A STUDY OF HUMIDITY EFFECT TOWARD THE QUALITY OF AIR FROM AIR CONDITIONING SYSTEM

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Thesis submitted in fulfillment of the requirements for the award of the degree of
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SUPERVISOR'S DECLARATION

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DEDICATION

Special Dedication to my beloved father (Mohd Kama Bin AB Rahman) and my mother (Jamah Bt Tokachil), for their love and encouragement.

And,

Special Thanks to my friends, my fellow course mates and all faculty members.

For all your care, support and best wishes.

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Last but not least, to my family members for support and courage given. Thank you.

ABSTRACT

This thesis is about study of humidity effect towards quality of air using air conditioning unit at Mechanical Engineering Faculty (FKM) University Malaysia Pahang (UMP). Humidity is the quality of how much water or moisture content in the air. This project is to analyze the effect of dehumidification towards quality of air from air conditioning unit. The dehumidification method is using heater which is supplied before and after the evaporator. Variable speed of air flow is conducted to determine the effect of air speed toward dehumidification. Analysis is done by giving different value of air speed and different humidity. Experiment is conducted using air conditioning unit at thermodynamic laboratory which 24 experiments were done by giving different value of fan speed and humidity. Effect of pre-heater and re-heater also being monitored by varies the situation inside the air conditioning duct by switch on and off both of the heaters. After each experiment is being conducted, the quality of air at the exit is monitored and plotted on Psychrometric chart. Standard ASHRAE thermal comfort zone is used to determine the optimum temperature and humidity for thermal comfort. Various graphs is plotted and to determine the effect of humidification toward various parameters such as Coefficient of Performance (COP) of refrigerant, point temperatures, amount of heat being transferred and humidity. From the results, by increasing the velocity will help to make the environment become more comfortable. Secondly, increasing air velocity flow through evaporator increase its heat transfer and be calculated using energy balance equation. Besides that, from the experiment pre-heater and re-heater help to adjust the humidity and temperature at each point. Then, usage of humidifier causing the temperature and humidity to became further away from thermal comfort zone. Thus without using the humidifier, the quality of air from air conditioning unit FKM UMP can be improved.

ABSTRAK

Tesis ini adalah mengenai kajian kesan kelembapan kepada kualiti udara menggunakan unit penghawa dingin Fakulti Kejuruteraan Mekanikal (FKM) Universiti Malaysia Pahang (UMP). Kelembapan adalah kandungan air di dalam udara. Projek ini adalah untuk menganalisis kesan penyahlembapan ke arah kualiti udara dari unit penghawa dingin. Kaedah penyahlembapan adalah dengan menggunakan pemanas yang dibekalkan sebelum dan selepas penyejat. Kelajuan udara selaku pembolehubah manipulasi untuk menentukan kesan kelajuan udara ke arah penyahlembapan. Analisis dilakukan dengan memberi nilai kelajuan udara dan kelembapan yang berbeza. Eksperimen dijalankan menggunakan unit penyaman udara di makmal termodinamik. 24 eksperimen telah dijalankan dengan memberi nilai kelajuan kipas dan kelembapan yang berbeza. Selepas setiap eksperimen dijalankan, dengan menggunakan carta psikrometri kualiti udara di bahagian keluar unit penghawa dingin dipantau dan diplotkan. Standard ASHRAE keselesaan zon terma yang digunakan untuk menentukan julat suhu dan kelembapan yang boleh membuat manusia berada dalam keadaan udara yang selesa. Pelbagai graf diplot dan untuk menentukan kesan pelembapan ke arah pelbagai parameter seperti pekali prestasi bahan pendingin, suhu setiap tempat, jumlah haba yang dipindahkan dan kelembapan. Setelah analisa di lakukan, dengan meningkatkan halaju kipas, ia akan membantu membuat suasana menjadi lebih selesa. Keduanya, meningkatkan halaju aliran udara melalui penyejat meningkatkan pemindahan haba dan dikira menggunakan persamaan keseimbangan tenaga. Selain itu, pemanas yang di gunakan membantu melaraskan kelembapan dan suhu pada setiap titik. Kemudian, penggunaan pelembap menyebabkan suhu dan kelembapan untuk menjadi lebih jauh dari zon keselesaan terma. Oleh itu, tanpa menggunakan pelembap, kualiti udara dari penghawa dingin unit FKM UMP dapat ditingkatkan.

TABLE OF CONTENTS

Page

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULT AND DISCUSSIONS

CHAPTER 5 CONCLUSION AND RECOMMENDATION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

HVAC	Heating, Ventilating and Air conditioning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
T_{db}	Dry bulb temperature
T_{wb}	Wet bulb temperature
T_{dp}	Dew point temperature
h	Enthalpy
Φ	Specific humidity
ω	Relative humidity
v	Specific volume
AHU	Air handling unit
FYP	Final year project
TT1	Refrigerant temperature point 1
TT2	Refrigerant temperature point 2
TT3	Refrigerant temperature point 3
TT4	Refrigerant temperature point 4
PT1	Refrigerant pressure at point 1 & 4
PT2	Refrigerant pressure at point 2&3
AT1	Air temperature at point 1
AT2	Air temperature at point 2
AT3	Air temperature at point 3
AT4	Air temperature at point 4
AT5	Air temperature at point 5

AH1	Air relative humidity at point 1
AH2	Air relative humidity at point 2
AH3	Air relative humidity at point 3
AH4	Air relative humidity at point 4
AH5	Air relative humidity at point 5
FT1	Refrigerant flow rate
DP	Orifice differential pressure
COP	Coefficient Of Performance
˚C	degree Celsius
%	Percentage
s	second
kJ	kilo joule
Kg	kilogram
m	meter
L	litre
h	hour

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

An air conditioner is a home appliance system, or mechanism designed to dehumidify and extract heat from an area. The cooling is done using a simple refrigeration cycle. Refrigeration is a cyclic device and the working fluid used in the refrigeration cycle is called refrigerant such as R22, R134a, and R12. Basically it is consist of four main components which are condenser, evaporator, compressor and expansion valve.

Air conditioning is an answer to overcome thermal discomfort in a building especially country with hot and humid climate. However, air conditioning process requires large energy and most of the country have limited affordability. The challenge to the related researchers is to come out with effective strategies to overcome the state of discomfort with minimum energy usage (Md Zain Z, Taib M.N, and Md Shah Baki S., 2007).

Humidity is the quality of how much water or moisture content in the air. Relative humidity and specific humidity are frequently used in engineering and atmospheric science. The amount of moisture in the air has a definite effect of how comfortable we feel in an environment. This specific range of comfort ability is called thermal human comfort or comfort zone.

The history has shown that there are many experiments that has been done to determine comfort definitions and applicable thermal comfort standards to be used and has proven to be essential in the understanding of the basic human processes as they relate to the interaction with surrounding environments (M. M. Andamon, T. J. Williamson, and V. I. Soebarto. 2007). Thermal comfort and air quality will be determine using Psychrometric chart based on thermal comfort zone of human and server room.

Actual thermal comfort standards are based on laboratory studies carried out in climatic chambers, ignoring the complex interaction between occupants and their environments that could affect their comfort (Hussein I. 2009). In reality, people are comfortable in large range of conditions. This is because people are able to adapt to the environment that they are used to. There are three factors that can affect human comfort which are temperature, moisture content in air and air motion (Hussein I., Md Ibrahim M.I., Yusoff M.Z., Boosroh M.H). In this project, the temperature and humidity will be determined by taking a various speed of air using air conditioning unit fan.

1.2 PROBLEM STATEMENT

Human being desires a place which is comfortable for their body condition. They want to live in an environment that is hot or cold, humid or dry. Each of human is like a heat engine which is the energy input is food. Just like heat engine, human body will generates heat to be rejected from time to time. But each heat dissipated is different due to level of activity and size of the body. A body will be able to feel comfortable in an environment of their comfort.

Air conditioning process is a process to maintaining a place with the desired temperature and humidity. It can help to make human comfortable with the environment by providing suitable temperature and humidity. However, it is a problem for us to determine what are the optimum humidity and temperature for human comfort. What are the effect of speed towards humidification and dehumidification in maintaining thermal comfort and does the application of heater really affect the quality of air in a real world.

1.3 OBJECTIVES OF STUDY

i) To study the effect of air humidification and dehumidification towards quality of air using an air conditioning unit.
ii) To determine quality of air using Psychrometric chart based on thermal comfort zone.
iii) To analyze the effect of humidification and dehumidification towards quality of air.

1.4 SCOPE OF STUDY

i) This project covers humidification and dehumidification causes by humidifier, pre-heater and re-heater before and after the evaporator.
ii) This project is to find quality of air using Psychrometric chart based on ASHRAE standard thermal comfort zone.
iii) Air conditioning unit of FKM UMP will used for this experiment.

CHAPTER 2

LITERATURE REVIEW

2.1 AIR CONDITIONING

An air conditioner is a home appliance, system, or mechanism designed to dehumidify and extract heat from an area. The cooling is done using a simple refrigeration cycle. In construction, a complete system of heating, ventilation and air conditioning is referred to as HVAC. Air conditioning implies the total automatic control of the internal environment primarily for the comfort of humans. There are two laws that are significant to understand the basic refrigeration cycle and air conditioning which is thermodynamic first law and second law. Thermodynamic first law explains that energy cannot be neither created nor destroyed, but can be changed from one form to another (Yunus A. Cengel, Micheal A. Boles, 2007). Thermodynamics second law can help us better understand how the basic refrigeration cycle works. Once of these laws state that heat always flows from a material at a high temperature to a material at a low temperature. In the refrigeration process there are two sections which produce a pressure difference which is high pressure and temperature section (condenser) and a low-pressure and temperature section (evaporator). The refrigeration system removes heat from an area that is low-pressure, low temperature (evaporator) into an area of high-pressure, high temperature (condenser). A hot refrigerant from the compressor flows to a cooler location the condenser medium (air surround condenser), the refrigerant will give up the hot vapor heat it absorbs from the indoor evaporator and becomes cool again and turns back to liquid.

2.2 REFRIGERATION PROCESS

Refrigeration process consists of 4 stages as shown in Figure 2.1.

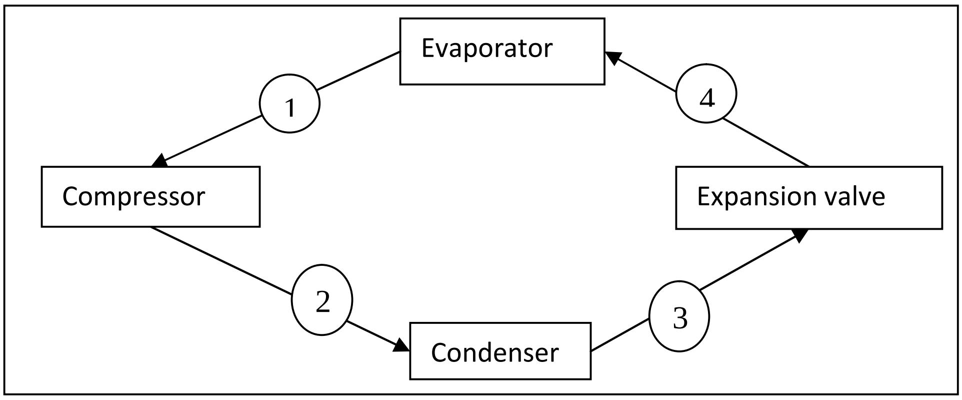

Figure 2.1 : Refrigeration cycle

i) Compression process (1 to 2)

Refrigerant gas R134a is at low pressure and low temperature. It will be compressed in order to bring back its liquid properties so that it can be use again in a cycle. Pressure and temperature will increase.

ii) Condensing process (2 to 3)

Refrigerant gasses leaves compressor at high pressure and temperature. To convert it to liquid, an amount of energy must be removed. It flow to condenser fan and is cooled down with condenser fan. Therefore heat is removed. Refrigerant is in liquid form.

iii) Expansion process (3 to 4)

Refrigerant loss it pressure due to restriction of expansion valve and and small portion of it vaporized into gas. Temperature and pressure is low.

iv) Vaporizing process (4 to 1)

The fluid to be cool down temperature is higher than refrigerant. So heat is transferred to refrigerant causing fluid became cooler. However the refrigerant boil causing it to vaporized and converted into gas.

2.3 REFRIGERANT

Refrigerant are the working fluids in refrigeration, air conditioning, and heat pumping systems. They absorb heat from one area, such as an air-conditioned space, and reject it into another such as outdoors, usually through evaporation and condensation (Ashrae, 2001). Refrigerant selection involves compromises between conflicting desirable thermodynamic properties. A refrigerant must satisfy many requirements, some of which do not directly relate to its ability to transfer heat. Chemical stability under conditions of use is the most important characteristic. The refrigerant should be non-flammable and non-toxic to avoid any unnecessary event. Next the coefficients of heat transfer and the viscosity should be conductive for good heat transfer rates. The refrigerant should be readily available, low in cost, and easily handled. Table 2.1 shows the chemical formula for common refrigerant. Refrigerant that can harm environment is ammonia, R12 and R22 because it contains chlorofluorocarbon (CFC) that can cause green house effect to earth. Meanwhile Table 2.2 shows the advantages and disadvantages each of the refrigerant commonly used.

NH_3 Ammonia	CCL_2F_2 R12	$CHCLF_2$ R22	CF_3CH_2F R134a

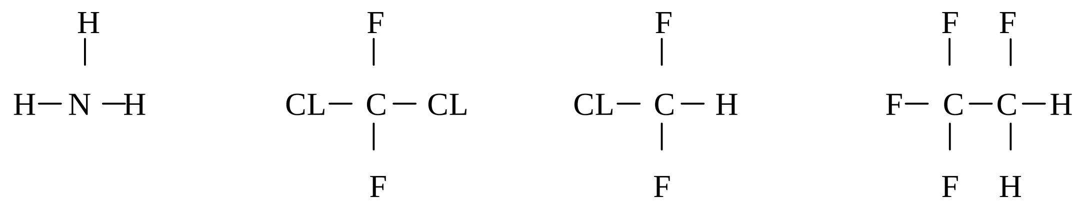

Table 2.1 : Chemical formula for refrigerant

Refrigerant	Boiling Temperature ^{o}C	Critical Temperature ^{o}C	Advantages	Disadvantages
Ammonia	-33	133	low cost low global warming potential	highly toxic flammable
R-12	-30	112	non flammable non corrosive Suitable for wide range of operating condition	It's a chlorofluorocarbon (CFC) which is danger to ozone Low refrigerating effect per weight
R-22	-41	96	non flammable non corrosive less effect on ozone higher refrigeration efficiency and lower power consumption	still affect the ozone layer
R-134a	-26	101	zero ozone depletion higher heat transfer coefficients	

Table 2.2 : Types of common refrigerant

Source : F. Porges (2001)

2.4 THERMAL COMFORT

Thermal comfort exist when an individual surrounded by an environment whose temperature and relative humidity allow the person to lose, with no conscious attempt, metabolic heat at the same rate he or she produces it (Y.H. Yau., 2008). Thermal comfort is affected by heat, convection, radiation and evaporative heat loss. It is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. There are three main factors that can affect the human comfort which are the effective temperature, moisture content of air also called relative humidity, and air motion. Comfort preferences are subjective but certain ranges of conditions accommodate the comfort sensations of a majority of people subject to a similar environment (Fuad H. Mallick, 1996). The tropical climate in Malaysia is hot and humid. Data obtained by the Malaysian Meteorological Service for ten-year period records the outdoor temperatures are relatively uniform with average temperatures between 23.7ºC to 31.3ºC throughout a day with the highest maximum recorded as 36.9ºC and the average relative humidity throughout a day between 67% to 95% (Hussein I., A Rahman M.H., 2009). In Malaysia, some buildings built have traditionally relied on a combination of cross-ventilation and mechanical ventilation by fans to achieve thermal comfort, such as in schools and other older buildings. Figure 2.2 shows ASHRAE standard thermal comfort zone that are being used by HVAC engineer nowadays.

