FIGURE 4.3 Room four dimensions and orientations

Width = 3m (north and south orientation),

Length = 3.2m (east and west orientation), height = 2.7m, thickness = 0.012 m

$A_{\mathbf{glass}}$ = 8.64m^2, $A_{\mathbf{roof}}$ = 9.6m^2, $A_{\mathbf{floor}}$= 9.6m^2, $A_{\mathbf{partition}}$ = 8.64m^2

$CLTD_{corrected}$ = (CLTD + LM) K + (25.5 – Ti) + (Ta – 29.4)

Where Ta = average temperature (ºC)

Ti = inside design temperature (ºC) = 24ºC

LM = correction of latitude month = 0

K = color correction factor = 0.5 for roof

For this case, roof conditions are with suspended ceiling and indoor temperature is 24ºC and daily range of 11.

TABLE 4.2 CLTD for flat roof for room4

CLTD for flat roof												
Hour	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
CLTD	27	26	24	23	22	21	22	22	24	25	27	26

Thus Ta = (34+23)/2 = 28.5ºC

From TABLE 4.2 for maximum temperature of 34ºC of the day at 16:00 hours, CLTD is 27 ºC. CLTD corrected and heat gain for the flat roof are:

CLTD corrected = (25 + (0)) 0.5 + (25.5 – 24) + (28.5 – 29.4) = 13.1ºC

Thus Q_{roof} = 1.369×9.6×7.4 = 172.165 W

- Heat gain via exterior glazed wall (conduction)

TABLE 4.3 CLTD for glazed wall of room4

CLTD for glazed wall												
Hour	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
CLTD	-2	0	2	4	7	9	12	13	14	14	13	12

Latitude and month factor LM for glass = 0

For clear glass and light color = 0.6

From TABLE 4.3 for maximum temperature of 34ºC of the day at 16hours, CLTD corrected and heat gain for flat roof are:

CLTD corrected = (14 + (0)) 0.6 + (25.5 – 24) + (28.5 – 29.4) = 9 ºC

$Q_{\mathbf{glass\_conduction}}$ = 5.459 ×9 ×8.64 = 424.49 W

- Heat gain through direct sunlight (solar radiation):

Q = A×Solar Factor×Shading Coefficient×Cooling Factor

TABLE 4.4 CLF for glass for room4

CLF for glass												
Hour	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
CLF	0.7	0.8	0.7	0.6	0.4	0.2	0.2	0.2	0.2	0.17	0.1	0.1

TABLE 4.5 Solar heat gain factor for 4 degree north latitude

Solar gain factor for 4 degree									
Hour	**N**	**NNE NNW**	**NE NW**	**ENE WNW**	**E W**	**ESE WS W**	**SE SSW**	**S**	**HOR**
Sep	39	75	156	231	216	170	93	44	293

From TABLE 4.4 the cooling load factor at 16.00 hours is 0.17.

From TABLE 4.5 the highest solar gain factor on the east side for room4 is 216 $Btu/hr.ft^2$,

Thus solar heat gain factor = 729 W/m^2

Shading Coefficient = 0.9

At 4pm: $Q_{radiation} = 9 \times 728.71 \times 0.9 \times 0.2 = 1180.51W$

- ❖ Heat Gain from Occupants

Sensible gain via occupants;

$Q_{s,person} = q_{s,person} \times$ No. of occupants × Cooling Factor

For activity office as seated and very light work: sensible gain per occupant = 70 W

Number of occupants = 3 people, Cooling factor = 1

$Q_{s,person} = 70 \times 3 \times 1 = 210$ W

Latent gain via occupants:

Unlike sensible heat gain, latent heat gain via people have no correction factor as it is directly converted into cooling load.

$Q_{s,person} = q_{l,person} \times$ No. of occupants

Where $q_{l,person}$ = latent heat gain per occupant

Latent gain per occupant = 45 W, No. of occupants = 3 people

$Q_{s,person}$ = 45×3 = 135 W (there is no latent heat gain at lunch time as the occupants left the room)

- ❖ Heat gain from lighting equipment

Q_{light} = Total wattage of light × Use factor × Allowance factor
Fluorescent lamp 129.6 KJ/h (36 W), Quantity = 4
Use factor is the proportion of real wattage usage to installed wattage. It differ with different types of usage. Most often factor of one is used for residential buildings. Allowance factor for fluorescent tube light considering the power of the ballast.

