A STUDY OF PERFORMANCE ANALYSIS OF FAN COIL UNIT SYSTEM FOR FKM'S AIR CONDITIONER

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DEDICATION

I specially dedicate to my beloved parents, my fiance,
and those who have guided
and motivated me for this project

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Alhamdulillah, praise to be Allah for His blessings and giving me the strength and ability along the though journey of completing my Final Year Project as well as this report writing, for without it, I would not have been able to come this far.

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ABSTRACT

Air conditioning system is a process of ventilation, air movement, air cleanliness, dehumidifying and cooling in order to give comfort to occupant. In tropical climate countries like Malaysia, air conditioner is very important to cool building space. Currently, most of commercial building in Malaysia is equipped with air conditioner either by using split unit or central unit types. Installation of air conditioner requires heat gain estimation, so that the capacity of the installed air conditioner is suitable for the particular area and gives the best performance in its operation. This project is carried out to determine the heat gain and analyze performance of air conditioner at second floor Block 2. FKM buildings start the operation in 2009. In 2009, every building in FKM building is window glass single glazing without tinted film. Started from year 2011, those windows glass have been tinted to reduce glare and heat gain inside the room. Besides that, factor of recommended setting temperature by Malaysia government at 24 °C also affected the design of air conditioning system. Generally, the main air conditioning system working at FKM is central air conditioning system. A method has been implemented to obtain the heat gain which is cooling load temperature difference/cooling load factor, (CLTD/CLF) while for cooling capacity, energy equation throughout fan coil has been used. The heat gain study have been considered five rooms in the second floor Block 2 (lecture rooms) which are Lecture Room 5 (BK 5), Lecture Room 6 (BK 6), Briefing Room 8 (BT 8), Briefing Room 6 and 7 (BT 6 and 7), and Discussion Room 6, 7 and 8 (BP 6, 7 and 8). From these five rooms, there are only two rooms have been analyze the performance which are Bilik Kuliah 5 and Bilik Taklimat 8. The study of heat gain is conducted from 8.00 am until 5.00 pm. The result shows that the heat gains are 14.43 kW, 14.31 kW, 8.35 kW, 15.61 kW and 7.3 kW, respectively. The percentage comparison heat gain against cooling coil load with load for Briefing Room 8 and Lecture Room 5 are 34.45 % and 47.98 % less than the heat gain by rooms. It happened because the data for cooling coil load were taken at steady state condition, while the heat gain data were measured in unsteady state condition. Thus, the fan coil still capable to cooled the rooms in steady state conditions.

ABSTRAK

Penghawa dingin adalah sistem pengudaraan, gerakan kawalan dalam udara, kebersihan udara, pengeringan dan penyejukkan bagi memberi keselasaan kepada penghuni. Di negara-negara yg beriklim tropika seperti Malaysia memerlukan penghawa dingin bagi menyejukkan bangunan. Kebanyakkan bangunan-bangunan komersial di Malaysia dilengkapi dengan penghawa dingin sama ada menggunakan jenis pecahan penghawa dingin atau pusat penghawa dingin. Pemasangan penghawa dingin memerlukan penganggaran perolehan haba supaya kapasiti penyaman udara dipasang sesuai dengan kawasan tertentu dan dapat memberikan prestasi yg terbaik. Projek ini dijalankan bagi menentukan perolehan haba dan analisis prestasi penghawa dingin di aras dua blok dua. Bangunan FKM memulakan operasinye bermula pada 2009. Pada tahun 2009, setiap bangunan FKM menggunakan cermin tingkap tanpa lapisan filem. Bermula tahun 2011, tingkap-tingkap kaca tersebut telah di lapiskan supaya dapat mengurangkan silau dan haba dari memasuki bilik tersebut. Selain itu, faktor menetapkan suhu bilik yg disarankan oleh kerajaan Malaysia kepada 24 °C juga akan mempengaruhi kepada reka bentuk system penghawa dingin tersebut. Secara lazimnya, sistem berkerja bagi penyaman udara di FKM yang utama adalah “central air conditioning”. Cara-cara untuk mengetahui jumlah perolehan haba ialah mengunakan cara CLTD/CLF sementara bagi mencari beban gelung penyejuk menggunakan persamaan penyejukan kapasiti. Perolehan haba yang diperolehi pada waktu puncak untuk Bilik Kuliah 5 (BK5), Bilik Kuliah 6 (BK 6), Bilik Taklimat 8 (BT 8), Bilik Taklimat 6 dan 7 (BT 6 and 7), dan Bilik Perbincangan 6, 7 dan 8 (BP 6, 7 dan 8) adalah masing-masing sebanyak 14.43 kW, 14.31 kW, 8.35 kW, 15.61 kW dan 7.3 kW. Data bagi gegelung penyejuk telah diambil di Bilik Kuliah 5 dan Bilik Taklimat 8. Peratusan perbezaan antara peroleh haba dan gegelung penyejuk bagi kedua-dua bilk tersebut adalah sebanyak 34.45 % dan 47.98 % kurang daripada jumlah peroleh haba di bilik tersebut. Ini terjadi disebabkan data bagi gegelung penyejuk telah diukur pada keadaan bilik sedang stabil sementara peroleh haba diukur pada keadaan bilik tidak stabil.

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LIST OF SYMBOLS

A	Area, m^2
DR	Daily temperature range, º C
kW	Kilowatt
m^3/s	Meter cubic per second
m^2	Meter Square
$\dot{m}$	Mass flow rate, kg/s
$\dot{Q}$	Volume flow rate, m^3/s
Qs, Q_L	Sensible and latent cooling loads from ventilation air, kW
U	Heat transfer coefficient, $W/m^2.K$
Wo’ – Wi’	Outdoor and inside humidity ratio, gr w/kg. d.a
ºC	Degree Celsius
%	Percentage
$W/m^2.K$	Watt per meter square kelvin

LIST OF ABBREVIATIONS

LHG	Latent heat gain
HVAC	Heating, ventilating and air conditioning
FKM	Fakulti Kejuruteraan Mekanikal
FCU	Fan Coil Unit
CLTD	Cooling load temperature difference
DX	Direct Expansion
CLF	Cooling load factor
B.F	Ballast factor
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineer
AHU	Air Handling Unit
BT	Briefing room
BK	Lecture room
BP	Discussion room

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Air conditioning can be refer as any form of cooling, ventilation or disinfection that modifies the condition of air, humidity and air cleanliness that controlled within limits determined by the requirements of the air conditioned enclose (Hundy et al., 2008). In modern society, air conditioners are commonly found in homes, schools, offices, vehicles and public enclosed spaces due to the demand for thermal comfort. During hot weather, it is very important for human to feel comfortable and healthy indoor environment in which to carry out their activities by using an air conditioner. The actual process of air conditioner is to reduce the ambient air temperature in a room based on a simple scientific principle. The rest is achieved with the application of a few clever mechanical techniques.

There are various types of air conditioning systems, such as window air conditioner, packaged air conditioner, split air conditioner and central air conditioner. There are some factors to consider choosing best air conditioning unit like how large the area to be cooled and total heat generated inside the enclosed area. The basic air conditioning system is working based on vapor-compression refrigeration cycle which consists of an evaporator, a condenser, a compressor and a metering device. In the vapor-compression refrigeration cycle, heat is transferred from a lower temperature medium to a higher temperature heat sink. From the second Law of Thermodynamics, heat naturally flows in a certain direction and not in the reverse direction which is heat will be moved through spontaneous flow of heat from hot to cold (Cengel and Boles, 2006).

Most of commercial building in Malaysia is equipped with air conditioner because of Malaysia is located in hot climate countries. This is included building for Faculty of Mechanical Engineering (FKM), Universiti Malaysia Pahang in Pekan, which started it operation in July 2009. In general, the building is divided into 5 blocks which are consists of Block 1, Block 2, Block 3, Block 4, and Admin Block. Each block will get different amount of cooling load of air conditioning due to factor of people in the cooled space, equipment inside the space, heat leakage from the outside leaks through door, windows, and other potential factors. Block 1, 2 and 3 are consist of laboratories, preparation rooms and lecturer rooms, meanwhile Block 2 consists of lecture block, 2 laboratories and few rooms for lecturer. The lecture block consists of six lecture rooms with 60 person capacities of each, 8 tutorial rooms and 9 discussion rooms. All rooms in the lecture block are provided with air conditioner.

The main air conditioner at FKM is central type air conditioning system. The central air conditioning plants or the system is used when large buildings are to be air conditioned completely. Central air conditioner units operate with energy moving or converter machines that are designed to cool or heat the entire building. The machine does not create heat or cool, but it just removes heat from one area, where it is undesirable, to an area where it is less significant or makes no difference. In FKM building, chilled water and cooling tower also plays important role in order to support central air conditioner to give people's comfortability in their room. Chilled water system for FKM building consists of 4 nos. of chiller, 4 nos. of cooling tower, 4 nos. of chilled water pumps, and 4 nos. of condenser water pump. The cooling tower is placed on of chiller water plant room while the chillers and pumps are placed at ground floor (Hamzah, 2011).

Since FKM starts operate in July 2009, unpredictable performance is a common problem in air conditioner that always occurs. Since the system has been introduced, performance of the system will be the main issue and the problem needs to be solved as soon as possible in order to get the best performance of air conditioning system at FKM building. Besides that, the building in this faculty has been modified from window glazing without tinted into window glazing with tinted. In addition, government also decided temperature of all government's building must be regulated to be set at 24 °C.

1.2 PROBLEM STATEMENT

In the FKM building, air conditioning uses more electricity energy than others appliances. Reducing of air conditioner temperature will consumes more energy. It has been mentioned that the FKM building started it operation since July 2009. In early of 2011, the buildings in this faculty have been modified in form of window glazing with tinted. Thus, it will effect to radiation of heat gain and also original design of heat gain in the particular room. Windows glazing with tinted will reduce the amount of heat gain by radiation into the rooms without reducing the light receive. Therefore, new heat gain calculation is crucial to be obtained and air conditioning system performance as well. Besides the modification of windows glass with tinted that will reduce amount of heat gain into the building, fixing of temperature setting also gives a effect to the performance of air conditioning system. Fixing of temperature setting has been decided by government on 12 August 2011 which encourage all government offices have been ordered to set the air conditioner temperature no lower than 24 °C in order to give nature a helping hand and to save electricity energy (Ahmad, 2011). Air conditioning setting temperature at 24 °C gives less amount of refrigeration capacity and also affected original design of air conditioning system in term of air handling unit (AHU) and chiller plant. Therefore, the amount of refrigeration effect needs to be recalculated to fix with air conditioner setting temperature of 24 °C. This work also can resize of component of air conditioning used in the building.

1.3 PROJECT OBJECTIVES

This study was conducted at eight locations at second floor block 2 at FKM building. The objectives of this study as follows:

(i) To investigate the heat gain in the second floor Block 2 of FKM building.
(ii) To analyze performance of air conditioning system for Lecture Room 5 and Briefing Room 8 at FKM buildings.

1.4 PROJECTS SCOPES

Based on the objectives of this project, there are four scopes in this project in order to meet with the project objectives that have been addressed in previous section. The scopes are as follows:

(i) Fundamental study of central unit air conditioning system applied at FKM.

(ii) Carry out heat gain calculation generated in the particular room by using Cooling Load Temperature Different/Cooling Load Factor (CLTD/CLF) method.

(iii) Carry out data collection or measurement of the air conditioner in the particular rooms related to temperature inside the room and also to supply and return air velocity.

(iv) Carry out performance analysis fan coil (FCU) by using energy equation.

1.5 OVERVIEWS OF REPORT

Chapter 1: Chapter 1 is generally discuss about the function of air conditioning system. This chapter also explains types of air conditioner according to the suitable rooms. It also provides the problem statement, objectives, and scopes of the project in order to complete the research.

Chapter 2: In this chapter, it discuss about the literature review of the air conditioning system which is Central unit air conditioning. This chapter also explains more details about working principle of air conditioning system. Beside, the suitable method to obtain heat gain and cooling capacity in particular room also has been discussed. There are three subchapters on literature review such as central air conditioning system, cooling load concept, and FKM air conditioning system. All of these subchapters need to be study in order to gain idea and understanding the system of an air conditioning.

Chapter 3: Chapter 3 discuss details about the methods of experiment. In this chapter, it divided into two experiments which are heat gain and cooling capacity of particular rooms. Heat gain in the particular room can be determined by using CLTD/ /CLF method. While, energy equation are used in order to find cooling capacity for chiller plant system.

Chapter 4: The final outcome reaches in better result if the calculation performance of chiller plants gives in higher value than the cooling load calculation. This will give impact to the people in the room to be more comfortable since the result shows that the each components of the chiller are in good efficiency. The analysis and discussion can be defined from the results. The several factors influence the results can be obtained from the results such as position of the room relative to solar orientation, electric appliances, number of people in the room, wall material, windows material, and other potential factors. All of these factors are dividing into two parts which are external heat gain and internal heat gain. The total sensible heat can be determined from detail analysis.

Chapter 5: In this chapter, it discuss about the conclusion of this project. Conclusion is important in order to make sure the objectives are achieved. It also comes out with final results of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The development of air conditioning is one of the greatest engineering achievements of the 20th century. The temperature of a room or building can be easily modified and controlled by using a modern air conditioning. In harsh climates, an air conditioner allows people to live more comfortable without thinking about hot weather. In this chapter, concepts of performance and operation system of air conditioners have been thoroughly discussed and were divided into three subchapters which are fundamentals of central unit air conditioning system, FKM operation system, and concepts of cooling load. The objectives of this project can be achieved by studying and analyzing all of the references that have been done by professionals in the air conditioner field. All of these subchapters will be explain more detail based on referring to ASHRAE Fundamentals, journal, article, and others. Generally, there are various types of air conditioner have been used around the world such as window air conditioner, packaged air conditioner, split air conditioner and central air conditioner. However, this chapter will be focusing on central unit air conditioner which suitable for large building. This is because only this type of air conditioner is being used at FKM. For evaluating and checking the performance of central unit, CLTD/CLF method will be used in this project.

2.2 CENTRAL UNIT AIR CONDITIONING SYSTEM

Central air conditioning system also known as central system are designed to cool or heat the entire building by removing heat from one area to another area where it is less significant or makes no difference (Hundy et al., 2008). Central air conditioning plants are used for large building and it is very efficient to make the entire room to be air conditioned completely and successfully. In the central air conditioning systems there is a plant room where large compressor, condenser, expansion valve, and evaporator are kept. All of the function will be perform as usual similar to a typical refrigerator system but all these parts are larger in size and have higher capacities.

The FKM's central unit air conditioning system is divided into three parts system. The first part is a central plant in which a boiler and chillers are located. The second part is a water system which the function is to remove heat and to produce chilled water from the central plant to the heat exchanger unit and lastly, the third is a cool air supply system. The cool air supply system is using Fan Coil Unit (FCU) for lecture block in Block 2. The function of FCU is to prepare the mixture of outdoor air and recirculation air from the conditioned room and resupply the mixture of air to the space or room to be cooled. In a central air conditioning system, air is heated or cooled by the hot or chilled water from chiller plant that flows in FCU's coil. Conditioned air will be passing through ducts, terminals, and diffusers (Chadderton, 1997). Figure 2.1 shows working system of fan coil unit air conditioner.

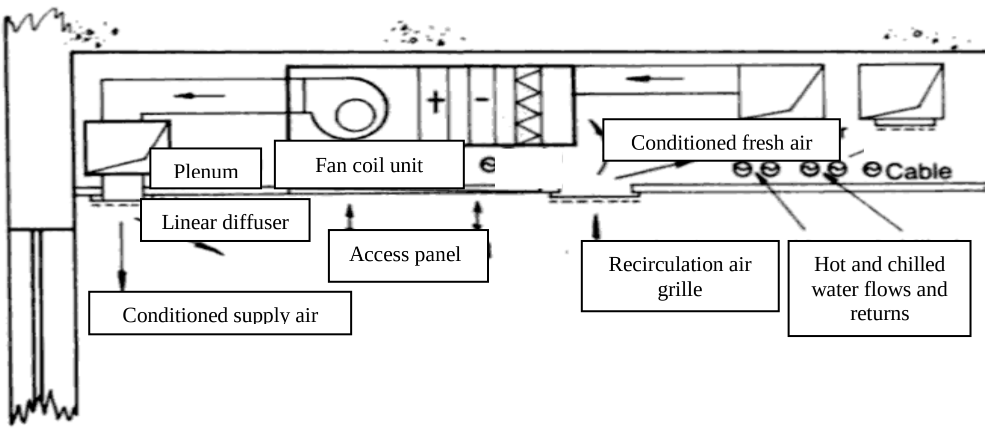


Figure 2.1: Fan coil unit air conditioning system

All type of air conditioner have the same principle when cooling the air with one propose that is converting and changing hot air into cool air. The cycle is closely similar to refrigeration system but is more purposed to cool large building. The key of the converting process is compressor cycle. The system will transfer the heat from inside to outside of the building in order to make people feels comfort during hot weather. In fact, central air conditioners always work more quietly than other types because of the condenser and compressor is usually installed at outside of the building.

There are three main parts in this working principle like compressor, condenser, and evaporator. Air conditioning compressor is the heart of the air conditioner units. The air conditioner compressor is responsible to compress the low pressure and low temperature of Freon gas to higher pressure and temperature before entering the condenser. Then the high pressure gas will be directly gone into coils of the condenser. The condenser is a heat transfer device which is located outside of the cooled space. The gas is condensed into a liquid by dissipate the heat. The liquid become cooler after going through the thermodynamic process in condenser. Then, the liquid will fed into evaporator by going narrow hole to decrease the pressure of the liquid and at the same time the process of producing cold gas is also started. The cold gas will be pushed out from the air conditioning unit to be distributed to all space of the room via ducts. The blower sucks the hot return air via ducts and blow into cooling coil. The system will always continue repeating.

2.3 TYPE OF CENTRAL UNIT AIR CONDITIONER

There are two general types of central air conditioner like direct expansion and chilled water. The concepts of operating system will be discussed below in further details.

2.3.1 Direct Expansion

In direct expansion or DX types of air central conditioning plants, the air used for cooling the room or space is directly passed over the cooling coil at the refrigeration plant. The efficiency of the DX plants is higher due to the air is cooled directly by the refrigerant. It is suitable for cooling the small building because it is not always feasible to carry refrigerant piping to the long distance (Balamugundan, 2008). In this system, there are two rooms. The first room consists of huge compressor, and the condenser which is called as plant room. For the second room known as air handling unit room consists of expansion valve, evaporator or the cooling coil, and the air handling unit. Figure 2.2 shows the layout of direct expansion air conditioning system. Inside the air handling unit, large blower house is in it while the cooling coil is fixed in the air handling unit. The function of blower is to sucks the hot air from the room via ducts and blows it through the cooling coil. After that, the cooled air will be supplied through the ducts into the rooms. This system will have higher efficiency if the area of the building is not too large (Shan, 2001).

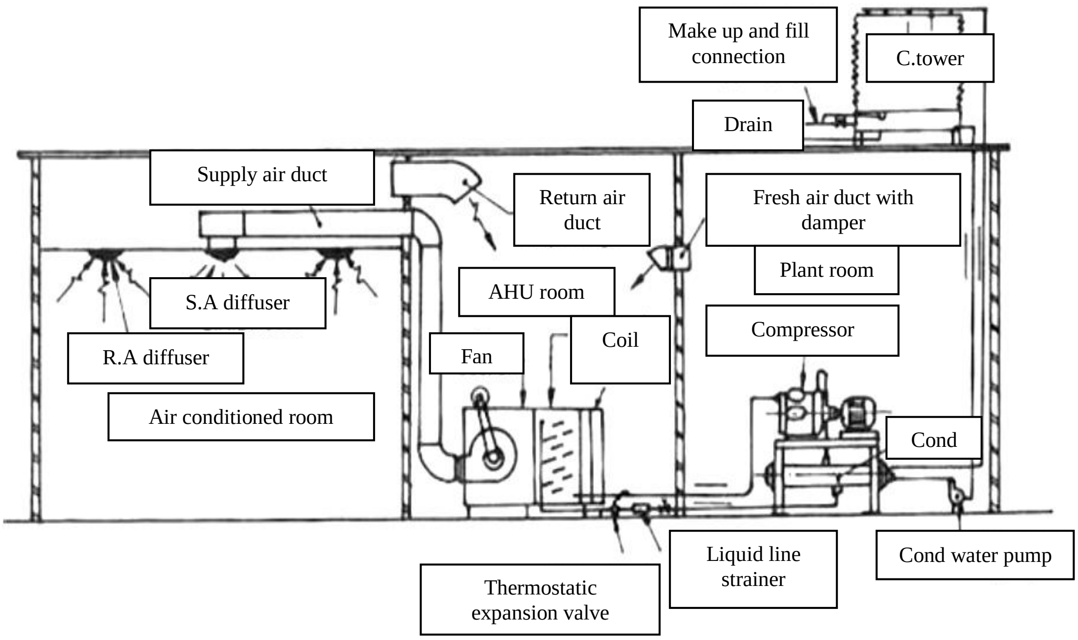


Figure 2.2: Direct expansion air conditioning system

2.3.2 Chilled water

The chilled water types of central air conditioning plants are very suitable for the large building which is has several floors like hotel, shopping mall, and so on. The different system operation of chilled water system compared to direct expansion system is the working principle. The chilled water system is shown in Figure 2.3.