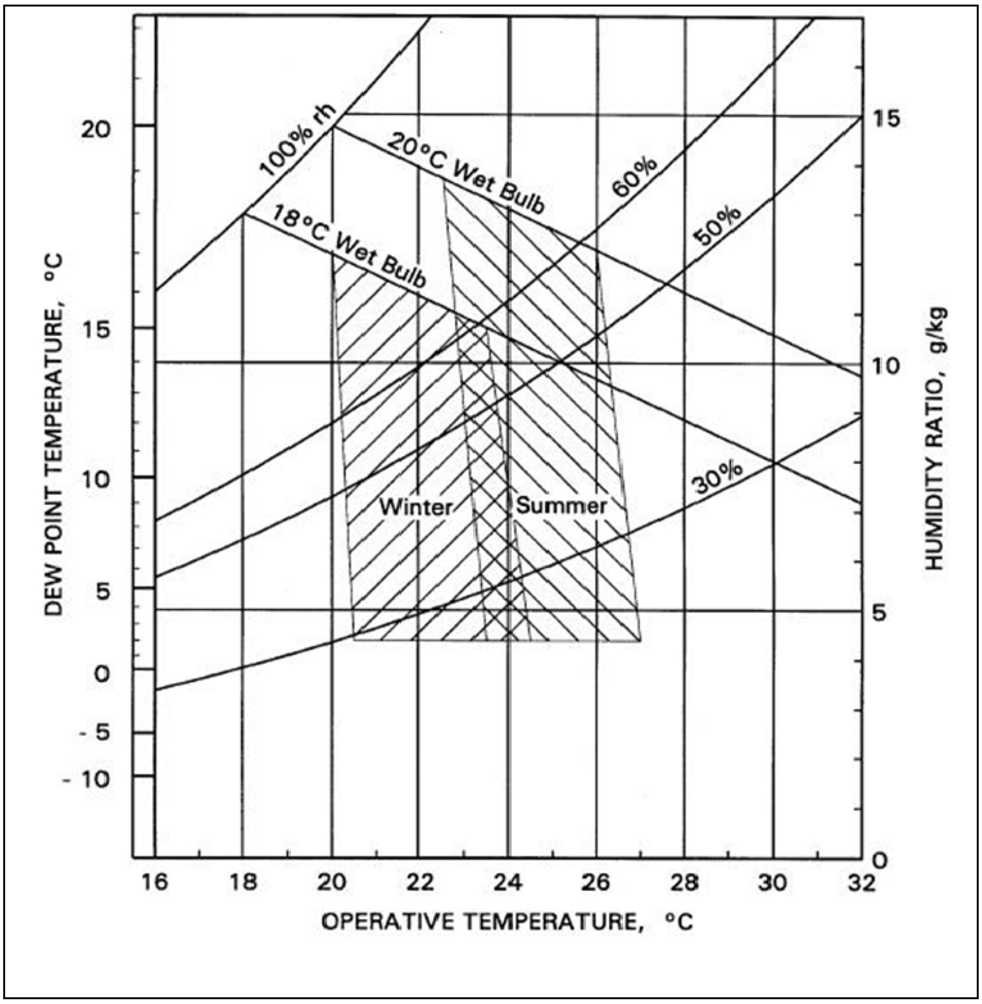

Figure 2.2 : Thermal comfort zone

Source : ASHRAE (2001)

2.5 PSYCHROMETRIC CHART

A Psychrometric chart graphically represents the thermodynamic properties of moist air. A chart with coordinates of enthalpy and humidity ratio provides easy graphical solutions of many moist air problems with a minimum of thermodynamic approximations. Although the principles of psychrometry apply to any physical system consisting of gas-vapor mixtures, the most common system of interest is the mixture of water vapor and air, because of its application in heating, ventilating, and air-conditioning.

Dry bulb temperature (T_{db}) refers basically to the ambient air temperature. It can be measured using a normal thermometer exposed to the air but covered from radiation and moisture. The wet bulb temperature (T_{wb}) is the temperature of adiabatic saturation. This is the temperature indicated by a moistened thermometer bulb exposed to the air flow. The wet bulb temperature is always lower than the dry bulb temperature but will be identical with 100% relative humidity.

Next is dew point temperature (T_{dp}) which water vapor starts to condense out of the air. If the dew-point temperature is close to the dry air temperature the relative humidity is high if the dew point is well below the dry air temperature the relative humidity is low. Meanwhile enthalpy (h) is the total energy of both the dry air and water vapor per weight of dry air. Specific volume per unit mass of dry air (V) is the total volume of both the dry air and water vapor per weight of dry air.

The amount of water vapor in the air can be specified in various ways. Most logical way is to specify directly the mass of water vapor present in a unit mass of dry air. This is called specific humidity (Φ). It can be calculate by using Eq. (2.1) below. Where P_v is vapor pressure and P is pressure.

$$\Phi = \frac{0.622\, Pv}{P - Pv} \tag{2.1}$$

Relative humidity (ω) is a term used to describe the amount of water vapor in a mixture of air and water vapor. It is defined as the ratio of the partial pressure of water vapor in the air-water mixture (e_w)to the saturated vapor pressure of water (e^*_w). The relative humidity of air depends not only on temperature but also on pressure of the system. Relative humidity is normally expressed as a percentage and is calculated by using the Eq. (2.2).

$$\omega = (e_w / e^*_w) \text{ X } 100 \tag{2.2}$$

Figure 2.3 shows the instruction on how to read the Psychrometric chart.

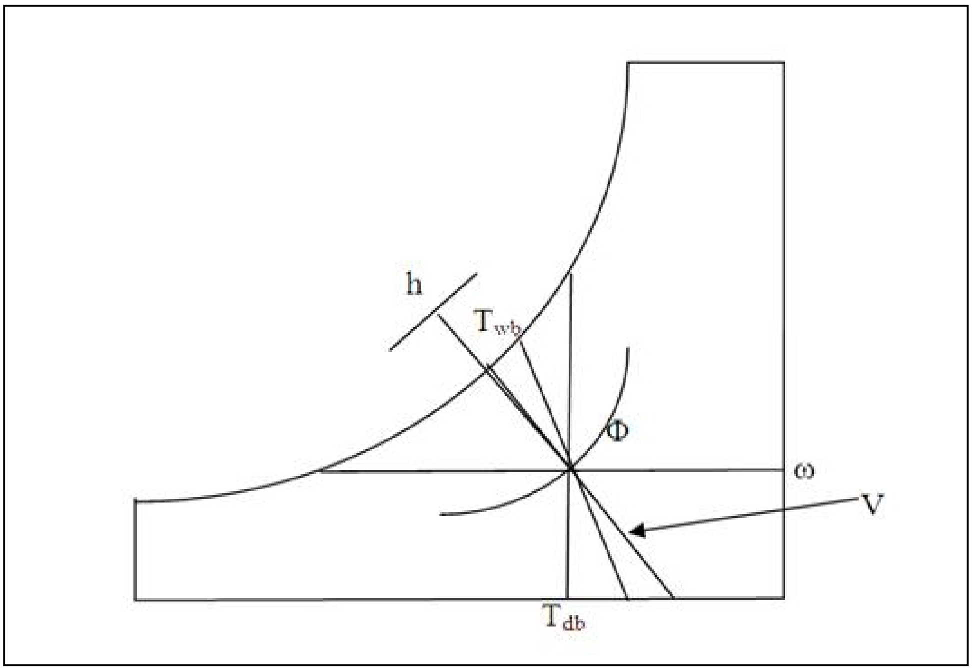

Figure 2.3: Psychrometric chart instruction
Source : Yunus A. Cengel and Micheal A. Boles (2007)

2.6 TYPES OF AIR CONDITIONING

There are various types of air conditioning systems. The application of a particular type of system depends on few factors like how large the area is to be cooled, the total heat produced inside the building or how much power is needed to cooled an area with many peoples.

2.6.1 Window Unit Air Conditioning System.

Window air conditioners are one of the most commonly used and cheapest types of air conditioners. A slot is needed at the wall for placing the unit and there should also be some open space behind the wall. Figure 2.4 shows block diagram for this type of air conditioning and commonly only consist of one unit body. Table 2.3 shows the advantages and disadvantages of window unit air conditioning system.

Advantages	Disadvantages	Application
Low in cost	Noisy in the room	Small building
Flexible	Poor control	Individual room
Simple		

Table 2.3 : Advantages and disadvantages of window unit air conditioning

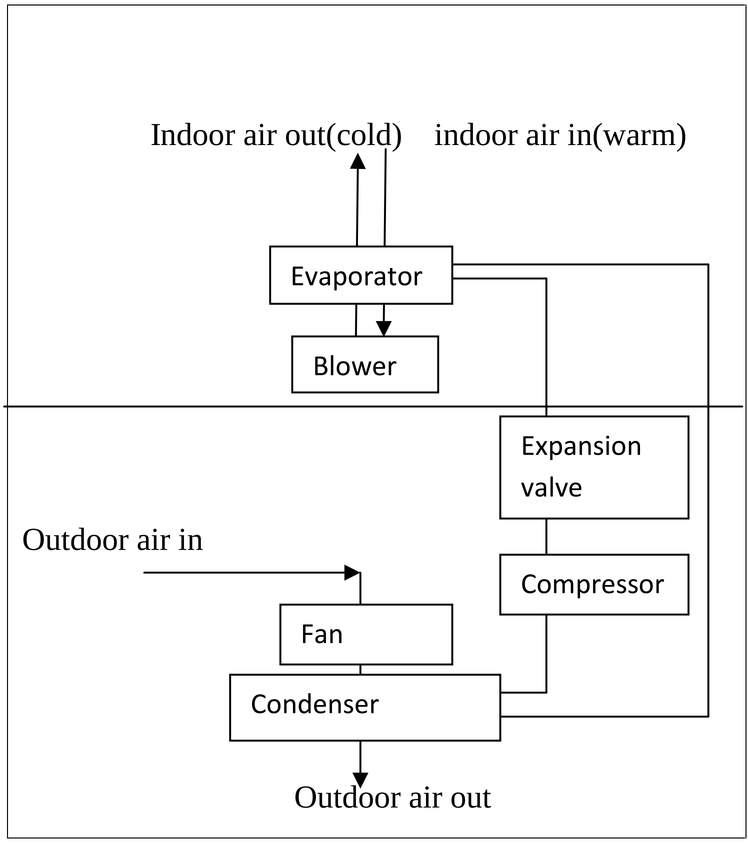

Figure 2.4 : Window unit system

2.6.2 Split Unit System

The split air conditioner consists of two main parts which are the outdoor unit and the indoor unit. The outdoor unit is placed outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit consist the evaporator or cooling coil and the cooling fan. The component and its system can be refers in Figure 2.5. Meanwhile Table 2.4 shows advantages, disadvantages and application for split unit system.

Advantages	Disadvantages	Application
Indoor unit can be ceiling mounted Simple	Restriction on length of piping between indoor and outdoor unit (heat loss) Limited fresh air supply	Small shops Small building Individual room

Table 2.4 : Advantages and disadvantages of split unit air conditioning

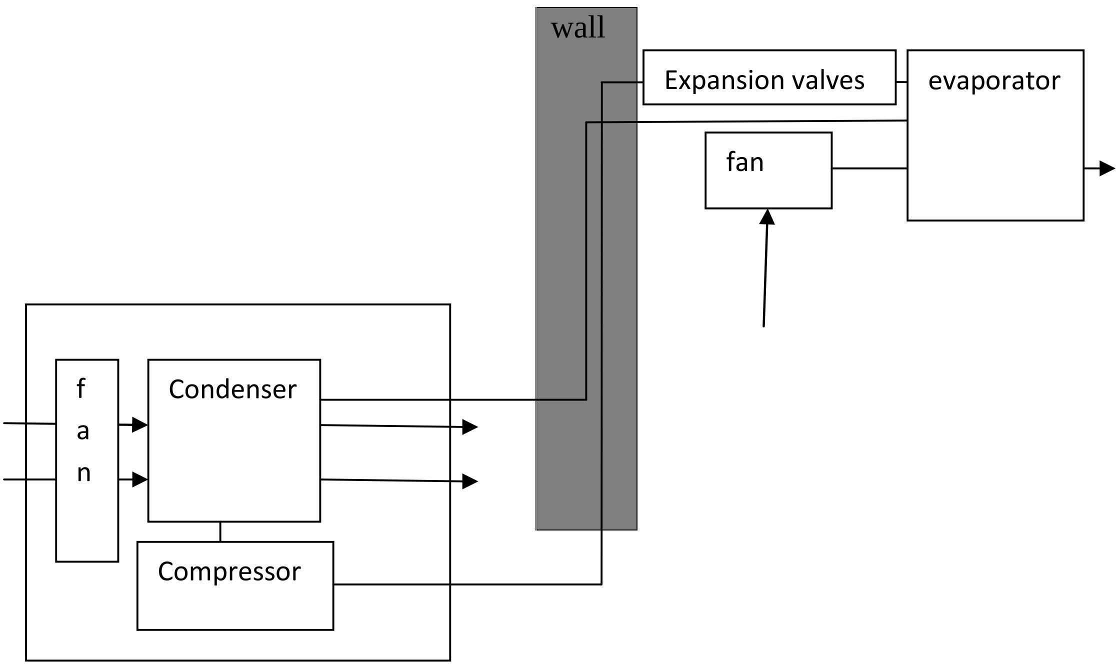

Figure 2.5 : Split unit system

2.6.3 Air Cooled Direct System

Based in Figure 2.6, an air cooled direct system is consists of two main parts. One part is installed at building roof meanwhile the other is install directly in the room. This type of system need a proper installation because heat loss will occur during refrigerant flow at piping section as stated is Table 2.5.

Advantages	Disadvantages	Application
Low cost Maintenance easy	Refrigerant piping must be installed properly Limited piping to avoid heat loss	Room Computers room

Table 2.5 : Advantages and disadvantages of air cooled direct system air conditioning

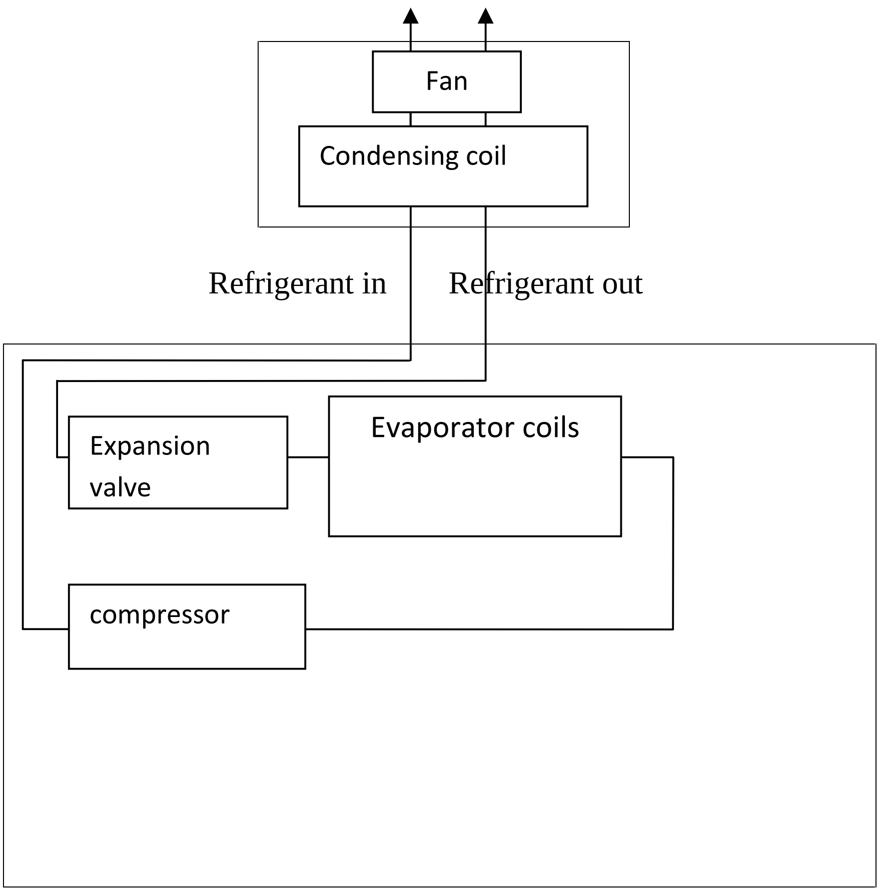

Figure 2.6 : Air cooled direct system

2.6.4 Water Cooled System

Water cooled system is using water to collect and transfer heat from room to the environment. In the room the refrigeration system will absorb heat from the environment and send it to heat exchanger as shown in Figure 2.7. Then the heat will be collected by the water and carried out to cooling tower to be rejected before the water return back to the room to collect heat again. Table 2.6 shows the detail about water cooled system air conditioning.