Q_{light} = 4×129.6(1000/3600)×1.25 = 180 W

- ❖ Heat gain from electric equipment

$Q_{elec,equip}$ = Total wattage of light × Use factor × CLF

PC with monitor (wattage = 1440KJ/h), cooling load factor = 1 as the system is off at night

$Q_{elec,equip}$ = 1440×1000/3600×0.98×1 = 392 W

- ❖ Gains via infiltration

Amount of the air (V_{inf}) = Room Volume × A_c /60 (m^3/min)

V_{inf} = 3×3.2×2.7×1/3600 = 0.0072 m^3/s = 15.255cfm

A_c is number of air fluctuation rate per hour

$Q_{infilterated}$ = 1.1× $V_{infiltrated}$ × ($T_{ambient}$- T_{indoor})

At 4PM: $Q_{infilterated}$ = 1.1×15.255 ×(34-24) = 167btu/h = 49W

- ❖ Heat gain due to ventilation

The American Society of Heating, Refrigeration and Air-condition Engineers AE provides allowable rate of fresh air for every occupant for variety of conditions.

Ventilation air components for office is 2.5L/(s-person) which is equivalent to (0.15 m^3 /min/person). Ventilation air for relative to the area is 0.3L/(s.m^2) which is equivalent to 0.02 m^3 /(min-m^2)

At 16.00: $Q_{\mathbf{ventilation}} = 1.1\times(0.02\times60)\times(2.7\times1.1)\times(34-24) = 39.2W$

TABLE 4.6 Total cooling load for *room4 using CLTD method*

Source	Heat gain (W)
Roof	172.17
Glass-conduction	424.49
Glass-radiation	1003.83
Occupants	210
Light	180
Electrical equipment	392
Total	2470

TABLE 4.6 shows the cooling load components for room4 which has been calculated in this reperted as a sample for room cooling load prediction using Cooling Load Temperature Difference method. The total cooling load for room4 from all heat gain componenets through the roof, conduction and radiation through glass, occopants, light and electrical equipment is 2470 W.

TABLE 4.7 CLTD and HAP results difference

	Cooling Load (W)
CLTD method result	2470
HAP program result	2558
Difference (%)	3.46

In TABLE 4.7 the cooling load result of the Cooling Load Temperature (CLTD) method is compared against the Hourly Analysis Program (HAP). The difference in the cooling load results for room4 between CLTD method and HAP program is just 3.46 %.

TABLE 4.8 Total cooling load for 24 temperature set point

Zone no. 1	**DESIGN COOLING**	
	Sep 1600 **Weather data DB / WB 34.0 °C / 26.6 °C**	
	THERMOSTAT TEMP 24.0 °C	
SPACE LOADS	**Info**	**Cooling Load(W)**
Solar radiation loads	150 m²	27202
Conduction through the roof	197 m²	4400
Glazed wall conduction	150 m²	6638
Overhead Lighting	3150 W	2974
Electric Equipment	5370 W	5241
Occupants	59	3710
Total Zone no.1 Cooling Loads	**-**	**52334**

TABLE 4.9 Total cooling load for 25 temperature set point

Zone no. 1	**DESIGN COOLING**	
	Sep 1600 **Weather data DB / WB 34.0 °C / 26.6 °C**	
	THERMOSTAT TEMP 25.0 °C	
SPACE LOADS	**Info**	**Cooling Load(W)**
Solar radiation loads	141 m²	26001
Conduction through the roof	187 m²	3863
Glazed wall conduction	141 m²	5485
Overhead Lighting	2970 W	2974
Electric Equipment	4970 W	4850
Occupants	56	3522
Total Zone no.1 Cooling Loads	**-**	**48413**

As shown in TABLE 4.8 the total cooling load of the zone which is the whole wing of offices is 52334 W under the temperature set point of 24°C. There is great effect of temperature set point on the cooling load. Increasing just one degree Celsius from 24℃ to 25℃ can decrease the cooling load from 52334 W to cooling load of 48413W as calculated in TABLE 4.9.

TABLE 4.10 Total cooling load for 26 temperature set point

Zone no. 1	**DESIGN COOLING**	
	Sep 1600 **Weather data DB / WB 34.0 °C / 26.6 °C**	
	THERMOSTAT TEMP 26.0 °C	
SPACE LOADS	**Info**	**Cooling Load(W)**
Solar radiation loads	141 m²	26001
Conduction through the roof	187 m²	3541
Glazed wall conduction	141 m²	4716
Overhead Lighting	2970 W	2804
Electric Equipment	4970 W	4850
Occupants	56	3522
Total Zone no.1 Cooling Loads	**-**	**47129**

Further increase of set point temperature of the air conditioning system decreased the total cooling load to 47129 W as shown in TABLE 4.10. Total Cooling load reduction is mainly contributed by reduction in roof heat gain, heat gain through the glazed wall by conduction and lighting heat gain.

