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Experimental Testing and Performance Analysis of "Room Air Cleaners"

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EXPERIMENTAL TESTING AND PERFORMANCE ANALYSIS OF "ROOM AIR CLEANERS"

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ABSTRACT

"HMI industries" are the manufacture of the air cleaners and vacuum cleaners, in which a solution is adapted for the current model of the volute to the new design of the volute in order to calculate the "Clean Air Delivery rate" and qualify for the "Energy Star requirements". For the above model to be employed as a Energy Star certificate, a test rig was made in which "air velocity" and "flow rate" was calculated for the three different air cleaners in two cases i.e.; (i) three different air cleaners with different filters and different rpm's (ii) three different air cleaners with the same filters and the same rpm's, in order to qualify for the Energy star requirements parameters like frequency, voltage and power output values also calculated. An important and primary objective of this study is the development of a volute of the air cleaner to characterize the major CADR value of the air cleaner. It is anticipated that the experience gained from this can be extrapolated to more complex systems like in the air purifiers with a view towards improving the optimization capability of the air cleaner analysis. It is also anticipated that the values of the flow rate and air velocity will improve the ability of the current model to satisfy for the Energy star and improve the energy conversion and the consuming power.

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NOMENCLATURE

Abbreviations

1/f	Frequency
AHAM	Association of Home appliance manufactures
ANSI	American National Standards Institute
ASHREA	American Society of Heating Refrigeration and Air Conditioning Engineers
CAD	Computer Aided Design
CADR	Clean Air Delivery Rate
CAE	Computer Aided Engineering
CFM	Cubic Feet Per Minute
CMM	Cubic Meter Minute
EPA	Environmental Protection Agency
FDM	Fused Deposition Machine
HEPA	High Efficiency particulate air filters
HMI	Health Mor Industries
HP	Horse Power
Hz	Hertz
IAQ	Indoor Air Quality
LCD	Liquid Crystal Display
m/sec	Meter Per Second
RMS	Root Mean Square
RPM	Revolutions Per Minute

RH	Relative Humidity
STL	Stereo-Lithography Tessellation Language
T	Time Period
V	Volts
VOC	Volatile Organic Compounds
W	Watts

CHAPTER I

BACKGROUND

1.1 Introduction

The HEALTH MOR, an HMI industry specializes in manufacturing of the FILTERQUEEN Indoor Air Quality System. The Filter queen system consists of Majestic 360^0 surface Cleaner and the Defender Room Air Cleaner. These are used to clean the air bone particles, dirt, dust, and prevent from the allergy. For the past 80 years these products have been sold through direct to the home and the filter queen products are selling throughout the United States, Canada and forty more countries through the world.

The Filter queen Air Quality System helps you and your family in benefit with living in a cleaner and healthy home environment, and for the past 80 years filter queen is on the best systems in removing the airborne particles in indoor environments, and the Majestic 360^0 Vacuum cleaner and the Defender 360^0 are the state of art technology to make the finest cleaning to the environments. Air cleaners' use filters or electronic precipitators to remove the contaminants from the indoor which include tobacco smoke, dust, airborne particles and pollen.

In the indoor room environment there are many unwanted particles which will be harmful for our life. Indoor pollution is one of the five environmental health risks. The best way to control the unwanted particles is to reduce the source pollutants and increase the ventilation of the home with clean air in order to control the health risks. The ventilation is however is taken care upon the weather conditions and the levels of the contaminated contained in the air. If these measures are insufficient, then air cleaning device can be used. Portable air cleaning devices are used to clean for only single use only not for the whole home filtration. There are several air cleaning devices in order to clean the indoor pollution.

As we are discussed above no air cleaners will remove the dust particle as clean as possible, as such the use of the air cleaners is considered to remove the air particles from the indoor environment. The typical air cleaning device does not contain the carbon generating device in to order to remove the radon gas to reduce the health risks. Although the other particles like animal dander, cat allergen, pollen, dust, tobacco smoke and large amounts of air are settling in the room, in the present study we will be calculating the air velocity and the flow rates of the air cleaner in order to increase the performance of the air cleaner.

