UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ASESSMENT ON THERMAL COMFORT AMONG STAFF IN LIBRARY CENTRE UNIVERSITI TEKNIKAL MALAYSIA MELAKA

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems (Hons.)

by

FATIN AFIQAH BINTI JAJULI

B071110308

910723-01-6392

FACULTY OF ENGINEERING TECHNOLOGY

2015

© Universiti Teknikal Malaysia Melaka

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK TAJUK: **Assessment of Thermal Comfort among Staff in Library Centre, Universiti Teknikal Malaysia Melaka (UTeM)**

SESI PENGAJIAN: **2014/15 Semester 2**

Saya **FATIN AFIQAH BINTI JAJULI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh:

Alamat Tetap:
No. 701, Jalan Seri Impian, 1/4
TamanSeri Impian, 86000, Kluang,
Johor Darul Takzim,

Tarikh: 18th Disember 2014

Cop Rasmi:
AZWAN BIN AZIZ
Pengarah
Pejabat Keselamatan dan Kesihatan Pekerjaan
Canselori
Universiti Teknikal Malaysia Melaka

Tarikh: 28/1/15

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

© Universiti Teknikal Malaysia Melaka

DECLARATION

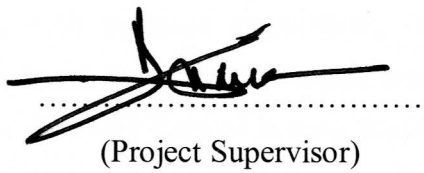
I hereby, declared this report entitled "Assessment of Thermal Comfort among Library Staff in Library Centre Universiti Teknikal Malaysia Melaka" is the results of my own research except as cited in references.

Signature	:	.....
Author's Name	:	Fatin Afiqah Binti Jajuli
Date	:	18th December 2014

© Universiti Teknikal Malaysia Melaka

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air Conditioning System) (Hons.). The member of the supervisory is as follow:



(Project Supervisor)

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Keselesaan terma adalah keadaan fikiran di mana menyatakan kepuasan dengan persekitaran nya. Ia adalah satu aspek penting dalam proses reka bentuk bangunan di mana manusia moden menghabiskan masa mereka di dalam bangunan.. Oleh kerana keselesaan terma mempunyai peranan yang besar kepada penghuni , kajian ini mensasarkan dalam menentukan tahap keselesaan terma di kalangan kakitangan di pusat perpustakaan Universiti Teknikal Malaysia Melaka (UTeM). Ini boleh diperolehi dengan mengambil ukuran faktor yang boleh mempengaruhi keselesaan terma iaitu suhu udara, suhu pancaran persekitaran, kelembapan, halaju udara, penebatan pakaian, dan kadar metabolism. Persepi penghuni juga diambil kira melalui soal selidik dan dihubung kaitkan dengan hasil ukuran parameter untuk mengesan hubungannya dengan tahap keselesaan terma. *Predicted Mean Vote (*PMV) dan *Predicted Percentage Dissatisfied* (PPD) yang telah dikira menggunakan data factor keselesaan terma menunjukkan bahawa ia memenuhi standard yang disyorkan oleh *American Society of Heating, Refrigerating and Air-Conditioning Engineers* (ASHRAE).

© Universiti Teknikal Malaysia Melaka

ABSTRACT

Thermal comfort is the state of mind in which expresses satisfaction with the thermal environment. It is an important aspect of the modern building design process as man spends most of the day indoors. As thermal comfort has a significant importance to occupants, this study mainly aiming on determining the level of the thermal comfort among the staffs in the library centre of Universiti Teknikal Malaysia Melaka (UTeM). This can be obtained from the measurement of the parameters that contributing to the thermal comfort which are air temperature, mean radiant temperature, relative humidity, air velocity, clothing level, and metabolic rate. The perception of the occupants were also been considered from the questionnaire survey and being correlated with the parameter measurement result in order to find its relationship with the thermal comfort evaluation. *The Predicted Mean Vote* (PMV) and *Predicted Percentage Dissatisfied* (PPD) that have been calculated from the comfort parameter data showed that it is comply with the *recommended American Society of Heating, Refrigerating, and Air-Conditioning* Engineers (ASHRAE) Standard.

