I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of the scope and quality for the award of the degree of Bachelor Degree of Mechanical Engineering (Thermal-Fluid).

Signature : .....

Name of Supervisor : TEE BOON TUAN

Date : 29 MAY 2006

A STUDY OF VENTILATION AND CARBON DIOXIDE IN A LECTURE ROOM

NORLIDAWATI BINTI DADAN

This thesis is submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor Degree of Mechanical Engineering (Thermal-Fluid).

Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

I declare that this thesis entitled "A Study of Ventilation and Carbon Dioxide in a Lecture Room" is the result of my own research except as cited in the references.

Signature : .....

Name : NORLIDAWATI BINTI PADAN

Date : 29 MAY 2006

Especially dedicated to father, mother, brothers and sisters,
Not forgetting to Noor Azlan bin Abd Rahman,
I love you all so much.

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Alhamdulillah, because of His blessing and His love, I could finally complete this thesis.

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ABSTRACT

This study was conducted to investigate the relationship between carbon dioxide (CO_2) concentration with air flow rate and indoor temperature inside a lecture room. Furthermore, it was conducted to determine the average and maximum carbon dioxide concentration in an occupied space. Lecture room that is using the mechanical ventilation system was selected as the occupied space for the physical measurement in this study. Environmental parameters considered in this study are CO_2 concentration, air flow rate, indoor temperature and relative humidity. Meanwhile the subjective measurement was involving 32 students as the untrained subjects. Their votes for Perceived Thermal Votes (PTVc), Perceived Airflow (PAF) and Skin Dryness (SD) were analyzed to determine their perception towards their environment. The measurement results stated that the CO_2 concentration was ranging from 769 – 2001 ppm, indoor temperature was ranging from 21.9 – 23.5°C, and the relative humidity was ranging from 54.4 – 65.7%. All these values were compared to the recommended values given by ASHRAE Standard. The statistical model was also developed to obtain the relationship between CO_2 concentration and air flow rate. Vote analysis conducted gave additional information regarding on the occupants' response towards the indoor environmental. Based on the result, majority of occupants (37.5 %) were having medium overall satisfactory level with their indoor environment. However, there were also large percentages of them (31.3%) to have low overall satisfactory level. Some suitable guidelines of building maintenance procedures were recommended based on the outcomes from this study.

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This study was conducted to investigate the relationship between carbon dioxide (CO_2) concentration with air flow rate and indoor temperature inside a lecture room. Furthermore, it was conducted to determine the average and maximum carbon dioxide concentration in an occupied space. Lecture room that is using the mechanical ventilation system was selected as the occupied space for the physical measurement in this study. Environmental parameters considered in this study are CO_2 concentration, air flow rate, indoor temperature and relative humidity. Meanwhile the subjective measurement was involving 32 students as the untrained subjects. Their votes for Perceived Thermal Votes (PTVc), Perceived Airflow (PAF) and Skin Dryness (SD) were analyzed to determine their perception towards their environment. The measurement results stated that the CO_2 concentration was ranging from 769 – 2001 ppm, indoor temperature was ranging from 21.9 – 23.5°C, and the relative humidity was ranging from 54.4 – 65.7%. All these values were compared to the recommended values given by ASHRAE Standard. The statistical model was also developed to obtain the relationship between CO_2 concentration and air flow rate. Vote analysis conducted gave additional information regarding on the occupants' response towards the indoor environmental. Based on the result, majority of occupants (37.5 %) were having medium overall satisfactory level with their indoor environment. However, there were also large percentages of them (31.3%) to have low overall satisfactory level. Some suitable guidelines of building maintenance procedures were recommended based on the outcomes from this study.

