THE EFFECTS OF FRESH AIR RATIO OF A CONSTANT AIR VOLUME AIR-CONDITIONING SYSTEM ON THERMAL COMFORT LEVELS INSIDE A LARGE HALL

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DEDICATION

I dedicate this work to:

JKR Malaysia which gave me permission to continue my studies:
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ABSTRACT

The government building energy consumption in the Federal Territory of Putrajaya continues to increase in line with its development day by day. Several control parameters and specifications have been set in the daily operation of government office buildings especially the guidelines set by the Public Works Department (JKR). However, JKR does not have thermal comfort standards made especially for non-office government buildings, especially government buildings that have been operating for more than 10 years. Various failures have occurred to the air conditioning system and equipment in the building which affects the thermal comfort. This field of study was conducted in the Plenary Hall, Putrajaya International Convention Centre (PICC) to identify thermal comfort. Experimental study of thermal comfort is done in current condition and after the repair is done. Each condition will be tested base on two loads through zoning during normal weather conditions. The two conditions were observed through load condition measurements and three different fresh air ratios using direct reading instruments. This study is focused on improving the capacity of the hall air conditioning system based on the existing standards by operating the ratio of fresh air, indoor temperature and even relative humidity which will be used as an indicator for air quality and indoor air comfort level. The results of this study shown that the comfort level of the occupants decreased while the indoor space temperature increased which eventually this research focused on optimized comfort parameters for the ratio of fresh air supply in the comfortable indoor space of the large hall. This paper contained experimental analysis and thermal comfort index calculation.

ABSTRAK

Penggunaan tenaga bangunan kerajaan di Wilayah Persekutuan Putrajaya terus meningkat sejajar dengan pembangunannya hari demi hari. Beberapa parameter kawalan dan spesifikasi telah ditetapkan dalam pengoperasian bangunan pejabat kerajaan seharian terutamanya garis panduan yang telah ditetapkan oleh Jabatan Kerja Raya (JKR). Namun yang demikian, pihak JKR tidak mempunyai piawaian keselesaan terma yang dibuat khas untuk bangunan kerajaan bukan pejabat terutamanya bangunan kerajaan yang telah beroperasi melebihi 10 tahun. Pelbagai kerosakan yang telah berlaku terhadap sistem dan peralatan penyaman udara di dalam bangunan yang mempengaruhi keselesaan terma. Bidang kajian ini dilaksanakan di dewan Plenari, Pusat Konvensyen Antarabangsa Putrajaya (PICC) bagi mengenalpasti keselesaan termal. Kajian eksperimen keselesaan terma dilakukan dalam dua keadaan iaitu pada keadaan terkini dan juga keadaan setelah pembaikan dilakukan. Setiap keadaan akan diuji menerusi dua beban secara pengezonan semasa cuaca normal. Dua keadaan tersebut diperhatikan menerusi pengukuran keadaan beban dan tiga nisbah udara segar yang berbeza menggunakan peralatan ujikaji bacaan secara langsung. Kajian ini difokuskan untuk meningkatkan keupayaan sistem penyaman udara dewan berdasarkan piawaian-piawaian yang wujud dengan mengendalikan nisbah udara segar, suhu dalaman dan juga kelembapan relatif yang akan digunakan sebagai petunjuk untuk kualiti udara dan tingkat keselesaan udara dalaman. Hasil kajian telah menunjukkan bahawa tahap keselesaan penghuni dewan menurun ketika suhu ruangan dalaman meningkat yang akhirnya penyelidikan ini difokuskan pada parameter keselesaan yang dioptimumkan bagi nisbah bekalan udara segar di persekitaran ruang dalaman dewan besar yang selesa. Tesis ini mengandungi analisis eksperimen dan pengiraan indeks keselesaan termal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

