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

Signature :.................................

Supervisor I : Mr. Tee Boon Tuan

Date : 30th May 2006

Signature :.................................

Supervisor II :.................................

Date :.................................

STUDY OF ENERGY CONSUMPTION AND HVAC SYSTEMS FOR ACADEMIC BUILDING

MOHD RASHDAN ABDUL RASHID

A report submitted in partial fulfillment of the
requirements for award of the degree of
Bachelor of Mechanical Engineering (Thermal-Fluids)

Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

"I admitted this report was my own work except summaries and except that each one of it I had clarified the resources"

Signature :...

Author name : Mohd Rashdan Abdul Rashid

Date : 27th May 2006

"I admitted this report was my own work except summaries and except that each one of it I had clarified the resources"

Signature :...

Author name : Mohd Rashdan Abdul Rashid

Date : 27th May 2006

ACKNOWLEDGEMENT

I dedicate this report especially to both of my lovely parents, my lovely brothers and sisters and also a thousand thank you to my supervisor Mr. Tee Boon Tuan; lecturer of faculty of Mechanical Engineering Kolej Universiti Teknikal Kebangsaan Malaysia.

Most sincere gratitude to Mr. Raemy; Civil Engineer at Development Units, KUTKM also Mr. Mohamad; Chief of Technician Faculty of Electrical Engineering and Mr. Anis; Technician at KUTKM Development Units.

Thanks are also due to IMS Consultant staff, and in particular Mr. Ir. Nohaimi Ismail and Mr. Ir Ismail Mohd Salleh for the IMS library used.

ABSTRACT

This project presents the Energy Consumption and HVAC Systems study of Academic Building. HVAC refers to the equipment, distribution network, and terminals that provide either collectively or individually the heating, ventilating or air conditioning processes to a building. The main objectives of this study are to investigate the relationship between building energy consumption and HVAC system and evaluate the building HVAC system performance through physical measurement. Improvement methods in HVAC system is later being proposed to reduce building energy consumption. This study is also tend to provide a baseline estimate of current energy use which can be used for calculation of the energy savings impact of various options for reducing energy usage. In doing this project, physical measurement is being conducted involving parameter measurements involving air velocity, temperature and air change rate. The analysis conducted consists of building cooling loads, energy savings estimates and costing for the building.

ABSTRAK

Projek ini adalah mengenai kajian tentang Penggunaan Tenaga dan sistem HVAC Untuk Bangunan Akademik. HVAC merujuk kepada peralatan, proses pemasangan rangkaian, dan terminal, sistem pendingin udara atau pemanasan dan pengudaraan yang digunakan didalam bangunan. Objektif utama kajian dan analisis projek ini adalah mengenai hubung kait antara penggunaan tenaga dan sistem HVAC, menilai prestasi rekabentuk sistem HVAC yang terdapat didalam bangunan melalui kerja-kerja pengukuran. Penambahbaikan sistem HVAC turut dicadangkan untuk tujuan penjimatan penggunaan tenaga. Kajian ini juga memberikan garis panduan melalui kaedah pengiraan tentang anggaran penggunaan tenaga dan beberapa cara untuk mengurangkan penggunaan tenaga pada sistem yang dikaji. Dalam kajian ini, pengukuran fizikal yang dijalankan melibatkan parameter seperti kadar alir udara, suhu dan kadar tukaran udara. Analisa yang dijalankan juga adalah mengenai beban sejuk bangunan, anggaran penggunaan tenaga dan kos untuk bangunan.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

Definition of Terms and Symbols

A	area
U	heat transfer coefficient
TD	temperature difference
CLTD	cooling load temperature difference
$CLTD_C$	corrected cooling load temperature difference
Q	cooling load
SHGF	solar heat gain factor
SC	shading coefficient
CLF	cooling load factor
LM	correction for latitude and month
DR	daily temperature range °F
t_a	average outside temperature on a design day °F
t_R	room temperature °F
c	specific heat
D,d	diameter
E	thermal emf
e	thermal emf in a junction
f	frequency, function
$G(s)$, $F(s)$	transfer function
$G(j\omega), F(j\omega)$	frequency response
I	Electric current
K	gain
k	general coefficient
L	time lag also called dead time
l	length
N	time constant
P	power