ABSTRAK

Kajian ini dijalankan untuk mengkaji hubungan di antara kepekatan karbon dioksida (CO_2) dengan kadar aliran udara dan suhu dalaman di dalam sesebuah bilik kuliah. Selain itu, ia juga dijalankan untuk menentukan nilai maksimum dan purata bagi kepekatan CO_2 dalam sesebuah ruang yang dihuni. Bilik kuliah yang menggunakan sistem pengudaraan mekanikal telah dipilih sebagai ruang kajian bagi melaksanakan pengukuran fizikal. Parameter persekitaran yang diukur adalah kepekatan CO_2, kadar aliran udara, suhu dalaman dan kelembapan relatif. Manakala pengukuran subjektif adalah melibatkan 32 orang pelajar sebagai subjek tidak terlatih. Undian mereka terhadap Anggaran Undian Terma Gabungan (PTVc), Anggaran Aliran Udara (PAF) dan Kekeringan Kulit (SD) dianalisa untuk mengetahui persepsi mereka terhadap persekitaran mereka. Hasil keputusan menyatakan bahawa kepekatan CO_2 berada di dalam julat 769 – 2001 ppm, suhu dalaman pula di dalam julat 21.9 – 23.5°C, dan kelembapan relatif di dalam julat 54.4 – 65.7%. Kesemua nilai ini dibandingkan dengan nilai yang dicadangkan oleh Piawaian ASHRAE. Model statistik juga telah dibangunkan untuk mendapatkan hubungan di antara kepekatan CO_2 dengan kadar aliran udara. Analisa undian yang dilakukan telah memberi maklumat tambahan berkenaan tindak balas penghuni terhadap persekitaran dalaman. Berdasarkan keputusannya, sebilangan besar daripada penghuni (37.5%) mempunyai tahap kepuasan menyeluruh yang sederhana terhadap persekitaran dalaman mereka. Walau bagaimanapun, terdapat juga peratusan besar daripada mereka (31.3%) mempunyai tahap kepuasan menyeluruh yang rendah. Beberapa garis panduan untuk prosedur penjagaan bangunan juga telah diusulkan berdasarkan hasil kajian ini.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
BK	*Bilik Kuliah* (Lecture Room)
CFM	Cubic Feet per Minute (ft^3/m)
CO_2	Carbon Dioxide
IAQ	Indoor Air Quality
ppm	Part per million
PTVc	Perceived Thermal Vote
PAF	Perceived Air Flow
RH	Relative Humidity
SD	Skin Dryness
T	Temperature

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CHAPTER 1

INTRODUCTION

Humans need building as a shelter from the sun, rain, wind and cold. A building begins as an idea in someone's mind, a desire for new and ample accommodations for a family, an organization or an enterprise. Previously, the designs of buildings were very simple and only considered the local environment conditions. Natural ventilation would provide the passive cooling or possible additional heating in order to achieve good indoor climate. The "builder" and the "occupant" were often the same; therefore the issue of personal comfort was given a high priority.

In building construction, there are several matters should be concerned such as ventilation, indoor air quality (IAQ) and thermal comfort. This is important to achieve a good environment control systems in a building. At the end of 19^{th} century, new building construction technology was introduced. This new technology made it possible to design higher and deeper building with new materials such as steel. Artificial lighting and ventilation created an indoor climate largely independent of outdoor climate conditions. The increased technological complexity and size of modern buildings lead to specialization in the building industry. As a result, buildings very often are not being built around the needs of individual occupants, but for broader functions.

There are very few things people can do outdoors. Most people spend majority of their time indoors, often in shared spaces. The introduction of mechanical environmental control systems and the result of increased control of the indoor climate have been raising the expectations of occupants for thermal comfort level for indoor climate. However, the thermal comfort conditions for a typical person within a building enclosure are limited to a narrow range and this range differs per individual (Fanger, 1970).

1.1 Background of the Problem

When talking about ventilation issues, indoor air quality (IAQ) and thermal comfort would be the most important topics to be concerned.

The problem was originated in the early 1970's energy crisis, when saving energy became a priority above all other requirement. From this time on building facades were gradually better insulated and sealed to prevent air leakage. Central mechanical ventilation replaced the natural or local mechanical ventilation. The air flow rate was also reduced. It was difficult to maintain acceptable conditions at occupant level due to a centrally controlled ventilation system with a low room ventilation rate. Fresh air cannot be provided directly to the occupant. Moreover, correction of the conditions via natural ventilation was no longer possible because of sealed facade.

The build up of outgases from modern building materials, furniture and cleaning products forced to the result of tightly sealing and reducing fresh air in building. The consequence of which manifested itself in an increased occurrence of mild to serious building related health problems to occupants.