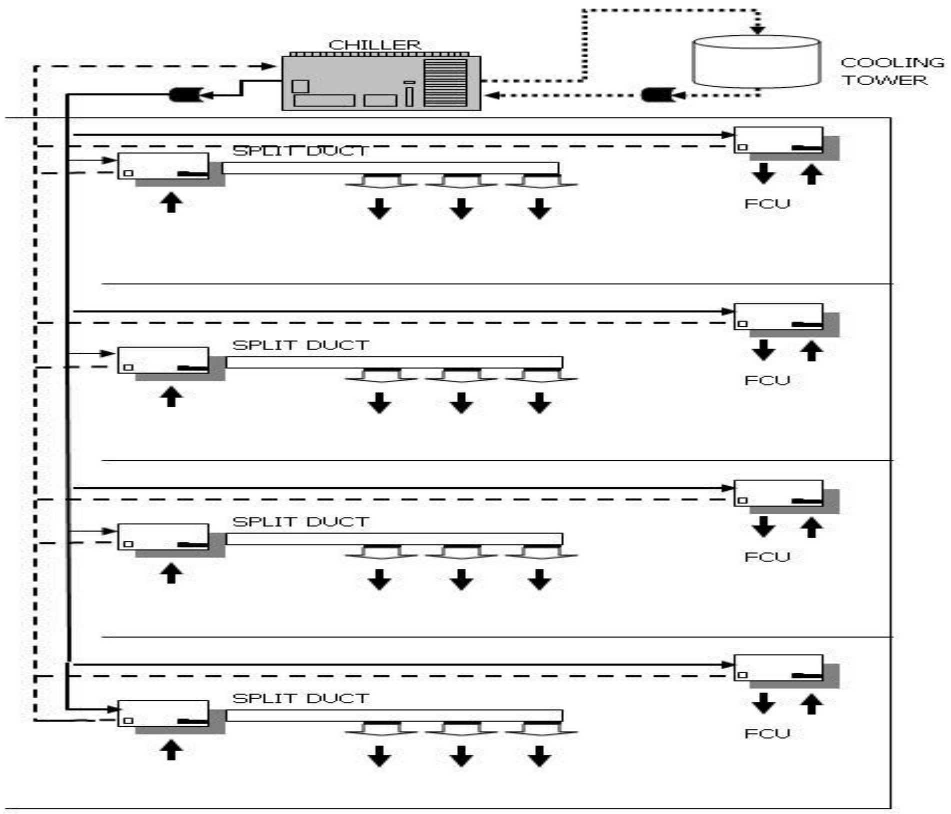


Figure 2.3: Chilled water central air conditioning plant

In chilled water plants, the water or brine solution is chilled to very low temperatures of about 6 to 8 °C by the refrigerant plant (Miller and Miller, 2006). The chilled water is pumped to various floors of the building which air handling units are installed. In this system, the type of evaporator that being used is a shell and tube. On the shell side the brine solution is passed while the other side the Freon fluid passes at extremely low temperature. The temperature of brine solution will drop after going through the evaporator and is pumped to cooling coil in air handling unit at every floors. Generally, in air handling unit comprises of the important part such as blower, cooling coil, and the ducts. The blower sucks the hot air via ducts and passes over the cooling coil and gets cooled. After that, the air is then passes to the air conditioned space through various ducts.

2.4 COOLING TOWER

A cooling tower is a heat rejection device, extract waste heat to the atmosphere in order to cool the room. Cooling towers are used to recover or preserve water in air conditioning system. Hot water from the condenser will pump to the cooling tower which is it will spray into the tower basin. The temperature of the water will be decrease after the water passing through the tower. When the wet-bulb temperature of the incoming air is decrease, the efficiency of the air will be increased in order to decrease the temperature of the water being fed into the tower (Miller and Miller, 2006). Figure 2.4 shows recirculation water system using cooling tower. There is several factors influence the efficiency of the cooling tower

(i) Mean difference between vapor pressure of the air and pressure in the tower water.

(ii) The amount of water surface exposed to air and the length of exposure time of the water to the air.

(iii) Direction of airflow relative to the exposed water surface whether it parallel, transverse or counter.

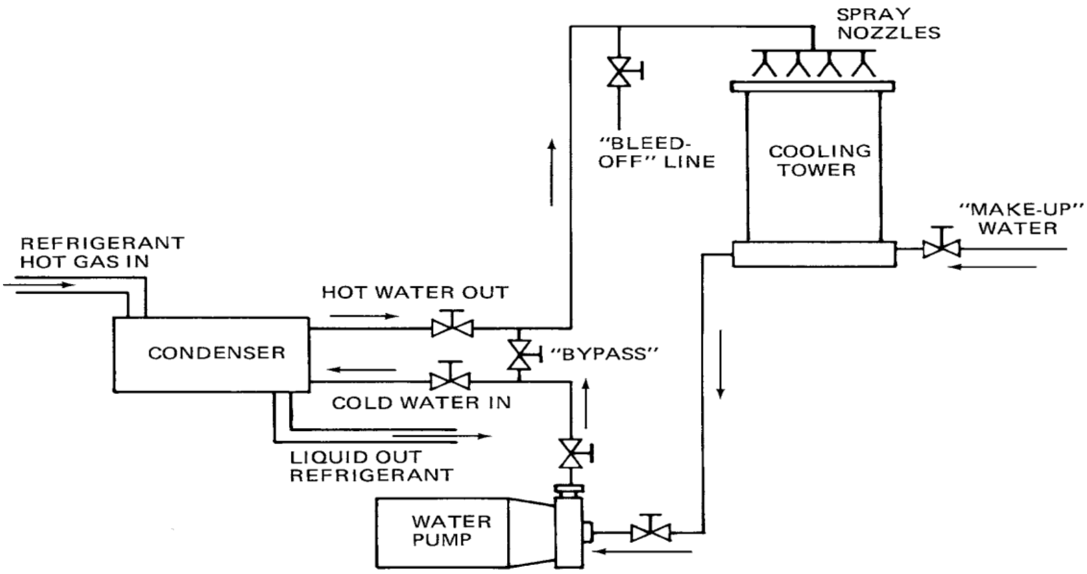


Figure 2.4: Recirculation water system using a cooling tower

Theoretically, the lowest temperature to which the water can be cooled is the temperature of the air (wet bulb) entering the tower. However, it is impossible for the temperature of the water at exit tower to reach the same temperature like of the air. The temperature of the water normally higher than the air temperature which are the temperatures are around 4 to 6 °C (Miller and Miller, 2006).

Cooling tower can be classified into three parts such as counter-flow induced-draft, cross-flow induced-draft, and counter-flow forced-draft. In a counter-flow, air motion is opposite to the downward motion of the water which the air will travels upward through the fill while the cross-flow, motion of the water is downward and air moves horizontally through the fill. The fan both of these types is located down-stream from the fill at the air exit. However, there are differ in performance of tower which is the counter-flow arrangement performance is higher than cross-flow arrangement performance (Shan, 2001). Figure 2.5 shows classification of cooling tower.

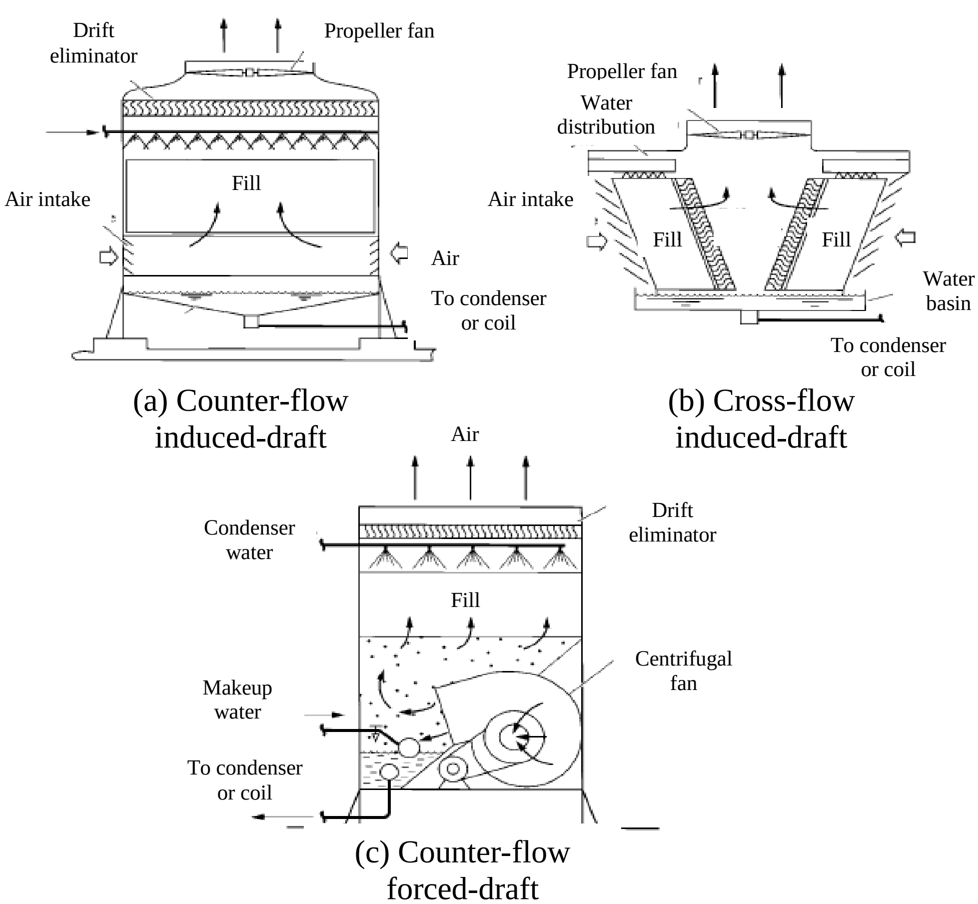
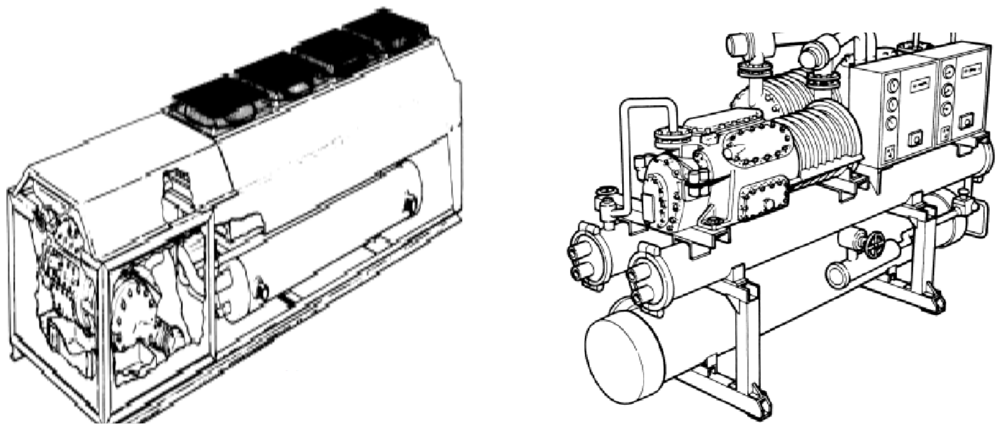


Figure 2.5: Cooling tower

2.5 CHILLERS

In a modern central unit air conditioning system, chiller is used as to cool water or brine solutions. After the water or brine solution cooled, it will feed through pipes to evaporators. In generally, the preferred secondary refrigerant will be water. The water can be circulated without risk of freezing even though the load temperature is sufficiently above 0 °C. In generally, chilled water for an air conditioning systems need the temperature of water is not lower than 5 °C.

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. There are basically five different types of chillers such as reciprocating compression, scroll compression, screw-driven compression, and centrifugal compression. Chiller can be water-cooled or air-cooled. A chilled water system provides chilled water for cooling purposes to all air conditioner equipments like AHU. The number of chillers in a building depends on the maximum expected cooling load in that particular building. Figure 2.6 shows packaged water chiller (Trot and Welch, 2000).



(a) Air-cooled (b) Water-cooled

Figure 2.6: Packaged water chiller

2.6 THE IDEAL VAPOR COMPRESSION REFRIGERATION CYCLE

By using the latent heat properties of the refrigerant, mechanical refrigeration is used to remove heat from a colder medium to a warmer medium. The temperature of refrigerant must be below the temperature medium to be cooled and raise the temperature of refrigerant above the temperature of the medium that is used for rejection. Figure 2.7 shows *T-s* diagram for the ideal vapor-compression refrigeration cycle.

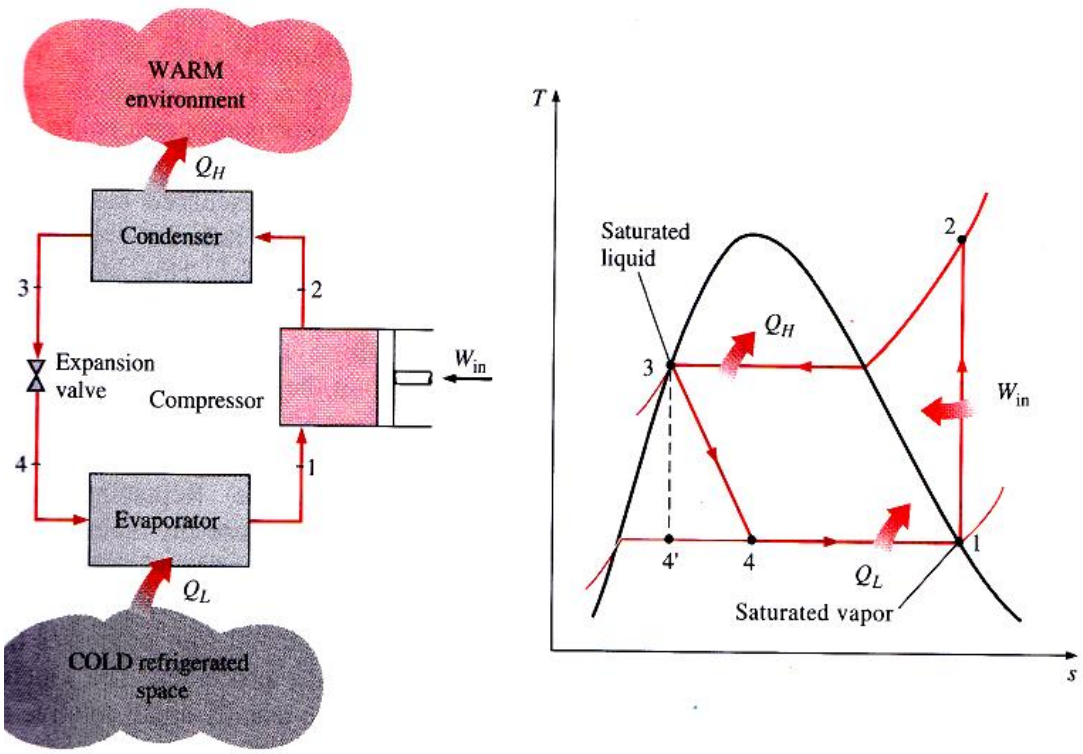


Figure 2.7: Schematic and T-s diagram for the ideal vapor-compression refrigerant cycle

The vapor-compression refrigeration cycle consists of four processes including:

Compression process: The refrigerant enters the compressor as saturated liquid at point 1 and the phase changes into superheated vapor as point 2 after through the compressor. Compression is used to raise the temperature and pressure of the refrigerant.

Rejection process: Rejection process occurred at stage 2-3. The refrigerant will be entering to the condenser with constant pressure. At this point, the temperature will be decrease because it rejects the heat into surrounding. After that, the refrigerant leaves the condenser as saturated liquid at state 3 which is the temperature of refrigerant at this state is still above than the temperature of surroundings.

Expansion process: The pressure and temperature are reduced in an expansion device. The temperature of refrigerant drop below than temperature refrigerated space, usually in air conditioning system is temperature of room or space to be cooled. This process occurred at stage 3-4.

Absorption process: In evaporator which is start from stage 4 to stage 1, the refrigerant enters the evaporator at state 4 which is low quality saturated mixture. After pass through the evaporator, the refrigerant completely evaporates by absorbing heat from the refrigerated space or room to be cooled. The refrigerant phase at this moment is a saturated vapor and reenters the compressor, finishing the cycle (Cengel and Boles, 2006).

2.7 COOLING LOAD

Cooling load is the total amount energy that must be removed from a room by HVAC equipment. The heat received from the heat sources such as people, conduction and convection through the wall or windows, solar radiation, lightning, and equipment inside the room. There are three methods of calculating air conditioning cooling load for nonresidential which are transfer function method (TFM), cooling load temperature differences and cooling load factor (CLTD/CLF) total equivalent temperature differential value and a system of time-averaging (TETD/TA). For this project, hand calculation method is needed to know the cooling load for entire room at FKM. The suitable method for this project is CLTD/SCL/CLF (Ashrae Fundamentals, 1997).

2.7.1 CLTD, SCL, and CLF Concepts

CLTD/SCL/CLF method is one of the members TFM. CLTD/CLF is method that has been simplified from two steps TFM and TETD/TA methods into a single step technique. This method is hand calculation method based on representative results from the transfer function method (TF). CLTD/CLF is one of the main methods can be used to calculate sensible cooling load based on transfer function method (TFM). In the CLTD/CLF method, the sensible cooling load for the exterior walls and roofs can be calculated by CLTD method while the internal sensible cooling loads can be determined by CLF method. The following additional errors can appear due to grouping of CLTD/CLF because of the limitations of the TFM (Shan, 2001). According to Spitler et al, 1993, CLTD/CLF method is derived from TFM method and more easy to use for hand calculation. However, there is limitation due to the use of tabulated data.

2.7.2 Components of Load

There are four components of cooling loads to maintain steady temperature and humidity in a conditioned space such as:

Heat leakage: Heat leakage through the wall by conduction from warmer surroundings. There is always some heat leakage through the walls due to no perfect insulation in the room. Heat always moves from hot temperature to low temperature. If the inside space is cooler than the outside, the movement of heat from the warmer to the cooler area will continuously until the temperature inside of the room is equal to the temperature outside of the room.

Radiation: Heat gain by radiation through transparent surfaces. Solar radiation through windows has no time lag and must be estimated in cooling load calculation. Special glasses and window have been developed due to solar gain can be a large part of the building load. The special glasses and window can reduce the energy passing into the conditioned space by as much as 75 %.

Internal heat: The sources of internal heat like lights, people and machines and any equipment in the space to be cooled will liberate all their heat into the conditioned space. These loads need to measured and taken as part of the total cooling load.

Convection: Heat gain by forced or natural convection such as air infiltration and fresh air supply. The heat gain by forced or natural convection consists of sensible and latent heat (Trott and Welch, 2000).

2.7.3 Cooling Load/Heat Gain Calculation Concepts

Cooling loads have been divided into two parts which are external cooling load and internal cooling load. External cooling loads consist of conduction of heat gain through the walls, conduction of heat gain through the glass window, conduction of heat gain through the door, solar radiation and heat gain from ventilation while internal cooling loads consist of heat gain from people, door and appliances. In heat gain calculation, there are some parameters need to be determined such as conduction heat gain, radiation, ventilation, peoples, appliances, and lights.

There are three types of heat gain from conduction which are heat conduction through walls, windows glass, and doors. The amount of heat gain from conduction can be obtained by using Eq. (2.1) (AHRAE Fundamentals, 1997).

$$Q = U \times A \times CLTDc \qquad (2.1)$$

where ;

Q = Cooling load of wall, door, and window glass, kW

U = Overall heat transfer coefficient for wall, door and window glass, W/m². °C

A = Area of wall, door, and window glass

$CLTDc$ = Corrected cooling load temperature difference, °C

The overall heat transfer coefficient, U for walls is calculated using Eq. (2.2) as following:

$$U = 1 / \sum R \tag{2.2}$$

where;

$\sum R$ = Overall thermal resistance, m².°C/W

Meanwhile, the corrected cooling load temperature difference, $CLTDc$ is obtain using Eq. (2.3) and average outside temperature different is calculated by using Eq. (2.4).

$$CLTDc = CLTD + (25.5 - Tr) + (Ta - 29.4) \tag{2.3}$$

with,

$$Ta = Tm - (DR/2) \tag{2.4}$$

where;

$CLTD$ = Cooling load temperature different, °C

Tr = Room temperature, °C

Ta = Average outside temperature on a design day, °C

Wall load calculation:

(i) Wall type was selected from ASHRAE Fundamentals 1997 (Appendix A14), thermal properties and code numbers of layers used in wall and roof) which is closest to matching actual wall construction.
(ii) Wall construction and overall heat transfer coefficient was determined.
(iii) $CLTD$ for walls for time of interest was selected from ASHRAE Fundamentals 1997 (Appendix A1), July cooling load temperature differences for calculating cooling load from sunlit walls 40° North latitude.
(iv) $CLTDc$ was determined by using $CLTDc$ equation.
(v) Area of the room was measured and calculated.

Window glass and door load calculation:

(i) Heat transfer coefficient for windows glass, U was selected from ASHRAE Fundamentals 1997 (Appendix A3), U-factors for various fenestration product in W/m². °C. and heat transfer coefficient for doors, U was determined from ASHRAE Fundamentals 1997 (Appendix A4), U -factors of doors in W/m². °C.
(ii) $CLTD$ for windows glass and doors for time of interest was determined from ASHRAE Fundamentals 1997 (Appendix A2), Cooling load temperature differences for conducting through glass.
(iii) $CLTDc$ was determined by using $CLTDc$ equation.
(iv) Area of the windows glass and doors was measured and calculated

Eq. (2.5) is shows equation to calculate solar radiation through windows glass. The unknown parameters such as shading coefficient (SC) and solar cooling load (SCL) can be determined by refer to ASHRAE table.

$$Q = A \text{ x } SC \text{ x } SCL \tag{2.5}$$

where;

Q = Solar radiation cooling load for windows glass, kW
A = Area of windows glass, m²
SC = Shading coefficient
SCL = Solar cooling load, W/m². °C

Solar radiation load calculation:

(i) Shading coefficient (SC) from ASHRAE Fundamentals 1997 (Appendix A5) visible transmission (VT), shading coefficient (SC), and solar heat gain coefficient (SHGC) at normal incidence for single pane glass and insulating glass was determined.
(ii) Solar cooling load (SCL) was determined from ASHRAE Fundamentals 1997 (Appendix A10), July solar cooling load for sunlit glass 40°North latitude.

(iii) Area of the windows glass was determined and calculated.