TABLE 4.11 Total cooling load for 27 temperature set point

Zone no. 1	**DESIGN COOLING**	
	Sep 1600 **Weather data DB / WB 34.0 °C / 26.6 °C**	
	THERMOSTAT TEMP 27.0 °C	
SPACE LOADS	**Info**	**Cooling Load(W)**
Solar radiation loads	141 m²	26001
Conduction through the roof	187 m²	3218
Glazed wall conduction	141 m²	3947
Overhead Lighting	2970 W	2804
Electric Equipment	4970 W	4850
Occupants	56	3522
Total Zone no.1 Cooling Loads	**-**	**45845**

Similarly, change of set point temperature of the air conditioning system decreased the total cooling load to 45845 W as shown in TABLE 4.11. Total Cooling load reduction is mainly contributed by reduction in roof heat gain, heat gain through the glazed wall by conduction whereas lighting heat gain remains constant.

TABLE 4.12 Total cooling load with tinted film

Zone no. 1	**DESIGN COOLING**	
	Sep 1600 **Weather data DB / WB 34.0 °C / 26.6 °C**	
	THERMOSTAT TEMP 27.0 °C	
SPACE LOADS	**Info**	**Cooling Load(W)**
Solar radiation loads	150 m²	27202
Conduction through the roof	197 m²	4400
Glazed wall conduction	150 m²	4645
Overhead Lighting	2970 W	2974
Electric Equipment	4970 W	5241
Occupants	56	3710
Total Zone no.1 Cooling Loads	**-**	**50341**

Applying tinted film to the glazed wall contributes to saving the building energy. A tinted film which decrease the heat transfer coefficient by 30% can cause reduction in the cooling load of the space. The total cooling load of the system decreases from 52334 W to 50341 W after applying the tinted film.

TABLE 4.13 Air handling unit information [19]

AHU	**Capacity (kW)**	**Supply Air (L/s)**	**Size (mm)**	**Operating Weight (Ibs)**	**Fan Motor (HP)**
AHU 16-03-02	72.4	3526	1054×1943×2210	3817	10

TABLE 4.13 provides the air handling unit specifications which provided from the maintenance depart of Universiti Teknologi PETRONAS for the block 16, level 3 air handling unit.

TABLE 4.14 Cooling load comparison against designed capacity

	HAP Program
Total cooling load (kW)	59.5
AHU Capacity (kW)	72.4
Difference (%)	17.8

As we can see in TABLE 4.14 the predicted total cooling load of the zone using Hourly Analysis Program is 59.5 kW while the air handling unit capacity is 72.4 kW.There is overdesign of 17.8% in the system as can be drawn from HAP program results.

TABLE 4.15 Effect of temperature set point on cooling load

	Total cooling load (kW)	**Difference (%)**
24°C temperature set point	59.5	0
25°C temperature set point	55.2	7.23
26°C temperature set point	53.9	9.41
27°C temperature set point	52.6	11.6

There is great effect of temperature set point on the cooling load as summarized in TABLE 4.15. Increasing just one degree Celsius from 24℃ to 25℃ can decrease the cooling load by 7.23% of the current one. Further one degree difference in temperature save capacity of 9.41%. However, changing temperature set point should also take into consideration the other buildings which the central UTP Gas District Cooling plant is supplying to as well.

TABLE 4.16 Effect of tinted film on cooling load

	Total cooling load (kW)
Without Tinted Film	59.5
With Tinted Film	57.5
Difference (%)	3.36

Applying tinted film to the glazed wall saves energy. A tinted film which decrease the heat transfer coefficient by 30% can cause reducing the cooling load of the space by 3.36% as it compared in TABLE 4.16. Applying such methods as tinted film to glazed walls and increasing temperature set points can contribute to the university savings on the utility bill. Most importantly, these solutions will help to increase the performance of the lecturers as they are now more comfortable. Saving our lovely environment by consuming less energy can be achieved as well. The cooling load estimation provide input for HVAC system design and a fundamental for building energy analysis