© Universiti Teknikal Malaysia Melaka

DEDICATION

Dedicated to my beloved parents, brothers, sisters, all my family and my friends.

Thank you for your support and encouragement.

You are all everything to me.

May Allah bless all of us. InsyaAllah.

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENT

I would like to thank express my sincere gratitude to my academic supervisor, Mr Azwan bin Aziz for his guidance, constant motivation and research support throughout my degree program. His technical advice and suggestion helped me overcome hurdles during this study and kept me enthusiastic and made this work a wonderful learning experience. I am grateful to my parents Mr Jajuli bin Anuar and Mrs. Rohana bin Ibrahim for their love, support and guidance. They have always been supportive of my academic pursuits and stood by me every step of the way regardless of my decisions. To all my fellow friends who involves directly or indirectly which always stay strong beside me in giving opinions and support throughout our relationship, I really thankful and appreciate it very much.

© Universiti Teknikal Malaysia Melaka

TABLE OF CONTENT

Declaration		i
Approval		ii
Abstrak		iii
Abstract		iv
Dedication		v
Acknowledgement		vi
Table of Content		vii
List of Tables		xi
List of Figures		xii
List Abbreviations, Symbols and Nomenclatures		xiv
CHAPTER 1: INTRODUCTION		**1**
1.1	Background of research	1
	1.1.1 UTeM Library Background	1
	1.1.2 Thermal comfort importance in library	2
1.2	Problem statement	3
1.3	Objectives	
	1.3.1 Main Objectives	4
	1.3.2 Specific Objectives	4
1.4	Scope and Limitation of Research	5
1.5	Expected Outcomes	5
CHAPTER 2: LITERATURE REVIEW		**7**
2.1	Introduction to thermal comfort	7
2.2	Factor Affecting Thermal Comfort	10
	2.2.1 Environmental factor	11
	2.2.1 Personal factors	12
2.3	Thermal Comfort Indices	14
	2.3.1 Wet Bulb Globe Temperature	15
	2.3.2 Operative Temperature	15
	2.3.3 Effective Temperature	16

© Universiti Teknikal Malaysia Melaka

2.3.4 Equivalent Temperature 16
2.4 Thermal Comfort Model 16
2.4.1 Fanger Model 17
2.4.2 Adaptive Model 19

CHAPTER 3: METHODOLOGY **24**

3.1 Study Design 24
3.2 Target Population 24
3.3 Sample Frame 25
3.4 Data Collection 25
3.5 Data Analysis 30
3.6 Expected Outcome 30

CHAPTER 4: RESULT & DISCUSSION **31**
4.1 Result of Parameters Measurement By Floor 31
4.1.1 Air Velocity 32
4.1.2 Temperature 33
4.1.3 Relative Humidity 34
4.2 Summary of Parameter Measurement By Floor 35
4.3 Discussion On The Parameter Measurement Result 36
4.4 Relationship Between Parameter Measurement 37
4.4.1 Temperature and Relative Humidity Correlation 37
4.4.2 Temperature and Air Movement Correlation 38
4.5 Discussion on the Correlation Between Parameter Measurement 39
4.6 Result for Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) 40
4.6.1 Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) Evaluation 40

© Universiti Teknikal Malaysia Melaka

4.7	Relationship Between PMV and Parameter Measurement	42
	4.7.1 PMV and Temperature Correlation	42
	4.7.2 PMV and Relative Humidity Correlation	43
	4.7.3 PMV and Air Velocity Correlation	44
4.8	Discussion on the Correlation Between PMV with Parameter Measurement	45
4.9	Questionnaire Respond Analysis	47
	4.9.1 Analysis of Respondents Demographic Data	47
	4.9.1.1 Gender	47
	4.9.1.2 Age	48
	4.9.2 Analysis of Respondents Working Background	48
	4.9.2.1 Working Unit	48
	4.9.2.2 Working Unit Description	49
	4.9.3 Analysis of Thermal Comfort	50
	4.9.3.1 Temperature	50
	4.9.3.2 Air Movement	51
	4.9.3.3 Humidity	52
	4.9.3.4 Clothing Insulation	53
	4.9.3.5 Source of Thermal Discomfort	54
	4.9.3.6 Working Productivity	55
	4.10 Result of Correlation between Satisfaction Votes on Actual Measurement	56
	4.10.1 Temperature	56
	4.10.2 Humidity	58
	4.10.3 Air Movement	59
	4.11 Discussion between Thermal Comfort Level with Thermal Satisfaction Response	60
CHAPTER 5: CONCLUSION		**62**
5.1	Summary of research	62
5.2	Summary of Research Result	64
5.3	Conclusion of Research	65

