STUDY OF A BACKUP VENTILATION SYSTEM FOR LECTURERS' OFFICE SPACE

by

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8408

Mechanical Engineering

Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

____
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CERTIFICATION OF ORIGINALITY

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

Muhammad Zahid Md Bahari

ABSTRACT

The primary functions of ventilation systems include the delivery of outdoor air to the occupants, the removal of indoor contaminants and the maintenance of thermal comfort conditions in the occupied zones. The objective of this project is to study a backup ventilation system for individual lecturers' office space mainly during power failure and when ventilation is not available such as during night. During blackout, the period to repair the power failure takes at least one day. Therefore, the backup ventilation design is important to make sure the lecturers feel comfortable when they are working in their office.

The project undertaken looked at the amount of air requirement to the office space in level 3 of Block 17. First, the flow rate of the main blower is determined. Then, the total flow rate at each VAV is compared with the main blower. The total flow rate at each VAV is much lower than the flow rate of the blower. It means that there is a lot of energy wasted during the ventilation process. After comparing these flow rates, the minimum requirement of the ventilation rate is individual lecturer's office rooms are calculated. The minimum requirement for the ventilation is much lesser than the flow rate supplied by the main blower to each room. Therefore, it will be a lot of energy wasted if we do the backup power supply for the main blower. Based on the results obtained from theoretical and experimental works in this project, the backup ventilation system is feasible to install.

ACKNOWLEDGEMENT

Throughout the completion of this Final Year Project (FYP), many people have provided a great deal of support, guidance, advice, assistance and idea to me. Without their help this FYP would not be that meaningful and successful. I would like to take this opportunity to appreciate all who had contributed in my learning and success.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

According to American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standards 62 [1], ventilation is defined as the process of supplying or removing air by natural or mechanical means to or from any space. This air may or may not have been heated or cooled. Ventilation is necessary to remove or dilute CO_2, odours, and other contaminants from occupied or production process spaces.

The performance of a ventilation system is determined by its contaminant removal effectiveness, air exchange effectiveness and the thermal conditions. In tropical regions, the hot and humid climate may have an adverse impact on occupant comfort indoors.

The reason for using heating, ventilation and air-conditioning (HVAC) systems is to satisfy the occupants when it comes to health, indoor air quality (IAQ) and thermal comfort. A variable air volume (VAV) system satisfies the health condition and IAQ by supplying a minimum amount of air flow based on national regulations and standards. When there is a cooling need, the thermal comfort is satisfied by increasing the air flow and supplying enough air colder than the room temperature. When the heat load increases in a zone controlled by a VAV system, the flow increases. A room controller controls the air flow to the room by measuring the room air temperature and the supply air flow. The supply air flow depends on the load and temperature difference between the zone and the supply air. A low temperature of the supply air requires a lower air flow than a high supply air temperature does. The supply air temperature is controlled in the HVAC unit [2].

To understand how the ventilation works at the lecturers' office (Level 3) in Block 17, one must first understand how a central air system works. Chilled water flows through the cooling coil within the Air Handling Unit (AHU). The main blower will blow the air passing through the cooling coil. The chilled water that was supplied from the Gas District Cooling (GDC) is normally at 7°C. When they entered the AHU unit, the temperature is 10°C due to the energy losses. Then the air will flow passed through the cooling coil. The air is cooled, and then blown into an air conditioning duct system, where it is distributed to various rooms. The cool air which is approximately at 12°C enters the rooms through air terminal units called Variable Air Volume (VAV) which is installed at the end of each duct line, which generally take the form of diffusers or grilles. If there is no chilled water supplied from the GDC, the blower will still operates as long as there is an availability of the electricity but the air supplied to each room is not cold. The VAV is shared between two or three rooms. There are about 19 lecturers' rooms at each wings of the building (Block 17). The ducts that transport the cool air from the unit to each room are called the supply ductwork. Each room have a return duct that sends air back to the heating and cooling equipment which is AHU. The lecturers' rooms are a closed space without any windows. Doors are only at the end of the building. Figure 1.1 shown below is the drawing of the ducting that already exists in the lecturers' office (Block 17).