Q	energy
q	heat flux density
R	resistance
r	radius
s	laplace operator
T	temperature in K
t	time, temperature in ° C
V	voltage, volume
v	velocity
W	thermal resistance, radiant intensity
α	heat transfer coefficient, coefficient of linear thermal expansion, temperature coefficient of resistance, absorbtivity
β	coefficient of cubic thermal coefficient
Δ	error, different, amplitude, sampling time
δ	relative error, penetration depth
ε	emissivity
9	temperature in ° C or F
Θ	excess temperature over a reference temperature such as ambient or original value
λ	wavelength, thermal conductivity
ρ	density, reflectivity, resistivity
ϕ	heat flux or rate of flow
φ	phase angle
ω	angular frequency
τ	transmissivity

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

The energy use estimates developed in this study are "bottom-up" estimates based on building floorspace and per-sqft energy use for typical building systems. The estimates are an "as-designed" estimate, which means that equipment is assumed to operate properly according to design intentions. For instance, modeling of chilled water systems does not allow for operation with reduced chilled water temperature to account for inadequate airflow in air handling units. Because the study takes an "as-designed" approach to energy estimates, the estimates are considered a conservative approximation of actual conditions. Unintended operation can result in increase or decrease in energy use. The magnitude of the uncertainty associated with the unintended operation is difficult to predict. It might be as much as 20% of overall estimates, but was not examined rigorously for this study. The baseline estimate starts with a segmentation of the Malaysia commercial building stock floor space by building type and region.

These loads are the heating and/or cooling requirement for the building interior required to maintain space thermal conditions, not including the impact of fresh air ventilation, which represents an additional load.

Energy use is calculated on a national basis by multiplying a floorspace segment's floor area (sqft) by the annual energy use intensity (EUI) of its cooling or heating system. EUI is in units of kWh/sqft/year for electricity and kBtu/sqft/year for gas and fuel oil.

HVAC system performance models were developed, using the building load data as input, and using HVAC equipment models reflective of typical equipment installed in buildings. Assumptions regarding equipment characteristics were derived from a number of sources, including the following:-

a) **Previous studies, journal, articles, etc.**
b) **Product literature.** Equipment load or efficiency data was in some cases taken from product literature.
c) **Lecturer review.** Review of selected interim results and final results of the project.
d) Study was provided by a number of active participants in the HVAC field.

Estimates of component design load intensities (DLI), (W/sqft) for the components of typical systems used for each of the building segments have been developed. These estimates are based on standard design practice and specifications for the equipment. For instance, supply fan DLI is based on typical values of CFM per square foot, required supply fan pressure, typical fan efficiency, and typical motor efficiency with a central VAV system. The EUI for a particular system component is equal to the DLI times the effective full load hours (EFLH) of operation in a year. In many cases, the EFLH is simply equal to the total number of hours of operation. However, some fans and pumps cycle depending on building conditions, and some fans and pumps operate with variable flow. System modeling was done to determine EFLH for system components with varying load or with varying percentage "on" time.

Component EUI's are combined to give building EUI's. The building EUI's are multiplied by the floorspace of a given building stock segment to give energy use for that segment. Summation over segments gives total energy use for a group of segments or for the entire commercial sector. Component EUI's themselves can also be multiplied by floorspace to give estimates of total energy use for a given component type.

1.1 Objectives

The objectives of this study are:

i. To investigate the relationship between building energy consumption and HVAC system.
ii. To evaluate the building HVAC system performance through physical measurement.
iii. To propose improvement methods in HVAC system design that can reduce building energy consumption.
iv. To provide a baseline estimate of current energy use which can be used for calculation of the energy savings impact of various options for reducing energy usage.

1.2 Scopes of The Study

The scopes of this study are:

i. To review and evaluate building load calculations through current approach.
ii. To conduct practical measurements involving temperature, humidity and air change rate.
iii. To propose standard guidelines of procedures for building maintenance based on the study.