To calculate heat gain from ventilation, the Eq. (2.6) and Eq. (2.7) are used to calculate sensible and latent cooling load from ventilation, respectively.

$$Qs = 1.23 \text{ x } Q \text{ x } \Delta T \qquad (2.6)$$

where;

Qs	= Sensible cooling load from ventilation air, kW
Q	= Air ventilation rate, m^3/s
ΔT	= Temperature change between outdoor and inside air, °C

$$Q_L = 3010 \text{ x } Q \text{ x } (Wo' - Wi') \qquad (2.7)$$

where;

Q_L	= Latent cooling load from ventilation air, kW
Q	= Total air ventilation rate, m^3/s
Wo'	= Outdoor humidity ratio, gr w/kg. d. a
Wi'	= Indoor humidity ratio, gr w/kg. d. a

Heat gain of ventilation calculation:

(i) Temperature change between outdoor and inside air were taken based on time of interest.
(ii) Humidity ratio changes between outdoor and indoor were taken based on time of interest.
(iii) Air ventilation rate of 10 L/s is selected and number of people in the room was estimated. Thus, the total air ventilation rate is equal to air ventilation rate times number of people in the room ($\sum Q = Q \, x \, n_{people}$).

Heat gain from lighting is expressed in using Eq. (2.8).

$$Q = (W \, x \, n) \text{ x } Fu \text{ x } Fsa \text{ x } CLF \qquad (2.8)$$

where;

Q	= Cooling load from lighting, kW
W	= Lighting capacity, W
n	= Number of light
Fu	= Lighting use factor
Fsa	= Lighting special allowance factor
CLF	= Cooling load factor for lighting

Heat gain of lighting calculation:

(i) Wattage (W) of light and lighting special allowance factor (Fsa) were selected from ASHRAE Fundamentals 2001 (Appendix A11), typical non-incandescent light fixtures.
(ii) Number of light was estimated.
(iii) Lighting use factor (Fu) was calculated based on ratio of the wattage which is the load estimate is being made to the total of wattage.
(iv) Cooling load factor (CLF) for lighting is equal to 1.0 was taken due to assumption the light will straightly switch on (Appendix A12).

There are two equations in order to find heat gain from people. Eq. (2.9) is used to obtain sensible heat while Eq. (2.10) for latent heat gain calculation.

$$Q_s = q_s \text{ x } n \text{ x } CLF \tag{2.9}$$

$$Q_L = q_L \text{ x } n \tag{2.10}$$

where;

Q_s	= Sensible cooling loads, kW
Q_L	= Latent cooling loads, kW
q_s	= Sensible cooling loads per person, kW/person
q_L	= Latent cooling loads per person, kW/person
n	= Number of people
CLF	= Cooling load factor for people

Heat gain from people (sensible load) calculation:

(i) Sensible cooling loads per person, kW/person was selected from ASHRAE Fundamentals (Appendix A7), rates of heat gain from occupants of conditioned spaces.
(ii) Number of people in the room was estimated.
(iii) Cooling load factor is equal to 1.0 was taken as maximum value for designing room (Appendix A6).

Heat gain from people (latent load) calculation:

(i) Latent cooling load per person was determined from ASHRAE Fundamentals (Appendix A7).
(ii) Number of people in the room was estimated.

To find heat gain from appliances, Eq. (2.11) are applied. Cooling load per equipment can be determined by refer to ASHRAE table.

$$Q = q \text{ x } n \text{ x } CLF \tag{2.11}$$

where;

Q	= Cooling load from appliances, kW
q	= Cooling load per equipment, kW/equipment
n	= Number of equipment
CLF	= Cooling load factor for appliances

Heat gain from appliances calculation:

(i) Cooling load per equipment was selected due to type of application equipment from ASHRAE Fundamentals 2001 (Appendix A8), recommended heat gain from typical computer equipment.
(ii) Number of equipment was estimated.

(iii) CLF is equal to 1.0 was taken because of the maximum heat was absorbed from the appliances when an air conditioning is switch off (Appendix A13).

2.8 AIR CONDITIONER SYSTEM

Central unit air condition is a system that has been applied and operated since July 2009. FKM has 5 block of building including Administration Block, Block 1, Block 2, Block 3, and Block 4. All of the building has been provided with Air Handling Units (AHU) and Fan Coil Units (FCU) which is the main medium to convert hot air into cool air. In FKM building, an air condition working by using 4 nos. of chiller, 4 nos. of cooling tower, 4 nos. of chilled water pumps, and 4 nos. of condenser water pumps.

2.8.1 Centrifugal Chillers

Centrifugal chillers are used for cooling large buildings in a centralized air conditioning system. Centrifugal chiller usually offer high reliability and low maintenance requirements. Centrifugal chillers are available in sizes ranging from 80 tons to 10000 tons. The most common used sizes ranging from 200 to 2000 tons. They use high-pressure refrigerants R-22, high-pressure R-134a, or low-pressure R-123. Chillers that use low-pressure R-123 currently have the highest efficiencies. Although low-pressure R-123 machines cannot achieve very low temperatures, this does not limit their use in most space cooling applications.

Basically, centrifugal chillers use centrifugal fans to move the refrigerant within the chiller system. The chiller system in an air conditioning system consists of a compressor, a condenser, an expansion device, and the evaporator. The fan will react as compressor in the centrifugal chiller. The fan will rotating at very high speeds and changes the low pressure and low temperature into high pressure and high temperature of refrigerant gas. The impeller of the compressor is required very careful design because the pressure is so dependent on the efficiency of the impeller. In order to reduce leaks back to the discharge, the clearance between the impeller and the housing at the impeller suction are made very small. Centrifugal chillers are usually designed for low-pressure R-123. Figure 2.8 shows centrifugal chiller at FKM building.

Figure 2.8: Centrifugal chiller in FKM building

2.8.2 Air Handling Unit

The air handling unit is an integrated of equipment such as fans, filters, cooling coil. The purpose of this equipment to suck air from the rooms to be cooled let it pass through chilled water cooling coils and then discharging the cooled air back to the rooms via duct. In FKM building, AHUs located at every floor. AHU’s come in many sizes and shapes. Usually, AHU designed based on the air flow requirements and the cooling capacity. If the air has to be cleaned, at the ducting outlet or the AHU filter box required installed of special HEPA filters. Temperature of the room can be controlled by controlling the flow of chilled water through the cooling coil. To throttle chilled water through the chilled water coils, control valves can be used. Figure 2.9 indicates the actual air handling unit in FKM building.

Figure 2.9: Air Handling Unit in FKM building

2.8.3 Fan Coil Unit

Fan coil is in part of air conditioning system. The fan coil components are fan, drain fan, coil and fin heat exchanger. If chilling water is used to pump into the heat exchanger, then the fan will send out cool air, if hot water is used to pump into the heat exchanger, the fan will send out warm air. Typically fan coils are located at above ceilings ducted to ceiling diffusers Usually, the fan coil is install at large buildings such as air port, hospital, office building, and hotel. To make a proper fan coil unit selection, the whole air conditioning need to be looked at because sizing a fan coil unit is not just matching the room load. The other criteria must be considered such as the minimum room load, fresh air requirements, with or without reheat, 2 or 4-pipe system, and zone size. The cooling capacity which is supplied to the room is the sum of cooling capacity of the fan coil unit and the cooling energy available in the primary air. The fan coil capacity is defined by the leaving and entering air conditions. There are two types of fan coil which are four-pipe fan coil and two-pipe fan coil.

Two-pipe coil system: A two-pipe fan coil system consists of single coils in fan coil units. The single coil is connected to two pipes which are one supply pipe and the other one is return pipe. It is impossible to cool some rooms while heating others room because the system of two-pipe is either entirely in a heating mode or entirely in a cooling mode. Two-pipe systems cannot operate for heating and cooling in same time and are not suitable where there are internal rooms with high internal gains such as computer rooms.

Four-pipe coil system: A four pipe system has fan coil units with separate heating and cooling coils. It can handle simultaneous heating and cooling, from the heating to the cooling mode or vice versa. (Shan, 2001)

A two-pipe or a four-pipe fan coil system consists of boilers and chillers in the central plant, water system supplying chilled water to the fan coil, a space recirculating system using fan coils to the condition the space recirculating air, and a dedicated outdoor ventilation air system using an out-door air AHU to condition the outdoor air. Both the space recirculating and dedicated outdoor air systems have ducts, diffuser, inlets, controls, and accessories. Fan coil system shown in Figure 2.10.

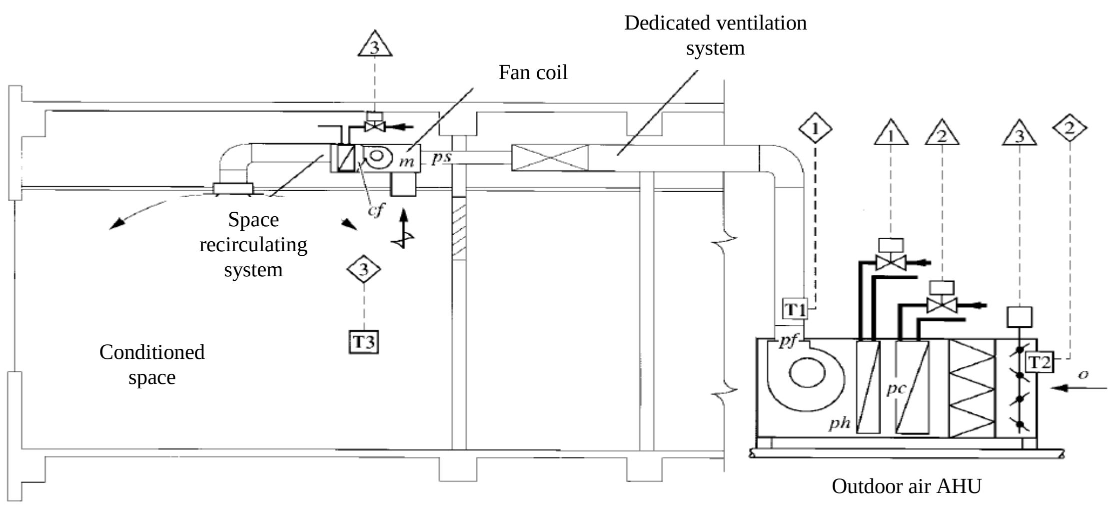


Figure 2.10: Fan coil system

2.8.4 Chiller Water Working System

In FKM's air central unit air conditioning system, there is a cooling tower that located at roof top of chiller plant room while the chillers and pumps located at ground floor chiller plant room. The AHU and FCU will suck the hot return air from the room via ducts and blown over cooling coil. There is chilled water inside the cooling coil. The chiller water pump circulated chilled water to every AHU and FCU. Before the chilled water is circulated to AHUs and FCUs, the chilled water will be passed through temperature sensor and flow meter where BTU consumption of the building is measured. Figure 2.11 shows system schematic diagram of FKM central unit air conditioning.

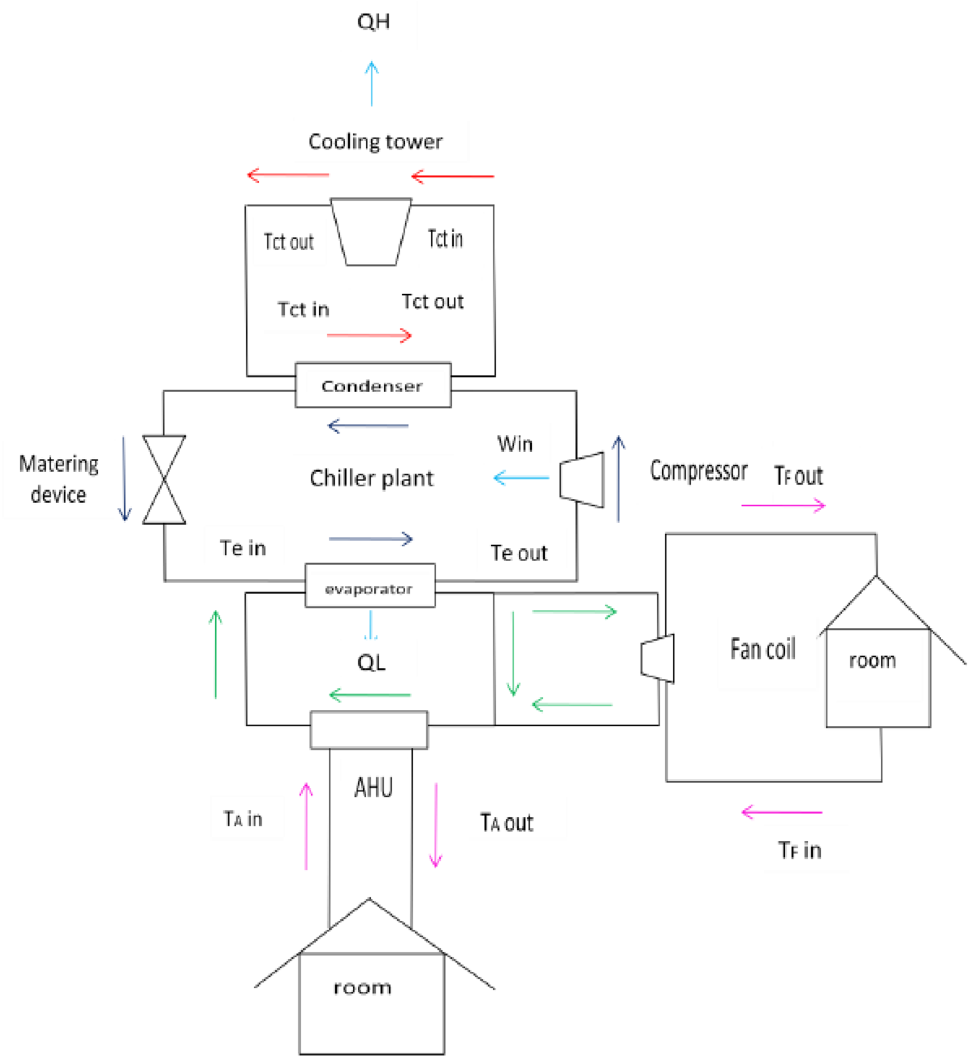


Figure 2.11: System flow of FKM central unit air conditioning

The heat rejection from AHUs and FCUs will cross cooling coil and transfer the heat into the chiller. Temperature of water inside the cooling coil will be increase while the hot return air will be changed into cooled air. After that, the cooled air will be supplied through the ducts into the rooms. The hot water from AHUs and FCUs will be circulated into evaporator to be chilled it again and then resupply to the all AHUs and FCUs. It will transfer the heat rejection (from AHUs and FCUs) into the cold refrigerant liquid inside the evaporator. Thus, the phase of refrigerant will changed into vapor condition. The refrigerant will pass through the compressor which is the temperature and pressure will increase. The refrigerant vapor will become very warm and will across the condenser chamber. Thus, the heat will be transfer into cold condenser water. After that, the hot condenser water will pass the hot water by condenser water pipe and discharged into basin in the cooling tower. At cooling tower, fans are installed. The function of fans to blew the air from atmosphere into the cooling tower. The air will cross over hot condenser water and absorbed the heat from it. After that, the cool air will changed into hot air. The fans inside the cooling tower will blew the hot air to atmosphere. The cool condenser water will recirculated back into chiller. This cycle will be repeating.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In any activity that requires concrete results, a well-defined methodology for achieving those results is important. With a methodology, the process of achieving a result can be studied and the result verified. Without a methodology, this type of debugging and assurance will be very difficult. A methodology helps to get things done. A methodology is closely related with literature review, where all of the information about air conditioning has been explained. The steps and procedure also explained here to make sure the progress study still following a right track until the project is complete. In addition, by doing a methodology, it will ensure the project is still within the objectives and scopes.

3.2 BUILDING PARAMETER AND DESIGN CRITERIA

Conduction and radiation heat transfer from outside to inside of the particular room is subjected to the specification of the room. Specification of the means dimensions like walls, windows, doors and material used are need to be measured and identified before proceeds to another steps. Figure 3.1, shows plant layout of lecture room in Block 2.

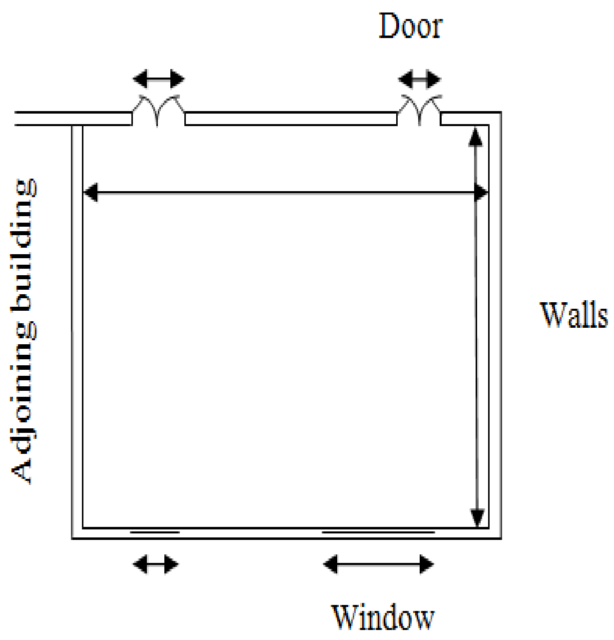


Figure 3.1: Plant layout room

The areas are important parameter in order to find heat gain for particular rooms. The equipment to measure width and height of walls, windows, and door is using measuring tape. Some of heat gain equation required temperature outside and inside room. Temperature will be taken by using a thermometer for every 1 hour which starts from 8.00 am until 5.00 pm. At the same time, temperature of dry bulb and wet bulb is determined by using the same method but different measuring instrument. A psychrometer is an instrument that measures both the wet bulb and dry bulb temperatures. All the data have been taken during sunny days in order to get maximum amount of heat gain. The results of the data heat gain are taken three days to get the accurate value. Figure 3.2 is referring to experimental device to determine heat gain parameter such as psychrometer, thermometer, and measuring tape.

(a) Psychrometer device

(b) Measuring tape

(c) Thermometer device

Figure 3.2: Experimental device for heat gain

3.3 SAMPLE OF COOLING LOAD CALCULATION USING CLTD/CLF METHOD

Heat gain calculation requires initial data about the building and surrounding. The data consists of ambient temperature, room temperature, range temperature, and relative humidity of specific room. By using calculation method known as Cooling Load Factor/Cooling Load Temperature Different, heat gain by each room has been determined. The heat gain calculations have divided into 2 parts which are internal heat gain and external heat gain. The internal heat gain consists of heat gain caused by lighting, heat gain caused by people, heat gain caused by appliances, and heat gain caused by air ventilation. The external of heat gain in a particular room can divided into two parts which are heat gain caused by conduction through exterior structure, heat gain by radiation through windows glass.

There are four components of heat gain to maintain steady temperature and humidity in a conditioned space such as heat leakage through the walls/windows/doors, heat gain by radiation through transparent surfaces, heat gain by forced or natural convection and internal heat sources like lights, people, and any equipment in the room to be cooled. All of these components have divided into two parts which are external cooling load and internal cooling load. In this chapter, the peak load at 3.00 pm is obtained in the example of cooling load calculation. The location study for example calculation at BK 5. In order to determine the cooling load for each room, CLTD/CLF method has been used.

1) Heat Gain Through the Walls/Windows/Doors

For heat gain through walls, windows, and doors can be determined by define overall heat transfer, U and Corrected Cooling Load Temperature Different, CLTDc. Overall heat transfer for windows and door can be selected from ASHRAE Fundamentals 1997 (Appendix A2) and ASHRAE Fundamentals 1997 (Appendix A3), respectively. However, for walls heat transfer coefficient can be determined by select thermal resistance for all of element layer in wall structure from ASHRAE Fundamentals 1997 (Appendix A14). All of equations related with heat gain through the walls, windows, and doors shown in previous chapter.

Heat gain through the walls: To determine overall heat transfer for walls, there are some wall characteristics of the rooms. The characteristics are listed as follow:

i. Indoor moving air and outdoor moving air
ii. 100 mm face brick
iii. 100 mm low density concrete block
iv. Inside surface resistance
v. 20 mm plaster
vi. 25 mm insulation

By referring to ASHRAE Fundamentals 1997, the characteristics are similar with wall type 10 as shown in Appendix A14. Table 3.1 is shows similarity between FKM building specifications for walls with table from ASHRAE handbook while Table 3.2 is representing total resistance for wall type 10.

Table 3.1: FKM building specification for walls

Structure	Material	
	Actual	**From ASHRAE handbook**
Wall	110 mm thick brick wall with 20 mm thick cement plaster on both side with groove line externally.	With indoor moving air and outdoor moving air and 100 mm face brick with 100 mm low density concrete block. Also inside surface resistance with 20 mm plaster and 25 mm insulation.

Table 3.2: Wall total resistance

Code No.	Element layer	R(m^2.C/W)
A2	100 mm face brick	0.0076
B5	25 mm insulation	0.587
C2	100 mm low density concrete block	0.266
E0	Inside surface resistance	0.121
E1	20 mm plaster	0.026
	Outside surface	0.059
	Inside surface	0.121
	Total	1.256

Table 3.1 shows the wall structure by element layer. From the table 3.1, the wall total resistance is 1.256 $m^2.\ °C/W$. By using Eq. (2.2), the overall heat coefficient factor is 0.796 $W/m^2.\ °C$.

CLTD for walls, windows and doors are not accurate due to different location, indoor temperature, and times. Therefore, the Eq. (2.3) and Eq. (2.4) will be used in order to get correct value of CLTD. For the ASHRAE table, the condition of CLTD as follows;

- Indoor temperature is 22.2 °C
- Outdoor average temperature on the design day is 33 °C
- The month is 21st July
- Location is 40 °N latitude

For this project are as follows:

- Indoor temperature is 26.5 °C
- Outdoor average temperature on the design day is 33 °C
- The month is on September
- Location is 4 °N latitude

CLTD for wall can be determining by referring to Appendix A1. From that, the CLTD is taken as below;

Table 3.3: CLTD for North West and South East Direction

Time	**CLTD**	
3.00 pm	North West Direction	South East direction
	7	18

From Eq. (2.3) and Eq. (2.4), average outside temperature is 31 °C .Thus, Corrected Cooling Load (CLTDc) for North West and South East are 7.6 °C and 18.6 °C. The area of the wall is taken as 93.2 m. The heat gain through the walls is calculated using Eq. (2.1). The heat gain for North West and South East are 563.82 W and 1379.88 W, respectively.