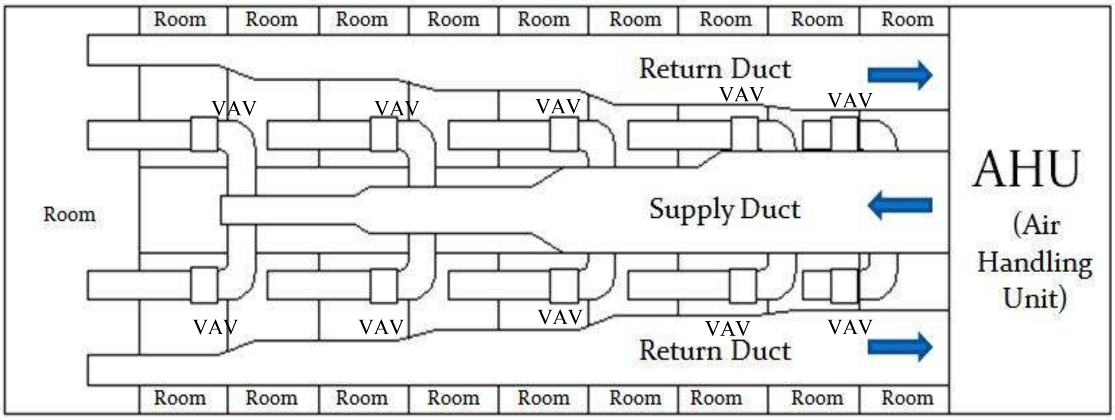

Figure 1.1: Ventilation in Block 17

During blackout, the motor that used to generate the blower fails to operate. Therefore, the blower cannot blow the air passing through the cooling coil. When this happened, there will be no air circulation and no proper ventilation system in the lecturers' office. The lecturers might feel uncomfortable in the office space due to lack of ventilation. When the power failure occurred, the VAV will stop working whether it leaves in opened or closed condition.

During non-office hours, the blower cannot operate because the main switch of the blower is at the control panel room under the Chancellor Hall. Only the authorized person has the authority to turn on the blower. Therefore, if lecturers have works to do during non-office hours, there is no proper ventilation in the lecturers' rooms.

Whenever there are changes in temperature in the room, the sensor in each room will detect it. The temperature in each room has been set to a default value of 24^0C. For example, when the temperature decrease below 24^0C, the sensor will detect it and send the signal to the damper motor. The motor will close the damper and therefore, the duct static pressure inside the ducting will increase. When the pressure increases, the inventor will send the signal to the motor of the main blower. The motor of the main blower will reduce its speed and makes the blower to decrease its speed also.

This project is only account for providing the air circulation and not for cooling. Also it is a temporary measure; hence the backup system is needed.

1.2 PROBLEM STATEMENT

The ventilation of the lecturer's office space (Level 3) in the academic building (Block17) rely on the availability of the air-conditioning system. In the event of electrical power failure (during office hours), the office space is uninhabitable due to lack of ventilation. There is a need to provide a backup system that would supply sufficient ventilation during blackout to the individual offices.

The main problem is whether the backup system is worth to install because the air flow rate of the blowers will be different. If the air supply for ventilation by the backup system is sufficient and uses less power, then the system can be considered.

Furthermore, lecturers can also work during non-office hours (night or weekends) when there is no air conditioning because this backup ventilation system can be turned on manually by them.

1.3 OBJECTIVE

The main objective of this project is:

1. To determine the air supply during the maximum cooling load including the speed of the blower, VAV position, mass flow rate and the temperature of the existing ventilation.
2. To determine the flow rate supplied by the main blowers to each room and total flow rate supplied by the system.
3. To determine the minimum flow rate required for each room.

In order to achieve this objective, a few tasks and research need to be carried out by collecting the technical details regarding the existing ventilation system that UTP has in the lecturers' office space. Some calculations were performed in order to determine the flow rate required in each room.

1.4 SCOPE OF STUDY

The Final Year Project has been divided into two parts which are Final Year Project I and Final Year Project II. During the Final Project I, the study and the analysis of the existing ventilation system were carried out. For example, the maximum flow rate given by the main blower is given in the technical drawing for ventilation system in Block 17. The flow rate at each VAV was also determined during this part.

In Final Year Project II, the minimum flow rate required in each room was calculated. After the data and the technical details have been gathered, a suitable fan sizing to provide the required flow rate to each room was determined.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Malaysia is a hot and humid tropical country that lies between 1° and 7° north and 100° and 120° east. Malaysia has a yearly mean temperature of between 26°C to 27°C [3] and has high daytime temperatures of 29°C to 34°C [4] and relative humidity of 70% to 90% throughout the year. In recent years, Malaysia's energy consumption has increased and become comparable to larger energy consumers worldwide. In 2002 the energy consumption was 2.8 MWh per capita and projections show a significant increase in the energy demand. Malaysia has one of the fastest growing building industries worldwide, where the corresponding energy demand would significantly increase in the next coming years [5].

The energy demand scenario in buildings can be understood from the experience of developed nation. Malaysia which is on the track towards a developed nation must understand and proactively be prepared for the potential implication. Considering the average temperature for typical towns in Malaysia, it seems that air conditioning during office hours is a must if people living in the hot and humid climate like Malaysia want a thermal comfort in the building space during the day.

The suitable office environment is a combination of lighting, temperature, humidity, air quality and decoration. The office can be a healthy and comfortable place to work in if the correct combination of these elements is maintained.

A comfortable temperature must be maintained between 20 - 26°C. Office temperature can be localized. A desk situated in direct sunlight will be much warmer than the average temperature in the office and a desk situated directly under an air-conditioning vent can be cooler than average. For humidity, low humidity can cause dryness of the eyes, nose and throat and may also increase the frequency of static electricity shocks. High humidity, above 80% can be associated with fatigue and report of "stiffness" [6].