Advantages	Disadvantages	Application
Refrigerant is sealed in room unit only (low cost) Water can run easily much longer distance (longer pipes)	High initial cost for cooling tower, pump and piping Very high maintenance for cleaning and water treatment	Room Computers room

Table 2.6 : Advantages and disadvantages of water cooled system

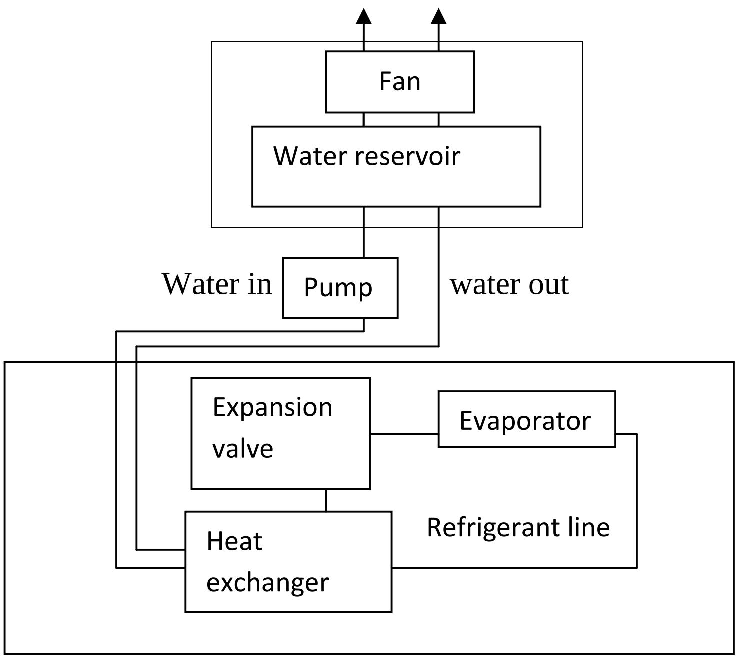

Figure 2.7: Water cooled system

2.6.5 Air Handling Unit System (AHU)

Air handlers usually connect to ductwork that distributes the conditioned air through the building and returns it to the AHU. Figure 2.8 shows the block diagram for AHU.

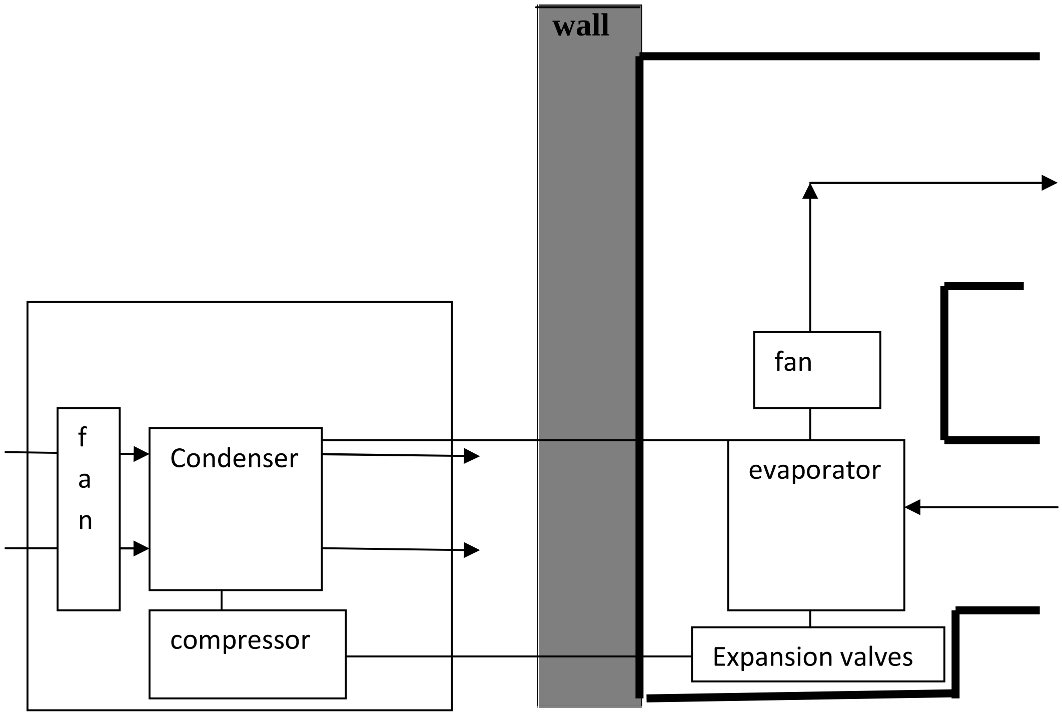

Figure 2.8 : Air handling unit (AHU)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter provide on a step by step review to complete the objective and scope of project entitled a study of humidity effect toward the quality of air from air conditioning system. First step started by introduction to air conditioning unit Faculty of Mechanical Engineering University Malaysia Pahang (UMP). Every component of the air conditioning unit is recognized and examined to ensure the ability of the unit so that the objective of this project can be achieved. Secondly, instrument that will be used to determine the quality of air and human thermal comfort will be studied. The instrument that will be used is Psychrometric chart. Then the experiment will be initially started by switching on the humidifier. Each of pre-heater and re-heater will be switch on and off to determine effect of dehumidification towards temperature and humidity. And three speed of air motion will be used by adjusting the speed of fan. After that, each of humidity and temperature from the outlet of air conditioning unit will be used to plot at Psychrometric chart to determine its thermal comfort. Coefficient of performance (COP) of refrigeration also will be calculated to determine performance of refrigeration system against temperature and humidity.

3.2 FLOW CHART

To accomplish the objective of this experiment, an experiment will be conducted at the laboratory and the data obtained will be analyze. Hence, a flow chart shown in Figure 3.1 has been created in order to accomplish the objective of this project.

PROJECT FLOW CHART

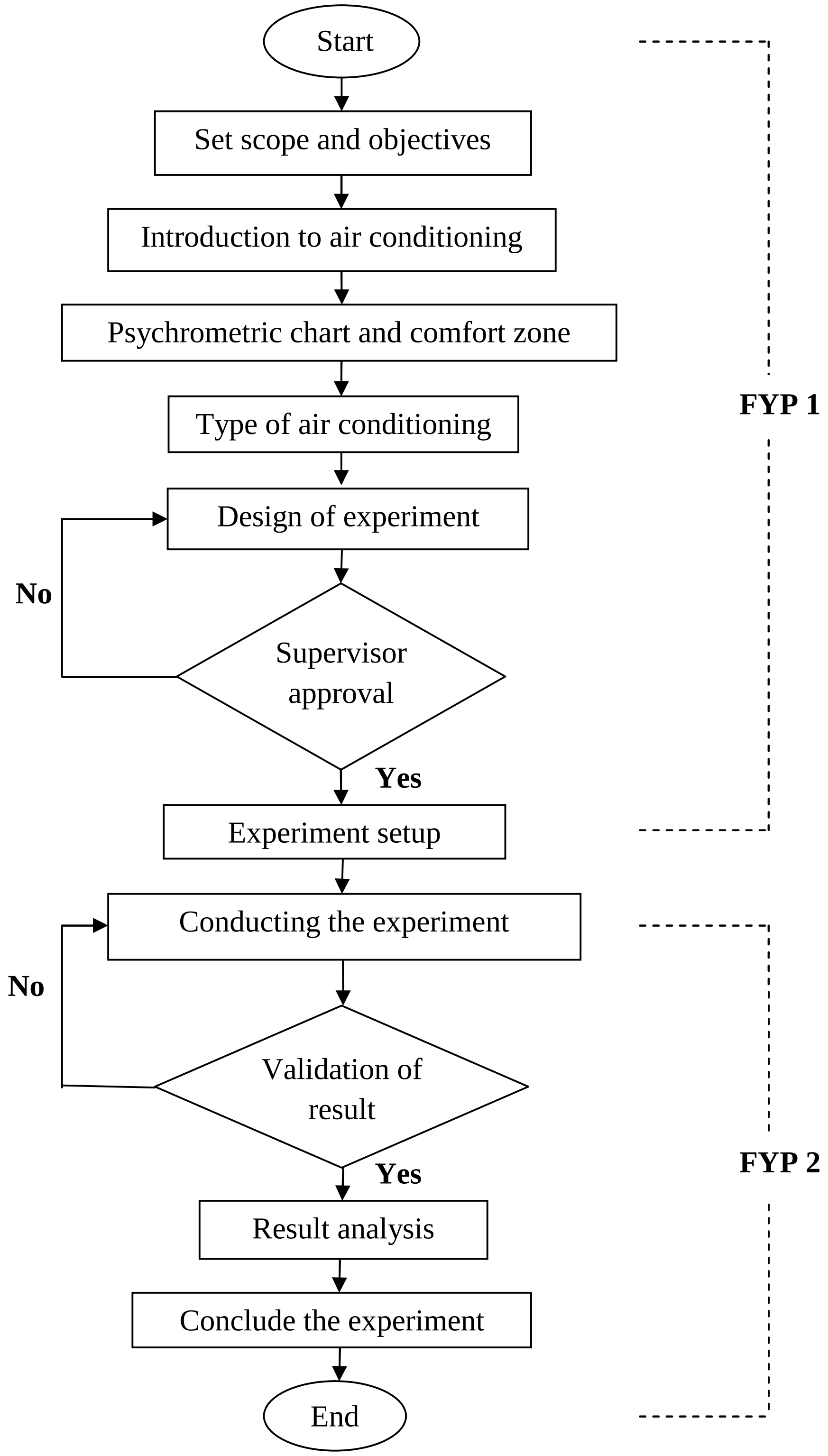

Figure 3.1 : Flow chart for Final Year Project

3.3 AIR CONDITIONING UNIT FKM UMP

Equipment shown in Figure 3.2 is an air conditioning unit FKM UMP. Each part in the figure was labeled and can be viewed in Table 3.1. Three velocity of fan will be used to determine effect of air motion to temperature and humidity. Then pre-heater and re-heater provided before and after evaporator will be switch on and off to obtain effect of dehumidification towards temperature and humidity. Temperature and humidity will be recorded at 5 points of the equipment as shown in Figure 3.2 below. Then the quality of air will be determined using temperature and humidity at point after re-heater.

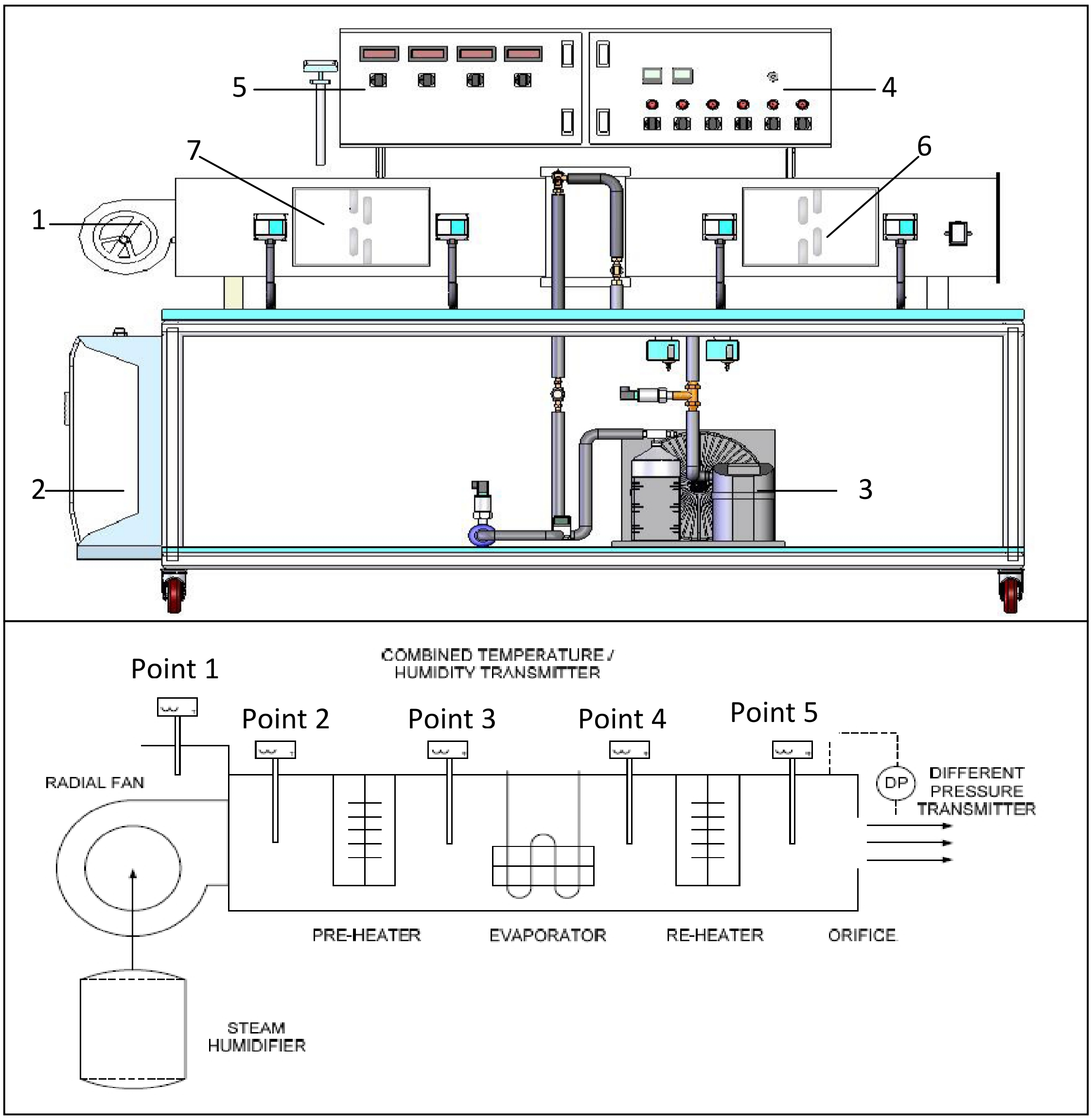

Figure 3.2 : Air conditioning training unit

No	Part name	Function and details
1	Radial fan	To increase air velocity. The air volume flow can be adjusted by using speed adjuster at control panel.
2	Steam humidifier	Provide moisture to humidify air conditioning unit. The steam air humidifier has an electric power consumption of 2 kW.
3	Refrigeration system	To chill the air that went through the evaporator. The refrigeration unit circulates the refrigerant R134a.
4	Control panel	For controlling each function of parts such as fan speed, humidifier, pre-heater and re-heater.
5	Indicator	Indicator that showing each result of each point so that temperature and humidity of each point can be determine.
6	Re-heater	Function as a dehumidifier of moisture provided from humidifier. The pre-heater consists of four electric air heaters, each with an output of 0.25 kW.
7	Pre-heater	Function is identical to re- heater. The pre-heater consists of four electric air heaters, each with an output of 0.5 kW.

Table 3.1 : Component of air conditioning training unit

3.4 PSYCHROMETRIC CHART AND THERMAL COMFORT ZONE

Psychrometric chart is used for determine the state of air in the air conditioning system. The change of the state of the air causes by humidifying and dehumidifying can be plotted. This chart variable can be view at Figure 2.3 in Chapter 2. To determine the quality of air, each of the humidity and temperature recorded will be plotted in Psychrometric chart. The value of humidity and temperature that will be used is the value at point 5 which is at the outlet of the air conditioning valve. If the humidity and temperature is in the range of thermal comfort zone, then the quality of air is high and comfortable for human.

3.5 EXPERIMENT SETUP

Experiment is done without making any modification to the parts of air conditioning unit. The experiment procedure can be referred at Figure 3.3 where experiment is done by giving different value of fan speed to obtain the effect of air motion to air quality. Meanwhile Table 3.2 show the experiment summary in table form.

3.5.1 Start up procedure

i) Check the condition of the air conditioning unit by performing quick inspection.
ii) The humidifier water supply must be connected to a tap water source.
iii) Turn on the power supply switch
iv) Switch on the main power switch for the air conditioning unit.
v) Proceed the experiment when all of the above is done.

3.5.2 Shut down procedure

i) Switch off the pre-heater and re-heater and let both heaters to be cooled down.

ii) Turn off the fan speed control knob then the fan switch.

iii) Switch off all of the control switch then the main switch and power supply.

iv) Close the water tap supply.

3.5.3 Safety precaution

i) Always check the water or refrigerant whether leakage is occurred.

ii) Do not touch the hot component of the unit.

iii) Make sure that the fan guard is properly installed to prevent damage.

iv) Ensure the humidifier water supply is connected to a tap water source.

3.5.4 Experiment procedure

Switch on the fan.

↓

Run the velocity of the fan at 50 % of its maximum speed

↓

Switch on the refrigeration unit

↓

Wait for approximately 10 minutes for the system to reach steady state

↓

Record temperature of the refrigeration circuit.

Record each temperature and each humidity at eachair conditioning indicator

↓

Repeat experiment by :

1) Turn on the pre heater
2) Turn pre-heater off and switch re-heater on
3) Both pre-heater and re-heater switch on
4) Repeat step 1 2 3 by switch on the humidifier

↓

Repeat all steps above using fan speed of 75% and 100% of its maximum speed

Figure 3.3 : Experimental procedure

Fan speed	Humidifier	Pre-heater	Re-heater
50 %	Off	Off	Off
	Off	On	Off
	Off	Off	On
	Off	On	On
	On	Off	Off
	On	On	Off
	On	Off	On
	On	On	On
75%	Off	Off	Off
	Off	On	Off
	Off	Off	On
	Off	On	On
	On	Off	Off
	On	On	Off
	On	Off	On
	On	On	On
100%	Off	Off	Off
	Off	On	Off
	Off	Off	On
	Off	On	On
	On	Off	Off
	On	On	Off
	On	Off	On
	On	On	On

Table 3.2 : Experiment procedure summary

3.6 DATA COLLECTION AND ANALYSIS

3.6.1 Experimental data

Experiment will conducted using air conditioning unit FKM UMP at the thermodynamic lab. 24 experiments will be conducted and each of experiment will be done in direct situation which is same temperature and condition. The result that will be collected is as shown in Table 3.3 below.