Heat Gain Through the Windows Glass: The overall heat transfer coefficient for window glass has decided based on their material. From manual master drawing, the material of windows glass is anodized aluminum frame window with single glass. Thus, by referring to Appendix A3 the overall heat transfer coefficient for window glass is 6.07 W/m^2. °C. The area of the windows glass is 6.5 m. For window's $CLTD_c$, refer to Appendix A2 in order to make calculated $CLTD_c$. $CLTD_c$ and heat gain for windows can be calculated using Eq. (2.3) and Eq. (2.1), respectively. From that, the amount of $CLTD_c$ is 8.6 °C while the heat gain is 339.31 W.

Heat Gain Through the Doors: By referring to Appendix A4, the overall heat coefficient for timber door is 2.73 $\mathrm{W/m^2}$.°C. The totals of door areas of all exposure are 8 m. From equation 3.3, the calculation for heat gain through the doors has been obtained which is 187.82 W.

2) Heat Gain by Solar Radiation for Window Glass

The type of window glass is uncoated single glazing (green). The shading coefficient of window glass is 0.61 by referring to Appendix A5. The solar radiation need to consider the direction of sunlight of window glass. Thus, the exposure areas are 2.17 $\mathrm{m^2}$ for North West and 4.33 $\mathrm{m^2}$ for South East. Solar cooling load need to select in order to find heat gain by solar radiation. From Appendix A6, the solar cooling loads are 202 $\mathrm{W/m^2}$ for North West and 161 $\mathrm{W/m^2}$ for South East. By using Eq. (2.5), the heat gain for North West and South East are 267.39 W and 425.25 W, respectively.

3) Heat Gain by Lights

The heat gained from lights in a room may be of a significant amount. However, to determine the maximum heat gain in a room, the heat gain by lights must be considered. All of rooms using same type of light which is Fluorescent 900, T12 lamp with 30 W of its load. The value ballast factor for this type is 1.25. The number of lamp in BK 5 is 32. Cooling load factor assume equal to 1 because of the usage for the light is 24 hours without switch off. However, lighting factor is equal to 1 due to maximum design number lights are on. Based on Eq. (2.8), the heat gain for lighting is 1200 W.

4) Heat Gain from People

There are two type of heat gain for people which are sensible heat and latent heat. The sensible heat will easy to absorb by surroundings and then will release into the air. There is no CLF for latent heat because it is an instantaneous cooling load. The values of solar heat gain (SHG) produces by people have been taken from Appendix A6 which are 75 W for sensible heat and 55 W for latent heat. The maximum numbers of people in a room is 60 persons. Cooling load factor is assumed equal to one due to the room used 24 hours occupancy. From previous chapter, heat gain produces by people can be calculated by using Eq. (2.9) and Eq. (2.10). Based on the equation, the heat gain for sensible heat gain is 4500 W while for latent heat gain is 3300 W.

5) Heat Gain from Appliances

Many of the electric use by the indoor electric equipment ultimately ends up in a space as heat. There are one projector, 60 notebooks and one desktop in BK 5. The power consumption desktop is about 155 W of power while 100 W for projector. However, for notebooks is 30 W. The value of consumes can be selected by refer to Appendix A7. Cooling Load Factor for computer and projector assume as one due to its operation is 24 hours without switch off. By using Eq. (2.11), the heat gain for computer, projector, and notebook are 155 W, 100 W, and 1800 W, respectively.

6) Heat Gain by Ventilation and Infiltration

Ventilation air is the amount of outdoor air required in order to maintain indoor air quality for the occupants by provide air leakage into a building .The equation used for ventilation and infiltration air has two components which are sensible heat and latent heat. Volume flow rate is 0.01 m^3/s or 10 L/s is selected from Appendix A8. To find outdoor and inside humidity ratio, the Psychrometrics chart has been used. The heat gain for latent and sensible can be determined by using Eq. (2.6) and Eq. (2.7). The amount of heat gain for sensible is 80 W while for latent is 23 W.

3.4 PARAMETERS OF PERFORMANCE ANALYSIS

Testing of the performance will be done on fan coil unit by measuring the actual condition. The velocity out from fan coil and temperature out from fan coil will be measured by using cone air flow and anemometer. The temperature out from fan coil also can be determined by using temperature probe device. The recording will be taken in peak load hour during system running on selected day. Figure 3.3 shows the experimental device in order to obtain cooling capacity.

(a) Cone air flow

(b) Anemometer device

(b) Temperature probe

Figure 3.3: Experimental device for cooling capacity

3.5 PERFORMANCE OF AIR CONDITIONING SYSTEM

To calculate performance of fan coil unit, there are some parameters should be determine such as temperature out from fan coil, temperature rooms, and velocity out from fan coil. All of these parameters will be useful in order to calculate capacity usage of the central unit air condition. By using refrigeration capacity equation at fan coil unit, energy in fan coil (Q_{cc}) can be obtained. From that, performance of air conditioning system will be determined by comparing the heat gain generated (room) with energy in fan coil (Q_{cc}).

The cooling capacity/ cooling coil load can be determined by using energy equation at fan coil unit. In fact, the net cooling capacity is equal to the net heat removed from the water as it passes through the fan coil. The net fan coil capacity is shows by the following equation:

$$Q_{cc} = \dot{m} \text{ x } C_p \text{ x } \Delta T \tag{3.1}$$

where;

$\dot{m}$	= Mass flow rate of air, kg/s
C_p	= Constant pressure specific heat, kJ/kg. °C
ΔT	= Temperature change across evaporator inlet, °C

In order to know mass flow rate air across fan coil, there is equation which is representing velocity after across the fan coil:

$$\dot{m} = n \text{ x } \rho \text{ x } A \text{ x } V \tag{3.2}$$

where;

n	= Number of fan coil
A	= Area of room, m^2
V	= Velocity air supply, m/s

3.6 SAMPLE OF COOLING CAPACITY CALCULATION

Cooling capacity for fan coil is the rate at which energy must be removed at cooling coil to conditioned space. It is consider instantaneous space cooling loads which are sum of space cooling load (sensible and latent), supply system heat gain (fan and supply air duct), return system heat gain (return air duct) and load due to outdoor ventilation rates. Space cooling capacity, on the other hand, is the rate at which heat must be removed from a space in order to maintain air temperature and humidity in conditioned space. There is only two rooms are considered to analyze the cooling coil load which are the analysis focus on cooling coil with load and without additional load. The calculations of cooling load fan coil as shown below;

Cooling coil calculation with load: Eq. (3.1) and Eq. (3.2) can be used in order to find cooling coil load for BK 5 and BT 8. The cooling capacity with load for BK 5 and BT8 are 5.79 kW and 4.39 kW.

Cooling Coil Calculation without Load: To find cooling capacity without load, equation 3.13 is referred. The cooling capacity for BK 5 is 4.64 kW while for BT 8 is 4.18 kW.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents details calculations in order to determine heat gain in particular room with specific time and calculation to determine the performance of chiller system at FKM building. The purpose of these calculation is to compare which one is more higher value of heat gain whether heat gain in particular room or cooling capacity in FCU. For this chapter, the best of cooling capacity provided to the building for each chiller has been determined by analysis the result of calculations.

4.2 HEAT GAIN CALCULATION

Heat gain calculation requires initial data about the building and surrounding. The data consists of ambient temperature, room temperature, range temperature, and relative humidity of specific room. By using calculation method known as Cooling Load Factor/Cooling Load Temperature Different, heat gain by each room has been determined. The heat gain calculations have divided into 2 parts which are internal heat gain and external heat gain. The internal heat gain consists of heat gain caused by lighting, heat gain caused by people, heat gain caused by appliances, and heat gain caused by air ventilation. The external of heat gain in a particular room can divided into two parts which are heat gain caused by conduction through exterior structure, heat gain by radiation through windows glass.

4.3 PEAK LOAD HEAT GAIN

Based on the calculation, the peak load of the room is occurring at 3.00 pm on the design day. Peak load time is referring to the highest heat gain starting from 8.00 am until 5.00 pm. The study for this project has been done at seven different rooms such as BT 8, BK 5, BK 6, and BT 6 & 7. All of these rooms are located at block 2 at FKM building. Table 4.1 show the calculated heat gain in each room from 9.00 am until 5.00 pm. Details of calculation and time for heat gain are attached in Appendix C2 until Appendix C25.

Table 4.1: Data of heat gain

Process	**Testing time**				
	9.00 am	**11.00 am**	**1.00 pm**	**3.00 pm**	**5.00 pm**
	BT 8				
External Heat Gain (kW)	4.072	4.520	6.329	6.485	3.843
Internal Heat Gain (kW)	4.755	4.755	4.755	4.755	4.755
Total (kW)	8.827	9.275	11.084	11.240	8.598
Process	**Testing time**				
	9.00 am	**11.00 am**	**1.00 pm**	**3.00 pm**	**5.00 pm**
	BK 5				
External Heat Gain (kW)	4.450	5.896	4.994	6.551	5.698
Internal Heat Gain (kW)	9.255	9.255	9.255	9.255	9.255
Total (kW)	13.705	15.151	14.249	15.806	14.953
Process	**Testing time**				
	9.00 am	**11.00 am**	**1.00 pm**	**3.00 pm**	**5.00 pm**
	BK 6				
External Heat Gain (kW)	4.934	4.926	4.960	6.066	5.698
Internal Heat Gain (kW)	9.255	9.255	9.255	9.255	9.255
Total (kW)	14.189	14.181	14.215	15.321	14.953
Process	**Testing time**				
	9.00 am	**11.00 am**	**1.00 pm**	**3.00 pm**	**5.00 pm**
	BT 6 & 7				
External Heat Gain (kW)	8.449	9.687	5.601	10.114	6.558
Internal Heat Gain (kW)	9.580	9.580	9.580	9.580	9.580
Total (kW)	18.029	19.267	15.181	19.694	16.138

4.4 ANALYSIS OF HEAT GAIN

From this chapter, the overall heat gain which is calculated by CLTD, SCL, and CLF had been analyzed in order to know the largest heat that contributes to the particular room. The data has been plotted in the graph according to the analysis. In this analysis, the focus is on the higher value of heat gain whether internal heat gain or external heat gain.

As been discussed in previous chapter, the higher heat gain occurred at 3.00 pm. However, the reason and causes of peak load will be discussed more details and specific in this section. The first analysis is comparison between external heat gain and internal heat gain has been carried out. Figure 4.1 shows graph of external and internal heat gain during peak time of the day.

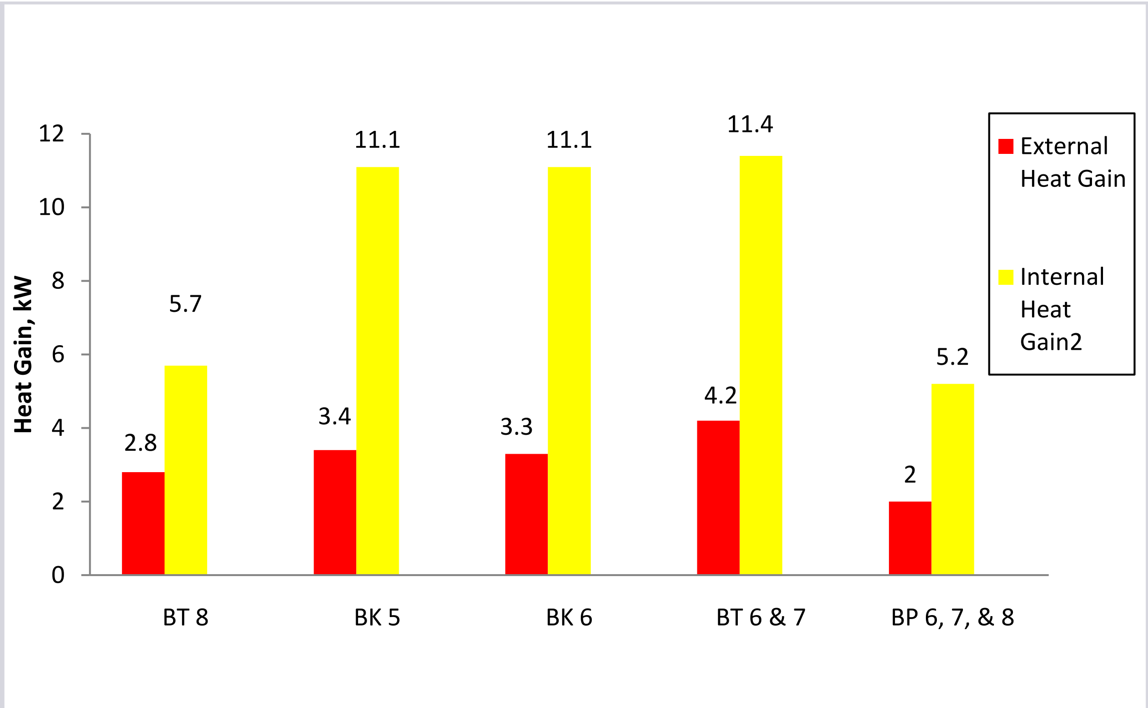


Figure 4.1: Internal and External Heat Gain for Different Rooms at 3.00 pm

The highest heat gain is produce by BT 6 and 7 according to highest value of internal heat gain. Usually, the largest sources of internal heat gain come from appliances. BT 6 and 7 have higher internal heat gain due to number of light and notebooks are more. These rooms also produces large amount of external heat gain which is about 4.2 kW due to larger areas. Thus, BT 6 and 7 can generate highest external heat gain due to the exposure area of wall, windows, and doors. However, the analysis is focusing more on BK 5 because this room is more frequently use rather than BT 6 and 7. Figure 4.2 shows external heat gain for BK 5.

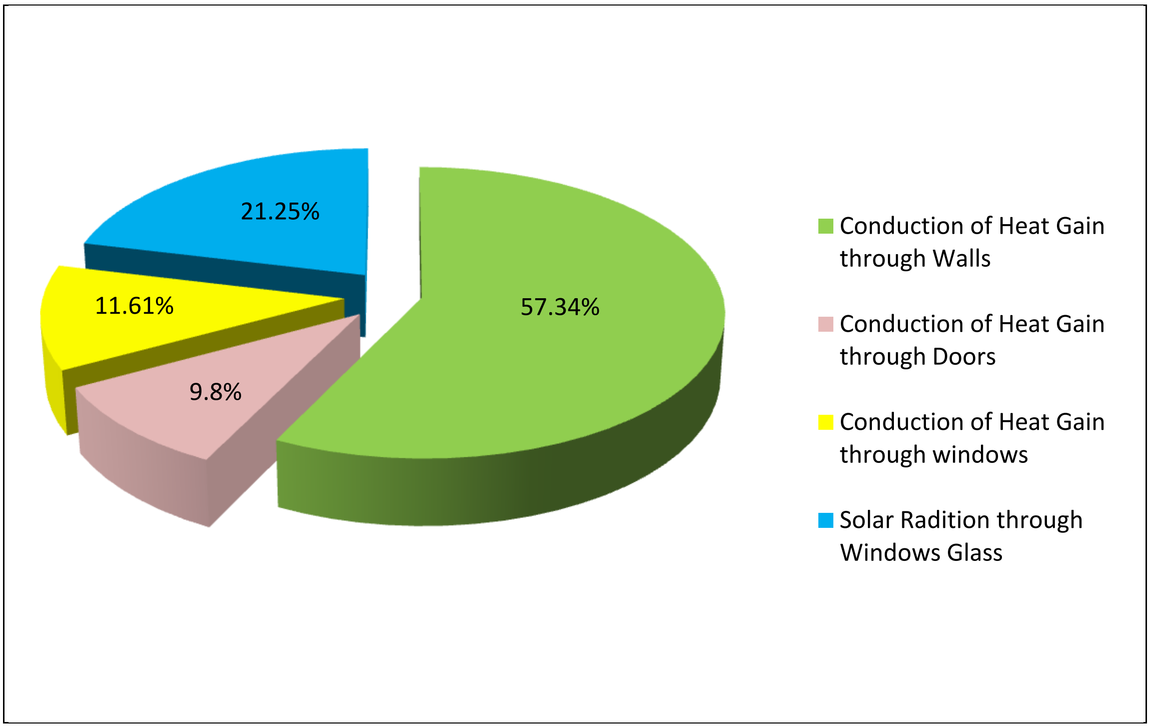


Figure 4.2: Heat gain contribution through exterior structure for BK 5

Figure 4.2 shows pie chart of exterior heat gain with specific sources of heat gain. From the figure, the chart describe that large heat gain is produce by conduction of walls. Walls can have an important effect on interior comfort conditions by direct contact with the exterior environmental conditions. Heat gain through walls is highest due to area of walls is more large compare to area of windows glass and door. The second higher exterior heat gain is solar radiation through windows glass. Heat gain through glass areas facing different directions would be unequal such that the one facing North West would have minimum heat gain and the one facing South East would gain most. The shading of windows glass can give effect to amount of heat. Therefore windows glass should have a low solar heat gain coefficient or low shading coefficient.

For FKM' building, the type of windows glass is uncoated single glazing (green) with fixed aluminum frame which is has small shading coefficient. Thus, the heat gain from solar radiation is not main sources heat gain in BK 5. This analysis also reported by Hamzah on 2011. In his analysis, he found that the highest heat gain occurs at computer lab and excellent center at FKM building is provided by solar radiation. It happened because the windows glass has been not tinted. Thus, it proves the low shading coefficient can give less amount heat into the rooms.

The third higher is heat gain from windows glass. The heat transfer coefficient of windows glass is more than others. If the exposure area of windows glass is larger or equal with exposure area of walls, the heat gain from windows glass will become as largest contributed heat gain in BK 5. The smallest contributed heat gain is heat gain by doors. It's provided the fewest heat gain due to exposure area of the doors is the small compared to others.

From Figure 4.3, the heat gain from internal is major contributed in BK 5. The sources of internal heat gain include of people, lights, and appliances. By referring to Figure 4.3, the main heat gain generate is heat gain by people. Generally, the amount of heat gain from people depends on their physical activity and capacity of room. For this project, 60 people have been used in order to get maximum design heat gain in BK 5. In addition, the room are assume in moderately active work. Thus, it's provided more heat gain due to maximum number of people in that room. The second highest is heat gain caused by appliances. Appliances have divided into three types of appliances which are notebooks, computer, and projector. The largest contributed heat gain in appliances is notebooks due to the number of notebooks are more than others appliance. However, value of cooling load per equipment computer is larger compared to notebooks. Since the number of computer only one, thus it's not a major contributed of heat gain by appliances.

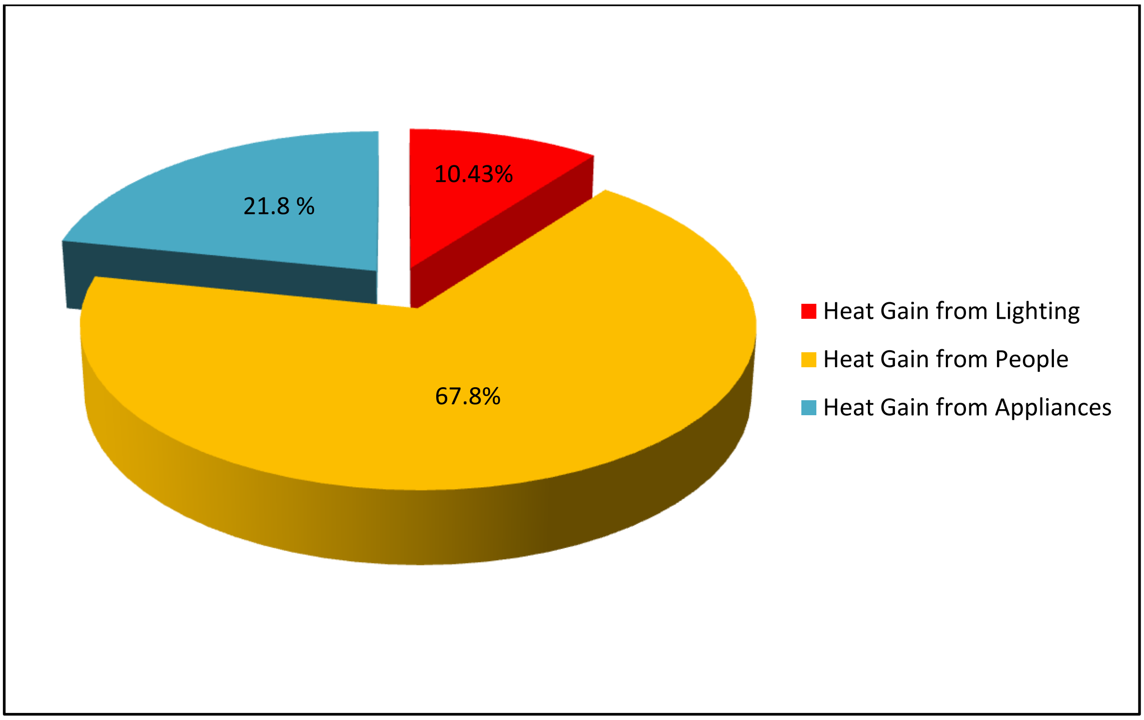


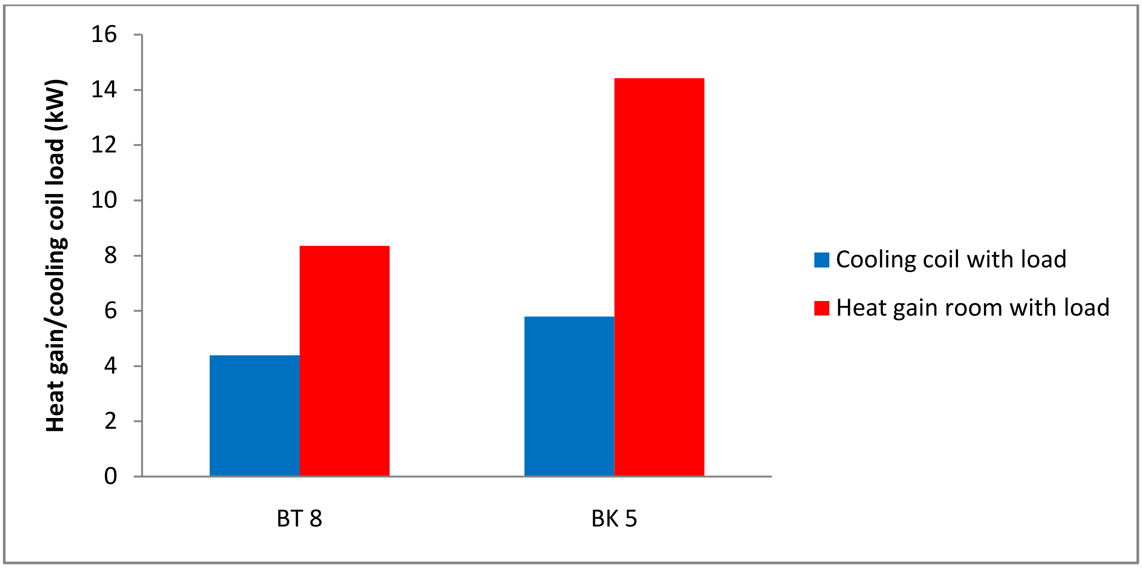
Figure 4.3: Heat Gain Contribution through Internal structure for BK 5