EPA	-	Artificial Neural Network
IAQ	-	Genetic Algorithm
PICC	-	Particle Swarm Optimization
AHU	-	Mahalanobis Taguchi System
O&M	-	Mahalanobis Distance
CAV	-	Taguchi Method
ACMV	-	Universiti Teknologi Malaysia
IEQ	-	Extensible Markup Language
USEPA	-	Artificial Neural Network
JKR	-	Genetic Algorithm
EPA	-	Particle Swarm Optimization
ASHRAE	-	American Society of Heating, Refrigerating and Air Conditioning Engineers
CFM	-	Cubic feet per minute
VOC	-	Volatile organic compound
VAV	-	Variable air volume
SRW	-	Sensible recovery wheel
HRW	-	Heat recovery wheel
ERW	-	Energy recovery wheel
EHW	-	Enthalpy heat wheel
SWH	-	Sensible heat wheel
DB	-	Dry bulb
WB	-	Wet bulb
CO2	-	Carbon dioxide
DCV	-	Demand control ventilation
PMV	-	Predicted Mean Vote
PPD	-	Predicted Percentage Dissatisfied
ISO	-	International Organization for Standardization
EN	-	European Union
BAS	-	Building Automation System

LCD	-	Liquid crystal display
GDC	-	Gas district cooling
CO	-	carbon monoxide
ppm	-	parts per million
H2O	-	Hydrogen dioxide
HVA	-	Heat ventilation air-conditioning system
USB	-	Universal serial bus
NIST	-	National Institute of Standards and Technology
MS	-	Malaysia Standard
DOSH	-	Department of Safety and Health
RH	-	Relative humidity

LIST OF SYMBOLS

°C	-	Degree Celsius
m^3	-	Meter cube
m	-	Meter
%	-	Percentage
m/s	-	Meter per second
L/s	-	Litre per second
ft^2	-	Feet square
m^2	-	Meter square
F	-	Fahrenheit
W/m^2	-	Watt per meter square
Btu/h	-	British thermal unit per hour
I_{cl}	-	Cloth insulation value
Clo	-	Cloth
Π	-	Pi
K	-	Kelvin
W	-	Watt
v	-	velocity

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

According to the Environmental Protection Agency (EPA), indoor air quality (IAQ) is “the air quality within and around buildings and structures, especially as it relates tothe health and comfort of building occupants” (US EPA, 2019). It has been shown that air quality and temperature comfort in work places, lecture halls, discussion rooms, prayer rooms and entertainment spaces should be emphasized as they affect the users of the space. A person who breathes stale air in a space over a long period of time may result in impaired health, lack of energy, less concentration, reduced productivity and drowsiness.

By analyzing recent studies, Yu, Hu, Liu, Yang, Kong and Liu (2008) foundthat effective design, installation and good maintenance to the air conditioning system are important in getting fresh air and comfort temperature. Indoor air management requires a system which capable to bring fresh air into the building with relatively controlled humidity and maintaining the set design temperature in energy-efficient conditions.A failure of the air conditioning system for the Putrajaya International Convention Centre (PICC) Plenary Hall has contributed to discomfort and unhealthy air production. The air conditioning system in this Plenary Hall, PICCis unable to maintain the set temperature when it is filled with occupants.This is most likely due to the air conditioning system and equipment failure itself. The investigation will be conducted on the chilled water to supply condition, heat recovery wheel, Air Handling Unit (AHU), feel devices, valves, air ducting, and fresh and return air damper.One or more of these equipments are believed to be the cause of failure. Operation and maintenance (O&M) manual including existing local guidelines and specification requirements will form the basis of this study. Therefore, forensic investigation will be conducted to determine the cause of the failure of the air conditioning system through these possibilities. A good air conditioning system will certainly provide fresh air and temperature comfort in the indoor environment of the hall.It is expected that a good suggestion can be made to making good the system and improve the indoor air quality performance in order to make sure the environment in the hall is comfortable to occupants.

1.2 Problem Statement

Thermal comfort in a large hall is very important because it is one of the factors that attract customers in choosing a venue to organize a program or event. Every occupant of the hall in attendance wants optimal thermal environment conditions so that they remain comfortable and focused throughout the program or event that takes place. The optimal thermal environment can be achieved with the uniform distribution of temperature and relative humidity as well as the appropriate fresh air ratio. In this situation, all occupants in the hall whether at the front, back, centre and sides are in a comfortable condition with comfortable air throughout the hall.