The air cleaner which we will be studying in the future chapters is a continuous working model for a whole day to remove the air pollutants for your home at a filtration level which is required higher than the hospitals. Defender 360^0 reduces the most tiny particles upto 0.1 microns where the HEPA filter does not reduce, the other air cleaners will emit ozone which will be harmful for your health in which the Defender 360^0 does not emit ozone and it is also better than HEPA filtration, In the Defender 360^0 medi-filter cartridge is used i.e.; single layer , non-woven, wet laid fiber glass media and Charcoal filter is used to reduce the gases and odors, and the construction is very simple with high impact plastic with a filter replacement indicator.

In this study, an experimental setup is made in order to improve the air velocity and flow measurements of the air cleaner and also to calculate the air velocity, flow measurements, relative humidity, and temperature with the specified room size. All these measurements are calculated according to the ENERGY STAR eligibility criteria and AHAM (Association of Home appliance manufactures), and EPA (Environmental Protection Agency) eligibility criteria, and also to design and import the results of the Air cleaner a CAD/CAE and PRO-Engineer software has been used to design and model the concerned parts.

1.2 Motivation and Objectives

This study supports the efforts underway in the Air Cleaners research community to develop a high efficiency Air Cleaner by changing the model of the volute and the motor parameters in order to increase the performance. There are two main objectives for Air Cleaner applications (1) To maximize the performance is by reducing the height of the volute and some changes in the volute to improve the performance of the air cleaner compared to old one. In order to increase the performance of the certain air cleaner there is an important and primary objective i.e;

An important and the primary objective of the air cleaner is to calculate the CADR (Clean Air Delivery rate) for the air cleaners in low, medium and high speeds. In order to calculate CADR (Clean Air Delivery Rate) there are certain parameters required for calculating the value of the CADR there are:

Parameters required:

CLEAN AIR DELIVERY RATE (CADR)

(i) Air Velocity (m/sec)

(ii) Flow Rate (in terms of cubic feet per minute)

(iii) Room size

(iv) Relative Humidity

(v) Frequency (in Hz)

(vi) Voltage (in volts)

(vii) Power output in standby mode and in running mode.

1.3 Literature Survey

Indoor air quality (IAQ) has become an increasingly significant issue. In the past two decades, to improve the energy efficiency has led to build the experimental setup. In the past two decades there are several trials made for making the air cleaner qualify for the Energy star, but they failed to qualify for the Energy star since the performance level is very low compared with the eligible requirements by the Energy star. The methods of improving the performance level of the air cleaners are the most established techniques that have taken during the past years. Past studies have described various analytical and empirical techniques for calculating the air velocity and flow rates. Raman sagar has focused on calculating the CADR values for the certain air cleaners in the air cleaning technology. Numerous and other investigations (mostly numerical results) have been performed to determine the different parameters in order to qualify for the Energy star.

1.4 Chapter Organization

Chapter 1 provided the background information on the research problem and a brief literature survey of the related previous investigations. The plan of the rest of thesis is as follows: Chapter 2 represents overview of the air cleaners, different types of air cleaners, brief description of the air cleaners, parts description, operating conditions, programming Instructions and Troubleshooting in order to provide clear context. Chapter 3 presents description of the experimental setup, instrumentation, explanation of the experimental procedure, Energy star and CADR (Clean Air Delivery Rate) , and the calculation of the room size. Chapter 4 explains about the Numerical results of the two cases for three air cleaners and the comparison between them and also presents a discussion of the numerical values and results of the Air Flow process (Air Velocity, Air Flow Measurements and Temperature, RPM) (i) using different filters for three different Air Cleaners (ii) using the same filter for the three different air cleaners. In Chapter 5 discusses about the Conclusions and recommendations for future studies.