Data to collect	Unit of measurement
Refrigerant temperature at point 1, TT1	˚C
Refrigerant temperature at point 2, TT2	˚C
Refrigerant temperature at point 3, TT3	˚C
Refrigerant temperature at point 4, TT4	˚C
Air temperature at point 1, AT1	˚C
Air temperature at point 2, AT2	˚C
Air temperature at point 3, AT3	˚C
Air temperature at point 4, AT4	˚C
Air temperature at point 5, AT5	˚C
Air relative humidity at point 1, AH1	%
Air relative humidity at point 2, AH2	%
Air relative humidity at point 3, AH3	%
Air relative humidity at point 4, AH4	%
Air relative humidity at point 5, AH5	%
Refrigerant pressure at point 1 & 4, PT1	bar
Refrigerant pressure at point 2 & 3, PT2	bar
Refrigerant flow rate, FT1	L/h
Orifice differential pressure, DP	Pa

Table 3.3 : Results to be collect during experiment

3.6.2 Analysis

Each of the result obtained will then be analyzed based on each experiment. To analyze the effect of dehumidification towards quality of air, various graphs will be plotted to determine the humidification and dehumidification effect towards temperature and relative humidity. 24 experiments will be conducted each experiment will be group into 4 group each and in this 4 group it will be divided to 6 experiment per group. Each group consists of different situation given to study the effect of humidifier, pre-heater and re-heater towards air quality. Then to determine the effect of humidifying and dehumidifying to refrigeration process, COP of each experiment will be calculate and graph of COP against fan speed will be plotted. Then for cooling process occur at evaporator, the amount of heat transfer of the air will be calculate using energy balance equation and the result will be plot against fan speed.

i) Graph temperature, ˚C versus point

Graph of temperature is plotted to determine the effect of humidifying and dehumidifying process towards temperature of each point. Every slightly change in temperature will be observe for each experiment. Effect of humidifier, pre-heater and re-heater can be observed at this graph where it will gives different pattern of graph for each group experiment. Experiment A and B is done with pre-heater and re-heater off. Experiment C and D is done by switch on the pre-heater and re-heater is switch off. Experiment E and F is done by switch off pre-heater and switch on the re-heater. As for experiment G and H is done with both pre-heater and re-heater on.

ii) Graph relative humidity, % versus point

Graph of humidity is plotted to determine the effect of humidifying and dehumidifying process towards humidity of each point. Every slightly change in humidity will be observe for each experiment. Effect of humidifier, pre-heater and re-heater can be observed at this graph where it will gives different pattern of graph for each group experiment. Experiment A and B is done with pre-heater and re-heater off. Experiment C and D is done by switch on the pre-heater and re-heater is switch off. Experiment E and F is done by switch off pre-heater and switch on the re-heater. For experiment G and H is done with both pre-heater and re-heater on.

iii) Graph COP versus fan speed

The coefficient of performance (COP) is calculated using the ideal vapor compression refrigeration cycle. The vapor compression refrigeration cycle is the most widely used for refrigerator and air conditioning unit. The purpose of analysis is to find the effect of air velocity to refrigeration performance and what will happen if humidifier is turned on or off to the refrigeration process. Eq. (3.1) shows how to calculate coefficient of performance for refrigerant. Value of h can be found in P-h diagram at Appendix C1.

$$COP = (h1-h4) / (h2-h1) \qquad (3.1)$$

iv) Heat transfer analysis (cooling process)

The cooling process that occur at the evaporator is analyze by using energy balance equation. The value of heat being transfer is the heat of the air that through the duct. Thus this analysis is to find the effect of air velocity in the duct to heat transfer by the air. The point taken is at point 3 to point 4 where the evaporative process occurs. Eq. (3.3) shows the equation used to calculate value of Q that has been transferred. Psychrometric chart is used to find enthalpy and others variable that needed to find the heat transfer.

Energy balance : $\sum_{in} \dot{m}h = \dot{Q} + \sum_{out} \dot{m}h$ (3.2)

: $\dot{Q} = \dot{m}$ (h3-h4) - $\dot{m}$h (water) (3.3)

v) Finding air quality using thermal comfort zone standard

The quality of air can be found by plotting the value of relative humidity and temperature at the outlet air temperature which is at point 5. By using the value obtained from the experiment, using thermal comfort zone we can finally find the level of thermal comfort of the air at various condition of air conditioning. CYTsoft Psychrometric is used to obtain an accurate value of plotted point. If the temperature and the humidity from point 5 in the range of thermal comfort, thus the air quality is high and the temperature is suitable for human to feel comfortable. Figure 3.4 shows the Psychrometric chart with thermal comfort zone that has been plotted.

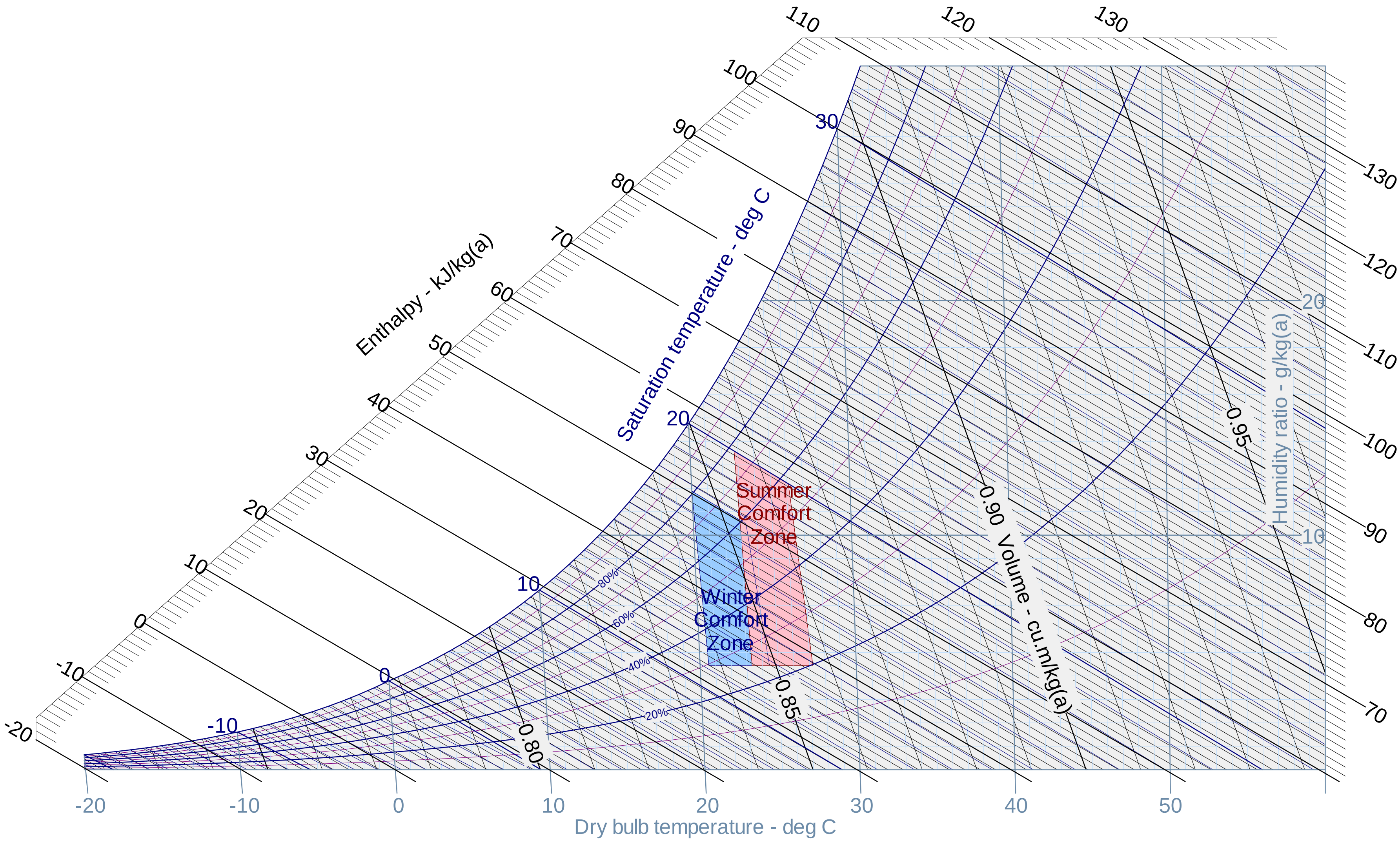

Figure 3.4 : Psychrometric with plotted thermal comfort

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this research, the experiment is done using different speed of air conditioning unit fan. 24 different experiments been done and speed used are 50%, 75%, and 100% of the fan speed. Half of the experiments were done by switch on the humidifier and the other half is otherwise. Then pre-heater and re-heater provided before and after evaporator will be switch on and off to obtain effect of dehumidification towards temperature and humidity. Temperature and humidity will be recorded at 5 points of the equipment. Then various graphs will be plotted to determine the effect of humidification and dehumidification toward refrigeration performance and quality of air.

4.2 RESULT AND ANALYSIS

The experiment conducted using different fan speed. Using anemometer, the value of 50, 75 and 100% fan speed is 0.8 m/s, 1.4 m/s and 1.8 m/s. For experiment A, humidifier, pre-heater and re-heater is turned off and as for experiment B, pre-heater and re-heater is still turned off but the humidifier is on. Experiment C was conducted with pre-heater on but humidifier and re-heater is turned off. Same goes to experiment D but it is run by turning on the humidifier. For experiment E and F, pre-heater is turned off and the re-heater is turned on with humidifier off for experiment E and humidifier on for experiment F. Lastly experiment G and H is conducted by turning on humidifier, pre-heater and re-heater.

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (°C)		Air Temperature (°C)		Relative humidity, %
50 %	0.8 m/s	47 L/h	Off	Off	Off	PT1	3.79	TT1	28.3	T_1	29.8	59.9
						PT2	12.91	TT2	67.0	T_2	30.5	56.0
								TT3	46.9	T_3	30.4	57.1
								TT4	17.8	T_4	25.1	87.7
										T_5	25.4	87.0
75 %	1.4 m/s	46 L/h	Off	Off	Off	PT1	4.10	TT1	28.7	T_1	28.5	73.6
						PT2	13.3	TT2	65.6	T_2	29.5	66.8
								TT3	48.0	T_3	29.0	67.8
								TT4	20.8	T_4	24.3	90.0
										T_5	24.4	88.9
100 %	1.8 m/s	44 L/h	Off	Off	Off	PT1	3.91	TT1	27.1	T_1	26.1	73.5
						PT2	12.44	TT2	63.2	T_2	28.2	66.2
								TT3	45.2	T_3	27.9	66.9
								TT4	19.4	T_4	22.9	89.7
										T_5	22.5	88.7

Table 4.1 : Data for experiment A(humidifier off, pre-heater off, re-heater off)

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (^oC)		Air Temperature (^oC)		Relative humidity, %
50 %	0.8 m/s	54 L/h	On	Off	Off	PT1	4.39	TT1	31.5	T_1	32.0	61.4
						PT2	14.8	TT2	71.6	T_2	33.5	67.5
								TT3	52.8	T_3	33.4	69.3
								TT4	23.4	T_4	26.9	91.3
										T_5	26.8	91.4
75 %	1.4 m/s	53 L/h	On	Off	Off	PT1	4.32	TT1	29.0	T_1	28.5	62.4
						PT2	13.68	TT2	67.5	T_2	30.4	69.7
								TT3	49.1	T_3	30.4	72.7
								TT4	22.2	T_4	25.4	92.9
										T_5	25.4	90.8
100 %	1.8 m/s	50 L/h	On	Off	Off	PT1	4.36	TT1	29.9	T_1	27.9	65.9
						PT2	14.0	TT2	72.9	T_2	30.0	73.7
								TT3	49.9	T_3	29.9	76.5
								TT4	22.2	T_4	25.0	96.7
										T_5	25.0	95.2

Table 4.2 : Data for experiment B (humidifier on, pre-heater off, re-heater off)

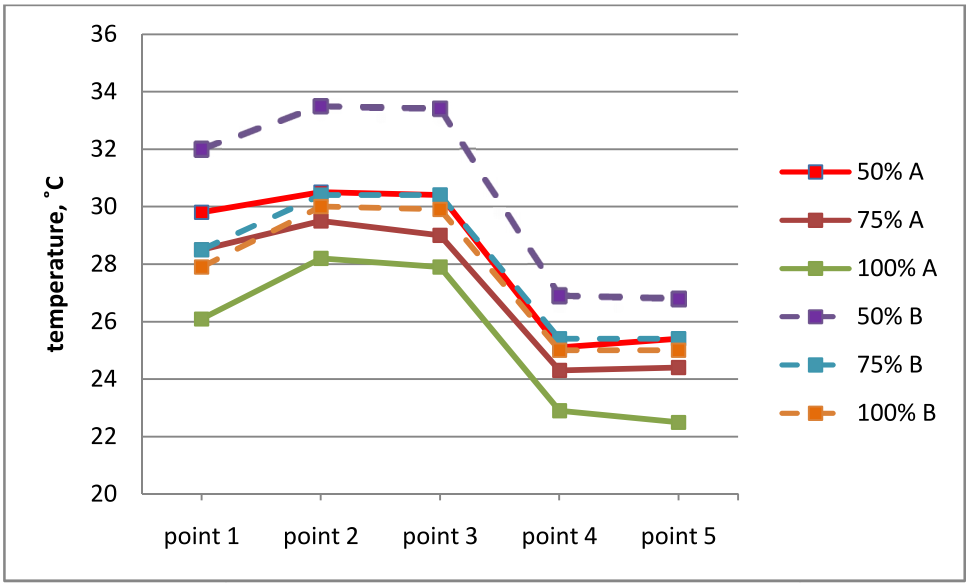

Figure 4.1 : Graph temperature versus point experiment A and B

For experiment A, the humidifier, pre-heater and re-heater were turned off. Without turning on the humidifier, this means that no humidity is supplied at starting point of the experiment meanwhile experiment B, the humidifier is turned on, pre-heater and re-heater is off. This process is called humidification by supplying humidity to the system. Comparing both results, fan speed of 50% for experiment B has the highest temperature compare to others. This is because when the humidity supplied by humidifier is made of water vapor which is high in temperature and humidity. By referring to Figure 4.1, increment in temperature occur at point 1 to point 2 due to difference in environment temperature at inlet with temperature inside the duct. Point 2 to point 3 shows the temperature is unchanged because the pre-heater were turned off. Meanwhile at point 3 to point 4, there were a drastic decrement due to the existence of evaporator. For point 4 to point 5, no slight differences can be found because the re-heater is turned off.

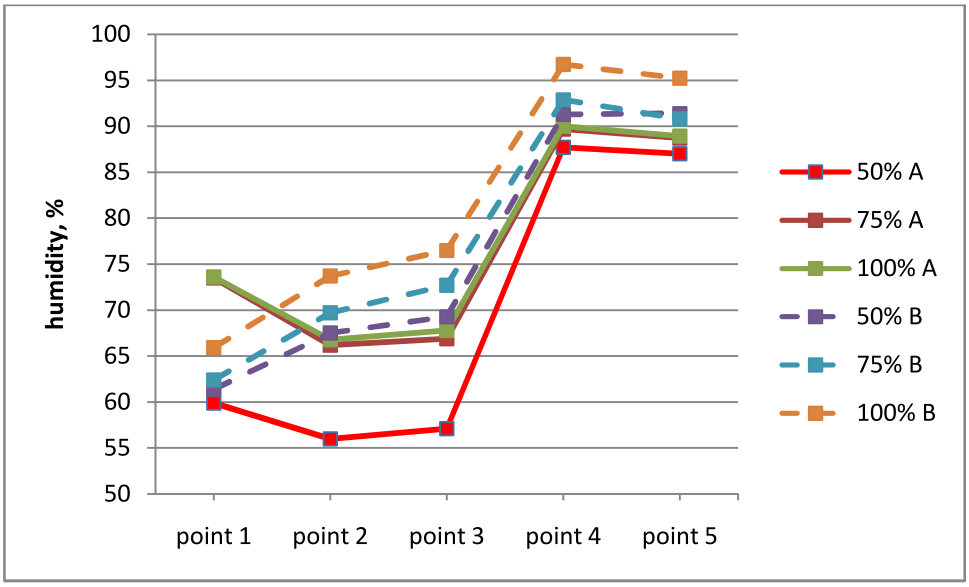

Figure 4.2 : Graph relative humidity versus point experiment A and B

For graph humidity in Figure 4.2, experiment B gives a direct jump in humidity due to humidity supplied by the humidifier. The humidity for experiment B is increasing until point 3. Both of the experiment doesn't have any dehumidifying process occur because the pre-heater is turned off. Thus no humidity decreased for both experiments. For point 3 to point 4, value of humidity increase drastically at one point because of the existence of the evaporator that absorb heat from the air. However for point 4 to 5, no changes occur because the re-heater is turned off.

