



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**FILTRATION TEST RIG PERFORMANCE BASED ON  
DIMENSIONAL ANALYSIS AND SIMILARITY CHECK**

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Refrigeration and Air Conditioning Systems) with Honours.

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## DECLARATION

I hereby, declared this report entitled “Filtration Test Rig Based on Dimensional Analysis and Similarity Check” is the results of my own research except as cited in references.

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## **APPROVAL**

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigeration and Air Conditioning Systems) with Honours. The member of the supervisory is as follow.

.....

(Amir Abdullah Bin Muhammad Damanhuri)

## ABSTRAK

Penapis udara ialah untuk menapis zarah-zarah yang ada di dalam udara yang akan dibekalkan di ruang yang diinginkan, ini bermakna penapis udara adalah satu komponen yang penting untuk mengawal zarah-zarah yang terkandung di dalam udara yang bakal dibekalkan ke ruang yang diinginkan. Penapis udara perlulah di uji tahap prestasi dengan menggunakan pelantar ujikaji penapis udara. Untuk menjimatkan masa dan wang, pelantar ujikaji mestilah dikecilkan saiz nya dengan menggunakan teknik “dimensional analysis and similarity”. Had batas bagi kajian ini adalah untuk sistem ialah untuk unit pengawal udara yang menggunakan penapis udara yang boleh dibasuh yang mengandungi dimensi asalnya ialah 24 inci lebar dan 24 inci tinggi. Bagi unit pengawal udara, data bagi udara yang disalurkan ialah 3200 CFM, putaran bilah penghembus ialah 1208 RPM. Data yang diperolehi daripada model pelantar ujikaji adalah kecekapan atmosfera pengesanan zarah penapis udara, tekanan yang hilang bagi aliran udara, kebolehtelapan udara bagi melalui penapis udara, dan tenaga yang diperlukan bagi menggerakkan sistem. Dengan penjimatan masa ketika mengambil data, kerja dan tenaga yang digunakan untuk sistem asal, kewangan juga adalah salah satu faktor utama apabila kaedah pengiraan telah dipilih hal ini kerana pelantar ujikaji penapis udara tidak mengganggu sistem asal yang sedang beroperasi dan saiz pelantar ujikaji juga lebih kecil berbanding sistem asal. Kaedah analisis dimensi dan persamaan boleh digunakan untuk kegunaan semasa kerana ianya dapat mengurangkan masa dan modal untuk melakukan ujikaji prestasi bagi sistem yang digunakan.

## ABSTRACT

Air filter is to filtering the air contaminant that will be supplied to the conditioned space, that means the air filter was an important device to control the air contaminant that been supplied to the space. The air filter should be tested for their performance by making the air filter test rig. To reduce the time and money, the test rig was made by using dimensional analysis and similarity method to reduce the size scaled of the air filter system. This project limitation is for system air handling unit that used the washable permanent air filter with the actual dimension before scaled was 24-inch width and 24-inch height. For the Air Handling Unit, the actual air flow is 3200 CFM, the RPM for the blower is 1208 RPM. The data from the model was atmospheric dust spot efficiency, pressure drop for the air flow, air permeability that through the air filter and the energy demand for the system. By reducing the time taken to collected the data, work and energy consumption for the actual system, money also was the main reason when this analytical method was been choose because the air filter test rig was not affected the actual system from running and the size of the test rig also more smaller than the actual system. The dimensional analysis and similarity concept can be used for the current engineering field because it can reduced the time and cost to test the performance of the system.

## **DEDICATION**

This thesis is dedicated to my beloved parents that has teach me a lot of thing that have around the world. They also taught me a very special knowledge about being what I'm right now.

## ACKNOWLEDGEMENT

Thankful us to Allah S.W.T because still gives us health that is good and perfect so that can go through life as usual. The most thanks were also given to Allah with His grace and revelation to research these studies about Filtration Test Rig Performance Based on Dimensional Analysis and Similarity Check. Thankful again because it has been simplified all business by that Most Powerful Creator and special thanks to my beloved parents that give me a moral support to achieve what their son have right now. Thanks a Million also is expressed to our project supervisor, Mr. Amir Abdullah Bin Muhamad Damanhuri, Mr. Zulfattah Bin Zakaria and Engineer Instructor that already help a lot and oversee during this project implementation. Support and inducement that they give into this project was very value. Not to forget, also their merit for not bored given coaching and all advice during this research. Well done and congratulation also is expressed to member that indirectly help solely to complete this project. Thank you for all efforts and idea all of you and really appreciate to those that been directly involved or indirect in this project implementation.