© Universiti Teknikal Malaysia Melaka

5.4 Future work and recommendations 66

REFERENCES **67**

APPENDICES **73**

APPENDIX A 73

APPENDIX B 79

APPENDIX C 84

APPENDIX D 85

APPENDIX E 88

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

No.	Tables Description	Page No.
2.1	Table of factors affecting thermal comfort	11
2.2	List of representative metabolic rates in different states of	13
2.3	Insulating value of clothing elements	14
2.4	Acceptable thermal environment for general comfort	18
3.1	Details for the selected building	26
3.2	Equipment used for thermal comfort measurement	28
4.1	Comparison of air-velocity with ICOP and ASHRAE Standard	33
4.2	Comparison of temperature with ICOP and ASHRAE standard	34
4.3	Comparison of humidity with ICOP and ASHRAE standard	35
4.4	Summary of parameter measurement for Ground Floor to Second Floor	36
4.5	Three classes of thermal comfort environment	41
4.6	PMV and PPD results for all levels	42
4.7	Frequency table of respondents gender	47
4.8	Respondents distribution by age category	48
4.9	Respondent's working space description	49

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

No.	Figure Description	Page No.
1.1	Main Library in UTeM	1
2.1	Thermal interaction of Human Body and the Environment Cylindrical Model	8
2.2	Flowchart of thermal comfort estimation	9
2.3	Psychometric chart on determining comfort zone	16
2.4	PMV related parameters and its relation with PPD based on ASHRAE scale	19
2.5	The "adaption hypothesis" pf thermal perception	21
2.6	Three components of adaption to indoor climate	23
3.1	Field measurement of temperature, humidity and velocity data	29
3.2	Conceptual framework of study	30
4.1	Correlation between temperature and relative humidity	38
4.2	Correlation between temperature and air movement	39
4.3	PMV with PPD correlation	42
4.4	Scatterplot of PMV against the temperature	43
4.5	Scatter plot of PMV against the temperature	44
4.6	Scatter plot of PMV against the temperature	45
4.7	Bar chart of respondents' distribution by unit	49
4.8	Bar chart of respondents' working space	50
4.9	Respondent's satisfaction votes towards air temperature	51
4.10	Thermal satisfaction votes towards air movement	52
4.11	Thermal satisfaction votes towards relative humidity	53
4.12	Thermal satisfaction votes towards clothing insulation	54
4.13	Satisfaction votes of thermal comfort influence towards working productivity	55

© Universiti Teknikal Malaysia Melaka

4.14 Correlation of temperature satisfaction vote with the mean value of the measured temperature 57
4.15 Correlation of humidity satisfaction with the mean value of the measured humidity 58
4.16 Correlation of air movement satisfaction vote with the actual measurement 59

© Universiti Teknikal Malaysia Melaka

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ANOVA	~ Analysis of Variance
AMV	~ Actual Mean Vote
ASHRAE	~ American Standard Heating and
CEN	~
CO_2	~ Carbon Dioxide
DBT	~ Dry bulb Temperature
ET	~ Effective Temperature
EqT	~ Equivalent Temperature
F	~ T-Test
IAQ	~ Indoor Air Quality
ICOP	~ Industrial Code of Practice
ISO	~
HSE	~ Health and Safety Executive
HVAC	~ Heating Ventilation and Air Conditioning
LEED	~
M	~ Mean
OSH	~ Occupational Safety and Health
P/SIG	~ Significant Value
PMV	~ Predicted Mean Vote
PPD	~ Predicted Percentage Dissatisfied
RH	~ Relative Humidity
SPSS	~ Statistics Package for Social Science
SD	~ Standard Deviation
TWAG	~ Time Weighted Average
TSV	~ Thermal Sensation Vote
WGBT	~ Wet bulb Globe Temperature
VOC	~ Voltanic Organic Compound
>	~ More than