1.3 Problems Statement and Solution

In doing this project, the academic building at Faculty of Electrical Engineering was selected. There are a few problems has been identified before doing this project. First things, the building properties have been describe such as types/materials of building, building location, latitude of building, daily temperature, area of each room and total area of the building and then the types of system used and types of HVAC component in the building. To achieve the project objectives, there is some review about building load calculations and the HVAC systems from an articles, journals and references books. Identifying the best solutions from the problems statement is very important to get the best results. In doing this project, there are two methods have been used:-

1. Measurements, and
2. Building Loads Calculations.

The comparison from results, the energy estimations and costing for this building can be analyzed. In measurement works, the TSI"s Accubalance equipments will use to get the Air Flow Rate (CFM), temperature, and relative humidity. To achieve the objectives of this project, the several solutions will be identifying:-

i. Describes the building properties.
ii. Research and Find types of Air Conditioner and the systems of HVAC.
iii. Research and Find Cooling Load Calculations.
iv. Conduct the measurements with TSI"s equipment.
v. Energy estimates and Costing
vi. Propose standard guidelines of procedures for building maintenance

1.4 Expected Outcomes

During project researching and analyzing, the expected outcomes value is:-

i. Building cooling loads efficiency.
ii. Total Building Energy in kW
iii. Energy consumption in FKE building at block A.
iv. Comparison between measurement work data and results of calculation.
v. Data and Calculation analyzed.

An efficient cooling system can keep comfortable even during the hottest of days. Proper operation of system isn't just about comfort it can also affect safety. A good comfort system should protect from allergens, remove excess moisture, combat mold - in fact, it should ensure the quality of the entire indoor environment. It should also save energy electricity bills.

HVAC design considers all the interrelated building systems while addressing indoor air quality, energy consumption, and environmental benefit. Optimizing the design and benefits requires that mechanical system designer and architect these issues early in the schematic design phase and continually revise subsequent decisions throughout the remaining design process. It is also essential that implement well-thought-out commissioning processes and routine preventative maintenance programs.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This literature review is based on term on related topic that was study and has been discussed by a professional and has given a complete explanation on how the things of study work out. The stated review below is important hint in study of energy consumption and HVAC systems.

HVAC represent Heating Ventilation and Air Conditioning Systems. It fills the fundamental principles and systems in a manner that is technically accurate, yet of practical use in the real working world. Today's reality, which mandates time and cost effectiveness in HVAC work, dictates this principles approach. By doing this project, some research and observation needed to complete energy consumptions and HVAC systems reports.

- Research the energy consumption of Heating and Ventilation of Air Conditioner, HVAC by the journal by previous study, journals, articles, etc.
- Research the types of Air Conditioner and the systems of HVAC
- Research the Cooling Load Calculation
- Research the building thermal loads based on building plan.

2.2 High- Performance of HVAC Energy by I.G. Carl.

I.G Carl PE, (Steven Associates WBDG, 1998) stated the use of high performance HVAC equipment can result in considerable energy, emissions, and cost savings (10%-40%). Whole building design coupled with an "extended comfort zone" can produce much greater savings (40%-70%). Extended comfort includes employing concepts such as providing warmer, but drier air using desiccant dehumidification in summer, or cooler air with warmer windows and warmer walls in winter. In addition, high-performance HVAC can provide increased user thermal comfort, and contribute to improved indoor environmental quality (IEQ).

2.2.1 Heating, Ventilating, and Air-Conditioning (HVAC)

The term HVAC refers to the three disciplines of Heating, Ventilating, and Air-Conditioning. A fourth discipline, Controls, pervades the entire HVAC field. Controls determine how HVAC systems operate to meet the design goals of comfort, safety, and cost-effective operation. Heating can be accomplished by heating the air within a space (e.g. supply air systems, perimeter fin-tube "radiators"), or by heating the occupants directly by radiation (e.g. floor/ceiling/wall radiation or radiant panels).

Ventilating maintains an adequate mixture of gases in the air we breath (e.g. not too much CO2), controls odors, and removes contaminants from occupied spaces. "Clean" air helps keep occupants healthy and productive. Ventilation can be accomplished passively through natural ventilation, or actively through mechanical distribution systems powered by fans.

Air-conditioning refers to the sensible and latent cooling of air. Sensible cooling involves the control of air temperature while latent cooling involves the control of air humidity. Room air is cooled by transferring heat between spaces, such as with a water loop heat pump system, or by rejecting it to the outside air via air-cooled or water-cooled equipment. Heat can also be rejected to the ground using geothermal exchange.