CHAPTER II

OVERVIEW OF THE AIR CLEANERS

Portable air cleaners generally contain fan to circulate the air in the room by using one or more of the air cleaning devices. These portable air cleaners can move from one room to another room and can be used when continuous and localized air cleaning is needed. Air cleaners can be effectively used in order to reduce the air particles and gaseous pollutants. Air cleaners use filters or electronic precipitators to remove particle contaminant from the air you breathe. **[1]**

2.1 Introduction

Indoor air pollutants are unwanted, sometimes harmful in the air. They range from dusts to chemicals to radon. Air cleaning devices that attempt to remove such pollutants from the indoor air you breathe**. [1]** Many air cleaners also include a bed of sorption material to remove gaseous pollutants in order to control the indoor air quality. Air cleaners removed the contaminants contained in the air like tobacco, dust, pollen, animal dander and volatile compounds present in the room**. [2]**

Air cleaners are classified according to the technology to remove various sized of the particles in the air. The general types of technologies available for use in air cleaners are: **[3]**

(i) Mechanical filters

(ii) Electronic air cleaners

(iii) Hybrid filters to capture the particles and the gas phase filters to control odors.

2.2 Mechanical air Cleaners

Mechanical air filter is nothing but the air conditioning or heating in the room or may be used portable devices like a fan or blower to force the air through the filter. Mechanical filters work best at capturing larger than 0.5microns or very small particles (less than 0.2 microns). **[4]** Mechanical filters are very less effective in capturing between 0.1microns to 0.4 microns.

For example, air molecules heavily influence the motion of very small particles in the air stream. As a result the particles motion around the basic path becomes random, for these particles air will be traveling at lower velocities to move away from the primary path through the air stream and the chances of being caught will be increased. This process is called diffusion. Mechanical air filters on two-filtration principals primary air filtration or impingement of the dust on the media itself, and secondary air filtration, which is the dust or filter cake on the filter removing or filtering out smaller dust particles. Figure A1 shows the air filter when it is first installed. Most of the air filtration takes place in the media itself. Figure A2 shows the air filter with dust on the media and the particle reduction efficiency gets better as the filter loads up.

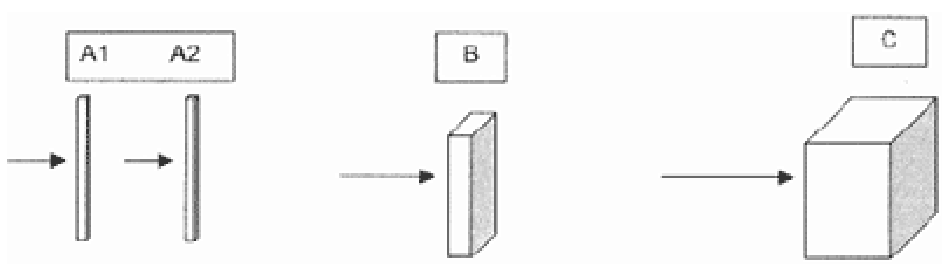


Figure 1. Mechanical Air Cleaner [4]

Mechanical air filters are of three major types:

(i) Flat Filters

(ii) Pleated filters

(iii) HEPA (High Efficiency particulate air filters)

2.2.1 Flat filters

Flat or panel filters contain low packing density fibrous medium that can be dry or coated with a viscous substance such as oil to increase particle adhesion. Dry type filter media may consist of open- cell foams, non-woven textile cloths, paper like mats of glass or cellulose fibers and synthetic fibers. These can be various materials in different kinds of sizes and thicknesses. Typically low efficiency furnace filter is used in many residential systems is a flat filter (one half inch to one inch thick) which is efficient to collect large particles, but removes a negligible percentage of smaller, respirable-size of particles**. [5]**