© Universiti Teknikal Malaysia Melaka

$<$	~ Less than
$\geq$	~ More or equal to
$\leq$	~ Less than equal to
m^2	~ Meter square
m/s	~ Meter per second
°C	~ Degree Celsius

© Universiti Teknikal Malaysia Melaka

CHAPTER 1
INTRODUCTION

In this chapter, some related information about the thermal comfort is discussed as the introduction for this research. In order to elaborate more ideas about this research, the background of research, problem statements, objectives and also scope and limitation of the research will also being explained in this chapter.

1.1 Background of research

The research is conducted to determine about the level of thermal comfort among the workers in the Universiti Teknikal Malaysia Melaka (UTeM) library. The library is situated at the UTeM's main campus.

1.1.1 UTeM Library Background

Figure 1.1 below shows the UTeM's library that is situated at the main campus. On 10 June 2001, the library started its operation at the Temporary Campus located in Taman Tasik Utama, Ayer Keroh, Melaka then it was been relocated to the Industrial Campus on 12 September 2005.Initially, this library could accommodate approximately 400 users in area of 2,229 square meters.

© Universiti Teknikal Malaysia Melaka

Figure 1.1: Main library in UTeM

In 1 October 2007, a new branch library was built in the City Campus located at Jalan Hang Tuah, Melaka. After two years been in operation, it then moved from Industrial Campus to Main Campus in Durian Tunggal. This main library can be filed about 500 users per time. It started the operation on September 2009. The Industrial Campus Library was closed on 3 September 2009. This library has about 81,530 collection of printed source including e-books, journals and database. The features of the existing facilities have been improved by the expansion of knowledge resource for the research, teaching, and learning needs.

1.1.2 Thermal comfort importance in library

Thermal comfort is one of six key metrics within indoor environmental quality. According to Nazanin *et al* (2008), each person has different physiological and psychological factors. In economically developed countries, it is commonly estimated that a person spend at least about 80% of their daily time in indoors. Thus, it is important to maintain the quality of the indoor environment. The quality of the indoor environment can have a large impact on comfort, health, and overall sense of well-being. In order to maintain the quality of the indoor environment, it is important to mechanically condition a buildings to provide constant, uniform, "comfortable" environments (ASHRAE, 1997) .The Health & Safety Executive (HSE) (2005) has assured that the "best that you can realistically hope to achieve is a thermal environment that satisfies the majority of people in the workplace, or can be simply

© Universiti Teknikal Malaysia Melaka

said as, 'reasonable comfort'. The HSE also has assumes that reasonable limit for the minimum number of people who should be thermally comfortable in an environment of occupants should be 80%".

It is important for an educational building such as library to have a comfortable and satisfying indoor environmental space. A staff perception of thermal comfort is affected by air temperature within the space, air movement or velocity, humidity, the clothing they worn, amount of physical work activity done in within their working period, mean radiant temperature, such as the average temperature of the walls, floor windows and many other factors (ASHRAE,1992). Thermal comfort in library should be considered seriously because of the high occupant density in the building. It will bring the negative influences to the not only to the staff but also the library user especially students which spend most of their free time in. Poor indoor air quality and thermal environment can causing occupants dissatisfaction and discomfort, a reduction in work performance and a greater incidence of absenteeism (HSE,2005). Poor conditions can also affect occupants health, causing some physical symptoms or also known as sick-building syndromes such as headaches, nose, throat, eye and skin irritation, nausea and drowsiness.

The assessment of thermal comfort has been done basically by referring to the number indices and standards that has been published. Fanger's Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) model was the most well-known model on determining the index of the thermal comfort (Fanger, 1967).