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## **LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE**

HEPA	-	High Efficiency Particulate Air Filter
ULPA	-	Ultra-Low Penetration Air Filter
CFM	-	Cubic Feet per Minute
RPM	-	Rotation Per Minute
HP	-	Horse Power
FLA	-	Full Load Ampere
LRA	-	Locked Rotor Amperage
V	-	Volts
ASHRAE	-	American Society of Heating, Refrigerating, And Air Conditioning Engineers
HVAC	-	Heating Ventilation and Air Conditioning
AHU	-	Air Handling Unit
IAQ	-	Indoor Air Quality
MERV	-	Minimum Efficiency Reporting Value
Std	-	Standard
>	-	More than
<	-	Less than

$\mu\text{m}$	-	Micrometer
$\leq$	-	Less than or Equal
Eurovent	-	Committee of Manufacturers of Ventilation, Air Conditioning and Refrigeration, Industrial Heating and Ventilation, and Air Handling equipment in Europe
EU	-	Classification of European Air filter
EN	-	Standard of European Air Filter
CEN	-	European Committee for Standardization
n/a	-	Not Applicable
$^{\circ}\text{C}$	-	Degree Celsius
$\text{m}^3/\text{s}$	-	meter cubic per second
$\text{m}^3/\text{h}$	-	meter cubic per hour
DEHS	-	Di-Ethyl-Hexyl-Sebacat
Pa	-	Pascal's
US	-	United States
$\Pi$	-	pi



# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Introduction**

This chapter will explain the overview of the case study and the purpose of this case study. For this chapter includes the background of the study, problem statement, objectives that is expected to be achieved and the scope of the case study that going to be conducted.

### **1.2 Background of Study**

In industrial nowadays, the air filter is widely used as a device to remove the unwanted contaminants at the conditioned space that will result, the comfortable to the consumer. The air filtration also can improve the healthful of the consumer and it is also can improved the conditioned air to protecting the equipment inside the building. The unwanted contaminants have many resources from the outdoor air and from the indoor air. The main source of the pollution that are coming from the outdoor air such as the combustion of fossil fuels that have been divide into three type that are domestic heating, power generation, and motor vehicles. Then the other main sources of the outdoor air are industrial process, agricultural process, waste incineration and the last one is natural process(WHO 2005) while the main source for the indoor air pollutant is come from outdoor air pollution such as vehicles and industrial plants, secondhand

tobacco smoke, fuels used for heating and cooking, confine and poorly ventilated spaces, overcrowded homes and insufficient living space(WHO 2005). That mean the higher of the efficiency of the air filter is really helps the consumer to removes the unwanted contaminants from their space. That why the air filter needed to be test to ensure their efficiency.

The air filter also needed to control the performance of the worker at the working area. For example, if the building area has bad air ventilation, the workers are easily having a sick building syndrome such as nasal manifestations, ocular manifestations, oropharyngeal manifestations, cutaneous manifestations, and general manifestations (Molina et al. 1989). The sick building syndrome can affect the productivity of the company because the worker can't give the 100% effort to job that they are do.

The air filter type nowadays also have many type of ability such as throwaway filter, permanent filter, contour pleated filter, roll filter, HEPA and ULPA filter(Jung 1987). Every air filter has own ability that has been measured by the manufacturer such as easy when doing the maintenance procedure, the porosity of the air filter has large and small to filtered the unwanted contaminant at the conditioned area, design of the air filter also can make the efficiency of the air filter and the maintenance period are changing. The media of the air filter also can be the issues when we wanted to calculated or find the efficiency of the air filter and it life cycle of the air filter.