4.5 PERFORMANCE ANALYSIS SYSTEM AIR CONDITIONING

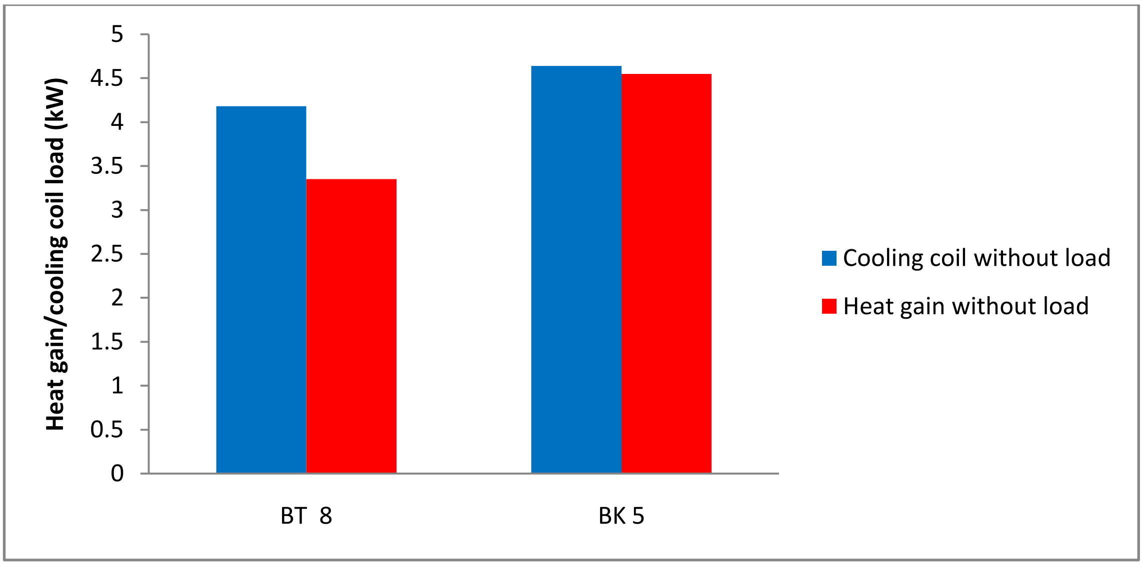
Performance system air conditioning can be determined by making comparison between cooling coil load and heat gain by rooms. Data collection for cooling coil and heat gain room was measured at 3.00 pm due to peak load at this time. Table 4.2 is about comparison value for cooling coil load and heat gain.

Table 4.2: Comparison value of cooling coil and heat gain room

Location	Cooling coil load		Heat gain room	
	With Load (kW)	Without Load (kW)	With Load (kW)	Without Load (kW)
BT 8	4.39	4.18	6.70	3.35
BK 5	5.79	4.64	11.13	4.55



(a) With load



(b) Without load

Figure 4.5: Comparison heat gain and cooling coil load

Analysis of cooling capacity and heat gain has been calculated with differences situation which are with load and without load. From the Figure 4.4, there is only one condition cooling coil load are greater than heat gain room. The condition is when there is no load in that room. In this condition, the room had occupied enough cooled temperature to create comfort space in that room. When the load is add up in that room, the cooling capacity becomes lower but still has big amount of cooling capacity with load compared to cooling load without load.

- Heat gain without load < Cooling load without load < cooling load with load < heat gain with load

By referring to the Table 4.6, heat gain by room with load is highest value compared to cooling coil with load. In logical approach, cooling coil must be higher than heat gain in order to cool the room. There are some reasons due to this condition. The reason is heat gain is not equal to cooling load. Cooling load is the amount of heat need to be removed to create comfortable condition. The total heat gain by room consist of heat gain by conduction, heat gain by solar radiation, heat gain from lighting, heat gain by people, heat gain from appliances, and heat gain through ventilation. However, not all of these heat gains go immediately to increase temperature of air inside the room. Only some portion will contribute heat to the air room and the rest portion will absorbed by internal surface. However, heat gain room on Table 4.6 is considering all of components produces their heat gain while the cooling coil not received all of heat sources during measured.

CLTD, SCL, and CLF methods have been calculated for conduction and radiation heat gain which are not instantaneous by using CLTD and CLF factor. A heat gain calculation requires that all of the heat flows into a building such as internal and external heat gain. The cooling coil load are normally less than heat gain calculation due to thermal mass effect and the dynamic nature of heat gain. Pita (1998) mentioned that, the amount of heat that must be removed is not always equal to the amount of heat received at a given time. The different occurs because of the heat storage and time lag effect.

The purpose of perform cooling load in order to determine the size of cooling system, design cooling system, and save money from waste energy due to oversized design air conditioning system. In an occupied building, the major power consumer is produce by air conditioning system. Excessive power consumption of air conditioning system may lead to high electricity cost. The calculation of the air conditioning system shows that, energy consumption in FKM building is utilized efficiently without any wasting electricity energy.

The other reason of why cooling capacity is lower than heat gain related to human body heat rejection. The largest value of internal heat gain is contributed by people. In this project, 60 people had been places at BK 5 and 30 people in BT 8. The numbers of people was determined by considering the maximum numbers of people in that room during the classes. Human comfort of people depends on the rate at which the body loses the heat. Heat rejection is an ongoing process with the human body due to natural function of human body which is the body always produces more heat than it needs. The purpose of air conditioner function is to help the body's system to control this heat loss. There are three ways human body rejects this extra heat which are by convection, radiation, and evaporation. All of this ways is simultaneously. There are only two method will contribute to air conditioning system which are convection and radiation.

A convection method is the processes which transfer temperature from higher temperature to the lower temperature. The temperature of human body will going upward to the cooler air space because the warmer air temperature are more light than cooler air temperature. The cooler air temperature will absorb heat from the human's skin and going upward. The process will continuously which maintain the temperature of human body at 36 °C. From this project, the measurement of velocity and temperature was collected after steady state condition occurs. That means, the data was taken after the human body was maintained. From the data, the ambient temperature for BK 5 and BT 8 are 24 °C and 24 °C respectively. While, the temperature of human body in is constant which is at 36 °C. Thus, it proves that air conditioning system worked in good condition by produce lower temperature in order to absorb heat from human's skin.

The other method to reject heat from human body is through radiation. The process is same with radiation from sun to the surface of earth. Convection and radiation will worked together to control and maintain temperature of the human body with their own style work. However, Billy (1931) mentioned that, the temperature of the air between two objects has little or no bearing on the heat transfer process by using this method during the heat transfer. From that statement, it clarify cooling coil load is cannot changed by people. However, at one condition the convection and radiation will give effect to cooling coil by added up numbers of people to fulfill all empty space.

From the comparison, it can determine the different capacity value between heat gain by rooms and cooling capacity by fan coil. Table 4.3 show the comparison in percentage between heat gains of room against cooling coil load.

Table 4.3: Comparison value of cooling coil and heat gain room with load

Location	**Cooling coil load (kW)**	**Heat Gain Rooms (kW)**	**Difference (kW)**	**Percentage of difference (%)**
		With load		
Bilik Taklimat 8	4.39	6.70	-2.31	-34.45
Bilik Kuliah 5	5.79	11.13	-5.34	-47.98
Location	**Cooling coil load (kW)**	**Heat Gain Rooms (kW**	**Difference (kW)**	**Percentage of difference (%)**
		Without load		
Bilik Taklimat 8	4.18	3.35	0.83	24.78
Bilik Kuliah 5	4.64	4.55	0.09	1.98

The percentage of different of cooling capacity without load for BK 5 is 1.98 % while the BT 8 is 24.78 %. Its shows that, the cooling capacity give occupied to that rooms. Thus, the rooms can be cooled with perfect performance.

The difference value of cooling capacity with load against heat gain by rooms for BT 8 and BK 5 are -2.31 kW and -5.34 kW respectively. From those differences, the cooling capacity shown that the capacity for that rooms are 34.45 % and 47.98 % less than the heat gain by rooms. It happened due to cooling capacity was measured after the rooms in steady state condition. While the heat gain are measured in unsteady state condition. Thus, even the value of cooling capacity is less than heat gain rooms, the air conditioner still can provided comfortable temperature to BK 5 and BT 8. This discussion also reported by Kelvin (2009). In his researches, he did analysis of heat gain of rooms against cooling capacity for split unit air conditioner occupied building. From the research, he found that cooling coil load is observed to be 852.74 kW, while the heat gain of room is 1172.43 kW. The researchers are done by same method with this research which is by using CLTD/CLF methods. In his research, he mentioned the existing cooling coil load is observed to be undersized in design and the cooling capacity should increase 27.3 %.

Jones et al. (2006) stated that the refrigeration capacity should less than the maximum heat gain because of any rise in space temperature under brief load will be minimal. His also mentioned that the heat gain is the maximum number of heat gain rooms from sensible heat gain and latent heat gain. Compressor performance at partial load is better if the compressor is not oversized. This is because of the oversized unit need more cost due to operate, do a poor job of comfort control, and poor installation can dramatically reduce the efficiency of the system.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The analysis for heat gains had been done by using CLF/CLTD method which is developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). The selected rooms are BK 5, BK 6, BT 8, BT 6 & 7, and BP 6, 7 & 8. The total heat gains are 14.43 kW, 14.31 kW, 8.35 kW, 15.61 kW and 7.3 kW. All of the selected rooms show the highest heat gains occurred at 3.00 pm on the design day.

Performance of fan coil at FKM has been done at BK 5 and BT 8 due to the frequently use. The objective also has been determined by making comparison between the heat gain of room and cooling capacity of fan coil. The difference value of cooling coil load with heat gain by rooms in percentages for BT 8 and BK 5 are 34.45 % and 47.98 % less than the heat gain by rooms. Air conditioner systems still capable to cool the room even the cooling capacity less than heat gain. This is because during measuring fan coil temperature and velocity, the rooms condition was in steady state condition.

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5.2 RECOMMENDATIONS FOR FURTHER WORK

There are some recommendations for further work for this project as follows:

1) To analyze the air flow in the rooms to the fan coil unit by using computational fluid dynamics (CFD).
2) To use any kind of software related to calculation of heat gain which is the software can be validate the manual heat gain calculation. The software in the market can be used to calculate heat gain such as ESP-r and TRNSYS.

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REFERENCES

Ansari F.A., Mokhtar A.S., Abbas K.A. and Adam N.M. 2005. Simple Approach for Building Cooling Load Estimation. Faculty of Engineering, UPM, Serdang, Selangor Darul Ehsan, Malaysia. *American Journal of Environmental Sciences* by Science Publications **1**(3): 209-212A.

Ahmad, Z.H. 2011. All government need keep air conditioner at 24°C from now. TheStar, December: 11

ASHRAE. 1997. *ASHRAE fundamentals handbook*. American Society of Heating, Refregerating and Air Conditioning Engineer 1997. Atlanta, Ga.

ASHRAE. 2001. *ASHRAE fundamentals handbook* . American Society of Heating, Refregerating and Air Conditioning Engineer 2001. Atlanta, Ga.

Billy, C.L. 1931. *Fundamentals of air conditioning systems*. India: The Fairmont Press.

Cengel, Y.A. and Boles, M.A. 2006. *Heat and mass transfer*: A practical approach. 3rd ed. Singapore: McGraw-Hill.

Chadderton, D.V. 1997. *Building services engineering spreadsheets*. UK: Thomson Professional.

Hamzah, A. 2011. *Performance analysis of air handling unit system for FKM's air conditioner*. Bachelor thesis. Universiti Malaysia Pahang, Malaysia.

Jones, G.M., Sanks, R.L., Tchonoglous, G. and Bosserman, B.E. 2006. *Pumping station design*. 3rd ed. UK: Elsevier.

Kelvin, K. 2009. *Analysis of heat gain against cooling capacity at occupied building*. Bachelor thesis. Universiti Malaysia Pahang, Malaysia.

Khemani, H. 2009. Electronic sources: Direct expansion type of central air conditioning system. http://www.brighthub.com/engineering/mechanical/article / 50158.aspx (9 August 2011).

Miller, R. and Miller, M.R. 2006. *Air conditioning and refrigeration*. UK: McGraw-Hill.

Pita, E.G. 1998. Air *conditioning principles and system*. 3rd ed. Columbus: Prentice Hall.

Shan, K.W. 2001. *Handbook of air conditioning and refrigeration*. 2nd ed. United States of America: McGraw-Hill

Trott, A.R. and Welch, T. 2000. *Refrigeration and air conditioning*. 3rd ed. UK: Butterworth-Heinemann.

APPENDIX A1

COOLING LOAD TEMPERATURE DIFFERENCE (CLTD) FROM SUNLIT WALL TYPE (ASHRAE, 1997)

Wall Number 1

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	1	0	–1	–1	–2	–1	4	6	6	7	9	12	14	15	16	16	16	16	15	9	6	4	3	2
NE	1	0	–1	–1	–2	1	13	23	26	24	19	16	15	16	16	16	15	13	11	8	6	4	3	2
E	1	0	–1	–1	–1	1	16	28	34	36	33	27	20	17	17	17	16	14	11	8	6	4	3	2
SE	1	0	–1	–1	–2	0	8	18	26	31	32	31	27	22	18	17	16	14	11	8	6	4	3	2
S	1	0	–1	–1	–2	–1	0	2	6	12	18	24	28	29	28	24	19	15	11	8	6	4	3	2
SW	1	0	–1	–1	–1	–1	0	2	4	7	9	14	22	29	36	39	38	34	25	13	7	4	3	2
W	1	1	–1	–1	–1	–1	1	2	4	7	9	12	15	23	33	41	44	44	34	18	9	5	3	2
NW	1	0	–1	–1	–1	–1	0	2	4	7	9	12	14	16	21	28	34	36	31	16	8	5	3	2

Wall Number 2

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	3	2	1	0	–1	–1	–1	2	4	5	6	8	10	12	13	14	15	16	16	15	12	9	7	4
NE	3	2	1	0	–1	–1	1	7	14	20	22	21	18	17	16	16	16	16	14	13	10	8	6	4
E	3	2	1	0	–1	–1	1	8	18	26	31	32	29	24	21	19	18	17	15	13	11	8	6	4
SE	3	2	1	0	–1	–1	0	4	11	18	24	28	29	28	25	22	19	17	16	13	11	8	6	4
S	3	2	1	0	–1	–1	–1	–1	1	4	8	13	18	23	26	27	26	22	18	15	12	8	6	4
SW	4	2	1	1	0	–1	–1	0	1	3	5	7	11	17	23	29	34	36	34	29	22	15	9	6
W	4	3	2	1	0	–1	–1	0	1	3	5	7	9	13	18	26	33	38	41	37	28	19	12	8
NW	4	2	1	1	–1	–1	–1	–1	1	3	5	7	9	12	14	18	23	28	32	30	23	16	11	7

Wall Number 3

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	4	3	2	1	1	0	1	3	4	4	6	8	9	11	13	13	14	14	15	13	11	9	7	6
NE	4	3	2	1	0	0	4	9	14	17	18	17	17	16	16	16	16	16	14	12	10	8	7	5
E	4	3	2	1	1	1	4	12	18	23	26	26	24	22	21	19	18	17	16	13	11	9	7	6
SE	4	3	2	1	1	0	2	7	12	18	22	24	26	24	23	21	19	18	16	13	11	9	7	6
S	4	3	2	1	1	0	0	1	2	5	9	13	17	21	23	23	22	20	17	14	12	9	8	6
SW	7	5	3	2	1	1	1	1	2	3	5	8	12	17	22	27	31	32	30	25	20	16	12	9
W	8	6	4	3	2	1	1	1	2	3	5	7	9	13	19	25	31	35	35	30	24	18	14	11
NW	7	4	3	2	1	1	0	1	2	3	5	7	9	11	14	18	22	27	28	24	19	15	12	9

Wall Number 4

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	6	4	3	2	1	0	0	1	2	3	4	6	7	9	11	12	13	14	15	15	14	12	11	8
NE	6	4	3	2	1	0	0	2	7	12	16	18	18	18	17	17	17	16	16	14	13	11	9	7
E	6	4	3	2	1	1	1	3	8	15	21	25	27	26	24	22	21	19	18	16	14	12	9	8
SE	6	4	3	2	1	1	0	1	4	9	15	20	24	26	26	24	23	21	19	17	14	12	10	8
S	6	4	3	2	1	1	0	1	0	1	3	7	11	16	19	23	24	23	22	19	17	13	11	8
SW	10	7	5	3	2	1	0	0	0	1	3	4	7	10	15	20	26	29	32	32	28	23	18	14
W	12	8	6	4	2	1	1	0	1	1	3	4	6	8	12	17	22	28	33	36	33	28	22	17
NW	10	7	5	3	2	1	0	0	0	1	2	4	6	8	11	13	17	21	25	27	27	23	18	14

Wall Number 5

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	7	6	4	3	3	2	1	2	3	3	4	5	7	8	9	11	12	13	13	13	13	12	10	8
NE	7	6	4	3	3	2	2	4	8	11	14	15	16	16	16	16	16	16	15	14	13	12	10	8
E	8	6	5	4	3	2	2	4	9	14	18	22	22	22	21	21	19	19	18	16	14	13	11	9
SE	8	7	5	4	3	2	2	3	6	10	14	18	21	22	22	21	21	19	18	17	15	13	11	9
S	8	7	5	4	3	2	2	1	2	2	4	7	11	14	17	19	20	20	19	18	16	13	12	10
SW	12	10	8	6	4	3	3	2	2	3	3	5	7	9	14	18	22	26	27	27	24	21	18	14
W	14	11	9	7	6	4	3	2	2	3	4	5	6	8	11	16	21	25	29	30	28	24	21	17
NW	12	9	7	6	4	3	2	2	2	2	3	4	6	8	9	12	15	19	22	23	22	19	17	14

Wall Number 6

Wall Face	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	7	6	5	4	3	3	2	3	3	4	4	6	7	8	9	10	11	12	12	13	12	11	9	8
NE	8	7	6	4	3	3	3	6	8	11	13	14	14	14	14	15	15	15	14	14	13	12	10	9
E	9	7	6	5	4	3	4	6	10	14	17	19	20	20	19	19	19	18	17	16	14	13	12	10
SE	9	8	6	5	4	3	3	4	7	10	13	16	18	19	20	19	19	18	18	16	15	13	12	10
S	9	7	6	5	4	3	3	2	2	3	5	7	10	13	16	17	18	18	17	16	15	13	12	10
SW	13	11	9	8	6	5	4	3	3	4	4	6	7	10	13	17	21	23	24	24	22	19	17	15
W	14	12	10	8	7	6	4	4	4	4	4	6	7	8	11	15	19	23	26	27	25	22	19	17
NW	12	10	8	7	6	4	4	3	3	3	4	5	6	8	9	12	14	18	20	21	20	18	16	14

Wall Number 7

Wall Face	Hour																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	7	7	6	5	4	3	3	4	4	4	5	6	7	8	9	9	10	11	11	11	11	10	9	8
NE	8	7	6	6	5	4	5	7	9	11	12	13	13	13	13	14	14	14	13	13	12	11	10	9
E	9	8	7	7	6	5	6	9	12	14	17	18	18	18	18	18	17	17	16	15	14	13	12	11
SE	9	8	7	7	6	5	5	7	9	12	14	16	17	18	18	18	17	17	16	15	14	13	12	11
S	9	8	7	6	6	4	4	4	4	5	7	8	11	13	14	16	16	16	16	14	13	12	11	10
SW	13	11	10	9	7	7	6	6	6	6	6	7	8	11	14	17	19	21	22	21	19	17	16	14
W	14	12	11	9	8	7	7	6	6	6	7	7	8	9	12	16	19	22	23	23	21	19	17	16
NW	11	10	9	8	7	6	5	5	5	5	6	6	7	8	9	12	14	17	18	18	17	16	14	13

Wall Number 9

Wall Face	Hour																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	9	8	7	6	5	4	3	2	2	2	3	4	4	6	7	8	9	11	12	12	13	13	12	11
NE	10	8	7	6	5	4	3	3	3	6	9	11	13	14	14	15	15	16	16	15	14	14	13	11
E	11	9	8	7	6	4	3	3	4	7	11	14	18	20	21	21	21	20	19	18	17	16	14	13
SE	11	9	8	7	6	4	3	3	3	5	7	11	14	17	19	20	21	20	19	19	18	16	14	13
S	12	10	8	7	6	4	3	3	2	2	2	3	6	8	11	14	16	18	19	19	18	17	15	13
SW	17	14	12	10	8	7	5	4	3	3	3	3	4	6	8	11	14	18	22	24	25	24	22	20
W	19	17	14	12	9	8	6	4	4	3	3	4	4	6	7	9	12	17	21	24	27	27	25	23
NW	16	14	12	9	8	6	5	4	3	3	3	3	4	5	6	8	10	12	16	19	21	21	20	18

