Study on Reduction of Cooling Energy for Air Conditioning by Flexible Space Compartmentalization in Residential Houses

By

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15765

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Ir. Shaharin Anwar Sulaiman)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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.

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Dionisio Miguel Ntutumu Nsang

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ABSTRACT

An increase consumption of electricity in the domestic sector is increasing sharply due to the high demand of air conditioning usage in homes. This situation can be observed worldwide, thus the emissions of greenhouse effect gases is increasing as a consequence of the high energy consumption in home cooling systems. Air conditioning consumes a lot of energy in domestic electricity use and there is a huge interest of finding ways to reduce this energy consumption. The use of air conditioner for many hours during sleeping time at night is considered to be one of the moments when a lot of energy is wasted to cool the whole room when the real area that needs to be cooled at that moment is the one covering the bed. One way of trying to reduce the energy use by air conditioner at night it is to reduce the cooling space so that the cooling energy required by the air conditioning unit can be decreased. However, it cannot be known theoretically what would be the performance of a domestic air conditioning unit when the designed cooling space is reduced by means of temporally partitions. The objective of this project is to perform an experimental study in order to assess the possibility of saving cooling energy by means of room's flexible space compartmentalization, and observe if the electrical power consumed by air condition unit can be reduced when the unit is required to cool a smaller space. Manual cooling load calculation is covered to analyse and estimate the heat gains in the room and therefore evaluate the cooling energy that will be required to cool the room. The experiment consists on taking measurement of current and voltage consumed by air conditioner in order to calculate the power used by the cooling unit. These measurements have been taken at room without partition and also at room with partition or space division. The results obtained are compared to evaluate a possible reduction of energy consumption when the room space is divided. There are some aspects that could affect the results of this project. The room where the experiment is performed is considerably wide compared to the average domestic bedroom. Nevertheless, since the main point is to compare the electrical performance of an air conditioner when operating at different space volumes, the results obtained can provide a general trend of electricity consumption by the air conditioning unit.

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CHAPTER 1
INTRODUCTION

The world's consumption energy nowadays is estimated to be more than 15 terawatts (TW) per year. In emerging countries the economic growth has caused a structural transformation never seen before. Hundreds of millions people have abandoned low-intensity energy activities, such as agriculture, to be employed in energy intensive activities, such construction and industry. This process of industrialization is the main cause of the increase of energy demand in developing countries and subsequently worldwide (Castro, 2011).

The accelerated process of industrialization and urbanization in emerging markets, especially in China and India, has also changed the lifestyles of the local people. Mobility and mass transfer are increased and generated an increase in consumption oil and other fossil fuels. The environmental impact of these changes is predictable: the Global emissions of carbon dioxide (CO_2) due to high consumption of energy worldwide are increasing. After a relatively moderate growth, Carbon emissions accelerated significantly in the late twentieth century, driven by rising demand energy in developing economies (Castro, 2011).

1.1 Background Study

The ten countries members of the Association of South East Asian Nations (ASEAN) will play an increasing important role in the world energy demand for decades. Brunei, Cambodia, Philippines, Indonesia, Laos, Malaysia, Myanmar (Burma), Singapore, Thailand and Vietnam make up one of the most dynamic and diverse regions in the world, and its present economic growth is comparable to that of Canada and Mexico together; and the population in the ASIAN exceeds that of the European Union. The energy consumption of this region, comparable to Middle East, will continue to increase rapidly from comparatively low level per capita, driven by rapid economic and population growth and the continued urbanization and industrialization (Castro, 2011).

Malaysia's energy consumption increases every year. In 2008, the total energy demand in Malaysia was estimated around 522,199 GWh, from which the industrial and transport sectors were the two largest users of energy, accounting more than three-fourths of this total demand. The residential and commercial sector was the third largest user (14%) of energy in Malaysia, and only 1% of the total energy was consumed by the agriculture sector (Boon, 2010).

Figure 1.1. shows the total energy consumption trend in Malaysia in the period of 1978 to 2012 for all energy resources such as petroleum, natural gas, coal, biomass, and electricity. The energy consumption is measured in kiloton of oil equivalent (ktoe).

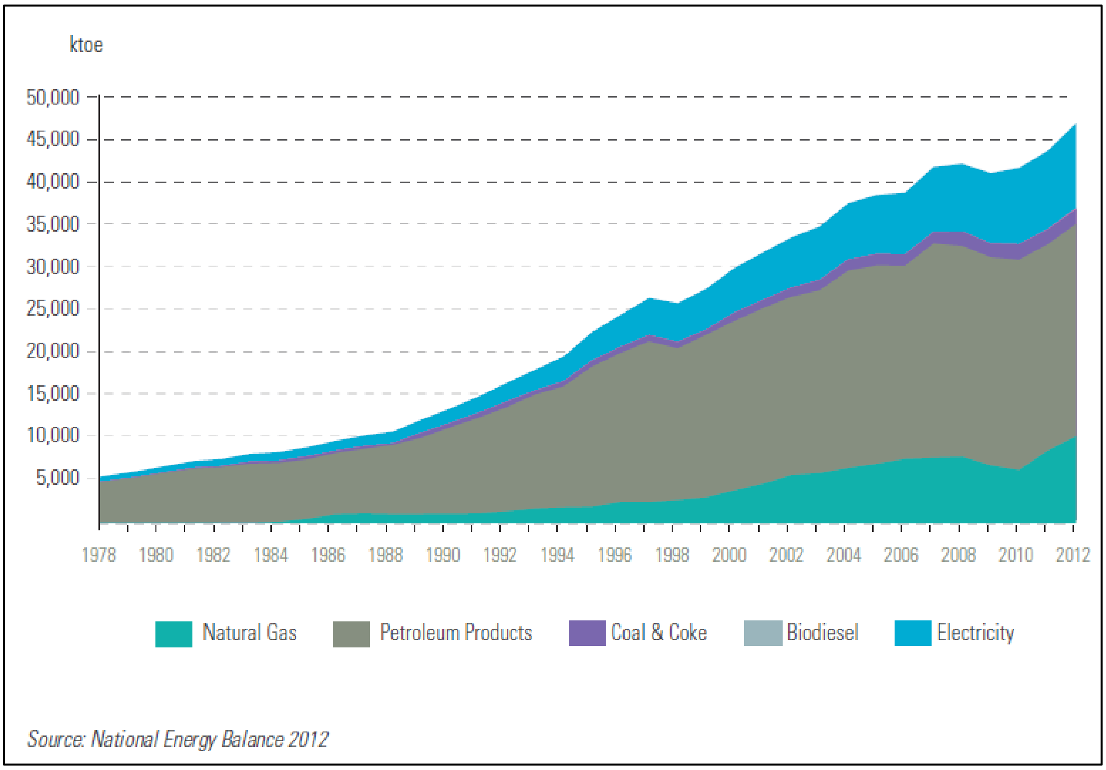


Figure 1.1: Malaysia's energy consumption by type (National Energy Balance 2012)

Electricity consumption in Malaysia increases sharply every year, the average of increase is estimated to be around 2,533 GWh per year. For instance, The electricity consumption in 1971 was estimated to be 3,464 GWh, and 94,278 GWh in 2008 (Figure 1.2). Among this increase of electricity consumption is the domestic and commercial use as stated before, which is around 14% of the total electricity produced in Malaysia (Boon, 2010).

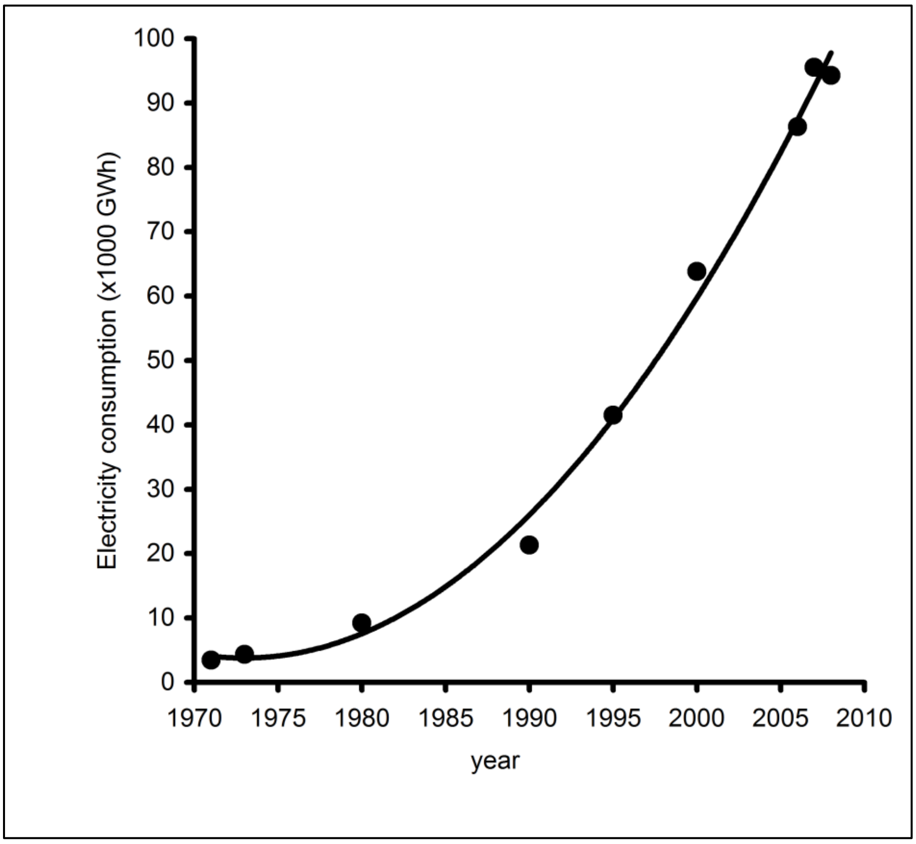


Figure 1.2: Malaysia's electricity consumption evolution from 1971 to 2008 (Boon, 2010)

One of the causes of the increase of energy demand nowadays is also the increase of use of air conditioning in residential houses or apartments all over the world. This trend implies high demand of energy consumption as well as the economic cost increase of the electricity bill. The main issue encountered by the use of air conditioning in houses and apartments is the high electricity consumption that air conditioning units can involve. This energy consumption is reflected directly in the bill of electricity to be paid by the house residents. Furthermore, the increase of energy consumption worldwide is affecting the sustainability of energy resources and it is also one of the causes of global warming.

An effective strategy on how to reduce the electricity consumed by air conditioning is highly required since the cost of electricity is estimated to increase with time, being this increase an economic issue for the majority population of the society.

1.2 Problem Statement

The energy required for cooling a room is directly proportional to the dimension of the space to be cooled. Reducing the cooling space could save the cooling energy from the air conditioning system and, subsequently, it could be possible to reduce the electricity consumed due to air conditioning operation. In order to contrast this supposition, one way of reducing the cooling space is by means of flexible walls that can easily be installed and removed to isolate the room’s side to be cooled from the rest of the room space.

For instance, there are certain times of the day when air conditioning is left operating for long period, like it happens at night when residents sleep. In this case, it may not be necessary to cool the whole room but only the side of the room that comprises the bed. By doing so, probably it could be possible to save cooling energy and therefore, save the energy consumption of air conditioning. Through the experiment that is going to be done in this project, the results will reveals if the idea of reducing the cooling space can also reduce the electrical consumption by the air conditioner.