Adequate lighting must be provided in the office environment. When artificial lighting is used it should be sufficient so as to avoid visual fatigue and prevent glare or refraction into the workers eyes. Light should fall from side rather than from the front to avoid refraction on the work surfaces. Glare causes visual discomfort and is usually caused by light sources which are too bright or inadequately shielded. It is advisable to ensure that lights are cleaned at regular intervals, at least every 6-12 months [6].

The office also should be ventilated where mechanical ventilation or air-conditioning is provided. The system must be regularly checked, kept clean and well maintained to prevent growth of bacteria or other organisms.

Without proper ventilation, the office space will, begin to emit unwanted odors of all kinds. Dols et al. [7] and Chung and Wang [8] reported that indoor air quality has a great impact on the health of human inhabitants. Sandberg and Blomqvist [9] and ASHRAE [10] revealed that indoor air pollutants are normally found at higher concentrations than their outdoor counterparts. However, effective ventilation systems are able to improve the indoor air quality.

2.2 VENTILATION SYSTEM

There are many types of mechanical ventilation systems, each type being adapted to particular needs (ventilation, contaminant extraction, heating, cooling, full air-conditioning, etc.) and to constraints such as available space, cost, etc. [11].

These are the types for mechanical ventilation system:

1) Natural Ventilation

- System where the air is moved through ventilation openings by natural forces such as wind pressure and stack effect. In many buildings, these openings are doors, windows, and leakage in the building envelope and partition walls and decks.

2) Extract-only Mechanical Ventilation

- Simple mechanical ventilation system extracts the air from the ventilated spaces with ducts and fans. The purpose of such systems is to extracts contaminants as close as possible to the source.

3) Supply-only Mechanical Ventilation

- This system blows the air into the ventilated space. The purpose of such systems is to introduce conditioned air into the ventilated space. This air could be only filtered, but also heated, cooled, humidified or dried.

4) Supply and exhaust or Balanced Mechanical Ventilation

- This system uses two fans, one to supply air and the other to extract vitiated air. This allows a proper balancing of pressure and a better control of the airflow pattern. In addition, a heat exchanger could be installed to recover heat from the extract air and gives it to the supply air.

2.3 VARIABLE AIR VOLUME (VAV)

Variable-air-volume system (VAV) is an air system that varies its supply air volume flow rate to match the reduction of space load during part-load operation to maintain a predetermined space parameter, usually air temperature, and to conserve fan power at reduced volume flow [12].

There are a number of reasons for using VAV systems for indoor climate control. Hung et al. [13] studied the performance of flow controllers in VAV systems. By simulations and field measurements, they found that the flow controllers were able to provide a stable zone air temperature. They also found that furniture and the zone interior surface stabilizes the zone air temperature dynamics. Inoue and Matsumoto [14] have made energy analyses of the VAV system and compared it with other systems such as dual duct constant air volume (CAV) and two-pipe induction unit.

With meteorological data from Tokyo, the VAV system was found to have the lowest cooling coil load and lowest annual fan energy use.

2.4 THERMAL COMFORT

The study of thermal comfort is very important because it is correlated not only with occupants' comfort, but also with energy consumption [15]. Indoor air quality and thermal comfort are two important aspects of indoor environmental quality that receive considerable attention (Huizenga et al., 2006) [16].

The comfort zone used by most engineers in designing air conditioning systems is normally based on those recommended by ASHRAE. However, due to the high relative humidity in Malaysia, the figures recommended by ASHRAE, particularly in relation to relative may not be easy to accomplish.

The comfort zone stipulated by American Society of Heating, Refrigerating and Air-conditioning Engineers, ASHRAE (ASHRAE, 1993), for summer season is in the following range [17]:

i. Dry Bulb Temperature is between 22^0C to 27^0C
ii. Relative Humidity is between 30% to 60%
iii. Air Motion Velocity is about 15 m/min

Guidelines for Energy Efficiency in Buildings for Malaysia produced by the Ministry of Energy, Telecommunications and Posts, Malaysia (1989) [18], quote the air-conditioned space requirements as follows:

i. Dry Bulb Temperature is between 22^0C to 26^0C, design temperature 24^0C
ii. Relative Humidity is between 55% to 65%, design relative humidity 60%

The climate in Malaysia is however, hot and humid. Data obtained by the Malaysian Meteorological Service (1997) [19], for a ten years period records the outdoor temperatures are relatively uniform with average temperatures of between 23.7^0C to 31.3^0C throughout a day with the highest maximum recorded as 36.9^0C and the average humidity throughout a day between 67% - 95%.

Comfort is a major concern of Heating, Ventilation and Air-Conditioning (HVAC) industry. To design air-conditioning systems, a numbers of factors, which physiologically affect human comfort, should be considered. Experience has shown that not everyone can make completely comfortable by one set of conditions but a controlled space can be developed to provide comfort to most of the occupants.

Thermal comfort as defined in the ISO 7730 standard (1994) [20], as being "that condition of mind, which expresses satisfaction with the thermal environment". A definition most people can agree on, but also a definition that is not easily converted into physical parameter [21].