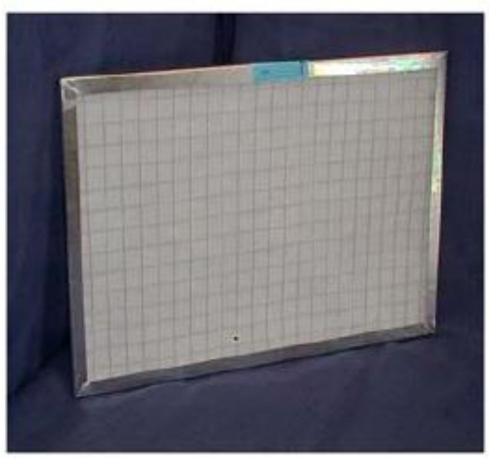


Figure 2. Flat Filter [5]

2.2.2 Pleated filters

One of the effective ways to increase the particle collection efficiency of the mechanical filters is to increase the filter media density using small fibers. This causes smaller media penetrations and increases the screening mesh size. However, any increase in the filter density significantly increases the resistance to airflow, causing decreased airflow through filter. The better way to solve this problem is to increase the surface area by filter. This decreases the airflow velocity through the filter and decreases the overall resistance to airflow such that pressure drop is reduced. Pleating of filter media increased the filter media and thus extends the filter life. These filters can be used without modification in side-access filter housing or built-in filter bank. They offer better efficiency than conventional permanent or disposable flat filters. The filters, when used as pre-filter. Substantially extend the life of more expensive high-efficiency filters. They are perfect filters for residential, commercial and industrial use. **[6]**

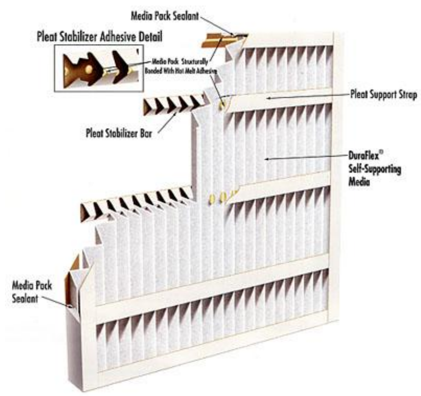


Figure 3. Pleated Filter [6]

2.2.3 High Efficiency particulate air filters (HEPA)

High efficiency particulate air filters are basically called as high efficiency particulate arrestors, are further extension of extended surface media filters. These filters are made during the World War II to prevent the radioactive particles from nuclear reactor facility exhausts. These become a vital technology in industries, medical and in the army clean rooms have grown in popularity for use in portable residential air cleaners. **[7]**

Figure 4. High Efficiency particulate air filters (HEPA) [7]

An HEPA filter has been traditionally defines as an extended surface dry type filter having a minimum particle removal efficiency of 99.98% for all particles of 0.3 micron diameter with higher efficiency of both larger and smaller particles. To qualify as a HEPA filter, the filter must not allow not more than three particles out of 10,000 particles to penetrate the filter media. The filter media is made up of submicron glass fibers in thickness and texture similar to the blot paper. HEPA filters have higher airflow, lower efficiency and lower cost than their original version. The true HEPA filter has low pressure drop performance.

2.3 Electronic Air Cleaners

These electronic air cleaners use an electrical field in order to capture the particles. Like mechanical air filters, they may be installed in the central air conditioning ducts or in portable fans. Electronic air filters are usually electronic precipitators. In these air cleaners using the series of flat plates captures particles. In most of the electronic precipitators particles are directly ionized with the filters before the collection process, resulting in high collection agency.