1.3 Objectives and Scope of Project

The objective of this project is to investigate how the reduction of cooling space of a room can affect the performance of an air conditioning unit in terms of electrical power consumption.

The study is limited to tropical weather, since the experiment is performed in Malaysia, a tropical country. The type of building to which the study is dedicated is for domestic house or apartment.

CHAPTER 2
LITERATURE REVIEW AND THEORY

Thermal comfort is known as “that condition of mind that expresses satisfaction with the thermal environment” (ASHRAE *Standard* 55). In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low, and the physiological effort of regulation is minimized. According to Busch (1992) and Dear et al. (1991) although climates, living conditions, and cultures differ widely throughout the world, the temperature that people choose for comfort under similar conditions of clothing, activity, humidity, and air movement has been found to be very similar. Environment thermal comfort is important because it has a high influence in human work productivity and health as well. Thermal discomfort has also been noticed to lead to sick building syndrome symptoms. The combination of high temperature and high relative humidity serves to reduce thermal comfort and indoor air quality.

2.1 Previous Studies about Air Conditioning Energy Consumption

According to a study carried out by Carlos III University of Madrid and the Spanish National Research Council (2011), air conditioning in homes may account for up to one third of peak electricity use in large cities during hottest seasons. The aim of the research, which was carried out by scientists from the Energy Systems Engineering Unit of Spain, was to measure the energy consumed by home air conditioning in a city and to determine how much energy could be saved by improving the efficiency of the equipment. In order to carry out this study, the researchers simulated electrical consumption in the Autonomous Community of Madrid. To do this, they used data from the National Institute of Statistics of Spain to determine the number of households and the number of climate control and air-conditioning systems installed in the Community. Afterwards, based on the seasonal consumption of the machines, they extrapolated the level of consumption by the entire population. The researchers point out that this method can be adapted for use in other regions. According to the authors of this study, it would be very interesting to determine the levels of carbon dioxide derived from energy consumption due to air conditioning on a national scale. Professor Amancio Moreno, one of the researchers involved in the study, pointed out that by reducing the electrical energy consumption due to air conditioning it could be probable to lower the emissions of carbon dioxide, which is one of the gases that lead to the greenhouse effect.

Yau and Pean (2011) conducted a research on the climate change impact on air conditioner system in terms of performance and reliability in the tropical countries. This study focuses mainly on three aspect of impact, which were cooling and heating load, electricity consumption and outdoor design conditions for the air conditioning system. This study reveals that the air conditioning has consumed more than 60% of electricity in a hot climate city like Jeddah, Saudi Arabia. Climate change has increased the ambient temperature. Consequently, the increased ambient temperature demands the growing need of electricity for the air conditioning and consumes a significant amount of electricity for Jeddah in the summer; this implied that the effect of climate change to the air conditioner power consumption is a reality. The research showed that the relationship between the climate change and energy sector is strongly linked to each other. Climate variability greatly affects the heating and cooling demand, and the combustion of fossil fuels in the energy sector due to the cooling or heating demand produces greenhouse gases that result in serious climate change.

Many other studies have been conducted to explore the climate change effect on air conditioning power consumption. The general methods extensively used are the degree days approach, the detail numerical building simulation and experimental studies. Moreover, there are some studies that use the mean outdoor temperature and the degree-days data to investigate the energy consumption at regional scales such as the gas and electricity consumption in the US (Mayer L.S. et al., 1994).

For instance, Kiattiporn et al. (2008) studied and claimed that the residential electricity consumption (REC) within Bangkok Metropolis rose over 200% since 1980. In this study, the REC of Bangkok Metropolis model was developed to investigate the climatic and economic factors affecting the REC in Bangkok Metropolis from 2002 to 2006 using the stepwise multiple regression technique. Figure 2.1 indicates the results showing the impact of weather change on the electricity.

Month	T_a (°C)	EC (actual)	ΔEC (T_a+1) (GWh)	ΔEC (T_a+2) (GWh)	ΔEC (T_a+3) (GWh)
January	27.9	611.73	87.26	140.05	192.84
February	29.4	684.67	102.5	155.29	208.08
March	30.2	818.88	30.71	83.5	136.29
April	30.8	834.28	45.32	98.11	150.9
May	30.1	811.53	80.06	132.85	185.64
June	29.4	788.96	55.03	107.82	160.61
July	29.5	766.34	61.06	113.85	166.63
August	29.2	766.85	31.36	84.15	136.94
September	28.8	772.81	34.34	87.13	139.92
October	29.2	745.37	85.92	138.71	191.5
November	29.9	781.77	59.95	112.74	165.52
December	27.5	695.97	7.18	59.96	112.75
Average		756.6	56.72	109.51	162.3
%Change			7.49	14.47	21.45

T_a is the monthly mean ambient temperature in Bangkok. ΔEC (T_a+1), ΔEC (T_a+2), and ΔEC (T_a+3) stand for the difference in consumption due to 1, 2, and 3 °C rise, respectively.

Figure 2.1: Impact of temperature increment in household power consumption

Some of the researches mentioned in this section reveal that the consumption of electricity in buildings due to air conditioner is affected by the cooling or heating load demand. Therefore, it could be observed that the cooling load demand plays an important role in terms of air conditioning system design and analysis.

2.2 Air Conditioning in Residential Building

In general, the types of air conditioners used for home application can be classified in two main branches: room air conditioners and central air conditioners (Air Conditioning Your Home, 2004). However, there are many different kinds included within each one of these two main types.

2.2.1 Room Air Conditioner

The room air conditioner type are window mounted units, wall mounted units and free standing units. Window mounted units are unitary air conditioning systems that can be installed in open windows. Wall mounted units are installed through a hole in the exterior wall of the room. Free standing portable units are easily moved on casters.

2.2.2 Central Air Conditioning System

The central air conditioning system is the most suitable cooling solution for homes. It is the quietest, best performing and most comfortable cooling system for houses. This group includes single-package unit, split unit, mini-split unit, mini-duct unit, water-cooled air conditioner.

2.3 Cooling Load Calculation Theory

Cooling load calculation is the first step to be considered in the design of air conditioning system (Burdick, 2011). The room cooling load is defined as the rate at which heat must be removed from a space to maintain it at the design temperature and humidity (Pita, 2002). Room cooling load calculation is essential for proper air conditioning system design and equipment sizing.

There are several methods available for the estimation of cooling load which are Heat Balance (HB) method, Radiant Time Series (RTS) method, Transfer Function Method (TFM), and Cooling Load Temperature Difference or Cooling Load Factor (CLTD/CLF) method. HB method is the most reliable method presented by ASHRAE of calculating cooling load. The rest of the other methods are basically simplifications which are derived from this method. It is an accurate method as it is based on heat balance model (Hassan, 2003). Nevertheless, this method is considerably tedious due to needs of iterative procedure because all of the heat balance equations must be solved simultaneously, and therefore, a computer program should be used (Hassan, 2001).

CLTD/CLF method derives from the Transfer Function method (TFM). The TFM involves tedious and monotonous calculation and is identified by ASHRAE as the fundamental methodology of peak cooling load calculation. Due to the complexity of TFM, ASHRAE developed CLTD/CLF method which highly depends on tabulated data to simplify its use for manual calculation. After several revisions of the method, ASHRAE has come out with a simplified method known as CLTD/SCL/CLF; where SCL stands for solar cooling load factor. Three factors are taken into account to estimate the conduction heat gains, solar heat gains, and internal gains. Those factors are respectively, CLTD/SCL/CLF, and they are calculated using the transfer function method (TFM) which yields cooling loads for standard environmental conditions and zone types. The main disadvantage of this method is the error due to inaccuracy of correcting the other months and latitude values than those given from the tables. By using spreadsheets, this method proves to be the most suitable for manual calculation. In terms of cooling load calculations by the CLTD/SCL/CLF Method, the cooling loads are differentiated as external and internal heat gains. The external heat gain includes heat gain through walls, floor and roof/ceilings; heat gain through windows, heat gain due to ventilation, and heat gain through infiltration. The internal heat gains are heat gain from Occupants, heat gain from illumination/lights, heat gain from electronic devices/equipment, and heat gain from installation.

2.4 Home Energy Monitoring System

The growing need of electricity for the air conditioning consumes a significant amount of electricity (Yau et al., 2011). As result, energy monitoring at homes has become an important practice for households in order to control the amount of energy consumed monthly. There are different types of home energy monitoring devices available. A typical home energy monitoring system includes sensors, a data gateway, and a display where the information monitored can be shown. Standard information includes energy consumption in kilowatt-hours (kWh) and power draw in kilowatts (kW). Frequently, monitors include the cost of the electricity consumed, and some devices allow programming with time-of-use rates.

The use of energy monitoring device is requested for this research as the project aims to measure the amount of cooling energy that can be saved from air conditioning operation. The model of energy monitoring device to be used is a Fluke meter. This device can measure the current and voltage consumed by the air conditioning unit and subsequently the power consume can be calculated.

CHAPTER 3
METHODOLOGY

In order to study the amount of cooling energy that could be saved by partition of the room by means of flexible walls, the first step will be the calculation of cooling load. Room dimensions and envelops characteristics have been considered for cooling load calculation. The calculation of room's heat gain is performed manually using Cooling Load Temperature Difference (CLTD) Method. Once the heat gain of the room is calculated, the results are compared for a realistic approach evaluation.

For the purpose of heat gain calculation, basic principles of heat transfer are studied and reviewed. The experimental study of this research has been conducted in V2 Meeting Room, located at level 1 of V2 Café Building.

After cooling load calculation is done, the experimental study has been conducted. For that, the air conditioning unit has been tested with the Fluke meter to monitor the current and voltage consumed during a certain number of hours of the day. These measurements are taken in order to evaluate the trend of energy usage. The relative humidity and temperature during air conditioning operation has also been taken to evaluate the performance of the unit. This operation has been done for both room's conditions, with and without partition. The results obtained are compared and discussed to evaluate if there is a decrease of energy consumption due to air conditioning when the room space is reduced by means of flexible partition.

3.1 Project Overview

Having the problem statement and objectives of the project clearly stated, several steps are followed in order to accomplish the objective of the project. Figure 3.1 shows all steps that this project comprises up to its completion.