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (^oC)		Air Temperature (^oC)		Relative humidity, %
50 %	0.8 m/s	45 L/h	Off	On	Off	PT1	3.98	TT1	28.2	T_1	30.4	57.5
						PT2	13.45	TT2	72.8	T_2	31.9	53.5
								TT3	48.6	T_3	33.3	51.1
								TT4	18.8	T_4	26.4	86.8
										T_5	26.6	86.5
75 %	1.4 m/s	45 L/h	Off	On	Off	PT1	4.21	TT1	30.8	T_1	29.5	69.1
						PT2	13.9	TT2	75.0	T_2	31.4	62.2
								TT3	49.6	T_3	32.2	59.2
								TT4	21.4	T_4	25.7	86.1
										T_5	25.8	85.0
100 %	1.8 m/s	44 L/h	Off	On	Off	PT1	4.03	TT1	30.5	T_1	27.7	71.9
						PT2	13.15	TT2	72.8	T_2	29.3	65.2
								TT3	47.2	T_3	31.9	62.4
								TT4	19.8	T_4	24.5	81.8
										T_5	24.6	81.0

Table 4.3 : Data for experiment C (humidifier off, pre-heater on, re-heater off)

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (°C)		Air Temperature (°C)		Relative humidity, %
50 %	0.8 m/s	54 L/h	On	On	Off	PT1	4.63	TT1	32.0	T_1	32.6	62.8
						PT2	15.50	TT2	78.5	T_2	34.8	59.1
								TT3	54.8	T_3	35.5	59.8
								TT4	23.8	T_4	26.8	91.2
										T_5	26.8	89.8
75 %	1.4 m/s	49 L/h	On	On	Off	PT1	4.44	TT1	31.8	T_1	30.0	66.8
						PT2	14.47	TT2	75.9	T_2	32.1	62.5
								TT3	51.1	T_3	34.4	58.4
								TT4	22.4	T_4	27.0	87.9
										T_5	27.1	85.7
100 %	1.8 m/s	49 L/h	On	On	Off	PT1	4.44	TT1	31.8	T_1	29.8	67.9
						PT2	14.43	TT2	76.0	T_2	31.8	64.3
								TT3	51.2	T_3	34.1	59.3
								TT4	22.8	T_4	27.2	86.5
										T_5	27.2	84.4

Table 4.4 : Data for experiment D (humidifier on, pre-heater on, re-heater off)

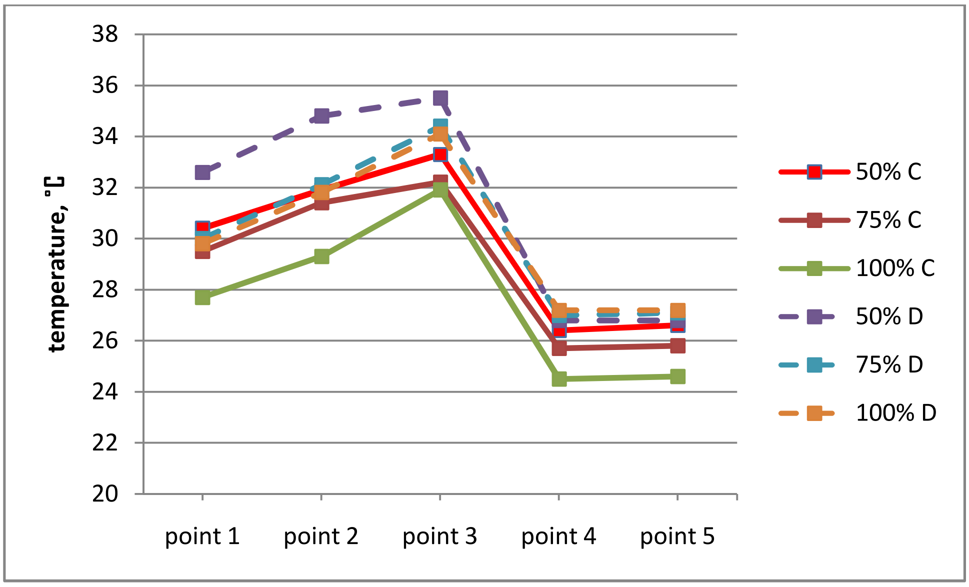

Figure 4.3: Graph temperature versus point experiment C and D

In experiment C, humidifier is turned off and the pre-heater which is installed before the evaporator is switch on meanwhile re-heater installed after the evaporator is switch off. Meanwhile experiment D is conducted by switch on the humidifier and pre-heater while re-heater is turned off. Figure 4.3 shows the value of 50% fan speed with humidifier on gives the highest value temperature than others. Meanwhile 100% fan speed with absence of humidity supplied by humidifier is the most low in temperature. By referring to the graph pattern, there was an increment at point 2 to point 3. This is because the pre-heater is turned on and increase heat of air inside the duct. Then the temperature dropped at point 3 to point 4 due to cooling process at the evaporator. For point 4 to point 5, no change can be seen as the result of re-heater is turned off.

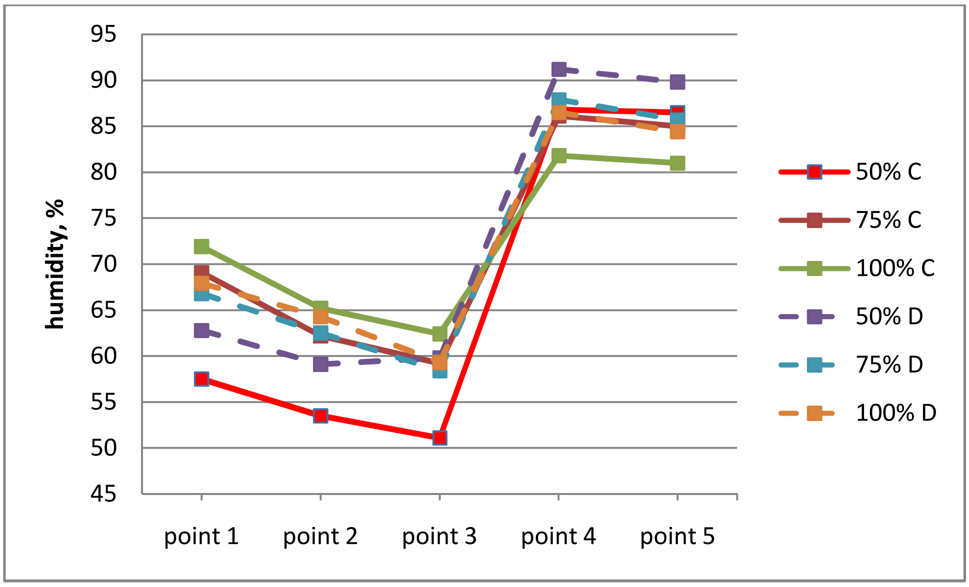

Figure 4.4 : Graph relative humidity versus point experiment C and D

For graph humidity, experiment with humidifier off show a great value of humidity compare to others. Based from the data obtained, decreasing in relative humidity can be seen at point 2 to point 3. This is because the pre-heater is turned on and this process is called dehumidification process where the humidity is being heated thus give a more comfortable temperature and also humidity. However, by referring at Figure 4.4, for experiment C with humidifier off the humidity causes by fan speed 100% after the point 3 are more humid than 50% and 75% of fan speed. This is because, while conducting this experiment, the weather suddenly change from rainy to sunny and causing the ambient humidity to decrease rapidly. But we still can see the uniform change of pattern of temperature and humidity from each point.

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (°C)		Air Temperature (°C)		Relative humidity, %
						PT1	4.04	TT1	28.3	T_1	30.5	61.3
						PT2	13.88	TT2	74.0	T_2	31.7	56.5
50 %	0.8 m/s	46 L/h	Off	Off	On			TT3	49.5	T_3	31.1	55.9
								TT4	19.5	T_4	25.4	85.9
										T_5	30.3	59.4
						PT1	4.14	TT1	30.5	T_1	29.5	69.5
						PT2	13.81	TT2	72.4	T_2	31	65.3
75 %	1.4 m/s	46 L/h	Off	Off	On			TT3	49.2	T_3	30.7	66.4
								TT4	20.9	T_4	24.6	85.8
										T_5	29.6	64.4
						PT1	3.85	TT1	28.3	T_1	27.3	70.5
						PT2	12.76	TT2	69.4	T_2	28.9	66.4
100 %	1.8 m/s	44 L/h	Off	Off	On			TT3	45.8	T_3	28.6	67.3
								TT4	18.5	T_4	23.3	86.8
										T_5	28.0	64.7

Table 4.5 : Data for experiment E (humidifier off, pre-heater off, re-heater on)

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (^oC)		Air Temperature (^oC)		Relative humidity, %
						PT1	4.62	TT1	31.1	T_1	32.5	64.3
						PT2	15.72	TT2	77.8	T_2	33.7	65.5
50 %	0.8 m/s	54 L/h	On	Off	On			TT3	55.0	T_3	33.6	67.6
								TT4	23.6	T_4	27.1	89.1
										T_5	34.0	57.7
						PT1	4.21	TT1	30.2	T_1	29.9	67.3
						PT2	13.74	TT2	73.9	T_2	31.8	66.3
75 %	1.4 m/s	51 L/h	On	Off	On			TT3	49.2	T_3	31.3	69.5
								TT4	21.3	T_4	26.3	89.3
										T_5	31.1	64.5
						PT1	4.31	TT1	30.2	T_1	29.1	69.1
						PT2	14.19	TT2	74.7	T_2	31.5	70.1
100 %	1.8 m/s	49 L/h	On	Off	On			TT3	5.03	T_3	30.6	72.1
								TT4	21.8	T_4	25.8	89.5
										T_5	30.8	66.9

Table 4.6 : Data for experiment F (humidifier on, pre-heater off, re-heater on)

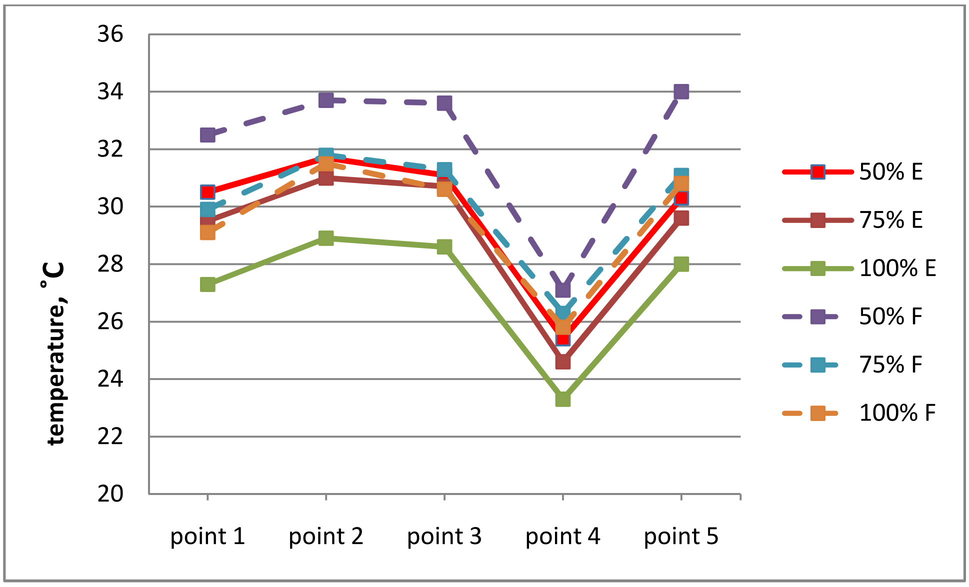

Figure 4.5 : Graph temperature versus point experiment E and F

For experiment E, humidifier and the pre-heater is turned off meanwhile re-heater is turned on. For experiment F the humidifier and re-heater is turned on and the pre-heater is turned on. Based from Figure 4.5, the differences between experiment E and F is for 50% fan speed for experiment F gives higher value of temperature, meanwhile for 100% experiment E gives most low temperature value. For the pattern of the graph, at point 1 no drastic change happen to the temperature because of the pre-heater is turned off. The effect of re-heater on can be seen at point 4 to point 5 as the temperature change drastically.

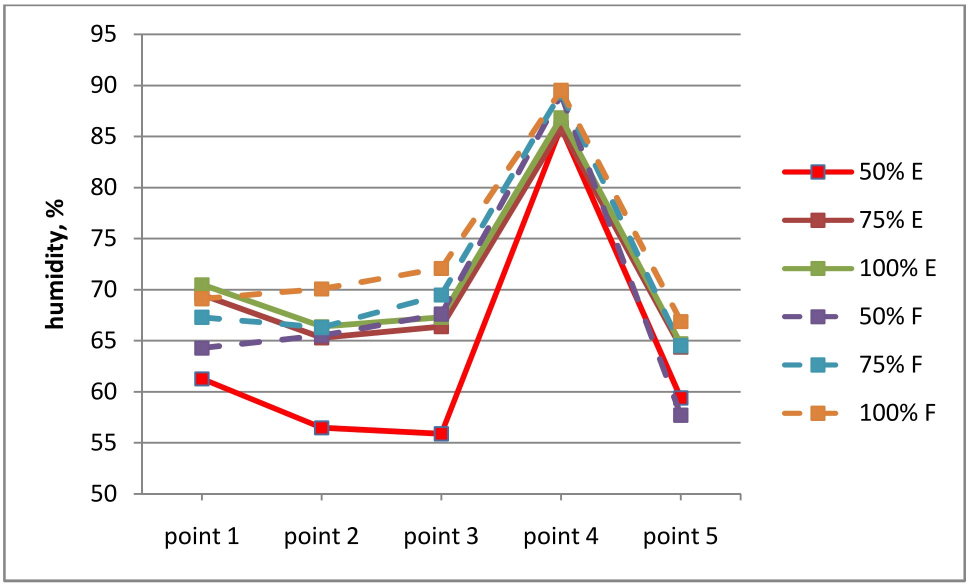

Figure 4.6 : Graph relative humidity versus point experiment E and F

From Figure 4.6, graph humidity for experiment E with humidifier off and experiment F with humidifier on was plotted. Both of the experiments run with pre-heater off and re-heater on. For experiment E the highest value of humidity is at fan speed of 100% and 50% of fan speed gives most low value in humidity. Experiment F shows 100% of fan speed gives the greatest value of humidity among all data. As for the pattern, the humidity can be seen decreasing after go through the re-heater at point 4 to point 5.