There have three variables of the proper filter selection and performance of the air filter. The first variable was efficiency of the air filter to remove the air contaminants from the air stream. Secondly is the resistance of the airflow by referring the static pressure drop across at the air filter at the given face velocity and for the last variables is dust holding capacity. It was amount of the air contaminant that air filter can hold during the process at the specified airflow (Facility Maintenance Decisions 2009).

### **1.3 Problem Statement**

At this century, the developing of the technology and industry are really growth faster. While the technology and industry are growing fast, the pollution at the environment are also increasing. For big industry and residential house nowadays was normal if they have the air conditioning system to ventilate their conditioned space. Every air conditioning system nowadays, equipped with air filter devices that was filtered the air from the unwanted contaminant. The efficiency of the air flow that through at the air filter was really important to be measured to ensure the performance of the air conditioning flow while filtering the air. To make the measuring of the parameter for the air filter is easier, the prototype of AHU need to build. From this condition, the dimensional and similarity analysis concept is needed to fulfill the requirement of actual AHU. From this concept, the dimension of the AHU can be build and resize for the new prototype. After the prototype has been build, the parameter data can be measured to compare with the actual AHU. This concept was been create to reduce, time, money and energy. This concept also useful because the current unit or system can be still operates and the test for the prototype can been repeated to gain the data.

### **1.4 Objectives**

The main objectives of these cases studies are too proved or to find the data performance between model and prototype of the air filter test rig. For more specific objectives for this project and the aims were shown as below.

- i. To develop and fabricate the prototype of air filter test rig based on dimensional analysis and similarity check for primary and secondary HVAC filter.
- ii. To compare the data performance between prototype of the test rig and actual of air filter.

## 1.5 Scope

Scope is a limitation of the project that to set the level of the research of the project. For this project, the scope for the air filter that been used is washable permanent air filter and bag type with the actual dimension is 24-inch width and height for one filter. The base guideline system that been used to be references to achieved the objectives for this project is Air Handling Unit with the actual air flow 3200 CFM, the RPM for the blower is 1208, with 3 HP, 4.7 FLA, 24.91 LRA, and with 415 V.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

From this chapter was discovered about the air filter purpose for the environment or to gain the higher comfort level at the conditioned space. From this chapter, it will discuss about the air filter selection. From this topic, it explained about the variable that should be calculated or been measured while selecting the air filter for the conditioned space. The variable that have been highlighted in this chapter is air filter efficiency, the resistance of the air filter to the air flow that will be supply to the conditioned space, and the lastly was air filter dust holding capacity. From this chapter also will exposed the type and media that been used for the air filter nowadays because the type and media of the air filter will affect the efficiency of the air filter and the air flow that shall be supply such as throwaway filter, permanent air filter, pleated filter, roll filter, HEPA and ULPA air filter, rigid air filter, and the last one is bag air filter and for the media of the air filter used was fibrous, porous membrane, capillary porous membrane, fabric, straight through pore, and the last one is granular foam. The media of the air filter will affect the life of the air filter to be service or change to the new one. From this chapter also will exposed about the standard air filter porosity that been used nowadays by referring the ASHRAE 52.2 user guideline. The porosity for the air filter was really important because it will affect the efficiency of the air filter to filtering the unwanted contaminant that flow through to the conditioned space. The lastly, from this chapter will also discuss about the

indoor air quality and the contaminant that will be effect the human when too much exposed to it.

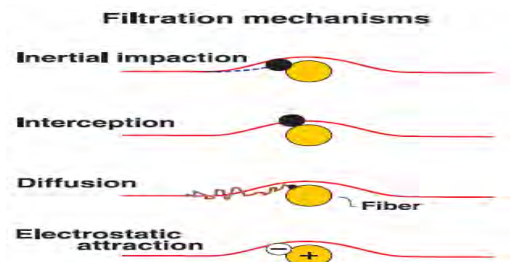
## **2.2 Air Filter**

In industrial nowadays, the requirement of air filter for their air conditioning is widely needed. It is because the clean air that wanted to be supply to the conditioned space are very importance to gain their comfort or maybe the clean air that been filtered by the air filter is needed to maintain their own equipment. Air filter is a device to remove the particle from the air that will may causes the uncomforted situation to the consumer of the air conditioning system. The purpose of the air filter is to improving the ventilation of the closed space building, to protecting the facility wall, ceiling, equipment from the airborne particle damage, protecting the content of occupied building spaces such as item of artistic, historic or cultural value, removing the airborne mould to improve shelf-life of perishable food product and the last purpose of the air filter is to removing the airborne microorganisms from controlled environments such as operating rooms (Tech & Eng 2010).