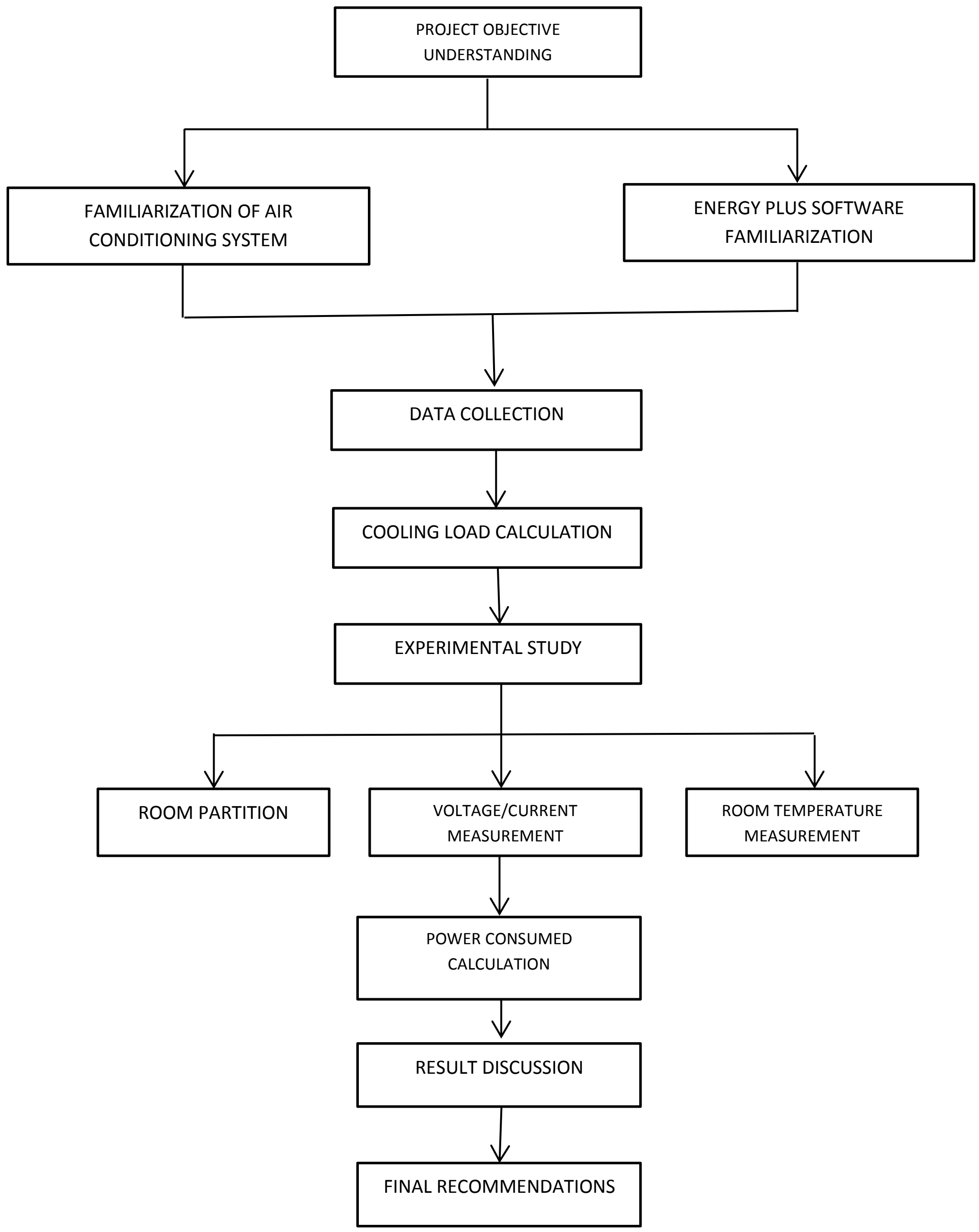


Figure 3.1: Project Flow Chart

3.2 CLTD/CLF Method

The CLD/CLF method is a one-step, hand calculation procedure, based on the transfer function method (TFM). It is used to approximate the cooling load corresponding to the first three modes of heat gain (conductive heat gain through surfaces such as windows, walls, and roofs or ceilings; solar heat gain through fenestrations; and internal heat gain from lights, people, and equipment) and the heating load from infiltration and ventilation.

3.2.1 Outdoor and Indoor Design Specifications

The indoor and outdoor conditions of the room for this studies will be based on those that most approaches the building location. The outdoor condition data to be considered is the one with highest value of Cooling Load Factor and Heat Gain Factor from Table 6.7 and 6.6 (Pita, 2002). The nearest place of reference for data selection is Sitiawan, Perak. The latitude is 4.22° N and 100.7° E. Design dry bulb temperature and wet bulb temperature are 32.5°C and 26.9°C respectively. Daily temperature range of dry bulb (DB) temperature for the location is 8.2°C. For indoor design condition, dry bulb temperature is 24°C with relative humidity of 50% (ASHRAE, 2001). Table 3.1 summarizes the data for indoor and outdoor design specifications.

Table 3.1: Indoor and outdoor design data

SITIAWAN, MALAYSIA	
Latitude	4° 22’ N
Outdoor Dry Bulb Temperature	32.5 °C
Outdoor Wet Bulb Temperature	26.9
Outdoor Relative Humidity	70-85 %
Indoor Dry Bulb temperature	24 °C
Indoor Wet Bulb Temperature	-
Indoor design relative humidity	50 %

3.2.2 Room Description

The room in which the experiment for this project is performed is located in the first floor of a building located in Universiti Teknologi PETRONAS (UTP) Campus. Figure 3.2 reveals the building location at UTP campus. The layout and dimensions of the room are shown in Figure 3.3 (refer to Appendix A for more details). The room dimensions have been measured and envelop characteristics are determined by visual inspection and analysis and they are described as follows:

- North-East (NE) Wall: external wall, 20 cm thick made of cement blocks.
- North-West (NW) Wall: internal partition wall, 10 cm thick. Material: cement blocks.
- South-East (SE) Wall: external wall; 20 cm thick. Material: cement blocks.
- South-West (SW) Wall: internal partition; 10 cm thick. Material: cement blocks.
- Windows: single glass.
- Ceiling: wood sheet ceiling tiles.
- Floor: made of concrete, 20 cm thick,

The room beneath the room is as non-conditioned space. The NW and SW interior walls face non-conditioned spaces. All these details are relevant for the calculation of heat gain through room envelops.

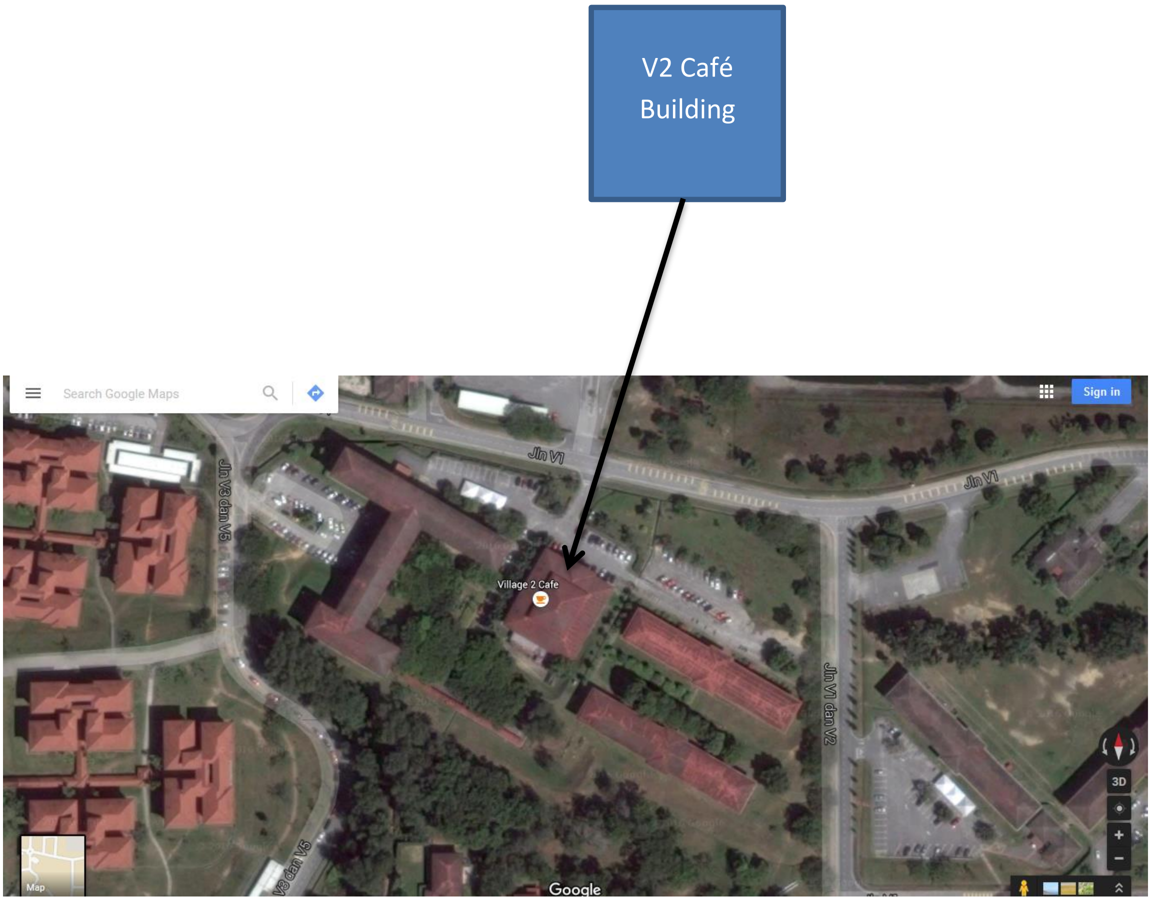


Figure 3.2: V2 Cafe Building at UTP Campus (Google Maps)

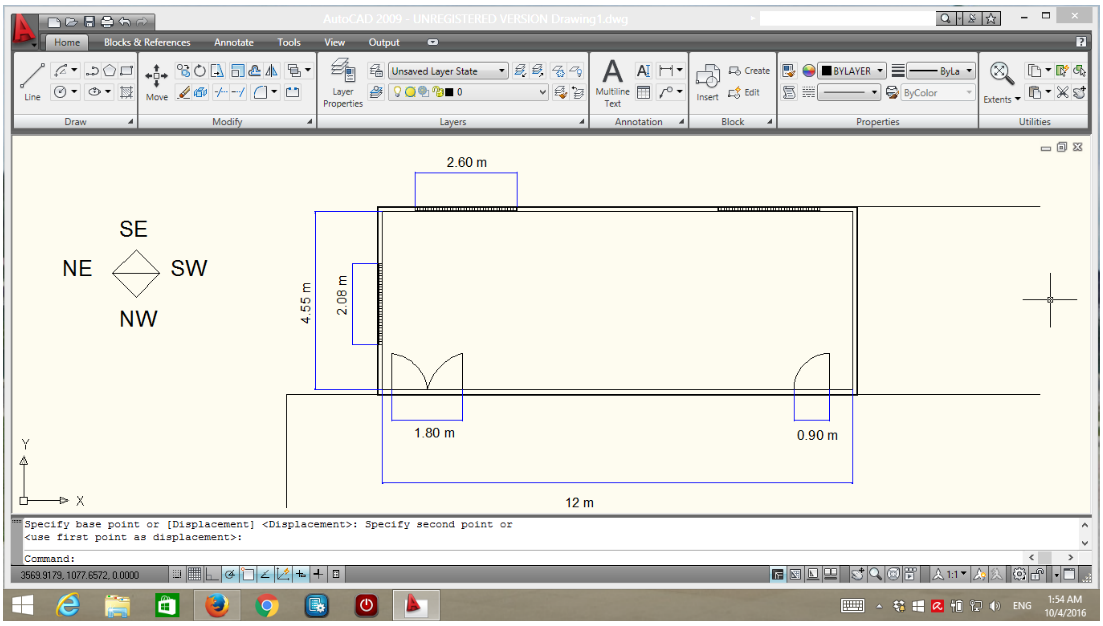


Figure 3.3: Room layout plan

3.2.3 Heat Gains Calculation

Different ways of heat gains are considered for the calculation of cooling load for the room, these are: heat gains through external walls and roof, heat gain through partitions, ceilings and floors, conduction and solar heat gain through fenestration, cooling loads due to ventilation, heat gain from people, Heat gain from Lights, Heat gain from equipment. The heat gain by conduction is calculated by:

$$q = U \times A \times CLTD \tag{3.1}$$

where Q (in watt) is the cooling load, U (in Btu/hr.ft^2.°F) is the overall heat transfer coefficient of the envelope, A is the area of the surface, and $CLTD_c$ (in °F) is the corrected value of CLTD. CLTD value is obtained from Table 6.1, 6.2 and 6.5 (Pita, 2002), Equation (3.2) is used to correct CLTD.

$$CLTDc = CLTD + LM + (78 - tR) + (ta - 85) \tag{3.2}$$

where LM (in °F) is obtained from Table 6.4 (Pita, 2002) which is based on fenestration orientation as well as location latitude, t_R and t_a is taken from the indoor and outdoor design condition (ASHRAE, 2001).