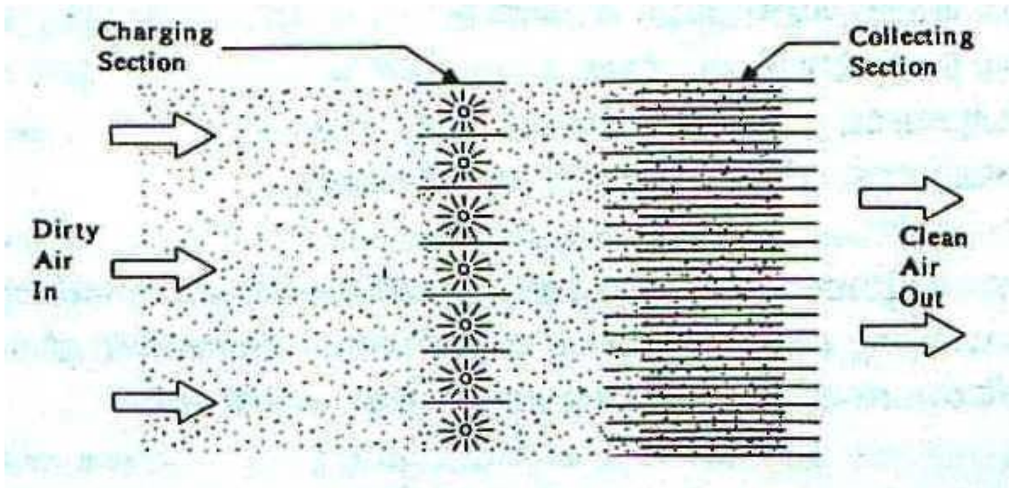


Figure 5. Electronic Air Cleaner [8]

Electronic air cleaners maintain relatively high efficient than the mechanical filters in a range of 0.1micron to 1 micron due to their inherently open cell designs and also it creates low pressure drop which greatly reduces the fan horse power and it leads to energy consumption as compared to other air cleaning devices. Lower fan power also reduces the noise. **[8]** But an important factor is the operational cost and the maintenance cost. The advantages of the electronic air cleaner are they generally have low energy costs because of lo pressure drop. The major disadvantages of the electronic air cleaner are (i) less efficient (ii) they produce ozone, which is very harm for health.

2.4 Hybrid Air cleaners

Hybrid filters incorporate two or more of the filter technologies. These hybrid filters uses one or two types of mechanical filters combined with a electrostatic precipitator or an ion generator. An example of hybrid filter is electrets media filter uses permanently charged media fabricated into either flat panel filters or extended media filters. **[3]** The media filters made from synthetic fibers is inherently charged in the manufacturing process and retains a charge, which attracts airborne particles that are trapped. These media filters have low airflow. The advantages of an electrets filter are (i) low energy cost (ii) high efficiency to clean, and the disadvantages are high maintenance costs due to frequent need to replace the filters and the efficiency drops. In this type of air cleaner, dust in the air is initially charged and then collected on a charged-media filter.

2.5 Defender Air Cleaner

HMI industries are the manufacturer of the Defender Air cleaner. The Defender is a medical device designed to remove airborne particles and allergens such as dust, smoke, pollen, mold spores, animal dander, dust mites, and harmful fibers that may lead to allergic reactions. The Defender works twenty-four hours a day to remove indoor air pollution for your home at a filtration level that is higher than required in many hospitals. Energy efficient and quiet, the Defender actually reduces more of the tiny, harmful particles HEPA cleaners leave behind. Beware of silent air cleaners; many produce ozone, which may be problematic to your health. **[9]**

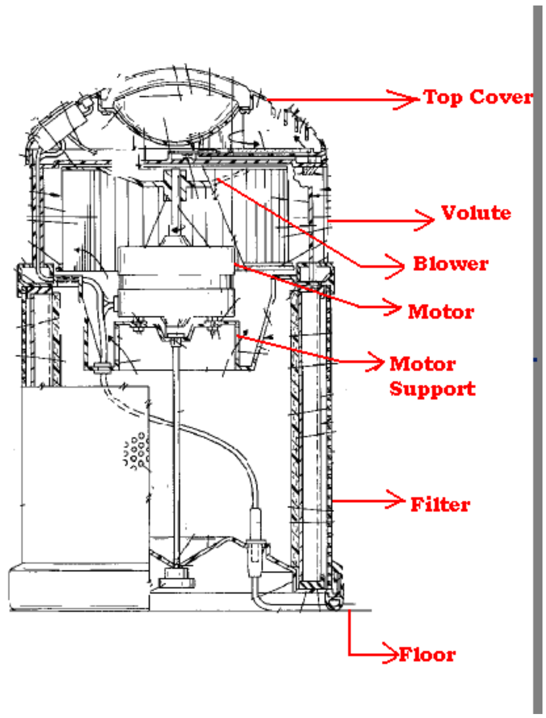


Figure 6. Defender Air cleaner (Courtesy: From US Patent 6511531 (B1))