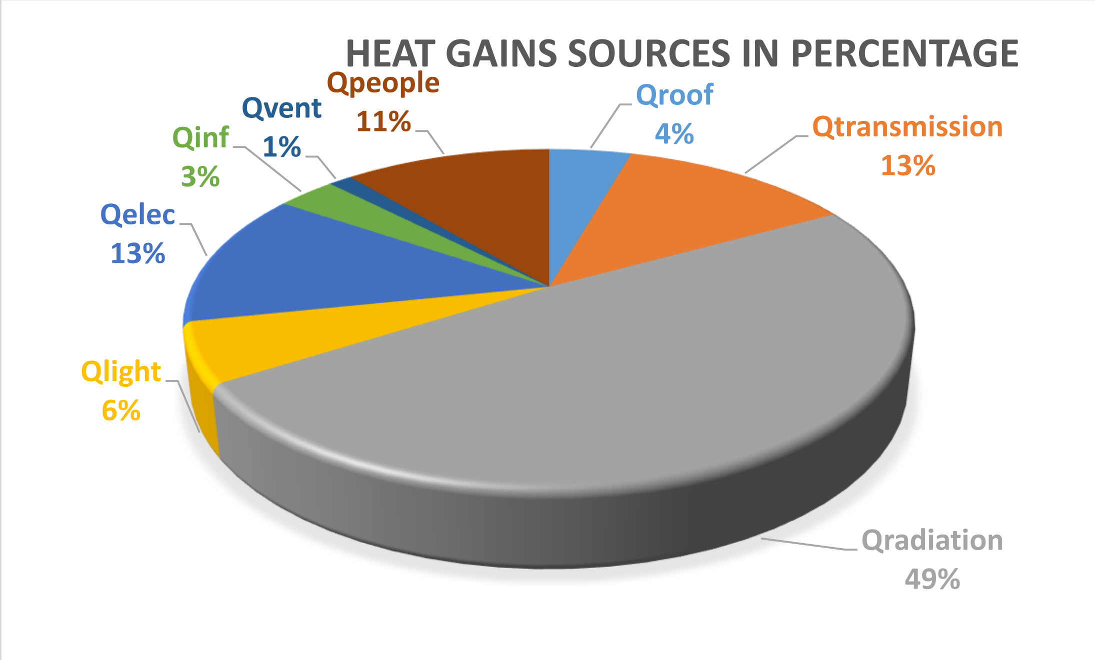

FIGURE 4.4 Heat gains sources in percentage

It can be seen from FIGURE 4.4 that the heat gain via the direct solar radiation penetrating the glass to the room in the east direction require around half of the total cooling load. Indeed, solar radiation effects mostly from morning till noon, then it decreases as the sun moves towards the other side (west). Second largest contributor of the heat gains is the transmission of heat through the glazed wall by conduction. The over-all U-value of the glass (coefficient of heat transfer) allows more heat to enter the space whether by direct sunlight or by conduction which summed up to 62% of the required cooling load. Heat gain through the fluorescent lamps is not much. It requires almost 6% of the cooling load thus introducing tinted films for the glazed wall will not affect the cooling load much due to less natural lighting. The top roof composite of materials which mostly aluminum and insulating materials allows only to 4% of the heat to go through to reach the inner space.

Overdesign is not an engineering practice and it is not preferable. Overdesign means more energy required to run the equipment and bigger in size which ultimately lead to higher capital and operational costs. However, reasonable overdesign percentage for valid reasons such near future expansion in the building or expected occupancy level rise.

Major change in some offices such as changing lecturer room to Surau. Additionally, combining two rooms connected together and removing the partition between them making it as one bigger room. Moreover, changing the academic executive room to store which suppose not to be conditioned has influence as well. Weather conditions have been changed and it is not the same as it were during the design stage around 20 years ago.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Energy consumption increased worldly every moment and that effects our lives and the environment around us. Buildings are one of the most places that consume electricity. The prime portion of the electricity consumption is involved in the cooling of the buildings through air conditioners. In order to lower consuming the energy, we need to have proper design of the heating, ventilation and air condition system of the building and air handling unit. The key to that is to have a good prediction of the cooling load of the building. Furthermore, direct sunlight into the building effects the comfort of the occupants which decrease the productivity and might cause illness as well.

In this project, the cooling capacity of a block 16 in Universiti Teknologi Petronas has been estimated. External and internal heat gains have been calculated for the 17 rooms which comprise of lecture rooms, surau, store and printing room. CLTD method has been used following the ASHRAE standards. Additionally, HAP program used to get more accurate findings. The results is compared against the designed cooling capacity.