There are three main factors that can affect the human comfort, which must be considered by engineers before designing air-conditioning systems. There is the effective temperature, moisture content of air (relative humidity) ad air motion. There are also other factors such as heat production and regulation in human body, cold and hot surfaces and air stratification.

2.5 VENTILATION RATE

In the Ventilation Rate Procedure, 4.1 [22], "acceptable air quality is achieved by providing ventilation air of the specified quality and quantity to the space." In the alternative Indoor Air Quality Procedure, 4.2 [22], "acceptable air quality is achieved within the space by controlling known and specifiable contaminants."

The ventilation rate is normally expressed by the volumetric flow rate of outside air being introduced to the building. The typical units used are cubic feet per minute (CFM) or litres per second (L/s). The ventilation rate can also be expressed on per person or per unit floor area basis, such as CFM/p or CFM/ft^2.

Current ASHRAE standards (Standard 62-89) [22] states that appropriate ventilation guidelines are 20 CFM (9.2 L/s) per person in an office building, and 15 CFM (7.1 L/s) per person for schools. In commercial environments with tobacco smoke, the ventilation rate may range from 25 CFM to 125 CFM.

For general mechanical ventilation, the equation to find the ventilation rate is given by:

$$\boxed{\textbf{Ventilation rate (m}^3\textbf{/h)} = \textbf{Air Change Rate (/h) x Room Volume (m}^3\textbf{)}}$$

2.6 FANS

The various mechanical devices used to move the air in heating, ventilating, and air-conditioning installations are known as fans, blowers, exhausts, or propellers.

Every fan is equipped with an impeller, which forces (impels) the airflow. The manner in which air flows through the impeller provides the basis for the following two general classifications of fans [23]:

1) **Centrifugal fans**

   - The air flows radially (that is diverging from the center) through the impeller, which is mounted in a scroll-type housing. Centrifugal fans are further subdivided into a number of different types depending on several design variations such as forward or backward inclination of the blade.

2) **Axial-flow fans**

   - Mounted within a cylinder or ring, and the airflows axially (that is parallel to the main axis) through the impeller. This type of fans can be divided into the following types:

     a) **Tube axial fan** which is consists of an axial-flow wheel within a cylinder. These fans are available in a number of different types depending on the design and construction of the impeller blades.
     b) **Vane axial fan** which is also consists of an axial-flow wheel but differs from a tube axial fan in that it uses a set of vanes to guide the air-flow and increase efficiency.
     c) **Propeller fan** consists of a propeller or disc wheel within a ring casing or plate. These fans are by far the simplest in construction and operate best against low resistance.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Project works are planned to be completed in two semesters in the form of Final Year Projects I and II.

3.2 RESEARCH

3.1.1 Introduction

A research were made through the internet, libraries, journal, technical paper and the engineers itself who are involved in the ventilation system in academic building to collect all available information regarding to the existing ventilation system.

To do the backup power supply for the blower will be expensive because the blower is used to supply air for the whole building and the size of the blower is big. But, it is possible that the new backup design will cost more than backup the power supply. Furthermore, we do not know the flow rate of the new blowers. If there are only slight different between the new flow rate and the existing flow rate, the backup ventilation design is not worth to be considered. Therefore, this project attempts to compare which is more efficient, whether to provide the new backup ventilation or do the backup power supply for the blower only.

The objectives of the project can be accomplished by determine the flow rate at the main blower and at each VAV. After comparing these to flow rate, the minimum requirement for ventilation rate is calculated. From these calculations, it is decided whether to provide the backup system or do the backup power supply for the main blower.

When the power failure occurred, the VAV will stop working whether it leaves in opened or closed condition. The assumption made in this project is the VAVs are in fully opened condition when the power failure occurred because it will give the maximum flow rate to the lecturers' rooms.