Defender air Cleaner has many important parts like

(i) Top Cover

(ii) Volute

(iii) Motor

(iv) Motor Support

(v) Filter

2.5.1 Top Cover

In the Top cover user interface will be assembled for the use of switching on and off and for the regulation of the speed i.e.; low, medium and high speed and the top cover will be assembled on the Volute in order to get rid of the air leakages.

Figure 7. Top Cover Courtesy: [HMI Industries]

2.5.2 Volute

Volute is the main of the Defender air cleaner, on the volute circuit board will be assembled and from the circuit board there will be three wires will be connected to the top cover user interface in order to run the air cleaner. In the Volute there will be four vanes each on one side for the air circulation, and this volute will be mounted on the motor support and the volute will be mounted on the filter.

Figure 8. CQ Volute Courtesy: [HMI Industries]

2.5.3 Motor

In the defender air cleaner the motor is also the main part of the air cleaner and the motor is designed as shaded pole type, brushless designed for longer life, and the motor has 1/20HP, 120V, 60 Hz, 175W and the current in amperes at low, medium and high are 0.7A, 1.2 A and 2.0A and the speeds at the low speed, medium and high speed are 550RPM, 1075 RPM and 1600RPm at the high speeds.

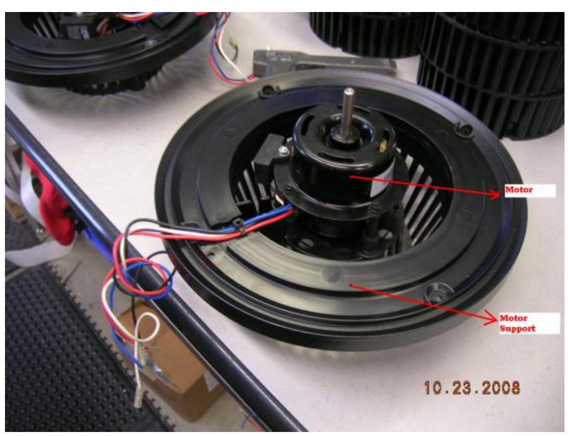


Figure 9. Motor and Motor Support Courtesy: [HMI Industries]

2.5.4 Filter

Filter is also important component in the air cleaner and this filter is a single layer, non-woven, wet laid fiberglass media and it is 4.13 cm combine to provide 43.9 sq feet and it is 99.98% efficient at 0.1 microns. Filter body is made of high impact ABS plastic due to high gas absorption media.

Figure 10. Filter Assembly Courtesy: [HMI Industries]

2.6 Air Cleaning Strategies

There are three basic methods to improve the Indoor air quality. They are:

(i) Sources of Pollution

(ii) Improving ventilation and

(iii) Air Cleaning devices

2.6.1 Sources of pollution

There are different kinds of source pollution in the indoor air quality in order to get diseases. They are:

(i) Tobacco smoke

(ii) Pollen

(iii) Animal Dander and

(iv) Mold and mildew

2.6.1.1 Tobacco

Tobacco Smoke is one of the smallest allergens and for the years EPA (Environmental Protection Agency) is reported about this issue between the second hand smoke and the health effects.

2.6.1.2 Pollen

Pollen comes from the trees, flowers and grass or even if a door is open allows millions of these particles into the home. Some people are very sensitive to the presence of certain pollen particles.

2.6.1.3 Animal dander

People who are allergic to cats and dogs are actually allergic to the dander flakes of their pets and dogs. Dander can remain in the home long time after removal of the dander too.

2.6.1.4 Mold and Mildew

Mold and mildew are typically found in the shower, kitchen and basement; these sneaky plant spores also grow any place that's warm and humid.