Wall Number 10

Wall Face	Hour																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	9	8	7	6	5	4	3	3	3	3	3	4	4	6	7	8	9	10	11	12	12	12	12	11
NE	10	9	7	6	5	4	3	3	4	7	9	11	12	13	14	14	15	15	15	15	14	13	12	11
E	11	9	8	7	6	4	4	4	6	8	11	14	17	19	19	20	20	19	19	18	17	16	14	13
SE	12	10	8	7	6	4	4	3	4	6	8	11	14	17	18	19	19	19	19	18	17	16	14	13
S	12	10	8	7	6	5	4	3	2	2	3	4	6	8	11	13	16	17	18	18	17	16	14	13
SW	17	15	13	11	9	7	6	4	4	3	3	4	4	6	8	11	14	18	21	23	23	23	21	19
W	19	17	14	12	10	8	7	5	4	4	4	4	4	6	7	9	13	17	21	23	25	25	23	22
NW	16	13	12	10	8	7	6	4	3	3	3	3	4	6	7	8	10	13	16	18	19	20	19	17

Wall Number 11

Wall Face	Hour																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	9	8	7	7	6	5	4	4	4	4	4	5	6	6	7	8	8	9	10	11	11	11	10	9
NE	10	9	8	7	7	6	5	5	6	8	9	11	12	12	13	13	13	13	14	14	13	13	12	11
E	12	11	9	9	8	7	6	6	7	9	12	14	16	17	17	17	17	17	17	17	16	15	14	13
SE	12	11	9	9	8	7	6	6	6	8	9	12	13	15	16	17	17	17	17	17	16	15	14	13
S	11	10	9	8	7	6	6	5	4	4	4	6	7	9	11	13	14	15	16	16	15	14	13	12
SW	16	14	13	11	10	9	8	7	6	6	6	6	7	8	9	12	14	17	18	20	20	19	18	17
W	17	16	14	12	11	10	9	8	7	7	6	7	7	7	8	11	13	16	18	21	22	21	20	18
NW	14	13	11	10	9	8	7	6	6	5	5	6	6	7	7	8	10	12	14	16	17	17	16	15

Wall Number 12

Wall Face	Hour																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	9	8	7	7	6	6	4	4	4	4	4	5	6	6	7	8	8	9	9	10	11	11	10	9
NE	10	9	8	8	7	6	6	6	7	8	9	11	12	12	12	13	13	13	13	13	13	12	12	11
E	12	11	10	9	8	7	7	7	8	9	12	14	16	16	17	17	17	17	17	16	16	15	14	13
SE	12	11	10	9	8	7	7	6	7	8	9	12	13	14	16	16	17	17	17	16	16	15	14	13
S	11	11	9	8	8	7	6	6	5	5	5	6	7	9	11	12	13	14	14	14	14	14	13	12
SW	15	14	13	12	11	9	8	8	7	7	7	7	7	8	9	11	13	16	18	19	19	19	18	17
W	17	16	14	13	12	11	9	8	8	7	7	7	7	8	9	11	13	15	18	19	21	20	19	18
NW	13	12	11	11	9	8	7	7	6	6	6	6	6	7	7	8	10	12	14	16	16	16	16	14

APPENDIX A2

COOLING LOAD TEMPERATURE DIFFERENCES FOR CONDUCTION THROUGH GLASS (ASHRAE, 1997)

Solar Time, h	CLTD, °C	Solar Time, h	CLTD, °C
0100	1	1300	7
0200	0	1400	7
0300	−1	1500	8
0400	−1	1600	8
0500	−1	1700	7
0600	−1	1800	7
0700	−1	1900	6
0800	0	2000	4
0900	1	2100	3
1000	2	2200	2
1100	4	2300	2
1200	5	2400	1

APPENDIX A3

U-FACTORS FOR VARIOUS FENESTRATION PRODUCT IN $W/m^2 . K$

(ASHRAE, 1997)

Product Type	Aluminum without Thermal Break	Aluminum with Thermal Break	Vinyl/Aluminum Clad Wood
Single Glazing			
3.2 mm glass	6.42	6.07	5.55
Double Glazing			
6.4 mm airspace	3.94	3.56	3.19
12.7 mm airspace	3.61	3.22	2.86
6.4 mm argon space	3.75	3.37	3.00
12.7 mm argon space	3.47	3.08	2.73

APPENDIX A4

U-FACTORS OF DOORS IN W/m^2.K (ASHRAE, 1997)

Door Type	No Glazing	Single Glazing	Double Glazing with 12.7 mm Airspace	Double Glazing with $e = 0.10$, 12.7 mm Argon
SWINGING DOORS (Rough Opening—970 mm × 2080 mm)				
Slab Doors				
Wood slab in wood frame[a]	2.61			
6% glazing (560 × 200 lite)	—	2.73	2.61	2.50
25% glazing (560 × 910 lite)	—	3.29	2.61	2.38
45% glazing (560 × 1620 lite)	—	3.92	2.61	2.21
More than 50% glazing		Use Table 5 (operable)		
Insulated steel slab with wood edge in wood frame[a]	0.91			
6% glazing (560 × 200 lite)	—	1.19	1.08	1.02
25% glazing (560 × 910 lite)	—	2.21	1.48	1.31
45% glazing (560 × 1630 lite)	—	3.29	1.99	1.48
More than 50% glazing		Use Table 5 (operable)		

APPENDIX A5

SHADING COEFFICIENT OF SINGLE AND DOUBLE GLAZING
(ASHRAE, 1997)

	Aluminum Frame		Other Frame	
	Operable	Fixed	Operable	Fixed
Uncoated Single Glazing				
1/4in. [6.4mm] clear	0.82	0.85	0.69	0.82
1/4 in. [6.4mm] green	0.59	0.61	0.49	0.59
Reflective Single Glazing				
1/4in. [6.4mm] SS on clear	0.26	0.28	0.22	0.25
1/4in. [6.4mm] SS on green	0.26	0.28	0.22	0.25
Uncoated Double Glazing				
1/4in. [6.4mm] clear-clear	0.70	0.74	0.60	0.70
1/4in. [6.4mm] green-green	0.48	0.49	0.40	0.47
Reflective Double Glazing				
1/4in. [6.4mm] SS on clear-clear	0.20	0.18	0.15	0.17
1/4in. [6.4mm] SS on green-green	0.18	0.18	0.15	0.16

APPENDIX A6

COOLING LOAD FACTOR FOR PEOPLES (ASHRAE, 1997)

Zone Type A

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	0	0	0	0	3	79	85	88	101	110	120	126	126	123	113	98	98	113	38	19	9	3	3	0
NE	0	0	0	0	6	268	406	422	353	236	173	151	139	126	117	101	82	57	22	9	6	3	0	0
E	0	0	0	0	6	293	495	583	576	485	334	211	167	142	123	104	82	57	22	9	6	3	0	0
SE	0	0	0	0	3	148	299	413	473	473	413	306	198	154	129	107	85	57	22	9	6	3	0	0
S	0	0	0	0	0	28	54	79	129	202	268	306	302	265	198	132	98	63	25	13	6	3	0	0
SW	0	0	0	0	0	28	54	76	95	110	123	202	318	419	476	479	419	293	110	54	25	13	6	3
W	3	0	0	0	0	28	54	76	95	110	120	126	205	359	498	589	605	491	180	85	41	19	9	6
NW	3	0	0	0	0	28	54	76	95	110	120	126	126	158	265	381	450	410	145	69	35	16	9	3
Hor	0	0	0	0	0	76	217	378	532	665	759	810	816	772	684	554	394	221	91	44	22	9	6	3

Zone Type B

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	6	6	3	3	3	69	72	76	88	101	110	117	120	117	110	101	98	110	50	32	22	16	13	9
NE	6	3	3	3	6	230	343	365	318	230	183	164	151	142	129	113	95	72	41	28	19	16	9	9
E	6	6	3	3	6	252	419	501	510	450	331	233	198	173	151	129	107	79	47	32	22	16	13	9
SE	6	6	3	3	3	126	255	353	413	422	384	302	217	183	154	132	110	82	47	32	25	19	13	9
S	6	6	3	3	3	25	47	66	113	176	233	271	274	249	198	145	117	85	50	35	25	19	13	9
SW	19	16	13	9	6	28	50	69	85	98	113	183	280	369	425	435	397	296	145	98	66	47	35	25
W	25	19	16	13	9	28	50	69	85	98	110	117	186	318	438	523	545	463	208	135	95	66	47	35
NW	19	16	13	9	6	28	50	69	85	98	107	117	117	145	239	340	403	375	161	104	69	50	35	25
Hor	25	19	16	13	9	69	189	328	463	583	674	734	753	731	668	567	432	284	167	117	85	60	44	35

Zone Type C

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	16	16	13	13	13	76	72	76	85	95	104	107	110	107	101	91	91	107	44	32	25	22	19	19
NE	22	19	19	16	19	236	334	337	277	192	154	148	142	135	126	113	98	79	50	41	35	32	28	25
E	28	25	25	22	25	261	410	466	457	391	280	195	176	164	148	135	117	95	63	54	47	41	38	35
SE	28	25	22	19	19	142	258	337	381	381	337	258	186	161	148	132	113	91	60	50	44	41	35	32
S	22	22	19	16	16	38	57	72	113	170	221	249	249	221	170	126	104	82	50	41	38	32	28	25
SW	44	38	35	32	28	47	66	82	91	104	113	180	271	347	391	394	350	252	117	88	72	63	54	47
W	54	47	41	38	35	54	69	85	98	107	113	117	186	309	416	482	491	403	158	110	88	76	66	60
NW	38	35	32	28	25	44	63	79	91	101	107	113	113	139	230	321	372	337	123	82	66	54	47	41
Hor	76	66	60	54	50	107	214	337	454	551	627	668	677	652	595	504	387	261	167	139	120	107	95	85

Zone Type D

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	25	22	19	19	19	66	66	66	76	85	91	98	101	98	95	88	91	101	54	44	38	35	32	28
NE	35	32	28	25	28	198	274	284	243	183	154	151	145	139	132	123	110	91	69	60	54	47	44	38
E	47	41	38	35	35	221	337	387	391	347	268	205	189	180	167	151	135	117	91	79	69	63	57	50
SE	44	41	35	32	32	123	214	284	321	328	299	246	189	173	161	148	132	110	85	76	66	60	54	50
S	35	32	28	25	22	38	54	66	101	145	186	211	217	198	164	129	113	95	69	60	54	47	44	38
SW	66	60	54	47	44	57	69	79	88	98	107	161	233	296	334	343	315	246	142	117	104	91	82	72
W	79	72	63	57	54	66	76	88	95	104	107	110	167	265	353	410	425	365	180	145	123	110	98	88
NW	57	50	47	41	38	54	66	76	85	95	101	104	107	129	202	274	318	296	132	104	91	79	69	63
Hor	117	104	95	85	76	120	202	299	391	473	539	583	602	592	554	491	403	302	227	198	176	158	142	129

APPENDIX A7

RATE AT HEAT AND MOISTURE BY HUMAN BEINGS WITH DIFFERENT ACTIVITY (ASHRAE, 1997)

Degree of Activity		**Sensible heat, W**	**Latent Heat, W**
Seated at theater	Theater, matinee	65	30
Seated at theater, night	Theater, night	70	35
Seated, very light work	Offices, hotel	70	45
Moderately active office work	Office, hotels	75	55
Standing, light work; walking	Department store	75	55
Walking, standing	Drug store, bank	75	70
Sedentary work	Restaurant	80	80
Light bench work	Factory	80	140
Moderate dancing	Dance hall	90	160
Walking 4.8 km/h; light machine work	Factory	110	185
Bowling	Bowling alley	170	255
Heavy work	Factory	170	255
Heavy machine work; lifting	Factory	185	285
Athletics	Gymnasium	210	315

APPENDIX A8

RECOMMENDED HEAT GAIN FROM TYPICAL COMPUTER EQUIPMENT
(ASHRAE, 2001)

	Continuous, W	Energy Saver Mode, W
Computer		
Average value	55	20
Conservative value	65	25
Highly conservative value	75	30
Monitor		
Small monitor (330 to 380 mm)	55	0
Medium monitor (400 to 460 mm)	70	0
Large monitor (480 to 510 mm)	80	0

APPENDIX A9

VENTILATION FROM THE BUILDING (ASHRAE, 1997)

Type of Space	Outdoor Air (per person)	Outdoor Air (per ft^2[m^2])
Auditorium	0.008	
Classroom	0.008	
Locker rooms		0.0025
Office space	0.010	
Public restrooms	0.025	
Smoking lounge	0.003	

APPENDIX A10

JULY SOLAR COOLING LOAD FOR SUNLIT GLASS 40°NORTH LATITUDE

(ASHRAE, 1997)

Zone Type A

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
											Solar Time													
N	0	0	0	0	3	79	85	88	101	110	120	126	126	123	113	98	98	113	38	19	9	3	3	0
NE	0	0	0	0	6	268	406	422	353	236	173	151	139	126	117	101	82	57	22	9	6	3	0	0
E	0	0	0	0	6	293	495	583	576	485	334	211	167	142	123	104	82	57	22	9	6	3	0	0
SE	0	0	0	0	3	148	299	413	473	473	413	306	198	154	129	107	85	57	22	9	6	3	0	0
S	0	0	0	0	0	28	54	79	129	202	268	306	302	265	198	132	98	63	25	13	6	3	0	0
SW	0	0	0	0	0	28	54	76	95	110	123	202	318	419	476	479	419	293	110	54	25	13	6	3
W	3	0	0	0	0	28	54	76	95	110	120	126	205	359	498	589	605	491	180	85	41	19	9	6
NW	3	0	0	0	0	28	54	76	95	110	120	126	126	158	265	381	450	410	145	69	35	16	9	3
Hor	0	0	0	0	0	76	217	378	532	665	759	810	816	772	684	554	394	221	91	44	22	9	6	3

Zone Type B

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
											Solar Time													
N	6	6	3	3	3	69	72	76	88	101	110	117	120	117	110	101	98	110	50	32	22	16	13	9
NE	6	3	3	3	6	230	343	365	318	230	183	164	151	142	129	113	95	72	41	28	19	16	9	9
E	6	6	3	3	6	252	419	501	510	450	331	233	198	173	151	129	107	79	47	32	22	16	13	9
SE	6	6	3	3	3	126	255	353	413	422	384	302	217	183	154	132	110	82	47	32	25	19	13	9
S	6	6	3	3	3	25	47	66	113	176	233	271	274	249	198	145	117	85	50	35	25	19	13	9
SW	19	16	13	9	6	28	50	69	85	98	113	183	280	369	425	435	397	296	145	98	66	47	35	25
W	25	19	16	13	9	28	50	69	85	98	110	117	186	318	438	523	545	463	208	135	95	66	47	35
NW	19	16	13	9	6	28	50	69	85	98	107	117	117	145	239	340	403	375	161	104	69	50	35	25
Hor	25	19	16	13	9	69	189	328	463	583	674	734	753	731	668	567	432	284	167	117	85	60	44	35

Zone Type C

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
											Solar Time													
N	16	16	13	13	13	76	72	76	85	95	104	107	110	107	101	91	91	107	44	32	25	22	19	19
NE	22	19	19	16	19	236	334	337	277	192	154	148	142	135	126	113	98	79	50	41	35	32	28	25
E	28	25	25	22	25	261	410	466	457	391	280	195	176	164	148	135	117	95	63	54	47	41	38	35
SE	28	25	22	19	19	142	258	337	381	381	337	258	186	161	148	132	113	91	60	50	44	41	35	32
S	22	22	19	16	16	38	57	72	113	170	221	249	249	221	170	126	104	82	50	41	38	32	28	25
SW	44	38	35	32	28	47	66	82	91	104	113	180	271	347	391	394	350	252	117	88	72	63	54	47
W	54	47	41	38	35	54	69	85	98	107	113	117	186	309	416	482	491	403	158	110	88	76	66	60
NW	38	35	32	28	25	44	63	79	91	101	107	113	113	139	230	321	372	337	123	82	66	54	47	41
Hor	76	66	60	54	50	107	214	337	454	551	627	668	677	652	595	504	387	261	167	139	120	107	95	85

Zone Type D

Glass Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
											Solar Time													
N	25	22	19	19	19	66	66	66	76	85	91	98	101	98	95	88	91	101	54	44	38	35	32	28
NE	35	32	28	25	28	198	274	284	243	183	154	151	145	139	132	123	110	91	69	60	54	47	44	38
E	47	41	38	35	35	221	337	387	391	347	268	205	189	180	167	151	135	117	91	79	69	63	57	50
SE	44	41	35	32	32	123	214	284	321	328	299	246	189	173	161	148	132	110	85	76	66	60	54	50
S	35	32	28	25	22	38	54	66	101	145	186	211	217	198	164	129	113	95	69	60	54	47	44	38
SW	66	60	54	47	44	57	69	79	88	98	107	161	233	296	334	343	315	246	142	117	104	91	82	72
W	79	72	63	57	54	66	76	88	95	104	107	110	167	265	353	410	425	365	180	145	123	110	98	88
NW	57	50	47	41	38	54	66	76	85	95	101	104	107	129	202	274	318	296	132	104	91	79	69	63
Hor	117	104	95	85	76	120	202	299	391	473	539	583	602	592	554	491	403	302	227	198	176	158	142	129

APPENDIX A11

TYPICAL NONINCANDESCENT LIGHT FIXTURES (ASHRAE, 2001)

Description	Ballast	Watts/Lamp	Lamps/Fixture	Lamp Watts	Fixture Watts	Special Allowance Factor	Description	Ballast	Watts/Lamp	Lamps/Fixture	Lamp Watts	Fixture Watts	Special Allowance Factor
Compact Fluorescent Fixtures													
Twin, (1) 5 W lamp	Mag-Std	5	1	5	9	1.80	Twin, (2) 40 W lamp	Mag-Std	40	2	80	85	1.06
Twin, (1) 7 W lamp	Mag-Std	7	1	7	10	1.43	Quad, (1) 13 W lamp	Electronic	13	1	13	15	1.15
Twin, (1) 9 W lamp	Mag-Std	9	1	9	11	1.22	Quad, (1) 26 W lamp	Electronic	26	1	26	27	1.04
Quad, (1) 13 W lamp	Mag-Std	13	1	13	17	1.31	Quad, (2) 18 W lamp	Electronic	18	2	36	38	1.06
Quad, (2) 18 W lamp	Mag-Std	18	2	36	45	1.25	Quad, (2) 26 W lamp	Electronic	26	2	52	50	0.96
Quad, (2) 22 W lamp	Mag-Std	22	2	44	48	1.09	Twin or multi, (2) 32 W lamp	Electronic	32	2	64	62	0.97
Quad, (2) 26 W lamp	Mag-Std	26	2	52	66	1.27							
Fluorescent Fixtures													
(1) 450 mm, T8 lamp	Mag-Std	15	1	15	19	1.27	(4) 1200 mm, T8 lamp	Electronic	32	4	128	120	0.94
(1) 450 mm, T12 lamp	Mag-Std	15	1	15	19	1.27	(1) 1500 mm, T12 lamp	Mag-Std	50	1	50	63	1.26
(2) 450 mm, T8 lamp	Mag-Std	15	2	30	36	1.20	(2) 1500 mm, T12 lamp	Mag-Std	50	2	100	128	1.28
(2) 450 mm, T12 lamp	Mag-Std	15	2	30	36	1.20	(1) 1500 mm, T12 HO lamp	Mag-Std	75	1	75	92	1.23
(1) 600 mm, T8 lamp	Mag-Std	17	1	17	24	1.41	(2) 1500 mm, T12 HO lamp	Mag-Std	75	2	150	168	1.12
(1) 600 mm, T12 lamp	Mag-Std	20	1	20	28	1.40	(1) 1500 mm, T12 ES VHO lamp	Mag-Std	135	1	135	165	1.22
(2) 600 mm, T12 lamp	Mag-Std	20	2	40	56	1.40	(2) 1500 mm, T12 ES VHO lamp	Mag-Std	135	2	270	310	1.15
(1) 600 mm, T12 HO lamp	Mag-Std	35	1	35	62	1.77	(1) 1500 mm, T12 HO lamp	Mag-ES	75	1	75	88	1.17
(2) 600 mm, T12 HO lamp	Mag-Std	35	2	70	90	1.29	(2) 1500 mm, T12 HO lamp	Mag-ES	75	2	150	176	1.17
(1) 600 mm, T8 lamp	Electronic	17	1	17	16	0.94	(1) 1500 mm, T12 lamp	Electronic	50	1	50	44	0.88
(2) 600 mm, T8 lamp	Electronic	17	2	34	31	0.91	(2) 1500 mm, T12 lamp	Electronic	50	2	100	88	0.88
(1) 900 mm, T12 lamp	Mag-Std	30	1	30	46	1.53	(1) 1500 mm, T12 HO lamp	Electronic	75	1	75	69	0.92
(2) 900 mm, T12 lamp	Mag-Std	30	2	60	81	1.35	(2) 1500 mm, T12 HO lamp	Electronic	75	2	150	138	0.92
(1) 900 mm, T12 HO lamp	Mag-Std	50	1	50	70	1.40	(3) 1500 mm, T8 lamp	Electronic	40	3	120	106	0.88
(2) 900 mm, T12 HO lamp	Mag-Std	50	2	100	114	1.14	(4) 1500 mm, T8 lamp	Electronic	40	4	160	134	0.84
(2) 900 mm, T12 lamp	Mag-ES	30	2	60	74	1.23	(1) 1800 mm, T12 lamp	Mag-Std	55	1	55	76	1.38
(2) 900 mm, T12 ES lamp	Mag-ES	25	2	50	66	1.32	(2) 1800 mm, T12 lamp	Mag-Std	55	2	110	122	1.11
(1) 900 mm, T12 lamp	Electronic	30	1	30	31	1.03	(3) 1800 mm, T12 lamp	Mag-Std	55	3	165	202	1.22
(1) 900 mm, T12 ES lamp	Electronic	25	1	25	26	1.04	(4) 1800 mm, T12 lamp	Mag-Std	55	4	220	244	1.11
(1) 900 mm, T8 lamp	Electronic	25	1	25	24	0.96	(1) 1800 mm, T12 HO lamp	Mag-Std	85	1	85	120	1.41
(2) 900 mm, T12 lamp	Electronic	30	2	60	58	0.97	(2) 1800 mm, T12 HO lamp	Mag-Std	85	2	170	220	1.29
(2) 900 mm, T12 ES lamp	Electronic	25	2	50	50	1.00	(1) 1800 mm, T12 VHO lamp	Mag-Std	160	1	160	180	1.13
(2) 900 mm, T8 lamp	Electronic	25	2	50	46	0.92	(2) 1800 mm, T12 VHO lamp	Mag-Std	160	2	320	330	1.03
(2) 900 mm, T8 HO lamp	Electronic	25	2	50	50	1.00	(2) 1800 mm, T12 lamp	Mag-ES	55	2	110	122	1.11
(2) 900 mm, T8 VHO lamp	Electronic	25	2	50	70	1.40	(4) 1800 mm, T12 lamp	Mag-ES	55	4	220	244	1.11
(1) 1200 mm, T12 lamp	Mag-Std	40	1	40	55	1.38	(2) 1800 mm, T12 HO lamp	Mag-ES	85	2	170	194	1.14
(2) 1200 mm, T12 lamp	Mag-Std	40	2	80	92	1.15	(4) 1800 mm, T12 HO lamp	Mag-ES	85	4	340	388	1.14
(3) 1200 mm, T12 lamp	Mag-Std	40	3	120	140	1.17	(1) 1800 mm, T12 lamp	Electronic	55	1	55	68	1.24
(4) 1200 mm, T12 lamp	Mag-Std	40	4	160	184	1.15	(2) 1800 mm, T12 lamp	Electronic	55	2	110	108	0.98
(1) 1200 mm, T12 ES lamp	Mag-Std	34	1	34	48	1.41	(3) 1800 mm, T12 lamp	Electronic	55	3	165	176	1.07
(2) 1200 mm, T12 ES lamp	Mag-Std	34	2	68	82	1.21	(4) 1800 mm, T12 lamp	Electronic	55	4	220	216	0.98
(3) 1200 mm, T12 ES lamp	Mag-Std	34	3	102	100	0.98	(1) 2400 mm, T12 ES lamp	Mag-Std	60	1	60	75	1.25
(4) 1200 mm, T12 ES lamp	Mag-Std	34	4	136	164	1.21	(2) 2400 mm, T12 ES lamp	Mag-Std	60	2	120	128	1.07
(1) 1200 mm, T12 ES lamp	Mag-ES	34	1	34	43	1.26	(3) 2400 mm, T12 ES lamp	Mag-Std	60	3	180	203	1.13
(2) 1200 mm, T12 ES lamp	Mag-ES	34	2	68	72	1.06	(4) 2400 mm, T12 ES lamp	Mag-Std	60	4	240	256	1.07
(3) 1200 mm, T12 ES lamp	Mag-ES	34	3	102	115	1.13	(1) 2400 mm, T12 ES HO lamp	Mag-Std	95	1	95	112	1.18
(4) 1200 mm, T12 ES lamp	Mag-ES	34	4	136	144	1.06	(2) 2400 mm, T12 ES HO lamp	Mag-Std	95	2	190	227	1.19
(1) 1200 mm, T8 lamp	Mag-ES	32	1	32	35	1.09	(3) 2400 mm, T12 ES HO lamp	Mag-Std	95	3	285	380	1.33
(2) 1200 mm, T8 lamp	Mag-ES	32	2	64	71	1.11	(4) 2400 mm, T12 ES HO lamp	Mag-Std	95	4	380	454	1.19
(3) 1200 mm, T8 lamp	Mag-ES	32	3	96	110	1.15	(1) 2400 mm, T12 ES VHO lamp	Mag-Std	185	1	185	205	1.11
(4) 1200 mm, T8 lamp	Mag-ES	32	4	128	142	1.11	(2) 2400 mm, T12 ES VHO lamp	Mag-Std	185	2	370	380	1.03
(1) 1200 mm, T12 ES lamp	Electronic	34	1	34	32	0.94	(3) 2400 mm, T12 ES VHO lamp	Mag-Std	185	3	555	585	1.05