The heat gain through solar radiation is calculated by using the following formula:

$$q = SHGF \times A \times SC \times CLF \tag{3.3}$$

where Q (in Btu/Hr) is the solar cooling load value, the max Solar Heat Gain Factor (SHGF, in Btu/hr.°F) is obtained from Table 6.6 (Pita, 2002); A (in ft^2) is the glass area that is exposed directly to the sun light at that particular time. CLF value and shading coefficient are from Tables 6.8 and 6.7 (Pita, 2002).

The heat gain due to light is sensible heat because it affects only the temperature, and it is calculated by:

$$q = P \times A \tag{3.4}$$

where, Q is sensible heat gain due to lights level in W; P is the heat produced by lights (W/m^2); and A is the area of the space to be conditioned (m^2).

Table 3.2 gives the values of heat produced by usual room’s electrical equipment. The heat gain from electric equipment is given by:

$$q = n \times P \tag{3.5}$$

where:

q = Heat gain due to electric/electronic equipment (W).

P = heat from electric equipment (W).

n = number of electric equipment.

Table 3.2: Heat produced by usual room's electric devices

Appliances	**Watt**	**Qty.**
PC	155	10
Photocopy Machine	400	1
Refrigerator	310	1
Laser Printer	320	2

Heat gains from people that occupy the conditioned spaces is a function of the level of activity, and it can be sensible and latent heat. The total heat gain due to occupants is given by:

$$q = N \times (qs + ql) \tag{3.6}$$

where q is the heat gain due to occupants (W), N accounts for the number of occupants, q_s and q_l in watt (W) are sensible and latent heat respectively from occupants and their values are obtained from Table 3.3.

Table 3.3: Rate of heat gain from occupants in conditioned space (ASRAE Handbook)

Degree of Activity		Total Heat, W Adult Male	Total Heat, W Adjusted, M/F[a]	Sensible Heat, W	Latent Heat, W	% Sensible Heat that is Radiant[b] Low V	% Sensible Heat that is Radiant[b] High V
Seated at theater	Theater, matinee	115	95	65	30		
Seated at theater, night	Theater, night	115	105	70	35	60	27
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	58	38
Walking, standing	Drug store, bank	160	145	75	70		
Sedentary work	Restaurant[c]	145	160	80	80		
Light bench work	Factory	235	220	80	140		
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking 4.8 km/h; light machine work	Factory	295	295	110	185		
Bowling[d]	Bowling alley	440	425	170	255		
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285		
Athletics	Gymnasium	585	525	210	315		

3.3 Project Planning

The project is planned to be carried out in two time frames which are Final Year Project 1 (FYP 1) and Final Year Project 2 (FYP 2). The activities to be covered in each part of the project are shown in Figure 3.2 and Figure 3.3.

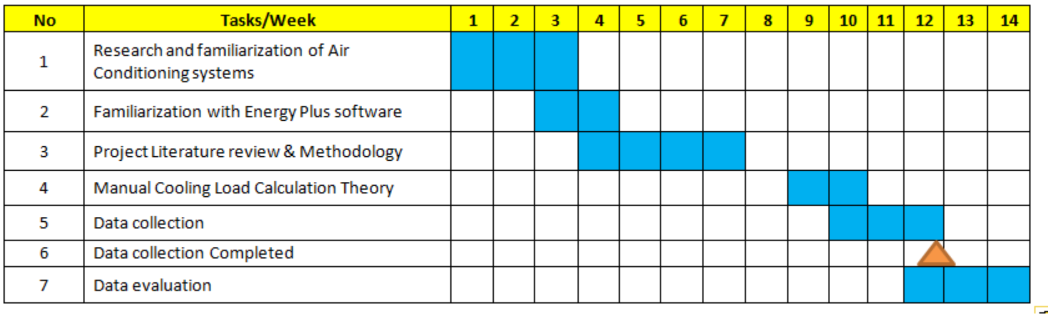
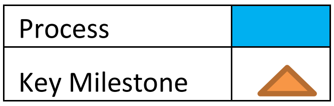


Figure 3.4: Gantt Chart-FYP 1



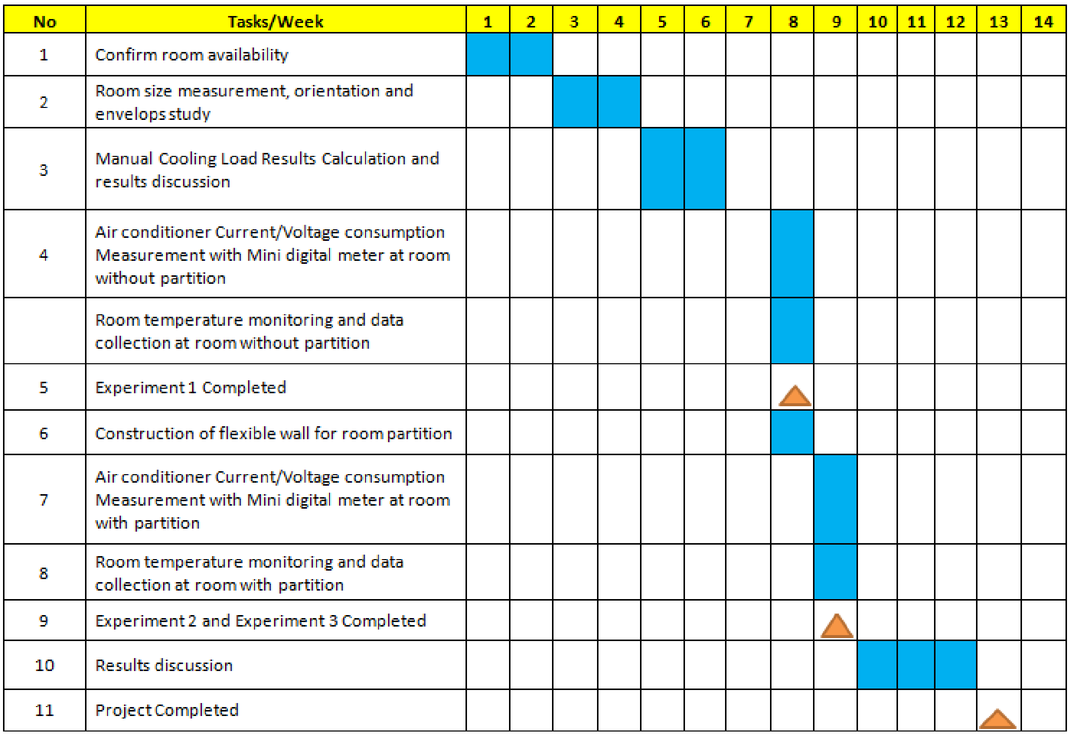


Figure 3.5: Gantt Chart-FYP 2

The project milestones mark the critical points of the project. Key milestones of each part of the project are listed in Table 3.4 and Table 3.5.

Table 3.4: Milestones for FYP 1

MILESTONES	DESCRIPTION
Data collection completed	Complete the acquisition of required data available to proceed the work planned for second part of the project

Table 3.5: Milestones for FYP 2

KEY MILESTONES	DESCRIPTION
Experiment 1 completed	Complete results measurement from experiment, analysis of result and discussion
Partition wall construction completed	Complete the construction of the moveable wall to measure the current and voltage consumed by air conditioner when room space is reduced
Project completion	Complete Experiment 2 and 3

3.4 Experiment

The experiment of this project consists in the measurement of the current and voltage at which the air conditioning equipment operates at the conditions under study, which are at room full space, and room with interior partition. In order to have a more realistic record of the values measured, the readings should be taken several times in a long period, however, the time of reading is 2 hours and the reading are taken in intervals of 10 minutes, which will give 12 readings in total. The values are recorded in Table 3. 6. With the values of current and voltage the power is calculated using the formula:

$$P = VI \tag{3.7}$$

where, P is the Power in Watts (W), I is the electrical Current (A) and V is the Voltage (V).

The results obtained in this table are plotted to evaluate the trend of energy consumption while the air conditioning unit is working. By plotting the results for both case studies, comparative analysis and is performed to evaluate whether there a decrease of energy consumption by air conditioning when the cooling space is reduced by means of flexible compartmentalization. The room temperature and relative humidity also are monitored; this is for the purpose of analysing the performance of the air conditioning unit in terms of air quality in the conditioned space. The measurement of room temperature and relative humidity is taken every 15 minutes, and values are recorded in Table 3.7. By evaluating the room temperature and relative humidity, it is possible to determine if the air conditioning system provide the desired conditions when the space for which it has been designed is modified.

Table 3.6: Current, voltage and power table

Time (min.)	I (A)	V (V)	P (W)
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
110			
120			

Table 3.7: Room temperature and relative humidity table

Time (min.)	Temperature (ºC)	RH (%)
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

3.5 Equipment Used

The following are the equipment and material used for the experiment:

- Mini Digital Clamp Meter (Figure 3.6): this is for the measurement of current and voltage. This clamp meter can also measure the room temperature.

Figure 3.6: Mini digital clamp meter

- Temperature and Humidity Kit (Figure 3.7): this device is used to measure the room temperature and humidity. The temperature can be measured in degree Celsius or Fahrenheit and the humidity is shown in percentage.

Figure 3.7: Temperature and humidity kit

- Mercury Thermometer (Figure 3.8): this thermometer is used to measure room temperature so that the temperature reading done by the temperature and humidity kit can be compared.

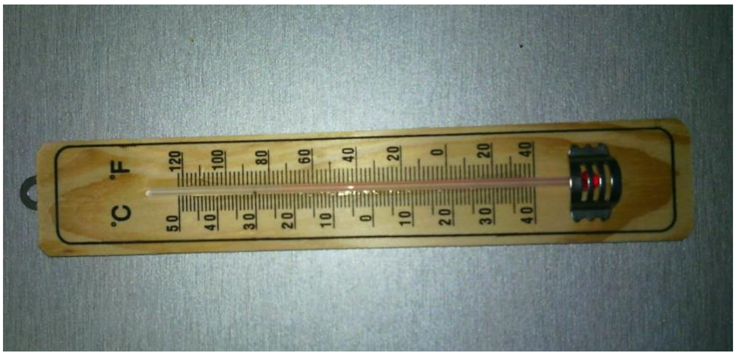


Figure 3.8: Mercury thermometer

3.6 Room Partition

Room partition construction is a key part of this project. It constitutes the main point of this study since air conditioning electricity usage is evaluated based on room with and without partition. A simple room partition has been built. The materials used are four wood poles of 1.73 m height and plastic sheet, commonly known as canvas. The wooden poles are used as supports and the plastic material is the covering to isolate wanted conditioned space from the rest of the room. Figure 3.9 summarizes the steps followed to construct the partition. The room’s envelops areas after partition construction are shown in Appendix C.