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (^oC)		Air Temperature (^oC)		Relative humidity, %
						PT1	4.21	TT1	28.9	T_1	30.7	59.1
						PT2	14.32	TT2	75.2	T_2	31.2	55.5
50 %	0.8 m/s	47 L/h	Off	On	On			TT3	51.2	T_3	32.9	53.1
								TT4	20.5	T_4	25.2	85.5
										T_5	30.7	55.3
						PT1	4.22	TT1	30.5	T_1	28.9	68.1
						PT2	13.15	TT2	72.8	T_2	29.9	64.7
75 %	1.4 m/s	47 L/h	Off	On	On			TT3	47.2	T_3	32.2	58.8
								TT4	19.8	T_4	24.5	83.5
										T_5	30.2	62.5
						PT1	3.96	TT1	30.3	T_1	28.1	71.9
						PT2	13.07	TT2	72.0	T_2	29.4	65.2
100 %	1.8 m/s	44 L/h	Off	On	On			TT3	46.9	T_3	31.6	62.4
								TT4	19.4	T_4	24.1	86.1
										T_5	29.4	58.5

Table 4.7 : Data for experiment G (humidifier off, pre-heater on, re-heater on)

Fan speed	Air speed	Refrigerant flow	Humidifier	Pre-heater	Re-heater	Refrigeration Pressure (bar) (Abs Pressure)		Refrigeration Temperature (°C)		Air Temperature (°C)		Relative humidity, %
50 %	0.8 m/s	54 L/h	On	On	On	PT1	4.67	TT1	31.9	T_1	33.0	58.4
						PT2	15.76	TT2	78.9	T_2	34.8	61
								TT3	55.3	T_3	35.5	60.8
								TT4	24.3	T_4	28.0	88.2
										T_5	34.7	58.6
75 %	1.4 m/s	49 L/h	On	On	On	PT1	4.37	TT1	31.9	T_1	30.2	59.4
						PT2	14.40	TT2	76.1	T_2	31.8	62.5
								TT3	50.8	T_3	34.2	57.4
								TT4	22.0	T_4	27.5	83.1
										T_5	32.2	62.0
100 %	1.8 m/s	49 L/h	On	On	On	PT1	4.37	TT1	32.1	T_1	28.3	61.2
						PT2	14.39	TT2	76.2	T_2	29.5	64.9
								TT3	50.9	T_3	32.0	56.3
								TT4	22.3	T_4	26.3	80.2
										T_5	30.0	61.1

Table 4.8 : Data for experiment H (humidifier on, pre-heater on, re-heater on)

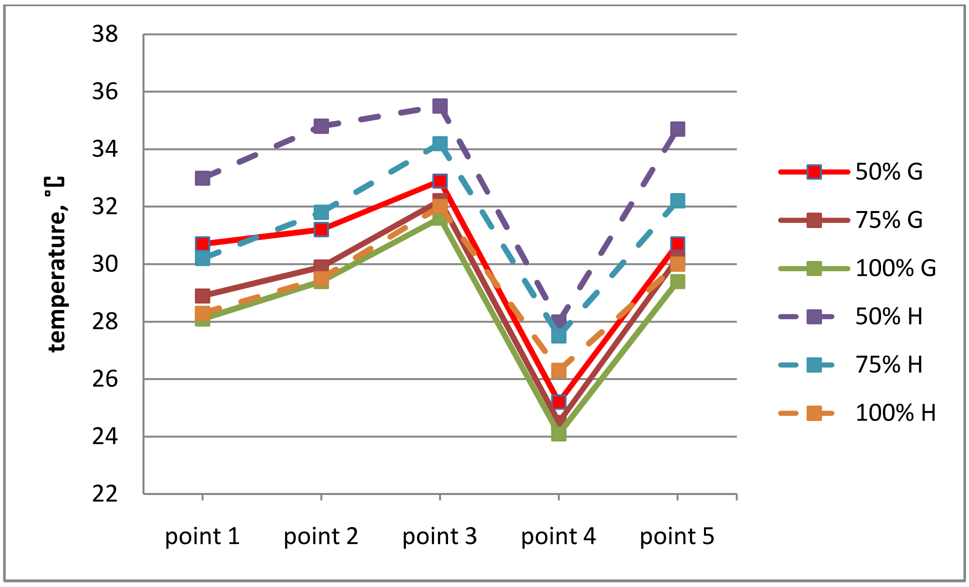

Figure 4.7: Graph temperature versus point experiment G and H

Experiment G was done by turned off the humidifier off but pre-heater and re-heater is turned on. Same goes for experiment H but the humidifier was turned on. The pattern of graph in Figure 4.7 shows the temperature keeps increasing due to the pre-heater supplying heat at point 2. The temperature still increase until point 3 which is at the evaporator where the temperature starts to decrease drastically until point 4. Then the temperature increase again at point 4 to point 5 because of re-heater action. 50% fan speed for experiment H gives highest value of temperature meanwhile 100% fan speed for experiment G gives the lowest value of temperature.

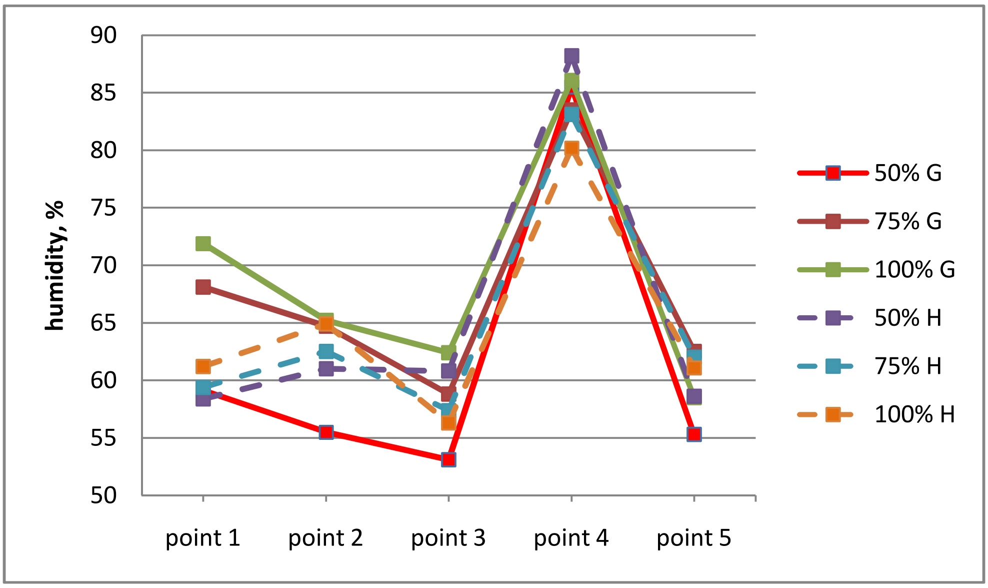

Figure 4.8: Graph relative humidity versus point experiment G and H

For graph humidity versus point in Figure 4.8, experiment G was done by turned off the humidifier but the pre-heater and re-heater is turned on. Experiment H was done by turning on humidifier, pre-heater and re-heater. For experiment G the pre-heater gives effect to the humidity by decreasing the value. From point 1 to point 3 the decrement of humidity can be seen. Then at point 3 to 4 the humidity increase due to evaporator is absorbing heat. Then at point 4 to point 5 the humidity starts to decrease again due to re-heater effect. For experiment H, the difference can be seen at point 1 to point 2 compare than point 1 to point 2 for experiment G. The humidity supplied helps to increase the humidity rate from point 1 to point 2.

4.3 COEFFICIENT OF PERFORMANCE (COP) FOR REFRIGERATION PROCESS

The coefficient of performance (COP) is calculated using the ideal vapor compression refrigeration cycle. Eq. (3.1) in Chapter 3 was used to calculate the COP. The vapor compression refrigeration cycle is the most widely used for refrigerator and air conditioning unit. But compare to actual vapor compression refrigeration cycle, the COP calculated is large than actual. Means a lot of energy losses occur in the refrigeration process. The purpose of analysis is to find the effect of air velocity to refrigeration performance and what will happen to the refrigeration process when humidifier is turned on or off. Referring to Appendix A1, the COP was calculated using Eq. (3.1) and the calculated value of COP for all experiment is as shown in Table 4.9.

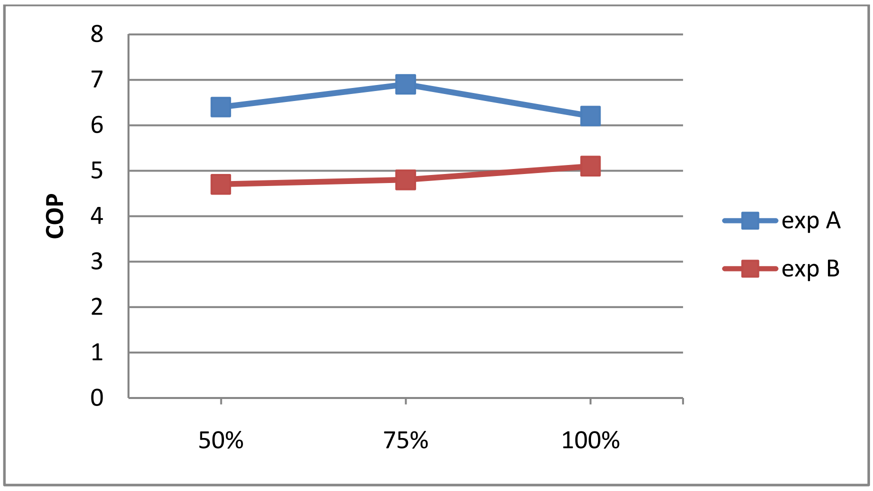

Figure 4.9 : Graph COP versus fan speed experiment A and B

Based from graph Figure 4.9, experiment A gives larger COP than experiment B. Show that humidifier effect causing COP to decrease. And by increasing air flow velocity, the COP experiment A increase from air velocity 50% to 75% which is 6.4 to 6.9. But start to decreasing from fan speed 75% to 100% which is 6.2. However for experiment B, COP increase from fan speed of 50% to 75% and continues to increase until fan speed of 100%. Maximum value of COP obtained for experiment B is 5.1.

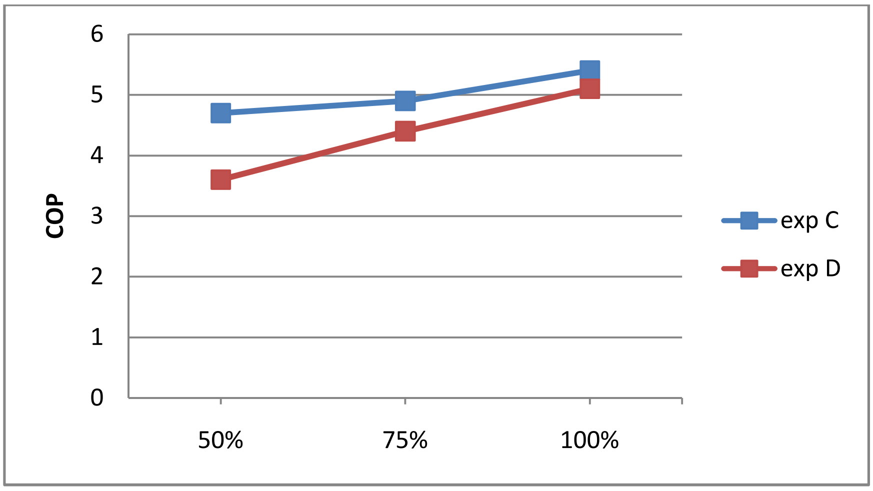

Figure 5.0 : Graph COP versus fan speed experiment C and D

As for graph from Figure 5.0, the pre-heater that has been turned on is helping the COP for experiment D to be higher compare to pre-heater off. However it is still cannot overcome the COP for experiment C. The graph pattern is still the same as experiment A and B where the COP increased with increasing fan speed. For experiment C, value of COP for fan speed of 50% is 4.7, 75% is 4.9 and for 100% fan speed is 5.4. Experiment D also gives the same pattern with increasing COP with increasing air velocity. Starting to increase from 3.6 to 4.4 for fan speed 50% to 75% and for 100% fan speed the COP is 6.1.

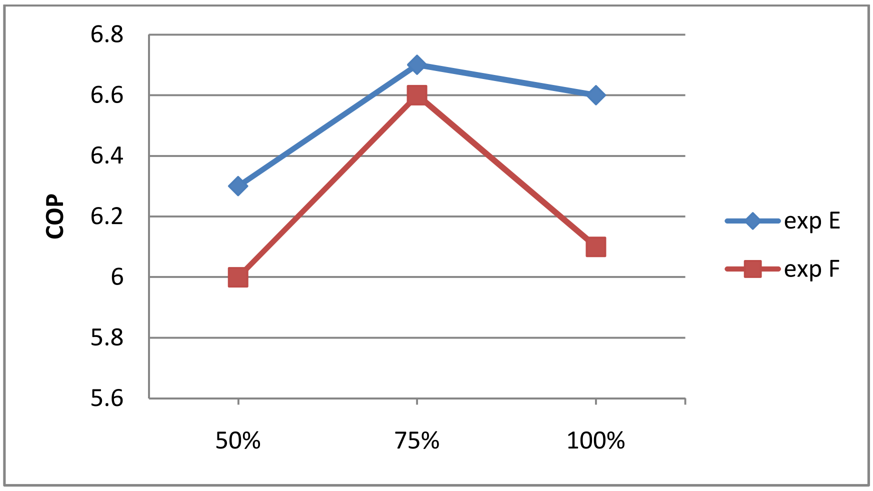

Figure 5.1 : Graph COP versus fan speed experiment E and F

Based from graph in Figure 5.1, experiment E gives larger COP than experiment F. Show that humidifier effect causing COP to decrease. This experiment is the same as experiment A and B where the pre-heater before the evaporator is turned off. And by increasing air flow velocity, the COP for experiment E increase from air velocity 50% to 75% which is 6.3 to 6.7. But start to decreasing at 100% fan speed which is 6.6. However for experiment F, COP increase from fan speed of 50% to 75% and start to decrease at fan speed of 100%. For fan speed 50% the COP is 6 and increase for 75% fan speed which is 6.6.

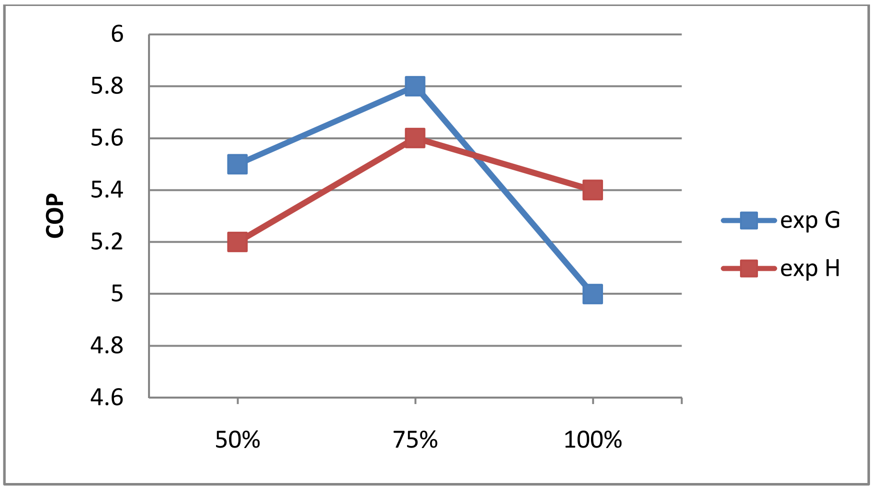

Figure 5.2 : Graph COP versus fan speed experiment G and H

Experiment G and H is done by turning on the pre-heater. Thus this experiment is the same as experiment C and D. From the graph in Figure 5.2, there were decrement occur for experiment Gat 100% fan speed. Experiment H graph pattern is still same as other graph where only increment occur. For 50% of fan speed for experiment G, value of COP is 5.5 and increase at fan speed 75% which is 5.8. However, the COP starts to decrease at fan speed 100% by 0.3 differences. Meanwhile for experiment H with humidifier on, value of COP is less than humidifier on for 50% and 75% fan speed but for fan speed 100% the value COP of experiment H is higher than experiment G.

Experiment	Fan speed	Coeficient Of Performance (COP)
A	50 %	6.4
	75 %	6.9
	100 %	6.2
B	50 %	4.7
	75 %	4.8
	100 %	5.1
C	50 %	4.7
	75 %	4.9
	100 %	5.4
D	50 %	3.6
	75 %	4.4
	100 %	6.1
E	50 %	6.3
	75 %	6.7
	100 %	6.4
F	50 %	6.0
	75 %	6.6
	100 %	6.5
G	50 %	5.5
	75 %	5.8
	100 %	5.0
H	50 %	5.2
	75 %	5.6
	100 %	5.4

Table 4.9 : Calculated COP for each experiment

4.4 HEAT TRANSFER ANALYSIS AT EVAPORATOR

The cooling process that occurs at the evaporator was analyzed by using energy balance equation. The value of heat being transfer is the heat of the air that through the duct. Thus this analysis is to find the effect of air velocity in the duct to heat transfer by the air. The point taken is at point 3 to point 4 where the evaporative process occurs. Psychrometric chart is used to find enthalpy and others variable that needed to find the heat transfer. In this experiment, no water is condensed because the outlet temperature is larger than dew point temperature. Thus the mass of the condensed water is zero. Appendix A2 shows the calculation to determine the air heat transfer towards evaporator by using Eq. 3.3 in Chapter 3. Calculated value of heat transfer for each experiment is shown in Table 5.0.

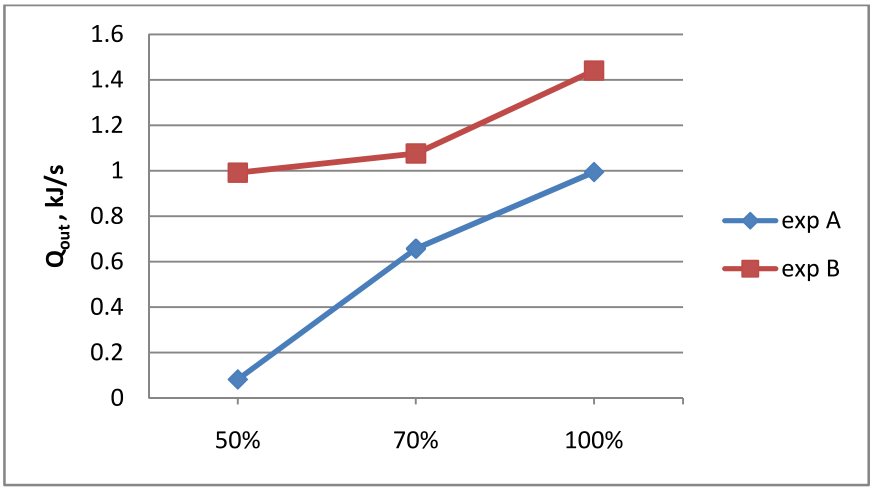

Figure 5.3 : Graph Q_{out} VS fan speed experiment A and B

From graph in Figure 5.3, value of energy out from air for experiment A is lower than experiment B. Showing that the air temperature for experiment B is larger than experiment A due to the effect of the humidity supplied. Value of Q_{out} keeps increasing with increasing fan speed for experiment A. For fan speed 50% is 0.082 kJ/s, for fan speed 75% is 0.657 kJ/s and for fan speed 100% is 0.994 kJ/s. Identical situation also occur for experiment B where the value of Q_{out} is increasing by increasing air velocity. For fan speed of 50% is 0.992 kJ/s, for 75% is 1.076 kJ/s and for 100% is 1.44 kJ/s.