3.3 FLOW CHART EXECUTION OF PROJECT

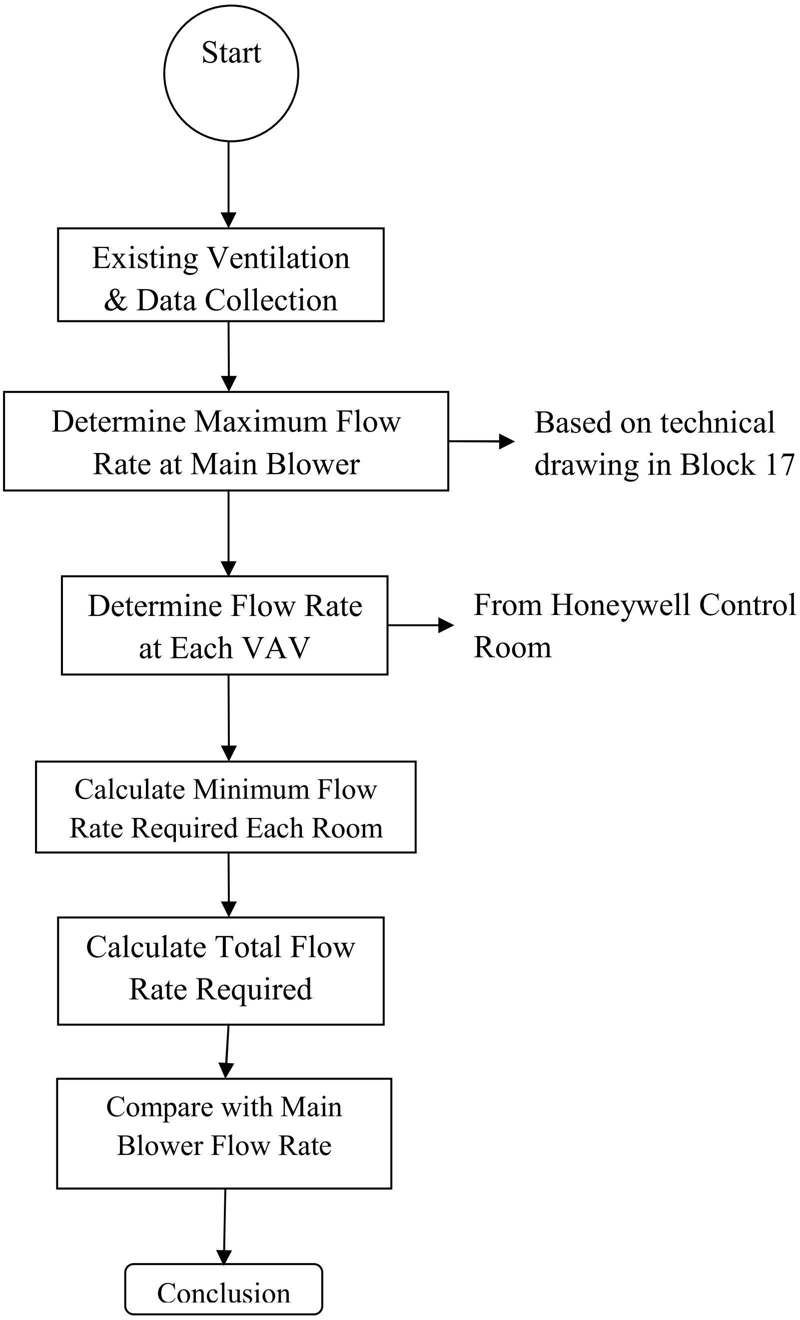

Figure 3.1: Flow Chart Execution of Project

3.1.3 Method

The parameters that were collected including the dimensions of the lecturers' room speed of the existing blower, temperature of the room, VAV position and the flow rate at each VAV. After having this all information by measurement and some calculations, the numbers of blowers required for the whole system will be determined. For measurement, the equipment such as anemometer is used to measure the velocity and temperature and each room.

Then, the total flow rate will be calculated and compared with the main blower supply. If the new flow rate is lower than the existing blower flow rate, therefore the backup design for ventilation system can be installed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 CURRENT AIR SUPPLY

4.1.1 Cooling Load

Cooling load is the rate at which heat is removed from the conditioned space to maintain a constant space air temperature. Building cooling load components are; direct solar radiation, transmission load, ventilation/infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load.

Software for Cooling Load Calculation

EnergyPlus is a building energy simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows. While it is based on the most popular features, it includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multi-zone air flow, thermal comfort, and photovoltaic systems. EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface. EnergyPlus reads input and writes output as text files.