APPENDIX A12

COOLING LOAD FACTOR FOR LIGHTS (ASHRAE, 1997)

Lights On For	Number of Hours after Lights Turned On																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Zone Type A																								
8	0.85	0.92	0.95	0.96	0.97	0.97	0.97	0.98	0.13	0.06	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.85	0.93	0.95	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.14	0.07	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
12	0.86	0.93	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.14	0.07	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
14	0.86	0.93	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.15	0.07	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.02
16	0.87	0.94	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.15	0.08	0.05	0.04	0.03	0.03	0.03	0.02
Zone Type B																								
8	0.75	0.85	0.90	0.93	0.94	0.95	0.95	0.96	0.23	0.12	0.08	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01
10	0.75	0.86	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.24	0.13	0.08	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02
12	0.76	0.86	0.91	0.93	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.24	0.14	0.09	0.07	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03
14	0.76	0.87	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.25	0.14	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.03
16	0.77	0.88	0.92	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.25	0.15	0.10	0.07	0.06	0.05	0.05	0.04
Zone Type C																								
8	0.72	0.80	0.84	0.87	0.88	0.89	0.90	0.91	0.23	0.15	0.11	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03
10	0.73	0.81	0.85	0.87	0.89	0.90	0.91	0.92	0.92	0.93	0.25	0.16	0.13	0.11	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.04
12	0.74	0.82	0.86	0.88	0.90	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.26	0.18	0.14	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05
14	0.75	0.84	0.87	0.89	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.27	0.19	0.15	0.13	0.11	0.10	0.09	0.08	0.08	0.07
16	0.77	0.85	0.89	0.91	0.92	0.93	0.93	0.94	0.95	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.28	0.20	0.16	0.13	0.12	0.11	0.10	0.09
Zone Type D																								
8	0.66	0.72	0.76	0.79	0.81	0.83	0.85	0.86	0.25	0.20	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.05	0.04	0.04
10	0.68	0.74	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.90	0.28	0.23	0.19	0.17	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.06
12	0.70	0.75	0.79	0.81	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.30	0.25	0.21	0.19	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.08
14	0.72	0.77	0.81	0.83	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.32	0.26	0.23	0.20	0.18	0.16	0.14	0.13	0.12	0.10
16	0.75	0.80	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.96	0.96	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14

APPENDIX A13

COOLING LOAD FACTOR FOR EQUIPMENTS (ASHRAE, 1997)

Hours in	Number of Hours after Equipment Turned On																							
Operation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
												Zone Type A												
2	0.64	0.83	0.26	0.11	0.06	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.64	0.83	0.90	0.93	0.31	0.14	0.07	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.64	0.83	0.90	0.93	0.96	0.96	0.33	0.16	0.09	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.64	0.83	0.90	0.93	0.96	0.96	0.97	0.97	0.34	0.16	0.09	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
10	0.64	0.83	0.90	0.93	0.96	0.96	0.97	0.97	0.99	0.99	0.34	0.17	0.10	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.64	0.83	0.90	0.94	0.96	0.97	0.97	0.97	0.99	0.99	0.99	0.99	0.36	0.17	0.10	0.06	0.04	0.03	0.03	0.03	0.01	0.01	0.01	0.01
14	0.66	0.83	0.90	0.94	0.96	0.97	0.97	0.99	0.99	0.99	0.99	0.99	1.00	1.00	0.36	0.17	0.10	0.07	0.04	0.04	0.03	0.03	0.03	0.01
16	0.66	0.84	0.91	0.94	0.96	0.97	0.97	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	0.36	0.17	0.10	0.07	0.04	0.04	0.04	0.03
18	0.67	0.84	0.91	0.94	0.96	0.97	0.97	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.36	0.17	0.10	0.08	0.07	0.04
												Zone Type B												
2	0.50	0.63	0.23	0.16	0.11	0.09	0.07	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.50	0.64	0.73	0.79	0.34	0.24	0.19	0.14	0.10	0.09	0.06	0.04	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
6	0.50	0.64	0.73	0.79	0.84	0.87	0.41	0.29	0.21	0.17	0.13	0.10	0.07	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00
8	0.50	0.64	0.73	0.79	0.84	0.87	0.90	0.93	0.44	0.31	0.24	0.19	0.14	0.11	0.09	0.07	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.01
10	0.50	0.64	0.73	0.79	0.84	0.87	0.90	0.93	0.94	0.96	0.47	0.34	0.26	0.20	0.16	0.11	0.09	0.07	0.06	0.04	0.03	0.03	0.03	0.01
12	0.51	0.66	0.73	0.80	0.84	0.89	0.91	0.93	0.94	0.96	0.97	0.97	0.49	0.34	0.27	0.20	0.16	0.11	0.09	0.07	0.06	0.05	0.04	0.03
14	0.53	0.66	0.74	0.80	0.84	0.89	0.91	0.93	0.94	0.96	0.97	0.97	0.99	0.99	0.50	0.36	0.27	0.21	0.16	0.13	0.10	0.08	0.07	0.06
16	0.56	0.69	0.76	0.81	0.86	0.89	0.91	0.93	0.94	0.96	0.97	0.97	0.99	0.99	0.99	0.99	0.50	0.36	0.27	0.21	0.16	0.14	0.13	0.10
18	0.59	0.71	0.79	0.83	0.87	0.90	0.93	0.94	0.96	0.97	0.97	0.99	0.99	0.99	0.99	0.99	1.00	1.00	0.50	0.36	0.27	0.23	0.21	0.16
												Zone Type C												
2	0.43	0.54	0.20	0.16	0.13	0.10	0.09	0.07	0.06	0.04	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
4	0.43	0.54	0.63	0.70	0.33	0.26	0.20	0.17	0.14	0.11	0.09	0.07	0.06	0.06	0.04	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01
6	0.44	0.56	0.63	0.70	0.76	0.80	0.40	0.31	0.26	0.21	0.17	0.14	0.11	0.10	0.09	0.07	0.06	0.04	0.04	0.03	0.03	0.02	0.01	0.01
8	0.44	0.56	0.64	0.70	0.76	0.80	0.84	0.87	0.46	0.37	0.30	0.24	0.20	0.16	0.13	0.11	0.09	0.07	0.06	0.06	0.04	0.03	0.03	0.03
10	0.46	0.57	0.64	0.71	0.76	0.80	0.84	0.87	0.89	0.91	0.50	0.40	0.33	0.26	0.21	0.17	0.14	0.11	0.10	0.09	0.07	0.06	0.06	0.04
12	0.47	0.59	0.66	0.73	0.77	0.81	0.84	0.87	0.90	0.91	0.93	0.94	0.53	0.41	0.34	0.27	0.23	0.19	0.16	0.13	0.10	0.09	0.09	0.07
14	0.50	0.60	0.67	0.74	0.79	0.83	0.86	0.89	0.90	0.91	0.93	0.94	0.96	0.96	0.54	0.43	0.36	0.29	0.24	0.20	0.16	0.14	0.13	0.11
16	0.54	0.63	0.70	0.76	0.80	0.84	0.87	0.89	0.91	0.93	0.94	0.94	0.96	0.97	0.97	0.97	0.56	0.44	0.36	0.30	0.24	0.22	0.20	0.16
18	0.60	0.69	0.74	0.79	0.83	0.86	0.89	0.90	0.91	0.93	0.94	0.96	0.96	0.97	0.97	0.99	0.99	0.99	0.56	0.44	0.37	0.33	0.30	0.24
												Zone Type D												
2	0.41	0.53	0.19	0.13	0.11	0.09	0.07	0.07	0.06	0.06	0.04	0.04	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.43	0.53	0.60	0.66	0.29	0.23	0.19	0.16	0.14	0.11	0.10	0.09	0.07	0.07	0.06	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.01	0.01
6	0.44	0.54	0.61	0.67	0.71	0.76	0.37	0.29	0.24	0.21	0.19	0.16	0.13	0.11	0.10	0.09	0.07	0.07	0.06	0.04	0.04	0.04	0.04	0.03
8	0.46	0.56	0.63	0.67	0.71	0.76	0.79	0.81	0.43	0.34	0.29	0.24	0.21	0.19	0.16	0.14	0.11	0.10	0.09	0.07	0.07	0.06	0.06	0.06
10	0.47	0.57	0.64	0.69	0.73	0.77	0.80	0.83	0.84	0.87	0.47	0.39	0.31	0.27	0.24	0.20	0.17	0.16	0.13	0.11	0.10	0.09	0.09	0.07
12	0.50	0.59	0.66	0.70	0.74	0.77	0.81	0.83	0.86	0.87	0.89	0.90	0.50	0.41	0.34	0.30	0.26	0.23	0.19	0.17	0.14	0.13	0.13	0.11
14	0.53	0.61	0.69	0.73	0.76	0.80	0.83	0.84	0.87	0.89	0.90	0.91	0.93	0.93	0.53	0.43	0.36	0.31	0.27	0.23	0.20	0.18	0.17	0.16
16	0.57	0.66	0.71	0.76	0.79	0.81	0.84	0.86	0.89	0.90	0.91	0.93	0.93	0.94	0.94	0.96	0.54	0.44	0.37	0.33	0.29	0.26	0.24	0.21
18	0.63	0.71	0.76	0.79	0.81	0.84	0.87	0.89	0.90	0.91	0.93	0.93	0.94	0.96	0.96	0.96	0.97	0.97	0.56	0.46	0.39	0.35	0.33	0.29

APPENDIX A14

THERMAL PROPERTIES OF LAYERS USED IN WALLS (ASHRAE, 1997)

Code Number	Description	Thickness and Thermal Properties					
		L	k	ρ	c_p	R	Mass
A0	Outside surface resistance	0	0.000	0	0.00	0.059	0.00
A1	25 mm Stucco	25	0.692	1858	0.84	0.037	47.34
A2	100 mm Face brick	100	1.333	2002	0.92	0.076	203.50
A3	Steel siding	2	44.998	7689	0.42	0.000	11.71
A4	12 mm Slag	13	0.190	1121	1.67	0.067	10.74
A5	Outside surface resistance	0	0.000	0	0.00	0.059	0.00
A6	Finish	13	0.415	1249	1.09	0.031	16.10
A7	100 mm Face brick	100	1.333	2002	0.92	0.076	203.50
B1	Air space resistance	0	0.000	0	0.00	0.160	0.00
B2	25 mm Insulation	25	0.043	32	0.84	0.587	0.98
B3	50 mm Insulation	51	0.043	32	0.84	1.173	1.46
B4	75 mm Insulation	76	0.043	32	0.84	1.760	2.44
B5	25 mm Insulation	25	0.043	91	0.84	0.587	2.44
B6	50 mm Insulation	51	0.043	91	0.84	1.173	4.88
B7	25 mm Wood	25	0.121	593	2.51	0.207	15.13
B8	65 mm Wood	63	0.121	593	2.51	0.524	37.58
B9	100 mm Wood	100	0.121	593	2.51	0.837	60.02
B10	50 mm Wood	51	0.121	593	2.51	0.420	30.26
B11	75 mm Wood	76	0.121	593	2.51	0.628	45.38
B12	75 mm Insulation	76	0.043	91	0.84	1.760	6.83
B13	100 mm Insulation	100	0.043	91	0.84	2.347	9.27
B14	125 mm Insulation	125	0.043	91	0.84	2.933	11.71
B15	150 mm Insulation	150	0.043	91	0.84	3.520	14.15
B16	4 mm Insulation	4	0.043	91	0.84	0.088	0.49
B17	8 mm Insulation	8	0.043	91	0.84	0.176	0.49
B18	12 mm Insulation	12	0.043	91	0.84	0.264	0.98
B19	15 mm Insulation	15	0.043	91	0.84	0.352	1.46
B20	20 mm Insulation	20	0.043	91	0.84	0.440	1.95
B21	35 mm Insulation	35	0.043	91	0.84	0.792	2.93
B22	42 mm Insulation	42	0.043	91	0.84	0.968	3.90
B23	60 mm Insulation	62	0.043	91	0.84	1.408	5.86
B24	70 mm Insulation	70	0.043	91	0.84	1.584	6.34
B25	85 mm Insulation	85	0.043	91	0.84	1.936	7.81
B26	92 mm Insulation	92	0.043	91	0.84	2.112	8.30
B27	115 mm Insulation	115	0.043	91	0.84	2.640	10.74
C1	100 mm Clay tile	100	0.571	1121	0.84	0.178	113.70
C2	100 mm low density concrete block	100	0.381	609	0.84	0.266	61.98
C3	100 mm high density concrete block	100	0.813	977	0.84	0.125	99.06
C4	100 mm Common brick	100	0.727	1922	0.84	0.140	195.20
C5	100 mm high density concrete	100	1.731	2243	0.84	0.059	227.90
C6	200 mm Clay tile	200	0.571	1121	0.84	0.352	227.90
C7	200 mm low density concrete block	200	0.571	609	0.84	0.352	123.46
C8	200 mm high density concrete block	200	1.038	977	0.84	0.196	198.62
C9	200 mm Common brick	200	0.727	1922	0.84	0.279	390.40
C10	200 mm high density concrete	200	1.731	2243	0.84	0.117	455.79
C11	300 mm high density concrete	300	1.731	2243	0.84	0.176	683.20
C12	50 mm high density concrete	50	1.731	2243	0.84	0.029	113.70
C13	150 mm high density concrete	150	1.731	2243	0.84	0.088	341.60
C14	100 mm low density concrete	100	0.173	641	0.84	0.587	64.90
C15	150 mm low density concrete	150	0.173	641	0.84	0.880	97.60
C16	200 mm low density concrete	200	0.173	641	0.84	1.173	130.30
C17	200 mm low density concrete block (filled)	200	0.138	288	0.84	1.467	58.56
C18	200 mm high density concrete block (filled)	200	0.588	849	0.84	0.345	172.75
C19	300 mm low density concrete block (filled)	300	0.138	304	0.84	2.200	92.72
C20	300 mm high density concrete block (filled)	300	0.675	897	0.84	0.451	273.28
E0	Inside surface resistance	0	0.000	0	0.00	0.121	0.00
E1	20 mm Plaster or gypsum	20	0.727	1602	0.84	0.026	30.74
E2	12 mm Slag or stone	12	1.436	881	1.67	0.009	11.22
E3	10 mm Felt and membrane	10	0.190	1121	1.67	0.050	10.74
E4	Ceiling air space	0	0.000	0	0.00	0.176	0.00
E5	Acoustic tile	19	0.061	481	0.84	0.314	9.27

APPENDIX B1

FORMULA HEAT GAINS BY USING CLTD/CLF METHOD

Type of heat gain	Equation used	Sources
Conduction of Heat Gains Through Walls	$Q = U\ x\ A\ x\ CLTD_C$ $U = \frac{1}{\sum R}$ $CLTD_C = CLTD + (25.5 - Tr) + (Ta - 29.4)$ $Ta = Tm - (\frac{DR}{2})$	R; Table 11, ASHRAE 1997, Chapter 28 CLTD; Table 32, ASHRAE 1997, Chapter 28
Conduction of Heat Gains Through Windows Glass	$Q = U\ x\ A\ x\ CLTD_C$ $CLTD_c = CLTD + (25.5 - Tr) + (Ta - 29.4)$ $Ta = Tm - (\frac{DR}{2})$	U; Table 5, ASHRAE 1997, Chapter 29 CLTD; Table 34, ASHRAE 1997, Chapter 28
Conduction of Heat Gains Through Door	$Q = U\ x\ A\ x\ CLTD_C$ $CLTD_c = CLTD + (25.5 - Tr) + (Ta - 29.4)$ $Ta = Tm - (\frac{DR}{2})$	U; Table 7, ASHRAE 1997, Chapter 29
Solar Radiation Through Glass	$Q = SC\ x\ A\ x\ SCL$	SC; Table 11, ASHRAE 1997, Chapter 29 SCL; Table 36(Zone D), ASHRAE 1997, Chapter 28
Heat Gain from Lighting	$Q = W\ x\ F_U\ x\ F_{Sa}\ x\ SCL$	
Heat Gain from People	$Q_S = q_S\ x\ n\ x\ CLF$ $Q_L = q_L\ x\ n$	q_S and q_L; Table 3, ASHRAE 1997, Chapter 28
Heat Gain from Appliances	$Q = q\ x\ n\ x\ CLF$	q; Table 8, ASHRAE 2001, Chapter 29
Heat Gain from Ventilation	$Q_S = 1.23\ x\ \dot{Q}\ x\ \Delta T$ $Q_L = 3010\ x\ \dot{Q}\ x\ (Wo' - Wi')$	$\dot{Q}$; Table 2, ASHRAE Standard 62-1999

APPENDIX B2

HEAT GAINS FROM CONDUCTION THROUGH WALL, WINDOWS GLASS, AND DOORS AT BT 8

				Tm	Dr/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
				33	1.5	31.5	33	2	31	33	2	31
				8.00 am			9.00 am			10.00 am		
Conduction	Direction	U(W/m^2.^{o}C)	A (m^2)	CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)
Wall	NW	0.796	88	4	5.6	392.2688	3	4.6	322.2208	3	5.1	357.2448
	SE	0.796	88	3	4.6	322.2208	4	5.6	392.2688	6	8.1	567.3888
Window Glass		6.07	4	0	1.6	38.848	1	2.6	63.128	2	4.1	99.548
Door	NW	2.73	4	0	1.1	12.012	1	2.6	28.392	2	4.1	44.772
	SE	2.73	4	0	1.1	12.012	1	2.6	28.392	2	4.1	44.772
						777.3616			834.4016			1113.7256

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.5	30.5	33	2	31	33	2.5	30.5
11.00 am			12.00 pm			13.00 pm			14.00 pm		
CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)
3	5.1	357.2448	3	4.6	322.2208	4	6.1	427.2928	6	5.6	392.2688
8	10.1	707.4848	11	12.6	882.6048	14	16.1	1127.773	17	16.6	1162.797
4	6.1	148.108	5	6.6	160.248	7	9.1	220.948	7	6.6	160.248
4	6.1	66.612	5	6.6	72.072	7	9.1	99.372	7	6.6	72.072
4	6.1	66.612	5	6.6	72.072	7	9.1	99.372	7	6.6	72.072
		1346.062			1509.218			1974.758			1859.458