The results show that there is 17.8% overdesign on the cooling capacity of the air handling unit compared to HAP results. While 20% overdesign on the supplied cooling load compared to CLTD method results.

There is great effect of temperature set point on the cooling load. Increasing just one degree Celsius from 24ºC to 25ºC can decrease the cooling load by 7.23% of the current one. Further one degree difference in temperature save capacity of 9.41%. However, changing temperature set point should also take into consideration the other buildings which the UTP Gas District Cooling plant is supplying as well as a central system.

Similarly, applying tinted film to the glazed wall will save energy. A tinted film which decrease the heat transfer coefficient by 30% can cause reducing the cooling load of the space by 3.36%. Applying such methods as tinted film to glazed walls and increasing temperature set points can contribute to the university savings on the utility bill. Most importantly, these solutions will help to increase the performance of the lecturers as they are now more comfortable. Saving our lovely environment by consuming less energy can be achieved as well.

It is recommended to do similar prediction of cooling load for other UTP buildings to get more savings. Consequently, we can know whether it is viable to increase the temperature set point and how it effects in all other related buildings. It is most important to carry out cooling load estimation whenever major changes in a building is carried out since it effects the cooling requirement.

REFERENCES

[1] C. L. W. Roger W. Haines, HVAC systems design handbook. United States of America: McGraw-Hill 2003.

[2] *Energy efficiency* available: https://www.iea.org/aboutus/faqs/energyefficiency/ retrivied on 19th April, 2016

[3] *Residental Sector*. Available: http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx/ retrivied on 19th April, 2016

[4] *Green Building Facts*. Available: http://www.usgbc.org/articles/green-building-facts retrivied on 19th April, 2016

[5] S. K. Sahu, "Cooling Load Estimation for a Multi-story office building," Master of Technology, Mechanical Engineering, National Institute of Technology,India// 2014.

[6] Y. M. Degu, "Cooling Load Estimation and Air Conditioning Unit Selection for Hibir Boat," *The International Journal of Engineering and Science,* vol. 3, p. 10, May, 2014 2014.

[7] H. H. Sait, "Auditing and analysis of energy consumption of an educational building in hot and humid area," *Energy Conversion and Management,* vol. 66, pp. 143-152, 2// 2013.

[8] K. Kulkarni, P. K. Sahoo, and M. Mishra, "Optimization of cooling load for a lecture theatre in a composite climate in India," *Energy and Buildings,* vol. 43, pp. 1573-1579, 7// 2011.

[9] A. Fouda, Z. Melikyan, M. A. Mohamed, and H. F. Elattar, "A modified method of calculating the heating load for residential buildings," *Energy and Buildings,* vol. 75, pp. 170-175, 6// 2014.

[10] A. Shariah, B. Shalabi, A. Rousan, and B. Tashtoush, "Effects of absorptance of external surfaces on heating and cooling loads of residential buildings in Jordan," *Energy Conversion and Management,* vol. 39, pp. 273-284, 2// 1998.

[11] K. W. Mui and L. T. Wong, "Cooling load calculations in subtropical climate," *Building and Environment,* vol. 42, pp. 2498-2504, 7// 2007.

[12] P. Edward G, Air Conditioning Principles and Systems, Fourth Edition ed. New York City: Prentice Hall// 2002.

[13] A. Hadi, "Study on Air Conditiong Cooling Load and Operational Practices Within Glazed Building ", Universiti Teknologi PETRONAS// 2009.

[14] *HVAC Cooling Load Calculatin* available: http://www.slideshare.net/quillshare/heat-load-calc

[15] V. C. Thomas, "*Energy Efficient Building Design*," Illinois Institute of Technology, Chicago// 2003.

[16] S.Sulaiman and A. H. Hassan, "Analysis of Annual Cooling Energy Requirements for Glazed Academic Buildings". *Journal of Applied Sciences*, 11: 2024-2029// 2011.

[17] ASHRAE, Cooling and Load Calculation Manual: U.S Department of Housing and Urban Development.