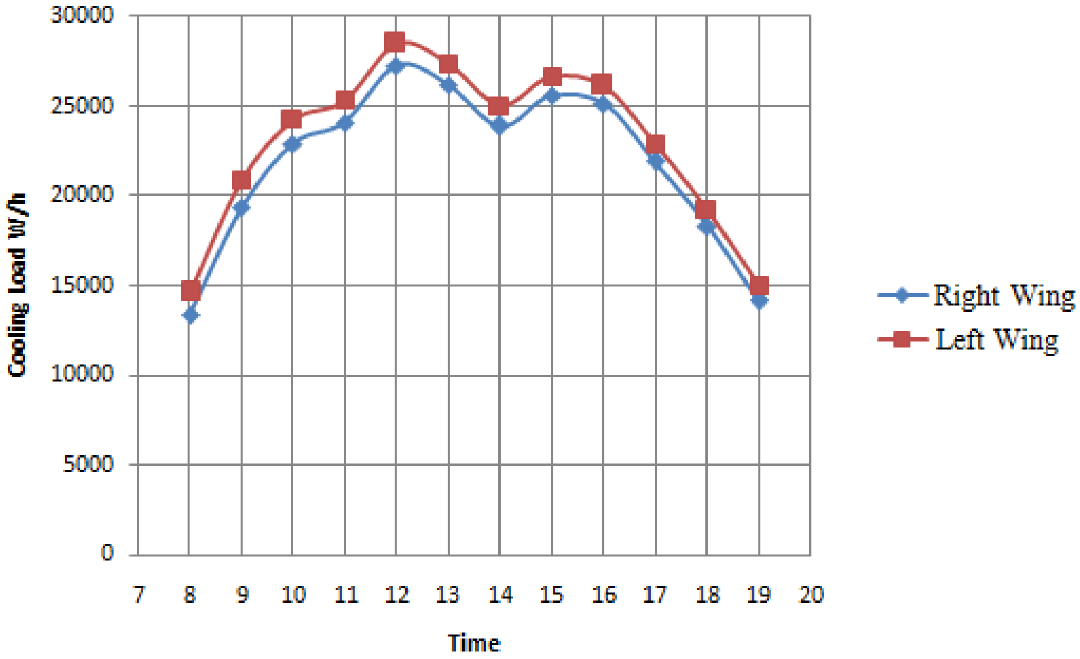

Figure 4.1: Cooling Load for Block 17

Figure 4.1 above shows the trends for cooling load in lecturers' rooms in Block 17. The graph shows that the maximum cooling load in Block 17 is from 11-1 pm.

4.1.2 Flow Rate at VAV

The maximum flow rate at the main blower in right and left wing is stated in the ventilation drawing for Block 17. The maximum flow rate means that the damper inside the ducting is in fully opened condition. Therefore, it will give the maximum speed of the blower.

The temperature and the flow rate at each VAV must be taken during the maximum cooling load which is from 11 am -1 pm in order to get the maximum flow rate. These measurements are taken from the Honeywell control panel room.

The data shown in Table 4.1 below is the temperatures and the flow rate at each VAV for the **Right Wing** at Block 17.

Maximum Flow Rate of Main Blower = **4334 L/s**

Maximum Static Pressure in Ducting = **500 Pa**

Table 4.1: Temperatures and Flow Rate (Right Wing)

VAV	Temperature (^{0}C)	Flow Rate (L/s)
1.1	23	216
1.2	22.8	204
1.3	23.1	257
1.4	24.4	164
1.5	22.7	415
1.6	24.1	301
1.7	23.9	206
1.8	22.5	333
1.9	22.8	338
1.10	23.3	238
1.11	22.1	342
1.12	22.9	300

Total flow rate at each VAV = **3314 L/s**

The data shown in Table 4.2 below is the temperatures and the flow rate at each VAV for the **Left Wing** at Block 17.

Maximum Flow Rate of Main Blower = **3330 L/s**

Maximum Static Pressure in Ducting = **500 Pa**

Table 4.2: Temperatures and Flow Rate (Left Wing)

VAV	Temperature (^{0}C)	Flow Rate (L/s)
2.1	24.7	228
2.2	23.4	148
2.3	25.0	269
2.4	22.8	186
2.5	24.0	265
2.6	22.7	237
2.7	23.6	217
2.8	23.5	260
2.9	23.9	338
2.10	23.0	275
2.11	22.1	202
2.12	23.9	207

Total flow rate at each VAV = **2832 L/s**

From all data that were gathered, it is shown that the total flow rate at each VAV is not same with flow rate at the main blower. The flow rate at each VAV is much lesser than the maximum flow rate given by the main blower. This means that there are a lot of pressure losses inside the ducting a lot of energy wasted during the ventilation process.

4. 2 VENTILATION REQUIREMENT

4.2.1 Ventilation Rate

Each VAV is shared between 2 rooms. Therefore, if we want to compare the VAV flow rate with the required flow rate in lecturers' room, the ventilation rate for 2 rooms must be determined. So, the room volume is doubled.

Unit Conversion:

1 L = 0.001 m^3

1 ft = 0.3048 m

1m = 1000 mm

Average flow rate at each VAV (covered for 2 rooms) for the **Right Wing**:

3314 / 12 = **276 L/s**

Average flow rate at each VAV (covered for 2 rooms) for the **Left Wing**:

2832 / 12 = **236 L/s**

$$\text{Ventilation rate } (m^3/h) = \text{Air Change Rate } (/h) \times \text{Room Volume } (m^3)$$

Air Change Rate per Hour for office space can be determined from the ASHRAE Standard 62.1-2004 (Minimum Ventilation Rates) [22]. From the Minimum Ventilation Rates Table, the recommended Air Change per Hour for private office space is 6.0.

The dimension of each lecturer's room is 9 ft x 10 ft x 11 ft.

The dimensions of the a room in meters are;

2.74 m x 3.05 m x 3.35 m = 28 m^3

Therefore,

Ventilation rate (m^3/h) = 6.0/hour x 28 m^3

= (168 m^3/ hour) x (1 hour/ 3600 s) x (1000 L/ 1 m^3)

= **47 L/s**

In order to compare the ventilation rate with the flow rate at each VAV, the flow rate at each VAV (covered for two rooms) must be divided by two because the calculation of the ventilation rate is only for one room.

Average flow rate at each room (Right Wing) = 276 L/s / 2

= 138 L/s

Average flow rate at each room (Left Wing) = 236 L/s / 2

= 118 L/s

The flow rate of each office room given by the main blower in Right Wing and Left Wing are higher than the ventilation rate required which are only 47 L/s. Therefore, there will be a lot of energy wasted if we want to do the backup power supply for the main blower in order to give the ventilation to the lecturers' office rooms during the power failure occur.