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.25	30.75	33	2.25	30.75
15.00 pm			16.00 pm			17.00 pm		
CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)	CLTD (^{o}C)	CLTD$_C$	Q (W)
7	8.1	567.3888	8	7.85	549.8768	10	8.85	619.9248
18	19.1	1337.917	19	18.85	1320.405	19	17.85	1250.357
8	9.1	220.948	8	7.85	190.598	7	5.85	142.038
8	9.1	99.372	8	7.85	85.722	7	5.85	63.882
8	9.1	99.372	8	7.85	85.722	7	5.85	63.882
		2324.998			2232.324			2140.084

APPENDIX B3

HEAT GAINS FROM CONDUCTION THROUGH WALL, WINDOWS GLASS, AND DOORS AT BK 5

				Tm	Dr/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
				33	1.5	31.5	33	2	31	33	2	31
				8.00 am			9.00 am			10.00 am		
Conduction	Direction	U(W/m^2.°C)	A (m^2)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
Wall	NW	0.796	93.2	4	5.6	415.4483	3	3.6	267.0739	3	3.6	267.07392
	SE	0.796	93.2	3	4.6	341.2611	4	4.6	341.2611	6	6.6	489.63552
Window Glass		6.07	6.5	0	1.6	63.128	1	1.6	63.128	2	2.6	102.583
Door	NW	2.73	8	0	1.6	34.944	1	1.6	34.944	2	2.6	56.784
	SE	2.73	8	0	1.6	34.944	1	1.6	34.944	2	2.6	56.784
						889.7254			741.351			972.86044

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.5	30.5	33	2	31	33	2.5	30.5
11.00 am			12.00 pm			13.00 pm			14.00 pm		
CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
3	4.1	304.1675	3	3.6	267.0739	4	4.6	341.2611	6	5.6	415.4483
8	9.1	675.1035	11	11.6	860.5715	14	14.6	1083.133	17	16.6	1231.508
4	5.1	201.2205	5	5.6	220.948	7	7.6	299.858	7	6.6	260.403
4	5.1	111.384	5	5.6	122.304	7	7.6	165.984	7	6.6	144.144
4	5.1	111.384	5	5.6	122.304	7	7.6	165.984	7	6.6	144.144
		1403.26			1593.201			2056.22			2195.647

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.25	30.75	33	2.25	30.75
15.00 pm			16.00 pm			17.00 pm		
CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
7	7.6	563.8227	8	7.35	545.2759	10	8.85	656.5567
18	18.6	1379.882	19	18.35	1361.335	19	17.85	1324.242
8	8.6	339.313	8	7.35	289.9943	7	5.85	230.8118
8	8.6	187.824	8	7.35	160.524	7	5.85	127.764
8	8.6	187.824	8	7.35	160.524	7	5.85	127.764
		2658.666			2517.653			2467.138

APPENDIX B4

HEAT GAINS FROM CONDUCTION THROUGH WALL, WINDOWS GLASS, AND DOORS AT BK 6

				Tm	Dr/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
				33	1.5	31.5	33	2	31	33	2	31
				8.00 am			9.00 am			10.00 am		
Conduction	Direction	U(W/m^2.^{o}C)	A (m^2)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
Wall	NW	0.796	93.2	4	5.6	415.4483	3	4.1	304.1675	3	4.1	304.16752
	SE	0.796	93.2	3	4.6	341.2611	4	5.1	378.3547	6	7.1	526.72912
Window Glass		6.07	6.5	0	1.6	63.128	1	2.1	82.8555	2	3.1	122.3105
Door	NW	2.73	8	0	1.6	34.944	1	2.1	45.864	2	3.1	67.704
	SE	2.73	8	0	1.6	34.944	1	2.1	45.864	2	3.1	67.704
						889.7254			857.1057			1088.6151

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.5	30.5	33	2	31	33	2.5	30.5
11.00 am			12.00 pm			13.00 pm			14.00 pm		
CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
3	3.1	229.9803	3	1.6	118.6995	4	4.1	304.1675	6	5.6	415.4483
8	8.1	600.9163	11	9.6	712.1971	14	14.1	1046.04	17	16.6	1231.508
4	4.1	161.7655	5	3.6	142.038	7	7.1	280.1305	7	6.6	260.403
4	4.1	89.544	5	3.6	78.624	7	7.1	155.064	7	6.6	144.144
4	4.1	89.544	5	3.6	78.624	7	7.1	155.064	7	6.6	144.144
		1171.75			1130.183			1940.466			2195.647

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.25	30.75	33	2.25	30.75
15.00 pm			16.00 pm			17.00 pm		
CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
7	7.1	526.7291	8	6.85	508.1823	10	8.85	656.5567
18	18.1	1342.788	19	17.85	1324.242	19	17.85	1324.242
8	8.1	319.5855	8	6.85	270.2668	7	5.85	230.8118
8	8.1	176.904	8	6.85	149.604	7	5.85	127.764
8	8.1	176.904	8	6.85	149.604	7	5.85	127.764
		2542.911			2401.899			2467.138

APPENDIX B5

HEAT GAINS FROM CONDUCTION THROUGH WALL, WINDOWS GLASS, AND DOORS AT BP 6, 7, AND 8

				Tm	Dr/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
				33	1.5	31.5	33	2	31	33	2	31
				8.00 am			9.00 am			10.00 am		
Conduction	Direction	U(W/m^2.^{o}C)	A (m^2)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
Wall	NW	0.796	60.5	4	5.6	269.6848	3	4.1	197.4478	3	3.6	173.3688
	SE	0.796	60.5	3	4.6	221.5268	4	5.1	245.6058	6	6.6	317.8428
Window Glass		6.07	4	0	1.6	38.848	1	2.1	50.988	2	2.6	63.128
Door	NW	2.73	2	0	1.6	8.736	1	2.1	11.466	2	2.6	14.196
	SE	2.73	2	0	1.6	8.736	1	2.1	11.466	2	2.6	14.196
						547.5316			516.9736			582.7316

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.5	30.5	33	2	31	33	2.5	30.5
11.00 am			12.00 pm			13.00 pm			14.00 pm		
CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
3	4.1	197.4478	3	3.1	149.2898	4	4.6	221.5268	6	5.6	269.6848
8	9.1	438.2378	11	11.1	534.5538	14	14.6	703.1068	17	16.6	799.4228
4	5.1	123.828	5	5.1	123.828	7	7.6	184.528	7	6.6	160.248
4	5.1	27.846	5	5.1	27.846	7	7.6	41.496	7	6.6	36.036
4	5.1	27.846	5	5.1	27.846	7	7.6	41.496	7	6.6	36.036
		815.2056			863.3636			1192.154			1301.428

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.25	30.75	33	2.25	30.75
15.00 pm			16.00 pm			17.00 pm		
CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)	CLTD (^{o}C)	$CLTD_C$	Q (W)
7	7.6	366.0008	8	6.85	329.8823	10	8.35	835.5413
18	18.6	895.7388	19	17.85	859.6203	19	17.35	257.6453
8	8.6	208.808	8	6.85	166.318	7	5.35	129.898
8	8.6	46.956	8	6.85	37.401	7	5.35	29.211
8	8.6	46.956	8	6.85	37.401	7	5.35	29.211
		1564.46			1430.623			1281.507

APPENDIX B6

HEAT GAINS FROM CONDUCTION THROUGH WALL, WINDOWS GLASS, AND DOORS AT BT 6 & 7

				Tm	Dr/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
				33	1.5	31.5	33	2	31	33	2	31
					8.00 am			9.00 am			10.00 am	
Conduction	Direction	U(W/m^2.°C)	A (m^2)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
Wall	NW	0.796	122.76	4	6.1	596.0735	3	4.6	449.498	3	5.1	498.3565
	SE	0.796	122.76	3	5.1	498.3565	4	5.6	547.215	6	8.1	791.50738
Window Glass		6.07	8	0	2.1	101.976	1	2.6	126.256	2	4.1	199.096
Door	NW	2.73	8	0	2.1	45.864	1	2.6	56.784	2	4.1	89.544
	SE	2.73	8	0	2.1	45.864	1	2.6	56.784	2	4.1	89.544
						1288.134			1236.537			1668.0479

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.5	30.5	33	2	31	33	2.5	30.5
	11.00 am			12.00 pm			13.00 pm			14.00 pm	
CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
3	4.6	449.498	3	3.6	351.7811	4	4.1	400.6395	6	6.1	596.0735
8	9.6	938.0828	11	11.6	1133.517	14	14.1	1377.809	17	17.1	1670.96
4	5.6	271.936	5	5.6	271.936	7	7.1	344.776	7	7.1	344.776
4	5.6	122.304	5	5.6	122.304	7	7.1	155.064	7	7.1	155.064
4	5.6	122.304	5	5.6	122.304	7	7.1	155.064	7	7.1	155.064
		1904.125			2001.842			2433.353			2921.937

Tm	DR/2	Ta	Tm	DR/2	Ta	Tm	DR/2	Ta
33	2	31	33	2.25	30.75	33	2.25	30.75
	15.00 pm			16.00 pm			17.00 pm	
CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)	CLTD (°C)	$CLTD_C$	Q (W)
7	7.6	742.6489	8	6.85	669.3612	10	8.85	864.7951
18	18.6	1817.535	19	17.85	1744.248	19	17.85	1744.248
8	8.6	417.616	8	6.85	332.636	7	5.85	284.076
8	8.6	187.824	8	6.85	149.604	7	5.85	127.764
8	8.6	187.824	8	6.85	149.604	7	5.85	127.764
		3353.448			3045.453			3148.647

APPENDIX B7

HEAT GAINS FROM SOLAR RADIATION AT BT 8

				8.00 am		9.00 am		10.00 am		11.00 am	
Solar	Direction	SC	A (m^2)	SCL	Q	SCL	Q	SCL	Q	SCL	Q
Glass	NW	0.61	1.33	76	61.6588	85	68.9605	95	77.0735	101	81.9413
Window	SE	0.61	2.67	284	462.5508	321	522.8127	328	534.2136	299	486.9813
					524.2096		591.7732		611.2871		568.9226

12.00 pm		13.00 pm		14.00 pm		15.00 pm		16.00 pm		17.00 pm	
SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q
104	84.3752	107	86.8091	129	104.6577	202	163.8826	274	222.2962	318	257.9934
246	400.6602	189	307.8243	173	281.7651	161	262.2207	148	241.0476	132	214.9884
	485.0354		394.6334		386.4228		426.1033		463.3438		472.9818

APPENDIX B8

HEAT GAINS FROM SOLAR RADIATION AT BK 5

				8.00 am		9.00 am		10.00 am		11.00 am	
Solar	**Direction**	**SC**	**A (m^2)**	**SCL**	**Q**	**SCL**	**Q**	**SCL**	**Q**	**SCL**	**Q**
Glass	NW	0.61	2.17	76	100.6012	85	112.5145	95	125.7515	101	133.6937
Window	SE	0.61	4.33	284	750.1292	321	847.8573	328	866.3464	299	789.7487
					850.7304		960.3718		992.0979		923.4424

12.00 pm		13.00 pm		14.00 pm		15.00 pm		16.00 pm		17.00 pm	
SCL	**Q**	**SCL**	**Q**	**SCL**	**Q**	**SCL**	**Q**	**SCL**	**Q**	**SCL**	**Q**
104	137.6648	107	141.6359	129	170.7573	202	267.3874	274	362.6938	318	420.9366
246	649.7598	189	499.2057	173	456.9449	161	425.2493	148	390.9124	132	348.6516
	787.4246		640.8416		627.7022		692.6367		753.6062		769.5882

APPENDIX B9

HEAT GAINS FROM SOLAR RADIATION AT BK 6

				8.00 am		9.00 am		10.00 am		11.00 am	
Solar	Direction	SC	A (m^2)	SCL	Q	SCL	Q	SCL	Q	SCL	Q
Glass	NW	0.61	2.17	76	100.6012	85	112.5145	95	125.7515	101	133.6937
Window	SE	0.61	4.33	284	750.1292	321	847.8573	328	866.3464	299	789.7487
					850.7304		960.3718		992.0979		923.4424

12.00 pm		13.00 pm		14.00 pm		15.00 pm		16.00 pm		17.00 pm	
SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q
104	137.6648	107	141.6359	129	170.7573	202	267.3874	274	362.6938	318	420.9366
246	649.7598	189	499.2057	173	456.9449	161	425.2493	148	390.9124	132	348.6516
	787.4246		640.8416		627.7022		692.6367		753.6062		769.5882

APPENDIX B10

HEAT GAINS FROM SOLAR RADIATION AT BP 6,7 and 8

				8.00 am		9.00 am		10.00 am		11.00 am	
Solar	Direction	SC	A (m^2)	SCL	Q	SCL	Q	SCL	Q	SCL	Q
Glass	NW	0.61	1.33	76	61.6588	85	68.9605	95	77.0735	101	81.9413
Window	SE	0.61	2.67	284	462.5508	321	522.8127	328	534.2136	299	486.9813
					524.2096		591.7732		611.2871		568.9226

12.00 pm		13.00 pm		14.00 pm		15.00 pm		16.00 pm		17.00 pm	
SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q
104	84.3752	107	86.8091	129	104.6577	202	163.8826	274	222.2962	318	257.9934
246	400.6602	189	307.8243	173	281.7651	161	262.2207	148	241.0476	132	214.9884
	485.0354		394.6334		386.4228		426.1033		463.3438		472.9818

APPENDIX B11

HEAT GAINS FROM SOLAR RADIATION AT BT 6 & 7

				8.00 am		9.00 am		10.00 am		11.00 am	
Solar	Direction	SC	A (m^2)	SCL	Q	SCL	Q	SCL	Q	SCL	Q
Glass	NW	0.61	2.67	76	123.7812	85	138.4395	95	154.7265	101	164.4987
Window	SE	0.61	5.33	284	923.3692	321	1043.667	328	1066.426	299	972.1387
					1047.15		1182.107		1221.153		1136.637

12.00 pm		13.00 pm		14.00 pm		15.00 pm		16.00 pm		17.00 pm	
SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q	SCL	Q
104	169.3848	107	174.2709	129	210.1023	202	328.9974	274	446.2638	318	517.9266
246	799.8198	189	614.4957	173	562.4749	161	523.4593	148	481.1924	132	429.1716
	969.2046		788.7666		772.5772		852.4567		927.4562		947.0982

APPENDIX B12

HEAT GAINS FROM LIGHTING AT BT 8

Light	Watt	n	Total Watt	Fu	Fsu	CLF	Q
Fluorescent 900mm, T12	30	16	480	1	1.25	1	600

APPENDIX B13

HEAT GAINS FROM LIGHTING AT BK 5 AND BK 6

Light	Watt	n	Total Watt	Fu	Fsu	CLF	Q
Fluorescent 900mm, T12	30	32	960	1	1.25	1	1200

APPENDIX B11

HEAT GAINS FROM LIGHTING AT BP 6, 7, AND 8

Light	Watt	n	Total Watt	Fu	Fsu	CLF	Q
Fluorescent 900mm, T12	30	8	240	1	1.25	1	300

APPENDIX B15

HEAT GAINS FROM LIGHTING AT BT 6 & 7

Light	Watt	n	Total Watt	Fu	Fsu	CLF	Q
Fluorescent 900mm, T12	30	38	1140	1	1.25	1	1425

APPENDIX B16

HEAT GAINS FROM PEOPLES AND APPLIANCES AT BT 8

Type		n	SHG (W)	CLF	Q
People	SH	30	75	1	2250
	LF	30	55	nil	1650
appliance computer		1	155	1	155
Projector		1	100	1	100
Notebooks		30	30	1	900
					4963

APPENDIX B17

HEAT GAINS FROM PEOPLES AND APPLIANCES AT BK 5 & 6

Type		n	SHG (W)	CLF	Q
People	SH	60	75	1	4500
	LF	60	55	nil	3300
appliance computer		1	155	1	155
Projector		1	100	1	100
Notebooks		60	30	1	1800
					9855

APPENDIX B18

HEAT GAINS FROM PEOPLES AND APPLIANCES AT BP 6, 7, & 8

Type		n	SHG (W)	CLF	Q
People	SH	30	75	1	2250
	LF	30	55	nil	1650
appliance computer		1	155	1	155
Notebooks		30	30	1	900
					4955

APPENDIX B19

HEAT GAINS FROM PEOPLES AND APPLIANCES AT BT 6 and 7

Type		n	SHG (W)	CLF	Q
People	SH	60	75	1	4500
	LF	60	55	nil	3300
appliance computer		1	155	1	155
projector		2	100	1	200
Notebooks		60	30	1	1800
					9955

APPENDIX B20

HEAT GAINS FROM VENTILATION AT BT 8

			8.00 AM		9.00 am		10.00 am		11.00 am	
Ventilation	Factor	Q(m^3/s)	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
Sensible heat	1230	0.008	2	19.68	3.5	34.44	4	39.36	4	39.36
			ΔW		ΔW		ΔW		ΔW	
Latent heat	3010000	0.008	0.00325	78.26	0.0015	36.12	0.00125	30.1	0.00125	30.1
				97.94		70.56		69.46		69.46

12.00 pm		1.00 pm		2.00 pm		3.00 pm		4.00 pm		5.00 pm	
ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
5	49.2	4	39.36	3	29.52	4	39.36	2.5	24.6	1.5	14.76
ΔW		ΔW		ΔW		ΔW		ΔW		ΔW	
0.001	24.08	0.00275	66.22	0.00325	78.26	0.0025	60.2	0.00025	6.02	0.00075	18.06
	73.28		105.58		107.78		99.56		30.62		32.82

APPENDIX B21

HEAT GAINS FROM VENTILATION AT BK 5

			8.00 AM		9.00 am		10.00 am		11.00 am	
Ventilation	Factor	Q(m^3/s)	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
Sensible heat	1230	0.008	2	19.68	2.5	24.6	2.5	24.6	3	29.52
			ΔW		ΔW		60		ΔW	
Latent heat	3010	0.008	0.00325	0.07826	0.0015	0.03612	0.0025	0.0602	0.00125	0.0301
				19.75826		24.63612		24.6602		29.5501

12.00 pm		1.00 pm		2.00 pm		3.00 pm		4.00 pm		5.00 pm	
ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
4	39.36	2.5	24.6	3	29.52	2.5	24.6	2	19.68	1.5	14.76
ΔW		ΔW		ΔW		ΔW		ΔW		ΔW	
0.0005	0.01204	0.00025	0.00602	0.00075	0.01806	0.00075	0.01806	0.00025	0.00602	0.00075	0.01806
	39.37204		24.60602		29.53806		24.61806		19.68602		14.77806

APPENDIX B22

HEAT GAINS FROM VENTILATION AT BK 6

			8.00 AM		9.00 am		10.00 am		11.00 am	
Ventilation	Factor	Q(m^3/s)	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
Sensible heat	1230	0.008	2	19.68	3	29.52	3	29.52	2	19.68
			ΔW		ΔW		ΔW		ΔW	
Latent heat	3010	0.008	0.001	0.02408	0.0005	0.01204	0.0005	0.01204	0.00075	0.01806
				19.70408		29.53204		29.53204		19.69806

12.00 pm		1.00 pm		2.00 pm		3.00 pm		4.00 pm		5.00 pm	
ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
2	19.68	2	19.68	3	29.52	2	19.68	1.5	14.76	1.5	14.76
ΔW		ΔW		ΔW		ΔW		ΔW		ΔW	
0.0005	0.01204	0.0005	0.01204	0.0005	0.01204	0.00075	0.01806	0.00025	0.00602	0.00075	0.01806
	19.69204		19.69204		29.53204		19.69806		14.76602		14.77806

APPENDIX B23

HEAT GAINS FROM VENTILATION AT BP 6, 7, & 8

			8.00 AM		9.00 am		10.00 am		11.00 am	
Ventilation	Factor	Q(m^3/s)	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
Sensible heat	1230	0.008	2	19.68	3	29.52	5	49.2	3	29.52
			ΔW		ΔW		ΔW		ΔW	
Latent heat	3010	0.008	0.001	0.02408	0.00275	0.06622	0.00275	0.06622	0.00025	0.00602
				19.70408		29.58622		49.26622		29.52602

12.00 pm		1.00 pm		2.00 pm		3.00 pm		4.00 pm		5.00 pm	
ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
3.5	34.44	2.5	24.6	3	29.52	2.5	24.6	1.5	14.76	1	9.84
ΔW		ΔW		ΔW		ΔW		ΔW		ΔW	
0.00025	0.00602	0.00025	0.00602	0.001	0.02408	0.001	0.02408	0.0015	0.03612	0.00075	0.01806
	34.44602		24.60602		29.54408		24.62408		14.79612		9.85806

APPENDIX B24

HEAT GAINS FROM VENTILATION AT BT 6 & 7

			8.00 AM		9.00 am		10.00 am		11.00 am	
Ventilation	Factor	$Q(m^3/s)$	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
Sensible heat	1230	0.008	2.5	24.6	4.5	44.28	4	39.36	3.5	34.44
			ΔW		ΔW		ΔW		ΔW	
Latent heat	3010	0.008	0.00325	0.07826	0.0015	0.03612	0.0025	0.0602	0.00225	0.05418
				24.67826		44.31612		39.4202		34.49418

12.00 pm		1.00 pm		2.00 pm		3.00 pm		4.00 pm		5.00 pm	
ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q	ΔT	Q
4	39.36	2	19.68	3.5	34.44	2.5	24.6	1.5	14.76	1.5	14.76
ΔW		ΔW		ΔW		ΔW		ΔW		ΔW	
0.00025	0.00602	0.0005	0.01204	0.0005	0.01204	0.00225	0.05418	0.00125	0.0301	0.00075	0.01806
	39.36602		19.69204		34.45204		24.65418		14.7901		14.77806