Figure 3.9: Sequential scheme of room's partition construction.

CHAPTER 4
RESULTS AND DISCUSSION

This chapter comprises the calculation of room cooling load using manual calculation CLTD Method; and the experimental part to study and evaluate the air conditioning unit performance for the two case studies for comparison. The cooling load calculation is done in this project not for air conditioning system design or selection, but for the purpose of comparing the required cooling energy for room with partition and room without partition.

For manual calculation, a specific solar hour is considered to determine the Cooling Load Temperature Difference for the envelops. In general the solar hours considered of maximum load are from 3 to 5 p.m. For this project the solar hour considered is 3 p.m.

4.1 Areas of the Envelops and Heat Transfer Coefficients

The surface area of sunlit walls and internal partitions, including the floor and the ceiling as well is shown in Appendix B. The area taken into account for the calculation of heat gains through room envelop is considered to be the net area, which is the real surface that is exposed to the type of heat transfer specified for each case. Table 4.1 summarizes the values of the general heat transfer coefficients (U) for the room’s walls based on its construction materials, and these values are obtained from Table 6.3, Table A.7 and Table A.8 (Pita 2002).

Table 4.1: Envelops heat transfer coefficients

Envelop	U (BTU/h*ft2 *F)
NE sunlit wall	0.27
NW Partition	0.32
SE sunlit wall	0.27
SW Partition	0.32
Ceiling	0.33
Glass NW	1.10
Glass SW	1.10
Door	0.47
Floor	0.59

4.2 Heat Gains Through Conduction

There are several ways of heat gain through conduction which are through walls, glass, ceiling, floor and door. The values of Cooling Load Temperature Difference (CLTD) are obtained from Table 6.1, 6.2, 6.4, and 6.5 (Pita 2002). Corrections due to latitude are made using equation 6.2 and 6.3 (Pita 2002). The results obtained, including the heat gains by conduction, are summarized in the following Table 4.2. The total heat gains in the room due to conduction through envelop is 3.7 kW. This value will be added to the heat gains by radiation through the windows glasses and the heat gain due to occupants and appliances.

Table 4.2: Heat gain by conduction result summary

Wall	**U (BTU/h*ft2 *F)**	**A (ft2)**	**CLTDc(F)**	**q (BTU/h)**	**q (W)**	**Total (W)**
NE	0.27	113.11	32.80	1001.67	293.56	3756.60
NW	0.32	282.88	18.80	1701.78	498.74	
SE	0.27	301.13	31.80	2585.51	757.74	
SW	0.32	133.70	10.80	462.08	135.42	
Ceiling	0.33	587.71	10.00	1939.44	568.39	
Glass NE	1.10	20.60	16.80	380.65	111.56	
Glass SE	1.10	51.49	16.80	951.62	278.89	
Doors (NW)	0.47	69.75	10.00	327.83	96.08	
Floor	0.59	587.71	10.00	3467.48	1016.22	

4.2 Heat Gain by Solar Radiation

Heat gains due to solar radiation are obtained from the windows glasses in the NW wall and the SW wall and are exposed to the sunlit. There are dark blue curtains in the interior covering the glasses of the windows. The Maximum Solar Heat Gain Factor (SHGF), The Glass Shading Coefficient (SC), and the Cooling Load Factor are obtained from Table 6.6, Table 6.7 and Table 6.8 Respectively (Pita, 2002). The results for the heat gains calculation due to sun radiation are shown in Table 4.3. The total heat gain due to solar radiation through windows estimated is 0.2 kW.

Table 4.3: Heat gain due to solar radiation through windows

Windows	A (ft2)	SC	MSHGF (W/m2)	CLF	q (BTU/h)	q (W)
Glass NE	20.60	0.30	189.00	0.22	256.94	75.30
Glass SE	51.49	0.30	108.00	0.25	417.11	122.24

4.3 Heat Gains due to Occupants, Lighting and Appliances.

For the calculation of heat gain due to occupants it is assumed that the room is for two occupants, with light activity. The values of sensible heat and latent heat are taken from Table 6.13 (Pita, 2002); and the Cooling Load Factor (CLF) for people is assumed to be 1 (Pita, 2002). Results for heat gain due to occupants is shown in Table 4.4.

Table 4.4: Heat gain due to occupants

People	Q_s/Q_L	n	CLF	q (BTU/h)	q (W)
Q_s	245	2	1	490	143.60
Q_L	155	2		310	90.85

In terms of lighting, there are 8 units of fluorescent lamps of 900 mm; the wattage of the lamps are obtained from table 29.2 (ASHRAE, 2001). The Ballast factor (BF) is 1.25 for fluorescent and the Cooling Load Factor (CLF) for lighting is 1 (Pita, 2002). The results for heat gain due to lighting are summarized in Table 4.5. The total heat gain due to lighting is 1.5 kW.

Table 4.5: Heat gain due to lighting

Light	Watt	W-Btu/hr	BF	CLF	n	q (BTU/h)	q (W)
Fluorescent 900mm	50	3.41	1.25	1	24	5115	1499.06

The appliances taken into account for the room are and the heat gain due to them is shown in Table 4.6. The rate of heat gain for each type of equipment is obtained from Table 6.15 (Pita, 2002). The total heat gain due to appliances is 0.89 kW.

Table 4.6: Heat gain due to appliances

Appliance	Watts	QTY.	q (W)
Desktop PC	500	1	500
Laser Printer	290	1	290
TV	100	1	100

The total amount of heat gains in the room is the sum of all types of heat gains calculated. As it can be observed from Table 4.7, the total heat gain in the room is 7.5 kW, which is the minimum amount of cooling energy required from the air conditioning installed to be cool the room. Notice that the heat gains due to infiltration have been neglected in this study since this room is assumed to be a bedroom and the frequency at which the door is open during air conditioning operation is very low.

Table 4.7: Total heat gain calculation

Source	q (BTU/hr)	q (W)	Total (W)
Heat gains by conduction	12818.05	3756.60	7515.48
Heat gains by solar radiation	674.04	197.54	
Heat gains by to occupants	4000	1172.28	
Heat gains by lighting	5115.00	1499.06	
Heat gains by appliances	N/A	890	

From Figure 4.1 it can be observed that the main source of heat gain in the room is from conduction through the room envelops; this represents 49.98 % of the total heat gains. The second source of heat gain for the room comes from the lighting with 19.95 %. In third place we have heat gain from occupants (15.60 %) fallowed by appliances (11.84 %). Finally solar radiation through the windows glass represents

2.63 % of total heat gain in the room; this amount is relatively low compared to the rest of heat gain sources. It is important to bear in mind that due to lack of appropriate facilities to carry out the experimental part of this project, the available room is a meeting room and in order to calculate the heat gain it is realistic to take into account the maximum number of occupancy of the room; that is the reason why the heat gain from this source is considerably high for this case.

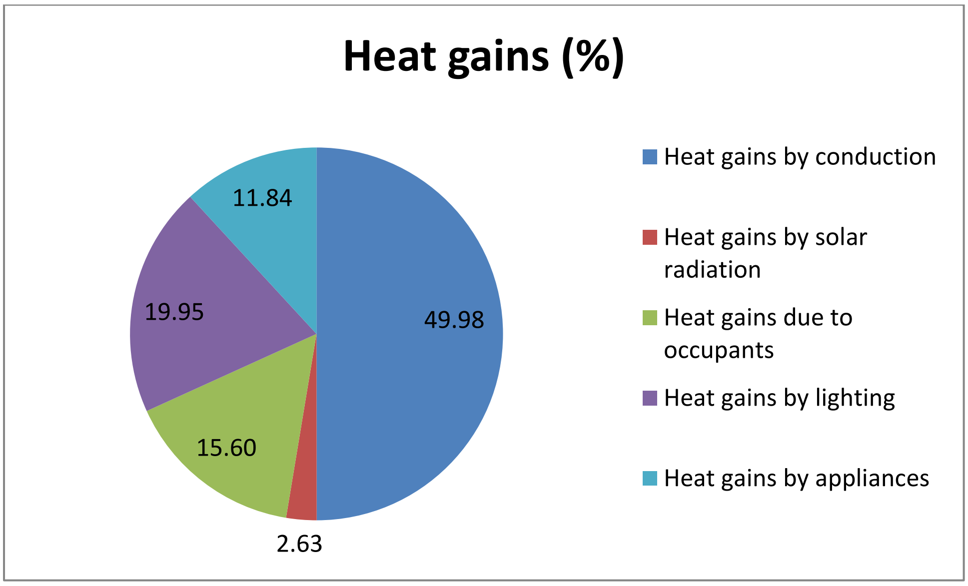


Figure 4.1: Percentage distribution of heat gain source

From this analysis it is possible to evaluate ways of reducing the cooling capacity required for the air conditioning unit at certain moments of the day. Theoretically, it can be observed that by reducing the cooling load or heat gain in the room, the cooling energy required for air conditioning to cool the room should also be reduced. However, this affirmation cannot be justified without practical experiments that support this statement. There are different reasons, for instance, the air conditioning installed in the room is designed for the total cooling load capacity estimated for the room and the consumption of electrical energy by the unit depends mainly on the design of the air conditioning equipment. Therefore, in order to know if the consumption of electricity by the air conditioning unit reduces if the cooling space reduces, experiments are performed to compare the performance of the air conditioning equipment at room full space and also at room with partition. The main parameters measured in the experiment are the current and the voltage during air conditioning operation in order to calculate the power consumed. Other parameters such as room temperature and relative humidity are also measured to evaluate the performance of the unit.

4.4 Heat Gain Calculation for Room with Flexible Partition

At room with partition the refrigerated area is reduces from 54 m^2 to 16 m^2. Table 4.8 summarizes the heat gain in the room when flexible partition is built to divide the room. It can be observed from this table that the total heat gain in the room has been reduced from 7.5 kW to 4.6 kW. This indicates that the amount of heat to remove to cool the room is reduced when the room space is divided. However, the tangible influence of this is discussed in the results obtained from the experiment.

Table 4.8: Total heat gain at room with partition

Source	q (BTU/hr)	q (W)	Total (W)
Heat gains by conduction	10117.19	2965.06	4600.70
Heat gains by solar radiation	465.49	136.42	
Heat gains by to occupants	800.00	234.46	
Heat gains by lighting	1278.75	374.76	
Heat gains by appliances	N/A	890	

4.5 Experiment Results And Discussion

The most important part of this project is the experimental part. The experiments conducted here are useful in determining the behavior of air conditioning equipment in terms of electricity consumption and cooling effect performance at room with and without internal partition. As mentioned previously, the objective of the project is to determine at what level it is possible to reduce electricity consumption by air conditioning when the space to be conditioned is reduce by means of flexible wall. In order to assess this objective, the experiments were carried out in a meeting room.