[18] S. I. U. H. G. Petrus Tri Bhaskoro, "Simulation of intermittent transient cooling load characteristic in an academic building with centralized HVAC system," *International Conference on Environment Science and Engineering*, Singapore// 2011

[19] Maintenance department, Univerisiti Teknologi PETRONAS

APPENDIX

Appendix A: Properties of common insulating and construction materials

Material	Description	Density	Specific heat	Thermal conductivity	Conductance
		kg/m^3	kJ/kg.K	W/m.K	W/m^2.K
Bricks	Common	1600	0.84	0.77	-
	Face	2000	0.84	1.32	-
Masonry materials	Concrete	1920	0.88	1.73	-
	Plaster cement	1885	0.796	8.65	-
	Hollow clay tiles				
	10 cm	-	-	-	5.23
	20 cm	-	-	-	3.14
	30 cm	-	-	-	2.33
	Hollow concrete block	-			
	10 cm	-	-	-	8.14
	20 cm	-	-	-	5.23
	30 cm		-	-	4.54
Wood	Ply	544	-	0.1	-
	Hard	720	2.39	0.158	-
	Soft	512	2.72	0.1	-
Glass	Window	2700	0.84	0.78	-
	Coro silicate	2200	-	1.09	-
Insulating materials	Fiberglass board	64-144	0.7	0.038	-
	Core board	104-128	1.88	0.038	-
	Mineral or glass wool	24-64	0.67	0.038	-
	Magnesia	270	-	0.067	-
	Asbestos	470-570	0.82	0.154	-

Appendix B: CLTD for cooling load calculation for flat roofs

Roof No	Description of Construction	Weight lb/ft^2	U-value $Btu/(h \cdot ft^2 \cdot °F)$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Hour of Maximum CLTD	Minimum CLTD	Maximum CLTD	Difference CLTD	Heat Capacity $Btu/(ft^2 \cdot F)$
	With Suspended Ceiling																															
1	Steel Sheet with 1-in. (or 2-in.) insulation	9 (10)	0.134 (0.092)	2	0	−2	−3	−4	−4	−1	9	23	37	50	62	71	77	78	74	67	56	42	28	18	12	8	5	15	−4	78	82	2.50
2	1-in. wood with 1-in. insulation	10	0.115	20	15	11	8	5	3	2	3	7	13	21	30	40	48	55	60	62	61	58	51	44	37	30	25	17	2	62	60	4.11
3	4-in. l.w. concrete	20	0.134	19	14	10	7	4	2	0	0	4	10	19	29	39	48	56	62	65	64	61	54	46	38	30	24	17	0	65	65	4.83
4	2-in. h.w. concrete with 1-in. insulation	30	0.131	28	25	23	20	17	15	13	13	14	16	20	25	30	35	39	43	46	47	46	44	41	38	35	32	18	13	47	34	6.94
5	1-in. wood with 2-in. insulation	10	0.083	25	20	16	13	10	7	5	5	7	12	18	25	33	41	48	53	57	57	56	52	46	40	34	29	18	5	57	52	4.21
6	6-in. l.w. concrete	26	0.109	32	28	23	19	16	13	10	8	7	8	11	16	22	29	36	42	48	52	54	54	51	47	42	37	20	7	54	47	6.17
7	2.5-in. wood with 1-in. insulation	15	0.096	34	31	29	26	23	21	18	16	15	15	16	18	21	25	30	34	38	41	43	44	44	42	40	37	21	15	44	29	6.89
8	8-in. l.w. concrete	33	0.093	39	36	33	29	26	23	20	18	15	14	14	15	17	20	25	29	34	38	42	45	46	45	44	42	21	14	46	32	7.51
9	4-in. h.w. concrete with 1-in. (or 2-in.) insulation	53 (54)	0.128 (0.090)	30	29	27	26	24	22	21	20	20	21	22	24	27	29	32	34	36	38	38	38	37	36	34	33	19	20	38	18	11.58
10	2.5-in. wood with 2-in. insulation	15	0.072	35	33	30	28	26	24	22	20	18	18	18	20	22	25	28	32	35	38	40	41	41	40	39	37	21	18	41	23	6.98
11	Roof terrace system	77	0.082	30	29	28	27	26	25	24	23	22	22	22	23	23	25	26	28	29	31	32	33	33	33	33	32	22	22	33	11	16.36
12	6-in. h.w. concrete with 1-in. (or 2-in) insulation	77 (77)	0.125 (0.088)	29	28	27	26	25	24	23	22	21	21	22	23	25	26	28	30	32	33	34	34	34	33	32	31	20	21	34	13	16.26
13	4-in. wood with 1-in (or 2-in.) insulation	19 (20)	0.082 (0.064)	35	34	33	32	31	29	27	26	24	23	22	21	22	22	24	25	27	30	32	34	35	36	37	36	23	21	37	16	9.64