In view of the importance of IAQ and thermal comfort, the study of ventilation is conducted to achieve acceptable indoors environmental conditions for each individual occupant of a building. The study is also to maintain adequate ventilation for the important of occupant health and productivity.

Currently, ventilation system of air-conditioned buildings in tropical regions and elsewhere are designed and evaluated based on the criterion as determined from the indoor environmental studies that had been conducted in Europe or United States. It is important to study the indoor environmental in our region since the conditions here are different in terms of climatic experience and activities. It also may create opportunities to save energy and cost investment in ventilation equipment. So, this ventilation and carbon dioxide study is carried out to investigate the effectiveness of current ventilation system in selected academic building in KUTKM based on Malaysian environmental conditions.

1.2 Statement of the Problem

This research is carried out to find answer of the following issues:

1. How does the indoor carbon dioxide concentration affect the building air flow rates?
2. What is the average and maximum carbon dioxide concentration in the occupied space?
3. What is the relationship between the carbon dioxide concentration and indoor temperature?
4. What is the occupants' perception towards their indoor environment?

1.3 Objectives of the Study

This research is carried out to study the ventilation and carbon dioxide in selected academic building in Malaysia, with the following objectives:

1. To investigate the relationship between the CO_2 concentration and indoor temperature.
2. To determine the average and maximum CO_2 concentration in the occupied spaces.
3. To investigate the relationship between the CO_2 concentration and building air change rate.

1.4 Importance of the Study

Most of the studies of ventilation had been carried out in United States, Europe and other regions. Standards such ASHRAE Standard and EPA Standard are formulated based on such studies might not be suitable to be adopted entirely in our region. Some factors such as geographical, climate, cultural and types of activities are expected to influence the ventilation perception.

By conducting this study, there may be opportunities to define the ventilation perception of our region since such studies conducted very few in the tropics or equatorial climate.

1.5 Scopes of the Study

The scopes of the study consist of:

1. To conduct practical measurement involving temperature, relative humidity, air flow rate and CO_2 concentration.
2. To develop statistical model to obtain the relationship between indoor CO_2 concentration and ventilation rate.
3. To recommend guidelines of procedures for building maintenance based on the study.

1.6 Expected Outcomes

In the end, the expected results or findings from this study are:

1. Data collection of environmental parameters such as temperature, relative humidity, air flow rate and CO_2 concentration.
2. Statistical model to obtain the relationship between indoor CO_2 concentration and ventilation rate.
3. Recommendations of guidelines of procedures for building maintenance based on the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Ventilation

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. or ASHRAE has defined ventilation as the process of supplying and removing air by natural or mechanical means to and from any space. Such air may or may not be conditioned.

Natural ventilation is the circulation of air in and out of a building by natural forces, unaided by mechanical equipment. The two primary forces that drive natural ventilation are thermal buoyancy and wind pressure.

The obvious advantages of natural ventilation are its simplicity, economy, and quietness. Mechanical equipment, with its associated first cost, fan energy consumption, and noise, is avoided. The main disadvantage is that the rate of outside air exchange varies widely in a somewhat uncontrolled manner.

A mechanical ventilation system uses one or more electrical blowers, and sometimes a system of ductwork, to move air in and out of a home. The primary advantage of this approach is the consistency and controllability of the rate of ventilation, provided that the building envelope is tight enough. Other advantages include opportunities to precondition outside air (filtration, dehumidification, preheating) and to apply various techniques of heat and energy recovery. The disadvantages are the cost of the mechanical equipment, the energy consumed by the blowers, the noise of operation, and perhaps maintenance requirements.

Ventilation has become an important issue to be concerned in building industry since it is closely related to the issue of indoor air quality (IAQ) and comfort level of environment. In occupied buildings, ventilation (either natural or mechanical) is necessary to maintain acceptable IAQ. At the same time, when buildings are heated or cooled, ventilation often constitutes a relatively large component of the heating or cooling load.

Inadequate or improperly operated or maintained ventilation system may result in sick building problems (SMCA, 1993). Poor ventilation may lead to reduction in the productivity of employees and increment of their absenteeism, the increment in sickness rates and dissatisfaction of employees.

2.2 Environmental Parameters

There are several parameters that characterize the ventilation in this study, which are carbon dioxide concentration, indoor temperature, and relative humidity.