The experimental part of the project consisted mainly in different measurement taken during air conditioning unit operation at room without partition, known as Experiment 1, and also at room with partition for Experiment 2 and Experiment 3. The activities carried out to complete the experimental part of the project are divided in the following phases:

- Phase 1 (Experiment 1): Measurement of electrical current and voltage, as well as temperature and relative humility in the room without internal partition while the air conditioner is running.
- Phase 2 (Partition construction): Construction of the flexible wall. The partition was built after completed Experiment 1. The materials used are wood poles as supports and canvas (plastic material) for covering.
- Phase 3: (Experiment 2 and Experiment 3): Measurement of electrical current and voltage, temperature and relative humility in the room with internal partition while the air conditioner is running. These measurements are performed separately for Experiment 2 and Experiment 3 carried out in the room with partition.
- Phase 4: Analysis and discussion of results. At this stage of experimental work the results of the three experiments are analyzed and discussed to draw some observations and conclusions regarding the project objectives.

4.5.1 Phase 1: Experiment 1

The first experiment or first practical part of the project was carried out by switching on the air conditioning. Then, electrical current and voltage measurements were taken from the air conditioning unit electrical control box installed in the room such as shown in Figure 4.2. The measures were taken every 10 minutes to keep a record of voltage and current at time intervals. Table 4.9 shows the results obtained in the specified columns. The results in the last column are obtained by multiplying the current by the voltage to calculate the electrical power consumed as indicated in Equation 3.7. Apart from the electrical parameters measurements, the temperature and relative humidity indoor room are also measured using the devices shown in Figure 4.3. These readings are carried out in order to know how the air conditioning is reaching the set point condition required in the room.

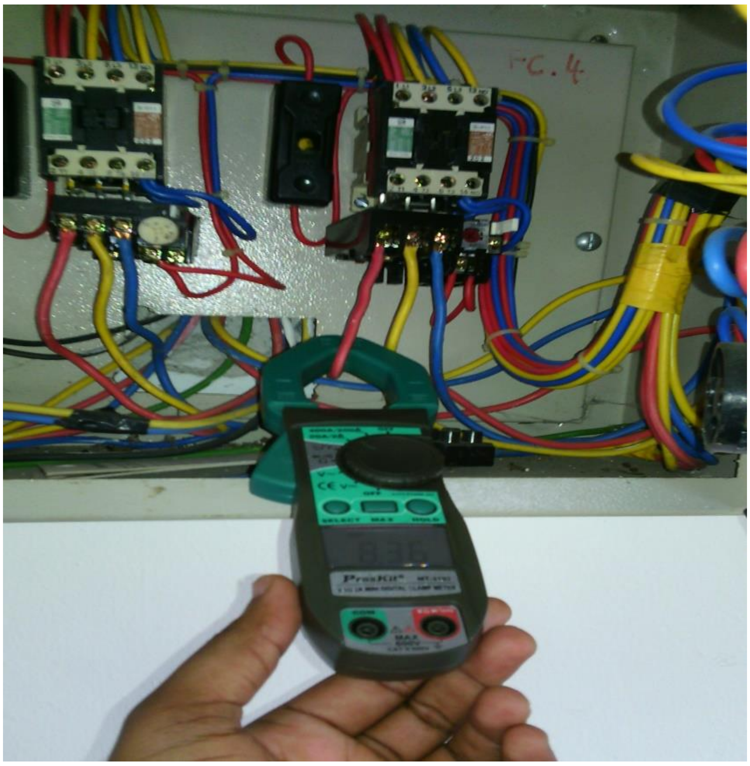


Figure 4.2: Measurement of electrical current and voltage of air conditioning unit using mini multi meter

Figure 4.3: Digital temperature and RH measuring kit and mercury thermometer

The characteristics conditions of Experiment 1 are as follow:

- Initial room temperature: 31°C.
- Initial room Relative humility: 62 %
- Set point temperature: 20 °C.
- Fan speed : High

Once these initial parameters were recorded, the air conditioning was switched on and measurement of current, voltage were recorded in Table 4.9 and the temperature and relative humidity (RH) are recorded in Table 4.10. This experiment was conducted during 2 hours in day time between 12 to 2 pm.

As it is shown in Table 4.9, the values of electric current oscillate between 8.0 A and 8.5 A, with frequent fluctuations in some decimal digits. The idea of taking measurements every 10 minutes is to have close time measurements that are more realistic to the actual electrical consumption of the air conditioning unit. Note that using longer intervals of time to take the readings increases the error in the estimation of the actual trend of power consumption. The voltage values vary between 80 volts and 110 volts. The difference in the voltage fluctuation has more significant variation. Knowing the voltage and current the electrical power consumed by the air conditioner indoor unit is calculated in the last column. The average power calculated for Experiment 1 is 805 W. Table 4.10 records measurement of temperature and relative humidity in the room taken during Experiment 1. It can be observed that both temperature and relative humidity are decreasing with time as the air conditioning keeps working. Note that the cooling temperature reached in Experiment 1 is 23.3°C compared to the set point temperature which is 20°C. The temperature is a key parameter to evaluate the performance and operation of the air conditioning unit in terms of room cooling effect for the case studies included in this project.

Table 4.9: Current, voltage and power results from Experiment 1

Time (min.)	Current (A)	Voltage (V)	Power 1 (W)
10	8.03	97	778.91
20	8.08	93	751.44
30	8.3	87	722.1
40	8.03	103	827.09
50	8.26	106	875.56
60	8.2	104	852.8
70	8.28	90	745.2
80	8.4	98	823.2
90	8.38	86	720.68
100	8.45	96	811.2
110	8.5	107	909.5
120	8.36	101	844.36

Table 4.10: Room temperature and RH measurement from Experiment 1

Time (min.)	Temperature (°C)	Relative Humidity (%)
10	30	55
20	28.2	43
30	26.3	40
40	25.6	39
50	25.3	37
60	24.6	37
70	24.3	36
80	24	38
90	24.8	37
100	24.5	36
110	24.1	36
120	23.3	38

In order to have an overview of the energy consumed and the operation of the air conditioning in meeting the required temperature in the room during Experiment 1, the graphs in Figure 4.4 were plotted. The blue line (above) shows the electrical power consumption trend versus time; its values are shown in the left Y-axis. The red line represents the temperature versus time, and it is values are in the right Y-axis.

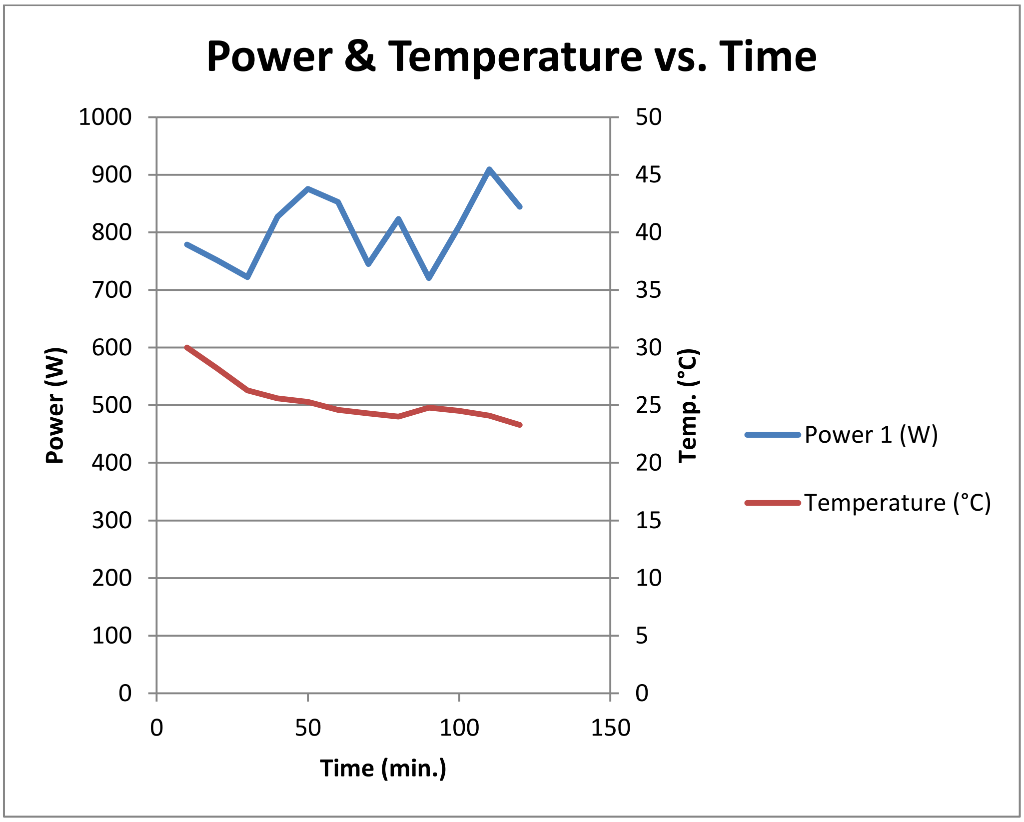


Figure 4.4: Experiment 1 power and temperature profiles

4.5.2 Phase 2: Partition Construction

The partition construction has been discussed in section 3.6 and shown graphically in the following Figure 3.9. The steps followed to build the partition are preparation of construction material, wood poles erection and plastic covering colocation respectively.

4.5.3 Phase 3: Experiment 2 and Experiment 3

Experiment 2 and Experiment 3 were carried out after the partition construction was completed. Figure 4.5 and Figure 4.6 illustrate the room with internal partition.

Figure 4.5: Internal room's partition top view

Figure 4.6: Internal room's partition bottom view

Experiment 2:

Experiment 2 is carried out in the room with internal partition.The characteristics conditions of Experiment 2 are as follow:

- Initial room temperature: 32°C.
- Initial room Relative humility: 64 %
- Set point temperature: 20 °C.
- Fan speed : Medium

By repeating the same procedure as in Experiment 1, measurement of electrical current and voltage of air conditioning unit, and room temperature and relative humidity are taken every 10 minutes during 2 hours of experiment. The results are shown in Table 4.11 and Table 4.12 for Power and Temperature/ Relative Humidity respectively. In Table 4.11 it can be seen that the values of the electric current range between 8.0 A and 8.30 A for Experiment 2. There is a slight decrease in the maximum current value reached compared to that observed in Experiment 1, which maximum is around 8.50 A. The maximum voltage observed in Experiment 2 is 101 V, this is considerably less than the maximum voltage of the Experiment 1 which is 110 V. Same as in observed in Experiment 1, the voltage difference here has greater fluctuation than the current, which only fluctuates in small decimals. The average power of experiment 2 is 729.5 W. Regarding to the temperature it can be observed in Table 4.12 that the value reached Experiment 2 is 21.1°C, which is approaching the set point. Figure 4.7 shows the graph of electrical power and temperature evolution line trend in Experiment 2. Here we see that the power consumed by the air conditioning unit oscillates between 700 W and 800 W.