4.2.2 Fan Sizing

$$\boxed{\textbf{Air Flow Rate (cfm)} = \frac{\textbf{(Air Change per Hour) x (Volume of space (cubic feet))}}{\textbf{60}}}$$

Volume of lecturers office (cubic feet) = 10 ft **x** 11 ft **x** 9 ft = **990 ft^3**

Therefore, the air flow rate (cfm) = [(6/hr) x (990ft^3)] / 60 min

= **99 cfm**

Thus, 99 cfm are required to change the air in the office space for every 1 hour.

For most of the lecturers’ office, the ventilation system used the electricity as their power supply. Therefore, if in the event of electrical power failure (during office hours), the building is uninhabitable due to lack of ventilation. In order to make sure that the ventilation system can operate during the power failure, battery can be alternative source of the power supply.

It will be easier if the cooling fan is used for the backup ventilation system and the cooling fan is operating by the battery as the power supply. The cooling fan basically does not need a lot of voltage. Thus, battery is the best power supply that can be used during the absence of the electricity.

Normally, for a propeller fan that can supply 100 cfm, the power requirement needed is only 17 Watts. At block 17 Level 3, there are 24 rooms including pantry, meeting and stationary rooms. Therefore, the total power requirements to generate all the fans are 17 Watts x 24 rooms = 408 Watts.

CHAPTER 5

CONCLUSION & RECOMMENDATION

The ventilation of the lecturer's office space in the academic building (Block17) rely on the availability of the air-conditioning system. This project give a lot of advantages to the lecturers when there an electrical power failure during office hours.

Based on the results obtained from theoretical and experimental works in this project, the conclusions are the backup ventilation system is feasible because of these reasons:

- The maximum flow rate of the blower is much higher compared to the flow rate at each VAV. Therefore, there are lot of energy wasted during the ventilation process. A power backup to operate of the main blower is not an appropriate measure.
- The minimum flow rate required in each room is mush lesser than the flow rate supplied by the VAV. This means that only a small ventilation fan can provide sufficient air supply to the individual lecturer's room.
- The backup ventilation fan can be generated by the battery because the power requirement for these fans is quite low.

This backup ventilation system can be installed because with this backup ventilation, it will give the sufficient ventilation during blackouts to the individual offices.

Hence, it is concluded that this project is successfully completed, objectives of the project have been achieved and the project has progressed as planned.

For recommendation, hopefully there is a further study on this project on how to install the backup ventilation system because it is proved that the backup ventilation is worth to install and can give the comfort environment to the lecturers.

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APPENDIX A

Gantt chart and Key Milestone (FYP I)

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■	■												
	• Confirmation of Topic Selection														
2	Preliminary of Research Work			■	■	■	■								
	• Data Collection														
	• Literature review on ventilation system			■	■	■	■	■	■	■	■	■	■		
3	Submission of Preliminary Report							■							
4	Data Presentation								■						
5	Project Work									■	■	■			
	• Data Collection														
	• Analysis the existing ventilation system														
6	Submission of Progress Report									■					
7	Project Work Continue											■	■		
	• Determine total flow rate at each VAV														
8	Submission of Interim Report													■	
9	Oral Presentation														■

APPENDIX B

Gantt chart and Key Milestone (FYP II)

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue	▨	▨												
2	Do the calculation part			▨	▨	▨	▨								
	• Minimum Flow Rate Required														
3	Submission of Progress Report I							▨							
5	Project Work Continue							▨	▨	▨	▨	▨			
	• Calculate total new flow rate														
6	Submission of Progress Report II									▨					
7	Project Work Continue														
	• Determine the fan sizing in backup ventilation										▨	▨	▨	▨	
8	Submission of Draft Report (Dissertation)													▨	
11	Submission of Dissertation Report (Hard Cover)														▨

APPENDIX C

This measurement is collected on 28/10/2009 from 3:00 pm – 4:00 pm (Block 17)

LECTURER ROOM NO.	VELOCITY (m/s)	TEMPERATURE (°C)	REMARK
1	0.3	20.7	
	0.3	20.5	
	0.3	20.2	
3	0.3	20.4	
	0.2	20.2	
	0.2	20.6	
7	0.2	25.3	
	0.2	24.8	
	0.3	24.4	
8	0.3	25.2	
	0.2	25.0	
	0.2	24.5	
15	0.2	23.0	
	0.2	22.7	
	0.2	22.2	
16	0.1	22.5	
	0.2	23.0	
	0.2	22.6	

APPENDIX D

This measurement is collected at 3/11/2009 from 10:30 am – 11:30 am (Block 17)

LECTURER ROOM NO.	VELOCITY (m/s)	TEMPERATURE (^{0}C)	REMARK
1	0.2 0.2 0.3	20.5 20.5 20.7	
3	0.3 0.3 0.3	21.8 22.0 21.9	
7	0.3 0.2 0.2	22.8 23.2 23.0	
8	0.2 0.1 0.1	23.2 23.3 23.4	
15	0.1 0.1 0.1	22.4 22.6 22.2	
16	0.2 0.1 0.2	22.0 21.9 22.2	