1.2 Problem statement

For a past few decades, the public awareness towards thermal comfort in Malaysia is on the rise. As Malaysia is located in a hot and humid climate, a large number of the buildings are served by air-conditioning and other mechanical ventilation systems that are designed in order to maintain a comfortable indoor environment. Thus, there is a need to conduct a study on air-conditioning building such as library in university, especially in Malaysia because it is rarely been done. Recently, occupant's complaints have rising, productivity also has fall and in some cases people may

© Universiti Teknikal Malaysia Melaka

refuse to work in a particular environment as it causing uncomfortable feeling (Awbi, 1992). Symptoms of sick building syndrome to occupants will be affect occupants health if the environmental factors are not be maintained with adequate standard. Thermal comfort is a key component of ensuring a high indoor air quality. Environmental elements such as heat from electrical lighting, lack of adequate ventilation, high humidity levels can also resulting to poor thermal comfort.

It is essential in educational buildings to have a satisfactory and comfortable indoor conditions in order to achieved significant health, performance and learning improvements for students and staff (Kats, 2006; Corgnati, Filippi & Viazzo, 2007). Thus, due to the daily use of library, the problem arising is how the thermal comfort for the occupants is maintained within their working period. Some occupants' complaints that they were sometimes feel uncomfortable with the humidity and temperature. Thus, in order for a thermal comfort to be achieved, a good maintenance on heating, ventilation and air conditioning (HVAC) is necessary. Care should be taken when air conditioning systems are been used to ensure uniform air distribution throughout the workplace or otherwise some workers may complain regarding their satisfaction in the environment.

1.3 Objectives

1.3.1 Main Objective

- To determine the level of the thermal comfort among the staffs and its relationship with air conditioning status in the library centre of Universiti Teknikal Malaysia Melaka (UTeM).

1.3.2 Specific Objectives

1. To measure the thermal comfort parameters such as air temperature, mean radiant temperature, relative humidity, air velocity, clothing level, and metabolic rate.

© Universiti Teknikal Malaysia Melaka

2. To calculate the value of Predicted Mean Vote Index (PMV) and Predicted Percentage Dissatisfied Index (PPD) in determining the performance of the thermal comfort.
3. To determine the response of occupants regarding to thermal comfort in the Library centre, UTeM.
4. To correlate the relationship between thermal comfort and the air-conditioning status in the library.

1.4 Scope and Limitation of Research

This research is mainly focus on the thermal comfort at the library which including several units which are Administration unit, Automation unit, Circulation unit, Media unit, Reference unit, Indexing unit and Procurement unit. The focus of this research is to analyze how the effectiveness of the air-conditioning system in the library may have an effect on the thermal comfort of the occupants. Complaint from the library users especially the staffs has increase on how they sometimes feel uncomfortable with the air-conditioning system within the building which could become too cold or sometimes feel hot.

So, this research will be focusing on determining the level of the thermal comfort in order to detect the problem that has been affecting the effectiveness of the air-conditioning system. However, this study only proposes on obtaining the occupants' response on their awareness regarding thermal comfort only without considering the improvement or solutions to solve the problems.

1.5 Expected outcomes

This research projects expects to have some outcomes by the end of the project:

1. Able to determine the level of the thermal comfort measurements of environmental parameters by measuring the parameters contributing to thermal satisfaction.

© Universiti Teknikal Malaysia Melaka

2. An analysis on the factor that affect the level of the thermal comfort and also some of the consequences when the thermal comfort is decrease.

3. Provide the staff or occupants a comfortable thermal environment that will increase the working performance from the assessment of building occupant's thermal comfort over time.

4. Increase the awareness of the importance of the thermal comfort in order for the occupants to work on a healthy environment.

5. Ensure a healthy IAQ in the library when the air-conditioning system is in a good maintenance.

© Universiti Teknikal Malaysia Melaka

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to thermal comfort

A thermally comfortable environment is always been a priority for every human. American Society of Heating, Refrigerating and Air Conditioning Engineers , ASHRAE 55-92 and ISO/EN 7730 has stated thermal comfort as a condition of mind which expresses satisfaction with the surrounding thermal environment. There have been a complex relationship between physiological and psychology variation of each person and condition of their mind. In case for occupant in a building it basically will relate with the heating, ventilation and air conditioning system (HVAC) (ASHRAE, 1993; Humpreys, 2007). The complex relationship is presented in the Thermal Interaction of Human Body and the Environment in Figure 1.2. According to ASHRAE (1993) this cylindrical model displays the regulation of human body functions and activities in which will associate with the dissipation of heat, generation and storage of human body.

© Universiti Teknikal Malaysia Melaka