Appendix C: Corrected CLTD values for LM, North Latitude

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	−5
	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

Appendix D: Shading Coefficients

	Type of Glass	Nominal Thickness Each Light [a]	Solar Trans. [b]	No Interior Shading		Type of Interior Shading				
						Venetian Blinds		Roller Shades		
								Opaque		Translucent
				$h_o = 4.0$	$h_o = 3.0$	Medium	Light	Dark	Light	Light
SINGLE GLASS	Single									
	Clear	3/32 to 1/4	0.87-0.80	1.00	1.00					
	Clear	1/4 to 1/2	0.80-0.71	0.94	0.95					
	Clear	3/8	0.72	0.90	0.92	0.64	0.55	0.59	0.25	0.39
	Clear	1/2	0.67	0.87	0.88					
	Clear Pattern	1/8 to 9/32	0.87-0.79	0.83	0.85					
	Heat Absorbing Pattern	1/8		0.83	0.85					
	Heat Absorbing [c]	3/16 to 1/4	0.46	0.69	0.73					
	Heat Absorbing Pattern	3/16 to 1/4		0.69	0.73	0.57	0.53	0.45	0.30	0.36
	Tinted	1/8 to 7/32	0.59-0.45	0.69	0.73					
	Heat Absorbing or Pattern		0.44-0.30	0.60	0.64	0.54	0.52	0.40	0.28	0.32
	Heat Absorbing [c]	3/8	0.34	0.60	0.64					
	Heat Absorbing		0.44-0.30							
	or Pattern	1/2	0.24	0.53	0.58	0.42	0.40	0.36	0.28	0.31
	Reflective Coated Glass			0.30		0.25	0.23			
				0.40		0.33	0.29			
				0.50		0.42	0.38			
				0.60		0.50	0.44			

Appendix E: Maximum SHF for 4 ^{0}N latitude for glass

4 Deg										
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	33	33	79	170	229	252	237	193	141	286
Feb.	35	35	123	199	242	248	215	152	88	301
Mar.	38	77	163	219	242	227	177	96	43	302
Apr.	55	125	189	223	223	190	126	43	38	287
May	93	154	200	220	206	161	89	38	38	272
June	110	164	202	215	196	147	73	38	38	263
July	96	154	197	215	200	156	85	39	38	267
Aug.	59	124	184	215	214	181	120	42	40	279
Sep.	39	75	156	209	231	216	170	93	44	293
Oct.	36	36	120	193	234	239	207	148	86	294
Nov.	34	34	79	168	226	248	232	190	139	284
Dec.	33	33	62	157	221	250	242	206	160	277

Appendix F:

Appendix F1: Cooling load factor for glass

Wall facing	Solar time hr.											
	1	2	3	4	5	6	7	8	9	10	11	12
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.8	0.86	0.89
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.8	0.76	0.62	0.41	0.27
SE	0.03	0.03	0.02	0.02	0.02	0.3	0.57	0.74	0.81	0.79	0.68	0.49
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.2	0.21
HOR	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85

Appendix F1: Cooling load factor for glass

Wall facing	Solar time hr.											
	13	14	15	16	17	18	19	20	21	22	23	24
N	0.89	0.86	0.82	0.75	0.78	0.91	0.24	0.18	0.15	0.13	0.11	0.10
NE	0.26	0.24	0.22	0.20	0.16	0.12	0.06	0.05	0.04	0.04	0.03	0.03
E	0.24	0.22	0.20	0.17	0.14	0.11	0.06	0.05	0.05	0.04	0.03	0.03
SE	0.33	0.28	0.25	0.22	0.18	0.13	0.08	0.07	0.06	0.05	0.04	0.04
S	0.80	0.68	0.50	0.35	0.27	0.19	0.11	0.09	0.08	0.07	0.06	0.05
SW	0.59	0.75	0.81	0.81	0.69	0.45	0.16	0.12	0.10	0.09	0.07	0.06
W	0.31	0.53	0.72	0.82	0.81	0.61	0.16	0.12	0.10	0.08	0.07	0.06
NW	0.22	0.30	0.52	0.73	0.82	0.69	0.16	0.12	0.10	0.08	0.07	0.06
HOR	0.85	0.81	0.71	0.58	0.42	0.25	0.14	0.12	0.10	0.08	0.07	0.06