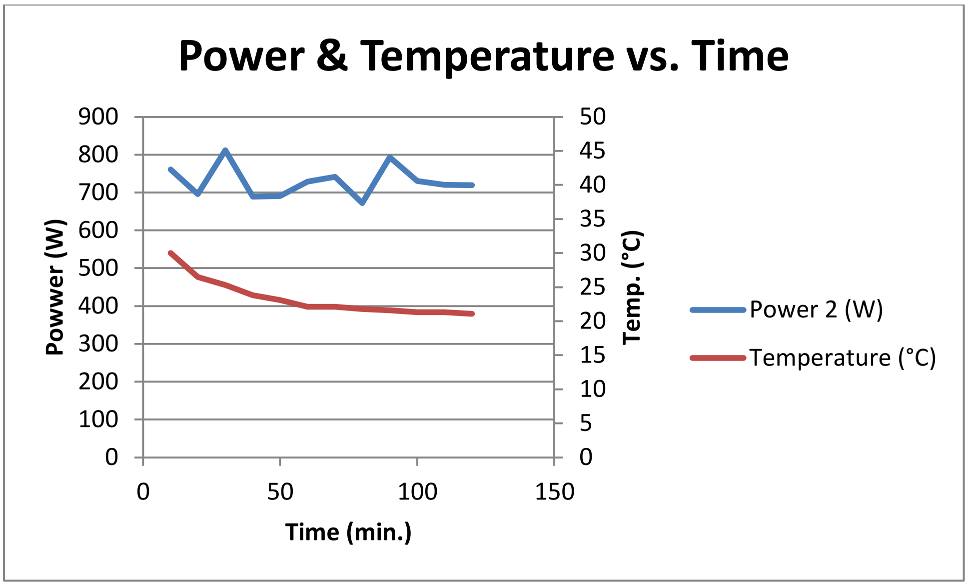


Figure 4.7: Experiment 2 power and temperature profiles

Table 4.11: Current, voltage and power results from Experiment 2

Time (min.)	Current (A)	Voltage (V)	Power 2 (W)
10	8.01	95	760.95
20	8.28	84	695.52
30	8.04	101	812.04
40	8.2	84	688.8
50	8.13	85	691.05
60	8.28	88	728.64
70	8.24	90	741.6
80	8.2	82	672.4
90	8.26	96	792.96
100	8.3	88	730.4
110	8.19	88	720.72
120	8.18	88	719.84

Table 4.12: Room temperature and RH measurement from Experiment 2

Time (min.)	Temperature (°C)	Relative Humidity (%)
10	30	42
20	26.5	40
30	25.3	39
40	23.8	38
50	23.1	37
60	22.1	36
70	22.1	37
80	21.8	37
90	21.6	36
100	21.3	37
110	21.3	37
120	21.1	37

Experiment 3

Experiment 3 is also performed in the room with internal partition. The characteristics conditions of Experiment 2 are as follow:

- Initial room temperature: 31°C.
- Initial room Relative humility: 64 %
- Set point temperature: 20 °C.
- Fan speed : Low

The results obtained for Experiment 3 are presented in Table 4.13 and Table 4.14 for power and temperature respectively. For experiment 3, it is notable that the average current at which the air conditioning unit works is slightly below 8 A. This can be translated as a slight decrease in electricity consumption. The voltage observed in this Experiment 3 is relatively similar to that of Experiment 2, which makes the difference in power consumption between Experiment 2 and Experiment 3 very small. The average power consumed is 721W for Experiment 3. From Table 4.14, note that the cooling temperature reached is 22.3°C, lower than in Experiment 1 but higher than Experiment 2. Figure 4.8 shows the graph of electrical power and temperature evolution line trend in Experiment 3.

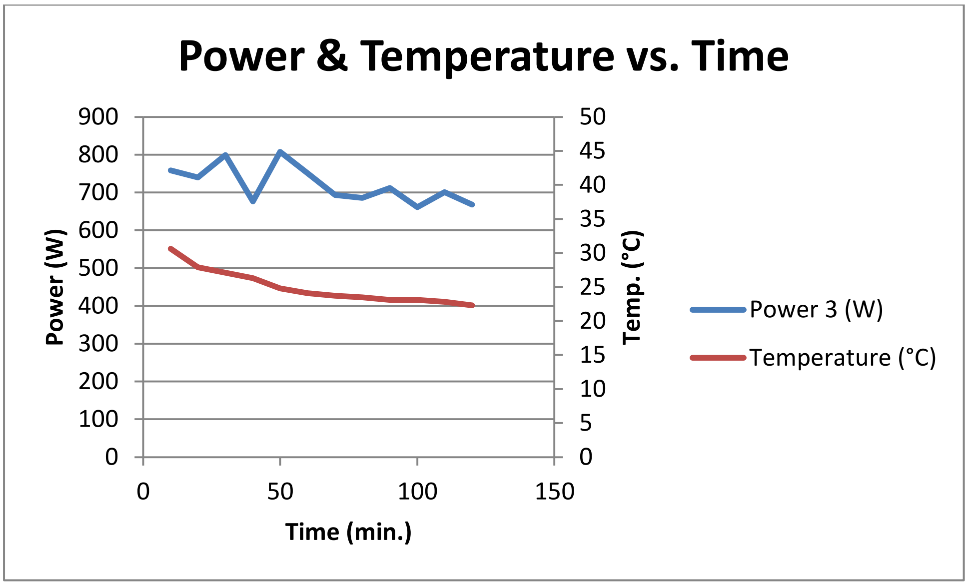


Figure 4.8: Experiment 3 power and temperature profiles

Table 4.13: Current, voltage and power results from Experiment 3

Time (min.)	Current (A)	Voltage (V)	Power 3 (W)
10	7.98	95	758.1
20	8.04	92	739.68
30	7.91	101	798.91
40	8.05	84	676.2
50	7.92	102	807.84
60	7.9	95	750.5
70	7.88	88	693.44
80	7.88	87	685.56
90	7.91	90	711.9
100	7.87	84	661.08
110	7.88	89	701.32
120	7.86	85	668.1

Table 4.14: Room temperature and RH measurement from Experiment 3

Time (min.)	Temperature (°C)	Relative Humidity (%)
10	30.6	57
20	27.9	48
30	27.1	43
40	26.3	40
50	24.8	38
60	24.1	39
70	23.7	39
80	23.5	38
90	23.1	38
100	23.1	38
110	22.8	37
120	22.3	37

4.5.4 Comparative Study and Discussion of Results

In order to carry out a comparative analysis and discussion of the results from the three experiments carried out this project, the resultant power consumption in the thee experiments have been deployed simultaneously in a single graph. The same thing has been done for the temperatures line profiles. The Figure 4.9 shows the trend in consumption of electric power for each experiment. We can see that, 10 minutes after the air conditioning unit is switched on the power consumption is similar for all three cases. This trend persists until the first 30 minutes of operation of the air conditioning unit. From this point more or less, it is noted that the consumption line of Experiment 1 (Power 1) remains above the consumption lines of experiments 2 and 3, represented by Power 2 and Power 3 respectively. Approximately after 70 minutes of operation of the air conditioning unit, the Power 1 decreases slightly approaching the values of Power 2 and Power 3, but this does not last long and Power 1 goes up and remains higher than the rest lines of consumption. By comparing the power consumption of Experiment 2 and Experiment 3, it can be seen a close parallelism in the trend of both curves. The first hour of operation of the air conditioner shows that electricity consumption is almost similar for Power 2 and Power 3 until approaching 80 minutes. From here, it is possible to begin to notice a clear difference between line for Power 2 and the line for Power 3. The line representing Experiment 3 consumption is clearly below the Power 2 line, indicating that electricity consumption is reduced in the case of Eexperiment 3 compared to Experiment 2. However, the difference is very small, since in terms of values we are talking about an average of 729.5 W for the Experiment 2 versus 721 W for Experiment 3. A t a more significant difference was expected, since we are considering different air conditioner operating conditions such as medium speed (Experiment 2) and low speed (Experiment 3). Note that different causes can be behind this insignificant difference in electricity consumption between Experiment 2 and Experiment 3. One of the possible causes can be the operation time. Since the experiment lasted just 2 hours for each study, maybe having the equipment running for longer time, for example 7 to 8 hours, the difference in the average power consumed could be more significant. Another aspect to consider is the life service of the air conditioner; usually the performance of mechanical and electrical equipment tends to deteriorate over time. The air conditioning unit used to do the experiments in the room seems to be installed long time ago based on the appearance it shows.

To determine the success in achieving the objectives of this experiment, it is not enough to analyze the electric power consumed alone. The temperatures profile of the three experiments also need to be compared; after all, it is the room temperature what determines if the air conditioning equipment is meeting the required comfort condition required in the room.

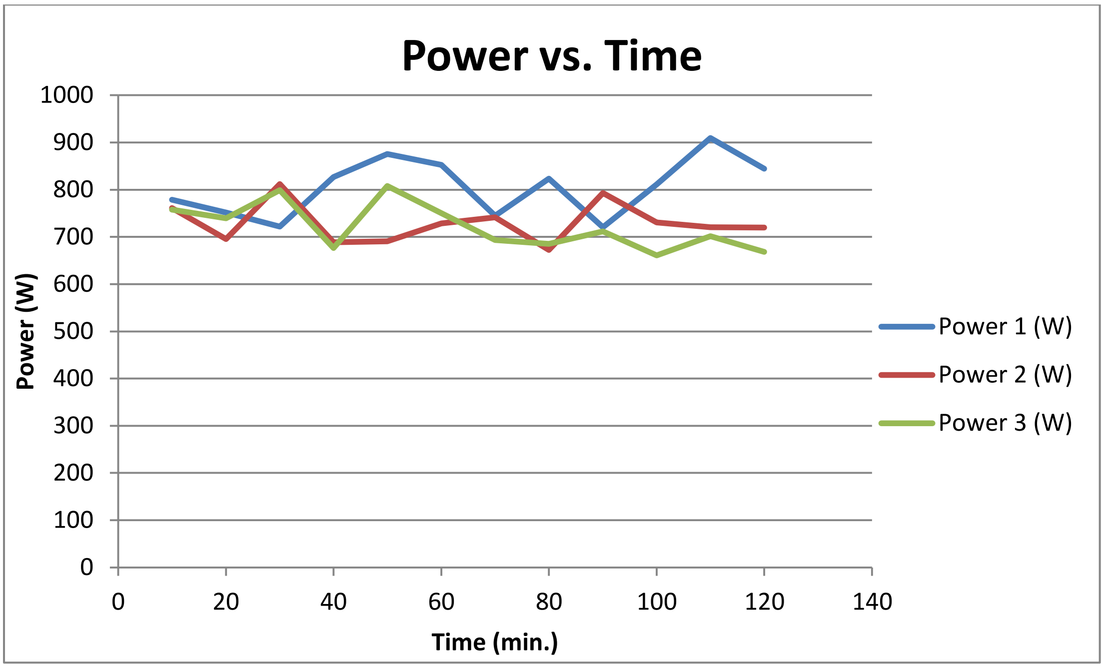


Figure 4.9: Electrical power profiles

Figure 4.10 represents the evolution of the temperature for each Experiment. The graph shows the temperature profile of each experiment from the initial room temperature up to the room temperature reached after 2 hours of operation. The blue line represents the temperature in Experiment 1, the red line is the temperature in Experiment 2 and the green represents the temperature of the Experiment 3. The set point temperature is 20°C and this will determine the degree of approximation to assess the performance of the air conditioner for each experiment. In the case of Temperature 1, which is measured when the room is without internal partition, it can be observed that the indoor temperature reached is above the rest. This means that Experiment 1 takes longer time to meet the set point temperature even though the air conditioner is working at maximum speed. However, with room partition the set point temperature can be met faster with air conditioner working at medium speed as Temperature 2 reveals. This fact shows that there is an improvement when the space to be cooled is reduced by means of flexible partition.