In HVAC system commonly the filter had been put at the Air Handling System for the bigger system that used the AHU. While inside the AHU, the air filter has been located before the air reach at the place to temperature treatment. That mean, the air filter must filtered the air from outside air and circulating air (return air) that coming from conditioned space just like the ASHRAE Standard 62.1 (3013b) (Schoen et al. 2015). The outside air or fresh air are not guarantee are clean because the environment from outside got many pollutant that will affect the Indoor Air Quality (IAQ) inside the conditioned space that will harm the consumer from aspect comfortable and sickness(Schoen et al. 2015).The air filter in industrial nowadays have many type of their mesh such as Mechanical Air filter and Electronic Air Filter and have also their own ability to which size of the particle, gases or the microbial contaminants. The Mechanical Air Filter use the material of the porous structures that contain fibers or

stretched membrane material(Schoen et al. 2015) to remove the unwanted contaminant in the air flow and the work principle of the Mechanical Air Filter is filtered the air that entering the airstream that flow through by attached the filter at the ducting or the air flow way while the Electronic Air Filter is a device that are connect with the electrical charging by using corona wires or through of the ions and collecting the particle on oppositely charged deposition plate (Schoen et al. 2015). While the filtration the unwanted contaminant in the air flow, there have four different collection mechanisms that have been govern the particulate air filter performance such as internal impaction, interception, diffusion, and electrostatic attraction (Niosh 2003) shown at figure 1 below. The effectiveness of the air filter also related of the class of the air filter (Schoen et al. 2015). That mean the air that must been supply must cleaned before it reaches to the conditioned space.

- Impaction mechanism happen when the particle that flow through the air stream that passing through around a fiber, it will deviates from the air stream (due to particle inertia) and collides with a fiber (Niosh 2003).
- Interception mechanisms happen when a large particle collides with a fiber in the filter that the air stream is passing through (Niosh 2003).
- Diffusion mechanisms happen when the random motion of a particle causes that particle to contact a fiber (Niosh 2003).
- Electrostatic mechanisms in mechanical filtration have a minor role. When the fiber contact with the particle, then the smaller particles are retained on the fibers by a weak electrostatics force (Niosh 2003).



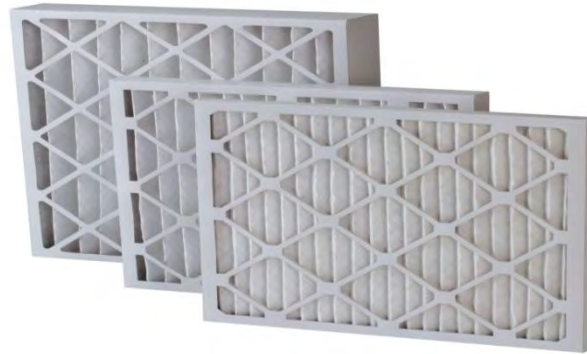
**Figure 2.2a** Four Primary Filter Mechanisms (Niosh 2003)

## 2.2.1 Type of Air Filter

Type of the air filter was too many in industrial nowadays, the classification of the air filter has been divided into two variables. It was the media of the fibrous that created the air filter and the porosity of the air filter. The media of air filter is most to the material that been chosen to make the fiber of the air filter. It is importance because the material of the air filter will be decided the life of the air filter to be clean or replace while the porosity or the mesh size of the air filter will decide the size of the air contaminant size that will be allowed to going through to the conditioned space.

### 2.2.1.1 Pleated Filter

Pleated Filter is commonly being in shaped into inflatable bags. This filter also can be attached into frame or basket or it is also come with their own frame (Jung 1987).



**Figure 2.2.1.1a** Pleated Air Filter