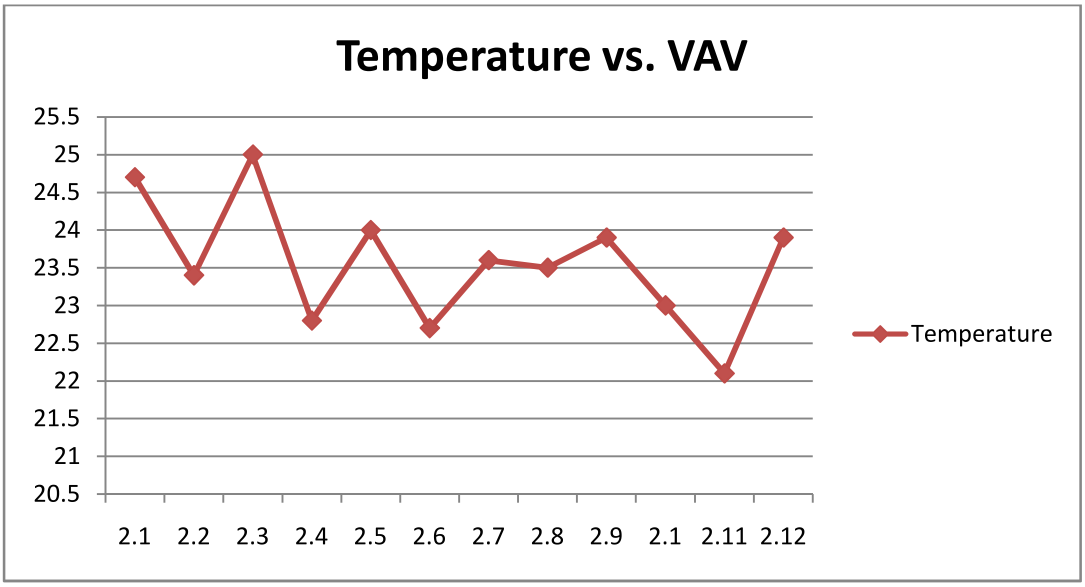
APPENDIX E

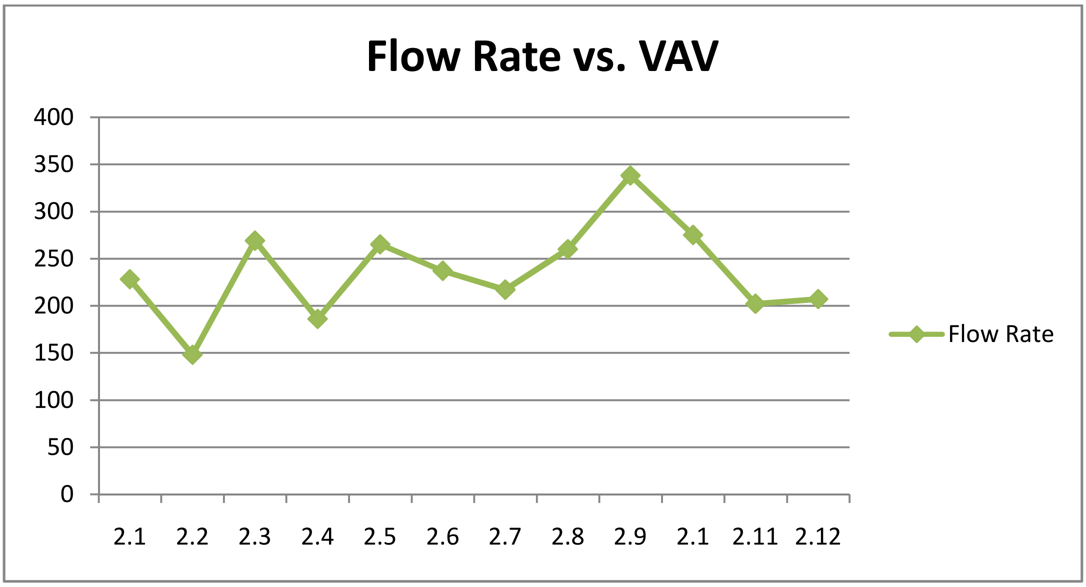
Cooling Load Calculation using EnergyPlus Software

Time	Cooling Load (W/h)	
	Right Wing	Left Wing
0800	32906.03	32911.79
0900	28069.23	28072.54
1000	35360.078	35362.43
1100	40786.55	40788.00
1200	41222.20	41223.01
1300	38732.91	38733.40
1400	39990.63	39991.04
1500	40343.81	40344.32
1600	38328.00	38332.17
1700	30301.34	30311.18
1800	26531.30	26543.96
1900	20175.891	20183.28

APPENDIX F

Temperature and flow rate graph at each VAV at Block 17 (Right Wing)





APPENDIX G

Temperature and flow rate graph at each VAV at Block 17 (Left Wing)