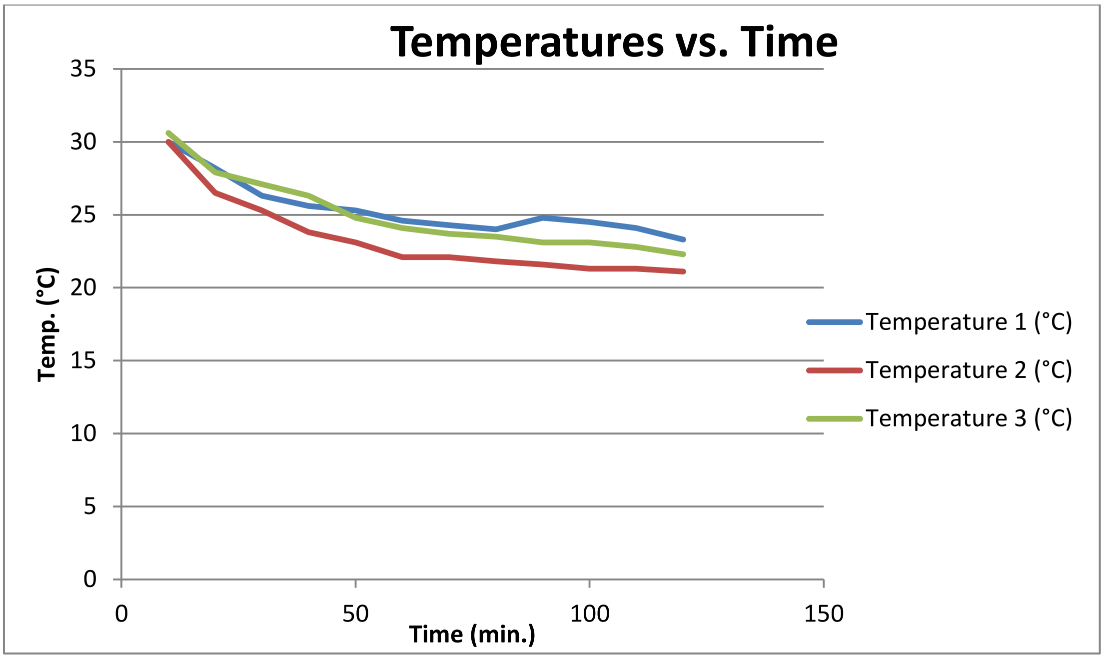


Figure 4.10: Temperature profiles

4.6 Economic Analysis

After determined and calculated the electric power consumed in each experiment, this section looks into the economic impact that the use of room partition can have in the electricity monthly cost for a householder. Table 4.15 summarizes the calculation of electricity monthly bill cost due to air conditioning for each case study. The cost per kWh of electricity consumed has been taken from the official website of the Malaysian electrical company, Tanaga Nasional. To calculate the cost of electricity consumed for each case study some assumptions have been made. The operating hour of the air conditioning is 8 hours per day and 30 days per month. From Table 4.15 it can be observed that the reduction in electricity cost between Experiment 1 consumption and Experiment 2 is around RM10 per room per month. Assuming that flexible partitions are carried out in all air-conditioned rooms of a house the savings can be more significant.

Table 4.15: Electricity cost estimation for each experiment

No.	Partition	Time operation (hrs/day)	Average Power (W)	Total kWh per day	Cost, RM/kWh	Cost (RM/Month)
Exp. 1	**NO**	8	805	6.44	0.571	110.31
Exp. 2	**YES**	8	729	5.83	0.571	99.90
Exp. 3	**YES**	8	721	5.76	0.571	98.80

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

This chapter focus on the conclusions observed after the analysis and discussion of results obtained in this project. There are also several recommendations given in order to improve the work done and the results of this study.

5.1 Conclusions

From the analysis and discussion of the results of the three experiments performed in this study it is possible to highlight different observations. In one hand it has been found that when the air conditioning unit has been cooling the room without internal partition the power consumption is higher than the energy consumed when cooling the room with partition. This is because at room without partition the air conditioning unit is required to work at high speed since the space to be cooled is greater and the cooling energy demand is high. However, at room with partition the cooling space is reduced and the cooling energy is less as shown in cooling load calculation section, therefore, the air conditioning can satisfy the cooling energy demand working at medium or low speed, and consequently reduce the electrical energy used. In the other hand, it has been observed that the cooling effect of the air conditioning unit in space without division is quite poor compared to what it is achieved when the space is reduced because the, as it is shown in Figure 4.11 the Temperature of Experiment 2, performed at room with partition, has better performance regarding the achievement of set point temperature compared to Experiment 1, performed at room without partition. In summary, it can be concluded that with room partition, Experiment 2 has less electricity consumption and also meet the room set point faster than Experimenter 1. Therefore, we can conclude that the partition make possible to reduce the cooling space and subsequently reduces the electrical energy consumption to cool the required space.

5.2 Recommendations

After completing this work and once studied the different facets that compose it, there are some recommendations that can help to improve it. The first recommendation is to conduct the experiment in a more suitable room that meets the actual conditions of rooms where flexible compartmentalization can be implemented such as living rooms and bedrooms of residential apartments or houses. Secondly, it is desirable that the experiment is carried out over a long period of time, between 6 to 8 hours, since the application of the findings of this project can be implemented for during sleep hours. Third, the design and construction of the flexible room partition need to be improved for reduction of infiltration into the cooling space and also to make it easy to be used. Finally, it is necessary to monitor assess the electricity consumption by the outdoor unit, as this plays an important role in the total electricity consumption by the air conditioning. This study has not carried out the evaluation of air conditioning outdoor unit because it requires more sophisticated tools to make continuous recording and uninterrupted electrical current and voltage measurement.

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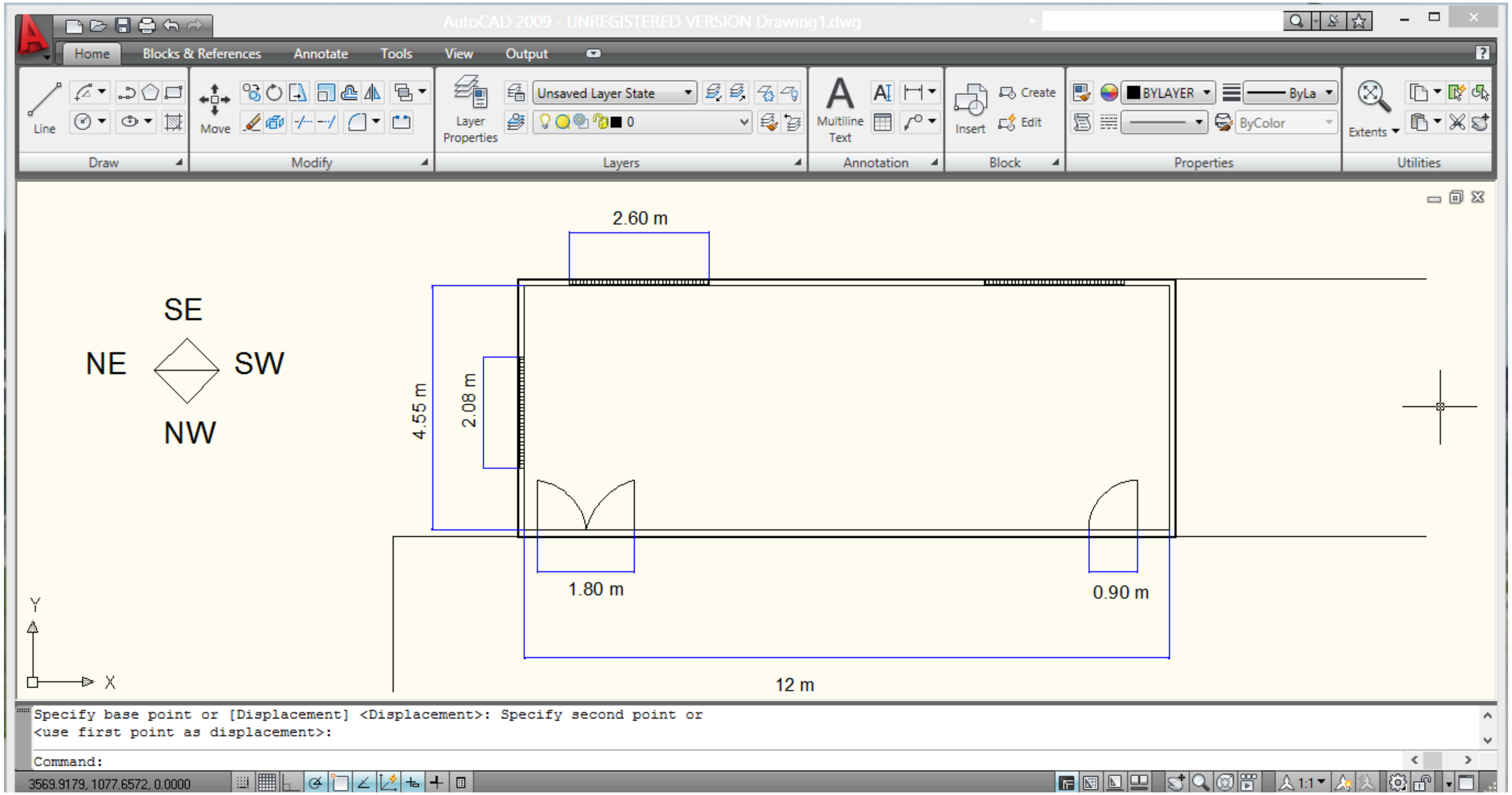
APPENDIX

APPENDIX A: Room plane



APPENDIX B: Room without partition envelops area

Wall	**Length (m)**	**High (m)**	**Area (m2)**	**Net Area (m2)**	**Net A(ft2)**
NE	4.55	2.73	12.42	10.51	113.11
NW	12.00	2.73	32.76	26.28	282.88
SE	12.00	2.73	32.76	27.98	301.13
SW	4.55	2.73	12.42	12.42	133.70
Ceiling	12.00	4.55	54.60	54.60	587.71
Glass NE	2.08	0.92	1.91	1.91	20.60
Glass SE	5.20	0.92	4.78	4.78	51.49
Doors (NW)	2.70	2.40	6.48	6.48	69.75
Floor	12.00	4.55	54.60	54.60	587.71

Appendix C: Room with partition envelops area

Wall	Length (m)	High (m)	Area (m2)	Net Area (m2)	Net A(ft2)
NE	4.55	2.73	12.42	10.51	113.11
NW	3.63	2.73	9.91	5.59	60.17
SE	3.63	2.73	9.91	7.52	80.92
SW	4.55	2.73	12.42	12.42	133.70
Ceiling	3.63	4.55	16.52	16.52	177.78
Glass NE	2.08	0.92	1.91	1.91	20.60
Glass SE	2.60	0.92	2.39	2.39	25.75
Door(NW)	1.80	2.40	4.32	4.32	46.50
Floor	3.63	4.55	16.52	16.52	177.78