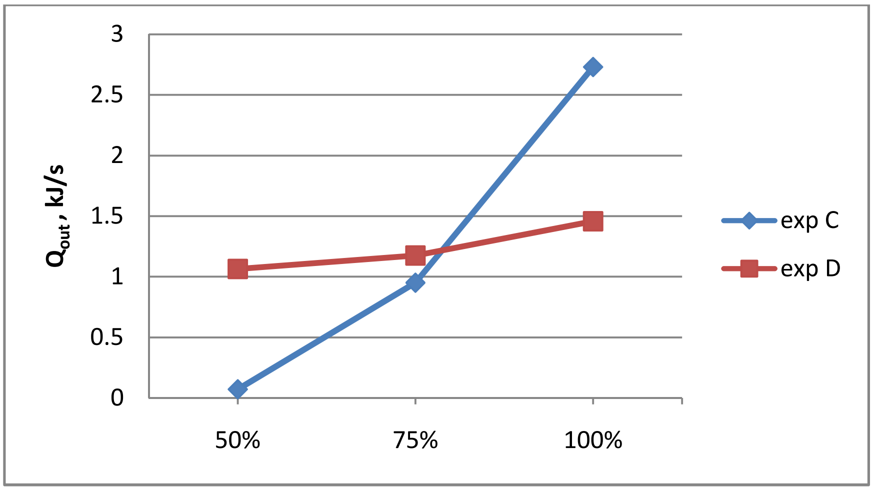

Figure 5.4 : Graph Q_{out} VS fan speed experiment C and D

Figure 5.4 shows Q_{out} for experiment C and D. Graph shows increasing air velocity increase energy taken by the evaporator (Q_{out}). This obeying the formula for Q_{out} which is increasing velocity will cause the Q_{out} to increase. For experiment C, the value of Q_{out} is higher than Experiment D. Experiment C is experiment with humidifier off, show for fan speed 50% to 75% the Q_{out} is 0.073 kJ/s and 0.951 kJ/s and for fan speed 100% is 2.73 kJ/s. For experiment D with humidifier on increasing Q_{out} is more constant with increasing from 1.064 kJ/s to 1.176 kJ/s for fan speed of 50% to 75% and increase to 1.458 kJ/s for 100% fan speed.

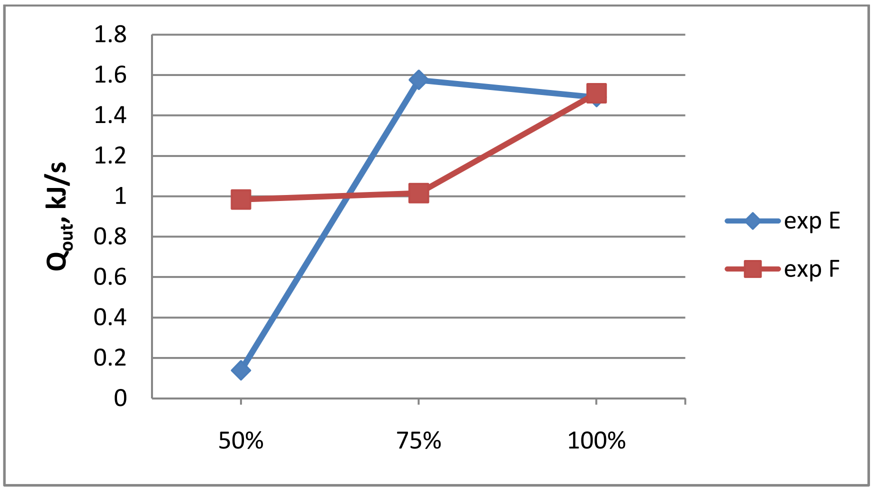

Figure 5.5 : Graph Q_{out} VS fan speed experiment E and F

For experiment E and F, it is done by turning off the pre-heater. From graph in Figure 5.5, the value Q_{out} keep increasing with increasing of fan speed for experiment E. For fan speed 50% the value of Q_{out} were 1.49 kJ/s and 1.575 kJ/s for 75% fan speed. Meanwhile for fan speed 100%, the Q_{out} is decreasing significantly which is 0.139 kJ/s. Same situation also occur for experiment F but there are no decreasing situation occur where the value of Q_{out} were increasing by increasing air velocity.

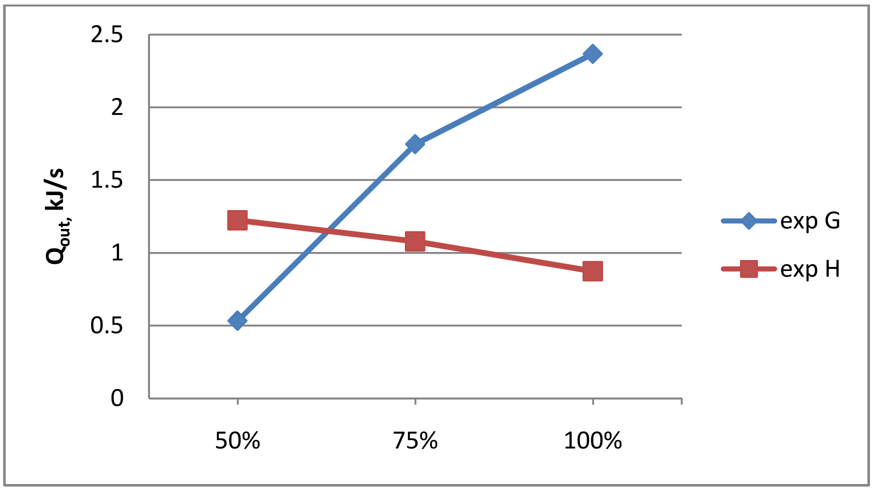

Figure 5.6 : Graph Q_{out} VS fan speed experiment G and H

Graph Q_{out} VS fan speed in Figure 5.6 shows there were decrement occur for experiment H compare to experiment G where on increment occur. For experiment G with humidifier off, the value of energy out increase from 0.534 kJ/s to 1.747 kJ/s for fan speed of 50% and 75%, and increase significantly for 100% fan speed which is 2.366 kJ/s. For experiment H, 50% fan speed gives higher value of Q_{out} compare to 75% fan speed which is 1.224 kJ/s and 1.078 kJ/s. And decrement was still occurs at 100% fan speed from 1.078kJ/s to 0.874 kJ/s.

Experiment	Fan speed	Amount of heat transfer (Q_{out}), k J/s
A	50 %	0.082
	75 %	0.657
	100 %	0.994
B	50 %	0.992
	75 %	1.076
	100 %	1.440
C	50 %	0.073
	75 %	0.951
	100 %	2.730
D	50 %	1.064
	75 %	1.176
	100 %	1.458
E	50 %	0.139
	75 %	0.143
	100 %	1.490
F	50 %	0.984
	75 %	1.015
	100 %	1.509
G	50 %	0.534
	75 %	1.747
	100 %	2.366
H	50 %	1.224
	75 %	1.078
	100 %	0.874

Table 5.0 : Calculated Q_{out} for each experiment

4.5 FINDING AIR QUALITY USING PSYCHROMETRIC CHART

The quality of air can be found by plotting the value of relative humidity and temperature at the outlet air temperature which is at point 5 to psychometric chart. By using the value obtained from the experiment, using CYTSOFT psychrometric software we can finally find the level of thermal comfort of the air at various condition of air conditioning. Thermal comfort zone that used is summer comfort zone. Because in Malaysia the climate is tropics and no winter occur yearly. Thermal comfort zone used is ASHRAE standard which is commonly used for HVAC engineer. Each experiment is paired to determine the effect of humidifier effect to air quality. Table 5.1, 5.2, 5.3 and 5.4 shows the value of temperature and relative humidity at point 5.

Label	Humidifier	Fan speed	Air temperature, (^{o}C)	Relative humidity, %
A1	Off	50%	25.2	87.0
A2	Off	75%	24.4	88.9
A3	Off	100%	22.5	88.7
B1	On	50%	26.8	91.4
B2	On	75%	25.4	90.8
B3	On	100%	25.0	95.2

Table 5.1 : Point 5 data for experiment A and B

Experiment A and B is basic structure of the experiment where the pre-heater and re-heater is turned off. From Figure 5.7, temperature and humidity at point 5 for experiment A and B is plotted. Comparing experiment A and B, the point for experiment B was plotted far away from comfort zone than point labeled A. Even though both experiments do not achieve thermal comfort temperature, the figure shows that experiment with humidifier off is better that humidifier on. Humidity supplied by the humidifier is too much to maintain thermal comfort. And absence of pre-heater and re-heater causing this bad result where no humidity is dehumidify before point 5.

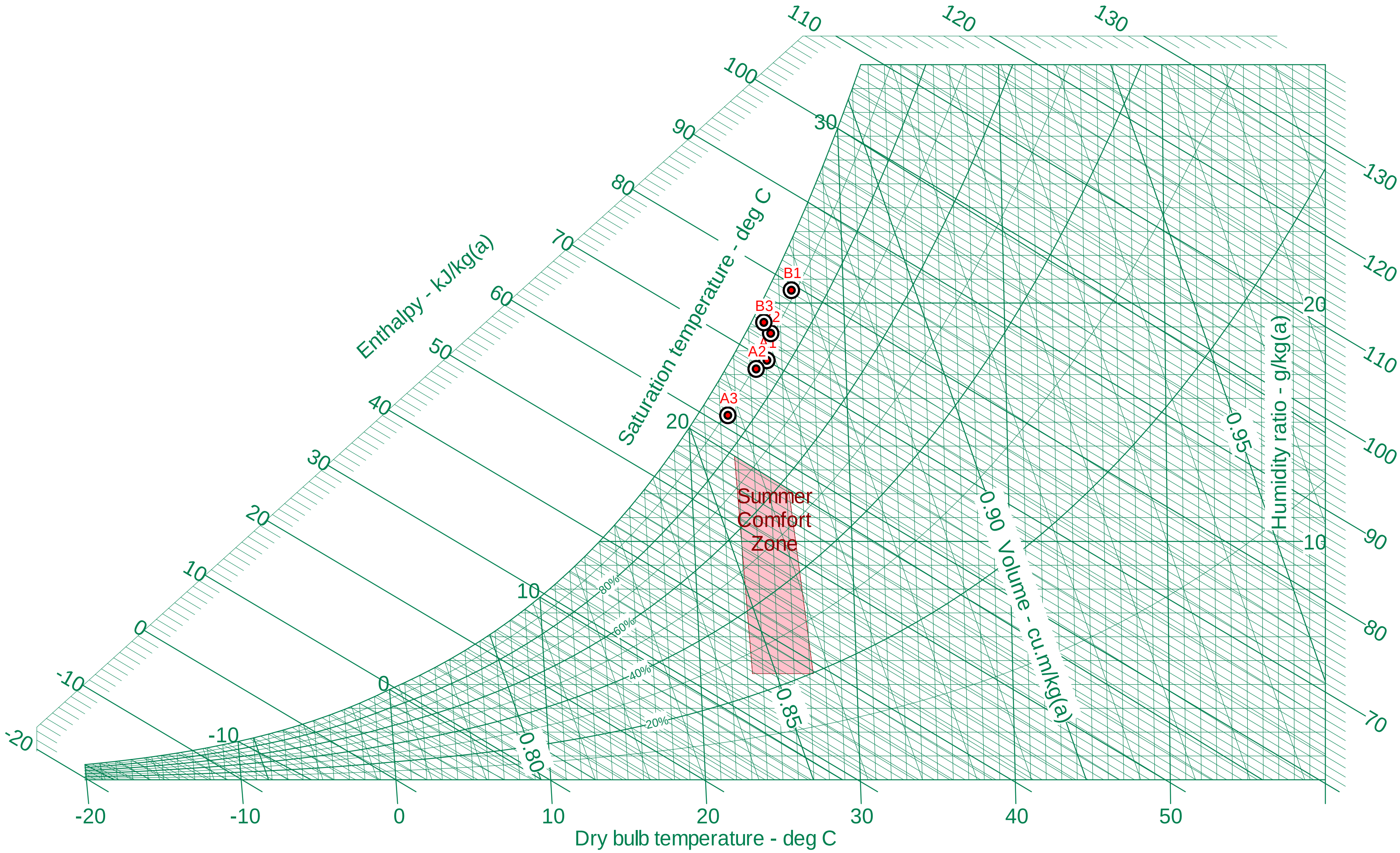

Figure 5.7 : Psychrometric chart data plotted for experiment A and B

Label	Humidifier	Fan speed	Air temperature, (^oC)	Relative humidity, %
C1	Off	50%	26.6	86.5
C2	Off	75%	25.8	85.0
C3	Off	100%	24.6	81.0
D1	On	50%	26.8	89.8
D2	On	75%	27.1	85.7
D3	On	100%	27.2	84.4

Table 5.2 : Point 5 data for experiment C and D

For experiment C and D, pre-heater is turned on. From Figure 5.8, the value of temperature and humidity is increase a little due to effect of the pre-heater. However, the thermal comfort zone still cannot be achieved. Point plotted shows both experiment were far from thermal comfort zone standard. Value of relative humidity is too high than needed. Comparing to experiment C and D, experiment C temperature is in thermal comfort range meanwhile experiment D is outside the thermal comfort range. Humidity supplied is hot and high humidity, thus high temperature and humidity for experiment D. Even though pre-heater is turned on between point 2 to point 3, it will only decrease humidity value but the temperature will become higher. Fan speed gives a big contribution where the point C3 and D3 is more near to thermal comfort than others shows that higher air velocity help to decrease temperature in the duct.