The indoor room temperature of the Plenary Hall, PICC is designed around 24°C ±1°C with relative humidity below 70%. However, the current situation that occurs in this hall isdifference where the whole hall feels hot and very uncomfortable. This is due to the failure of the Plenary Hall, PICC air conditioning system which occurred around 2009. The cause of this failure is due to excessive outdoor air entry into the system and insufficient air supply supplied inside the hall and not reaching the diffuser unit below the seating area. Therefore, the air in the hall becomes slow to be cool and the occupants will feel uncomfortable especially when sitting for a long time and the hall is full. This uncomfortable indoor environment is believed to be due to the failure of some components system and equipments related to the hall AHU system.

Inspired by this case, an investigation into the cause of the failure and a study of the thermal comfort level of the occupants in the hall was carried out. Investigations into the cause of the problem are conducted experimentally where temperature, relative humidity and air flow rate data are collected. Data collection is done on all AHU systems involved as well as the entire indoor space of the hall. In addition, the analysis of the Fanger model which includes Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) was conducted to obtain a measure of thermal comfort of the occupants in the hall. With this study, the condition of the current thermal comfort level and the effect of fresh air ratio on the indoor thermal environment should be determined.This study also can help the PICC management in improving the thermal comfort level in the hall as well as save energy. Good indoor air quality in the hall can provide comfort to the occupants so that they can focus fully on the event.

1.3 Research Objectives

This study aims to maintain a temperature of 24 °C in the Plenary Hall with optimal fresh air supply in order to achieve environmental comfort without wasting energy. Therefore, the objectives of this study are as follows as below:

a. To determine present/current thermal comfort level inside the Plenary Hall, PICC equipped with Constant Air Volume of air conditioning system through Predicted Mean Vote and Predicted Percentage Dissatisfied indices.

b. To investigate the effect of fresh air ratio of Constant Air Volume of air conditioning system on the air temperature distribution, Predicted Mean Vote and Predicted Percentage Dissatisfied inside the Plenary Hall.

1.4 Significant of Research

The inconvenient and non-conducive indoor environment reflects a sick and unfriendly building. Base on Kamaruzaman and Sabrani studies, this can lead to a decline in the quality of building occupants while also affecting the productivity. Quality of occupants is not only measured by the number of works that can be produced, but also through the ability to concentrate, smart, healthy and energetic. Hot temperatures and stuffy indoor air as a result of failure of the air conditioning system are a major concern for building owners and maintenance personnel. Failure of the air conditioning system may result in cold air supply and disrupted fresh air supply.

Changing the new air conditioning system and equipment as a whole involves very high installation costs. In fact, the dismantling and installation of the new system will involve building works such as demolishing walls, removing ceilings, mobilization and demobilization. It will also disrupt the day-to-day activities of the occupants as well as cause discomfort due to noise disturbance and messy environmental. Forensic studies and retrofitting are important to maintain the performance of air conditioning systems and equipment so that they can continue to function as design requirement.

This research will extend the life of the existing air conditioning system and improve it to maintain air temperature and fresh air supply in the building consistently to meet the specifications and standards of Indoor Environment Quality (IEQ).

1.5 Research Scope and Limitations

The scope of this study is focussed on the air-conditioning system of the Plenary Hall, PICC, which has failed. Forensic investigations will focus on design parameters, system performance testing of the air handling unit against temperature and airflow and observations on the state of the system and equipment involved. The temperature data in the hall and the percentage of fresh air supply before retrofitting will be collected with the permission of the Jabatan Perdana Menteri, Putrajaya Corporation, Convention & Exhibition (Putrajaya) Sdn. Bhd., and Maintenance Management Company. Through the data collected, it will be used to investigate the cause of failure of the air conditioning system in this hall. A thermal sensation and occupant comfort level study will be determined.

However, there were limitations to this study. It is difficult to collect temperature and airflow data when the hall filled with occupants. During the functions and events, there are involving large numbers of occupantsin this hall.

Pre-cooling for an hour before the event begins is a major risk to the building management. The building management worried when cold temperatures could not be supplied to the hall on a regular basis due to the very short pre-cooling period.

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