Appendix G: Heat gain from people

Degree of activity	Typical application	Total heat		Sensible heat	Latent heat
		Adult, Male	Adjusted		
Seated at Theater	Theater, matinee	115	95	65	30
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department store; retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurants	145	160	80	80
Light bench work	Factory	235	220	80	140
Moderate dancing	Dance hall	265	250	90	160
Bowling	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Athletics	Gymnasium	585	525	210	315

Appendix H: CLF factor for sensible gain via occupant

Total hrs. in space	Hrs. after each entry into space											
	1	2	3	4	5	6	7	8	9	10	11	12
2	0.49	0.58	0.17	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.03
4	0.49	0.59	0.66	0.71	0.27	0.21	0.16	0.14	0.11	0.10	0.08	0.07
6	0.50	0.60	0.67	0.72	0.76	0.79	0.34	0.26	0.21	0.18	0.15	0.13
8	0.51	0.61	0.67	0.72	0.76	0.80	0.82	0.84	0.38	0.30	0.25	0.21
10	0.53	0.62	0.69	0.74	0.77	0.80	0.83	0.85	0.87	0.89	0.42	0.34
12	0.55	0.64	0.70	0.75	0.79	0.81	0.84	0.86	0.88	0.89	0.91	0.92
14	0.58	0.66	0.72	0.77	0.80	0.83	0.85	0.87	0.89	0.90	0.91	0.92
16	0.62	0.70	0.75	0.79	0.82	0.85	0.87	0.88	0.90	0.91	0.92	0.93
18	0.66	0.74	0.79	0.82	0.85	0.87	0.89	0.90	0.92	0.93	0.94	0.94

Total hrs. in space	Hrs. after each entry into space											
	13	14	15	16	17	18	19	20	21	22	23	24
2	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01
6	0.11	0.10	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03
8	0.18	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06	0.05	0.05	0.04
10	0.28	0.23	0.20	0.17	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.06
12	0.45	0.36	0.30	0.25	0.21	0.19	0.16	0.14	0.12	0.11	0.09	0.08
14	0.93	0.94	0.47	0.38	0.31	0.26	0.23	0.20	0.17	0.15	0.13	0.11
16	0.94	0.95	0.95	0.96	0.49	0.39	0.33	0.28	0.24	0.20	0.18	0.16
18	0.95	0.96	0.96	0.97	0.97	0.97	0.50	0.40	0.33	0.28	0.24	0.21

Appendix I: Sample of the assessment done at block 16, lecturers' offices

Lecturers Thermal Comfort in their Offices Regarding Air-conditioning Survey

This survey prepared for FYP Project: Prediction of Cooling Load of a Glazed Building under Malaysia Weather Conditions

Lecturer Room No. : 16-03--5

- Most often while in office, do you feel overcooling, undercooling or comfortable?
  I feel comfortable but in certain times I feel overcooling.
- Does it happen that you wear coat in the office because of feeling overcooled?
  Yes it happens.
- In case you feel overcooling, when do feel it the most during the day?
  I would say monthly during the mornings and evenings.
- Does it happen in certain months of the year?
  It happens monthly however becomes more in the raining seasons such as the month of December
- Do you have a problem with the direct sun arrays (solar radiation) while in the office?
  Yes, especially early morning till about 11AM.
- Do you feel hot due to the direct radiation?
  Feeling warm while seated in my chair facing directly the sun radiation while the office is cool.
- Have you experienced any illness with regard direct solar radiation?
  It is annoying to my eyes when I want to read or do my job in my computer and making me sweat.
- Does it affect the level of lighting for reading or writing; in a positive or negative way?
  The natural lighting is nice however when it is directly exposed to the interior parts it is annoying. It is disturbing when the students come and consult me and it is difficult to read in their laptops as the diffused arrays pass through the screens.

- Do you have any suggestions with regards to the air-conditioning system?

  It will be nice if introduced tinting film to protect against the direct sun radiation as the installed blinds are not effective. Furthermore, eye protector for the computers should be installed.

Appendix J: Sample of the weather data from UTP solar research site

Timestamp	TZ	Pyranometer (W/m^2)	Ambient Temp ('C)	Wind Speed (m/s)
7	n	-2	24	0.300548
8	n	54	25	0.373288
9	n	224	27	-0.004737
10	n	446	29	0.846069
11	n	621	31	0.725678
12	n	757	33	0.964406
13	n	812	33	1.224091
14	n	625	34	0.801214
15	n	595	34	0.891227
16	n	475	34	1.22034
17	n	336	32	0.98531
18	n	60	31	1.578496