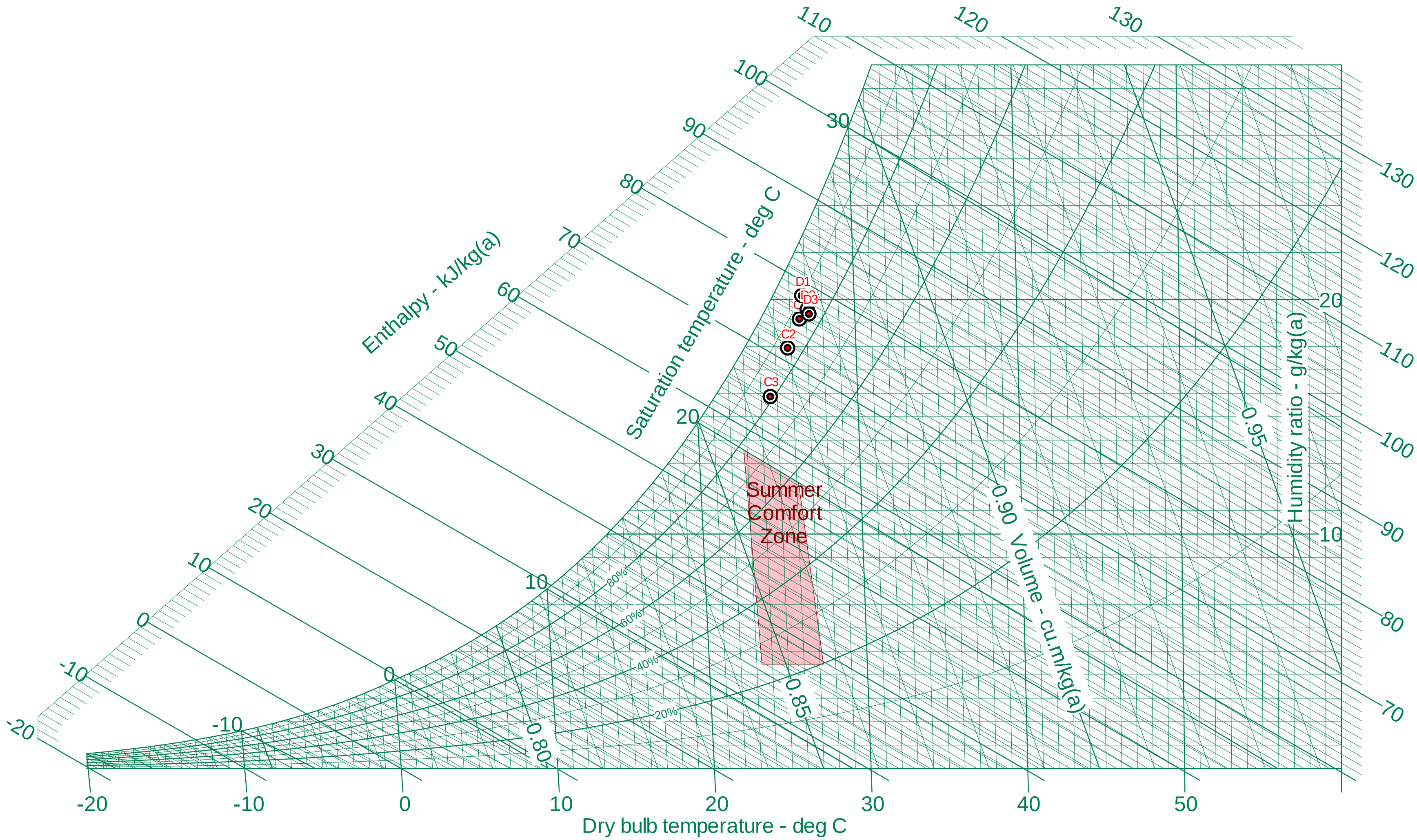

Figure 5.8 : Psychrometric chart **d**ata plotted for experiment C and D

Label	Humidifier	Fan speed	Air temperature, (^{o}C)	Relative humidity, %
E1	Off	50%	30.3	59.4
E2	Off	75%	29.6	64.4
E3	Off	100%	28.0	64.7
F1	On	50%	34.0	57.7
F2	On	75%	31.1	64.5
F3	On	100%	30.8	66.9

Table 5.3 : Point 5 data for experiment E and F

For experiment E and F, experiment is done by turned on the re-heater between point 4 to point 5. From Figure 5.9 both experiments don't achieve the thermal comfort standard. However, the humidity obtained by both experiment were in comfort zone range. But the value of temperature is over from the comfort zone range. Both experiment give high temperature at point 5. This is cause by re-heater effect where the temperature became higher comparing to previous experiment. Thermal comfort zone can be achieved by controlling the value of re-heater temperature so that the rates of heat transfer by the re-heater decrease.

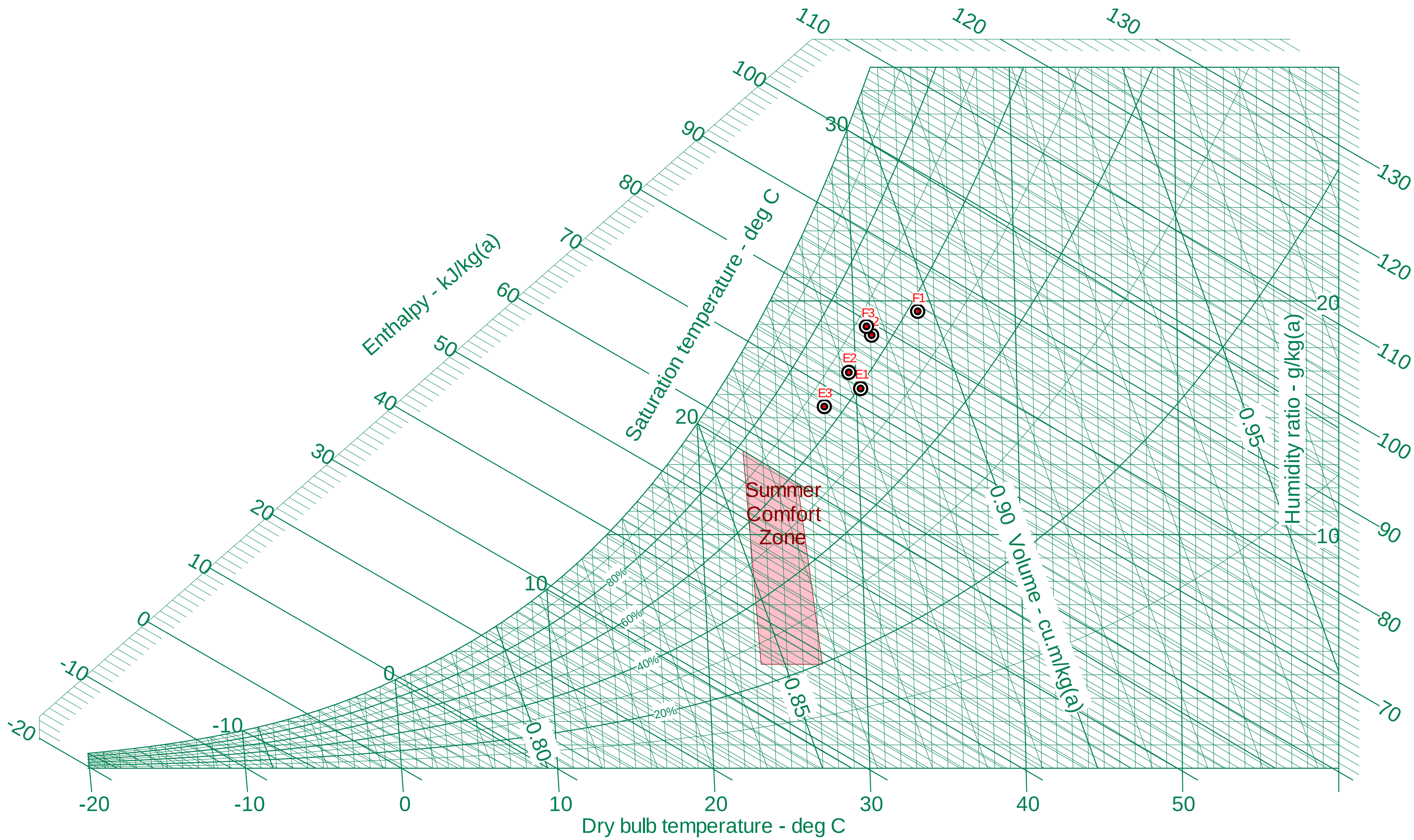

Figure 5.9: Psychrometric chart data plotted for experiment E and F

Label	Humidifier	Fan speed	Air temperature, (^{o}C)	Relative humidity, %
G1	Off	50%	30.7	55.3
G2	Off	75%	30.2	62.5
G3	Off	100%	29.4	58.5
H1	On	50%	34.7	58.6
H2	On	75%	32.2	62.0
H3	On	100%	30.0	61.1

Table 5.4 : Point 5 data for experiment G and H

Experiment G and H is done by switch on pre-heater and re-heater. Referring to Figure 6.0, not much change can be seen comparing to experiment F and G psychrometric plot. The temperature is too high to achieve thermal comfort zone but the relative humidity is in thermal comfort range. Increasing fan speed helped to lower the temperature and become more near to thermal standard. For experiment H with humidifier on, temperature is too high at point 5 causes by high starting temperature supplied by humidifier. 100% fan speed for experiment G and H shows nearest position to comfort zone range.

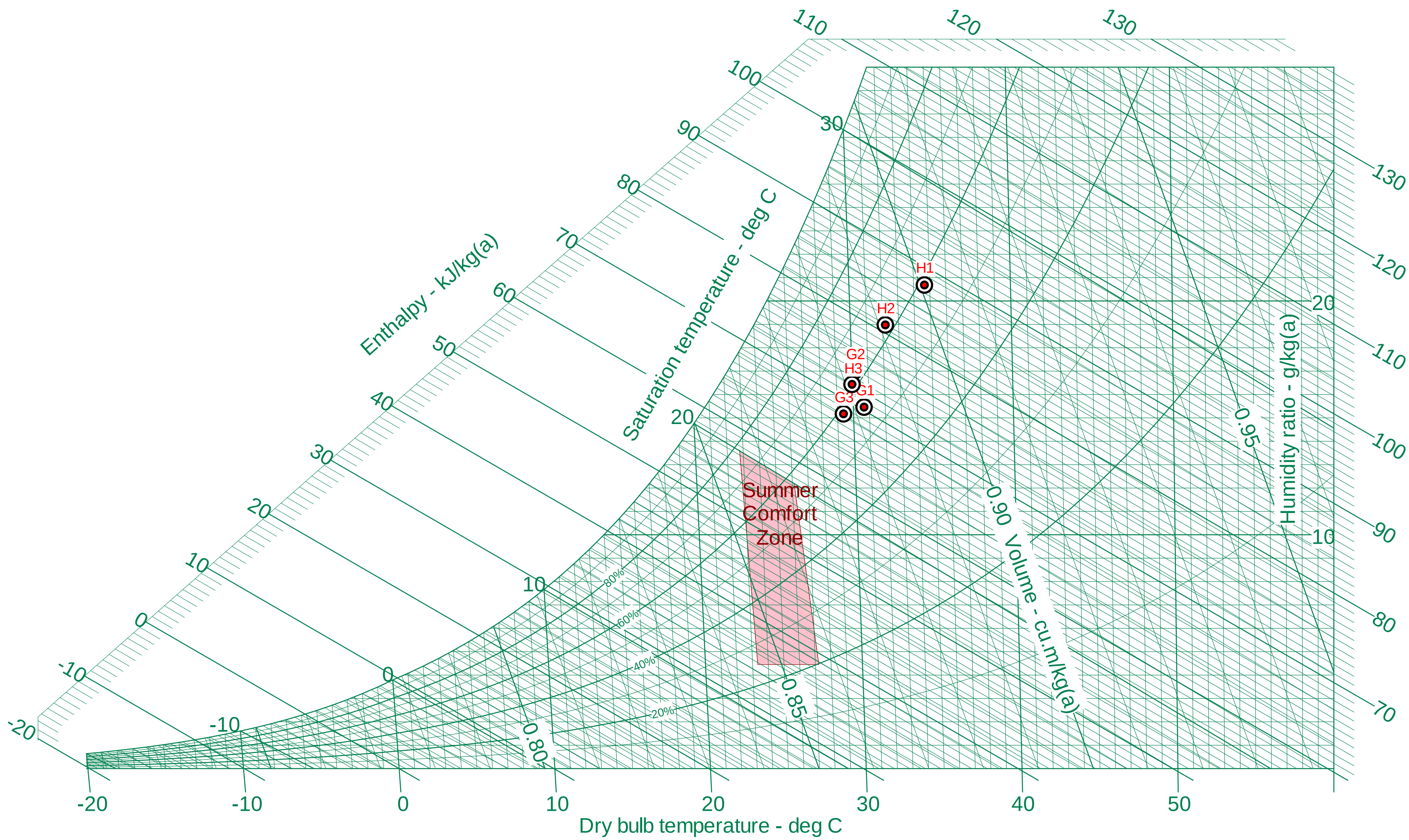

Figure 6.0 : Psychrometric chart data plotted for experiment G and H

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As conclusion, increasing air velocity will cause the air temperature to drop and humidity increase. By increasing the velocity, it will help to make the environment become more comfortable. Secondly, increasing air velocity flow through evaporator increase its heat transfer and be calculated using energy balance equation. This can be seen by multiplying the air velocity with area to determine the air mass flow rate at Eq. (3.2).

Then, usage of humidifier causing the temperature and humidity to became further away from thermal comfort zone. Thus without using the humidifier, the quality of air from air conditioning unit FKM UMP can be improve. Besides that, from the experiment pre-heater and re-heater help to adjust the humidity and temperature at each point. So that the quality of air can be maintain. So the usage of pre-heater and re-heater is suitable for an air conditioning unit.

5.2 RECOMMENDATION

Here are some recommendations to improve this research.

i) Taking more fan speed as variable. It can be done by taking 25%, 50%, 75% and 100% fan speed to increase more data for studies. Then more point can be plot in graph to observe the effect of air motion in air conditioning unit.

ii) Varies the value of temperature for pre-heater and re-heater. This can help to determine what are the optimum temperature for pre-heater and re-heater so that the air quality can be achieve.

iii) Determine an accurate value of air quality for Malaysian citizen. Psychrometric chart based on Malaysia thermal comfort zone standard can be used to achieve this objective.

iv) Refrigeration process can also be analyzed to determine effect of fan speed to refrigeration process. This can be done by analyzing the refrigeration process in P-h diagram for each fan speed to determine the efficiency for compressor, power input for the cycle and coefficient of performance (COP) for heat pump.

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APPENDIX A1

COEFFICIENT OF PERFORMANCE (COP) CALCULATION

1) Coefficient of Performance,

COP_R = (h_1- $h_{3/4}$) / (h_2 - h_1)

Using p-h diagram to find enthalpy of each point

h_1 = 420 kJ/Kg

h_2 = 445 kJ/Kg

h_3 = h_4 = 260 kJ/Kg (throttling process)

COP_R = (h_1- $h_{3/4}$) / (h_2 - h_1)

= (420 – 260) / (445 – 420) = **6.4**

2) Coefficient of Performance,

COP_R = (h_1- $h_{3/4}$) / (h_2 - h_1)

Using p-h diagram to find enthalpy of each point

h_1 = 425 kJ/Kg

h_2 = 448 kJ/Kg

h_3 = h_4 = 265 kJ/Kg (throttling process)

COP_R = (h_1- $h_{3/4}$) / (h_2 - h_1)

= (425 – 265) / (448 – 425) = **6.9**

3) Coefficient of Performance,

COP_R = $(h_1 - h_{3/4}) / (h_2 - h_1)$

Using p-h diagram to find enthalpy of each point

h_1 = 420 kJ/Kg
h_2 = 446 kJ/Kg
$h_3 = h_4$ = 258 kJ/Kg (throttling process)

COP_R = $(h_1 - h_{3/4}) / (h_2 - h_1)$
= (420 – 258) / (446 – 420) = **6.2**

APPENDIX A2

HEAT TRANSFER CALCULATION, Q_{OUT}

Fan speed 50% = 0.8 m/s

The inlet and the exit states of the air are completely specified, and the total pressure is 1 atm. Then the properties of the air at both states are determined from the Psychrometric chart.

		point 3	;	point 4
Temperature, ˚C	=	30.4	;	25.1
Relative humidity, %	=	57.1	;	87.7
Enthalpy, kJ/kg	=	70.6	;	69.6
Specific volume, m^3/kg	=	0.88	;	0.87
Dew point temperature, ˚C	=	20.9	;	22.9

Since air is cooled to 25.1 ˚C, which is above its dew point temperature, no moisture in the air is condensed.

$\dot{m} = VA / v_3$

$= (0.8)(0.3 \text{ X } 0.3) / 0.88 = 0.082$ kg/s

$\dot{Q} = \dot{m}\ (h3 - h4) - \dot{m}\, wh_w$

$= 0.082\ (70.6 – 69.6) – 0 =$ **0.082 kJ/s**

Fan speed 75% = 1.4 m/s

The inlet and the exit states of the air are completely specified, and the total pressure is 1 atm.

Then the properties of the air at both states are determined from the Psychrometric chart.

		point 3	;	point 4
Temperature, ˚C	=	29.0	;	24.3
Relative humidity, %	=	67.8	;	90.0
Enthalpy, kJ/kg	=	73.1	;	68.5
Specific volume, m^3/kg	=	0.88	;	0.87
Dew point temperature, ˚C	=	22.4	;	22.5

Since air is cooled to 24.3 ˚C, which is above its dew point temperature, no moisture in the air is condensed.

$\dot{m} = VA / v_3$

$= (1.4)(0.3 \text{ X } 0.3) / 0.88 = 0.143$ kg/s

$\dot{Q} = \dot{m}\ (h3 - h4) - \dot{m}\, w h_w$

$= 0.143\ (73.13 - 68.54) - 0 =$ **0.657 kJ/s**

Fan speed 100% = 1.8 m/s

The inlet and the exit states of the air are completely specified, and the total pressure is 1 atm. Then the properties of the air at both states are determined from the Psychrometric chart.

		point 3	;	point 4
Temperature, ˚C	=	27.9	;	22.9
Relative humidity, %	=	66.9	;	89.7
Enthalpy, kJ/kg	=	68.6	;	63.3
Specific volume, m^3/kg	=	0.87	;	0.86
Dew point temperature, ˚C	=	21.2	;	22.1

Since air is cooled to 22.9 ˚C, which is above its dew point temperature, no moisture in the air is condensed

$\dot{m} = VA / v_3$

$= (1.8)\ (0.3 \times 0.3) / 0.87 = 0.186$ kg/s

$\dot{Q} = \dot{m}\ (h3 - h4) - \dot{m}\ wh_w$

$= 0.186\ (68.64 – 63.3) – 0 =$ **0.994 kJ/s**

APPENDIX B1

COMPONENT OF AIR CONDITIONING UNIT

APPENDIX C1

P – H DIAGRAM FOR REFRIGERANT 134 A