2.6.2 Ventilation

Ventilation brings outside air into the room. It can be done by keeping the doors and windows or by turning on the exhaust fan in the kitchen and in the bathroom or by using the air conditioners and mechanical ventilators. These are some of the methods in order to keep the indoor environment from the air borne particles. By keeping the ventilation open to the indoor environment is much efficient to control the air borne particles in the air for better indoor air quality.

2.6.3 Air Cleaning Devices

Air cleaning devices may serve as an adequate source to control the ventilation. The use of air cleaning device is alone cannot assure an adequate air quality, where significant sources are present in order to the indoor air quality from the air borne particles. In addition to this air cleaners also remove gaseous pollutants by using the special material, such as activated charcoal, to facilitate removal of harmful gases.

2.7 Energy Star

The main advantage of the Energy star is to promote energy efficient appliances; the EPA has a responsibility to ensure that the Energy Star program does not promote products with significant performance disadvantages. This can be weaken the Energy Star brand in the mind of the consumers. The fact that the energy star would qualify air cleaners on the basis of energy consumption on the highest speed setting. By approving by the Energy star it shows that air cleaners can clean 95% of dirt from the indoor air and can reduce the power consumption less than the before. The main activities of the Energy Star may include:

(i) Increase the availability of Energy Star qualified products by converting the entire product to meet Energy star guidelines.

(ii) Demonstrate the economic and environmental benefits of energy efficiency.

(iii) Providing the information to the users and also about energy saving features and operating characteristics of Energy star products.

There are many eligible characteristics to qualify for the Energy star. They are:

(i) Room air cleaner must have minimum performance of >=2.0 watts

(ii) Air Cleaners must produce a minimum of 50 CADR to be considers as an Energy star.

(iii) The ambient room temperature should be 70^0 F ± 5^0F (21^0C ± 1.5^0 C)

(iv) Relative Humidity must be 40%RH ±5% RH

(v) Voltage must be 120volts ±1 volts

(vi) Electrical efficiency should be 60 Hertz ± 1 Hertz

(vii) Test should ensure that the air cleaner units motor is properly broken in by running the unit, without filters, for 48 hours

(viii) Under this a watt meter or equivalent instrument capable measuring true RMS watts with an accuracy of ± 1% at 120 volts, 60 Hz calibrated within last 12 months under the traceable of national institute of Standards and Technology.

(ix) Product energy consumption and performance can be measured and verified with testing

(x) Labeling would effectively differentiate products and be visible for purchasers.

(xi) In performing the tests, partner agrees to measure CADR according to the ANSI AC-1 standard. During this test voltage, frequency and power output should be measured by using a watt meter or digital power meter.

(xii) If the voltage or frequency is not matched with the requirements of the Energy star we have to adjust the voltage and the frequency by using power source.

In the event of the specification revision, please note that energy star qualification is not automatically granted for the life of a product model. To carry the Energy star, a product model must meet the Energy star specifications in effect on the models date of manufacture.

CHAPTER III

EXPERIMENTAL SET-UP AND INSTRUMENTATION

The objective of the experimental set up is to investigate air velocity, airflow measurements, voltage and power output, input for the given air cleaners in order to calculate the Clean Air Delivery Rate (CADR) to satisfy for the Energy star qualifications. This chapter also investigates the air velocity and flow performance of an intake system using numerical and experimental techniques**. [10]**

3.1 Introduction

Air cleaners have been recognized as one of the most effective strategies for removal of the indoor air contaminants and reduction of ventilation for saving energy in the buildings. Most of the filters remove the air contaminants from the indoor air, but some filter with some chemical adhesives, they do not give much performance quality for removing gaseous contaminants like Volatile organic Compounds (VOC).

3.2 Experimental Set-up

The main aim of the air cleaner is not only to measure the air velocity and flow measurements in the given chamber, but also to reduce the operational energy and the maintenance costs. The air cleaner consists of blower, motor, volute and filter to control the airflow and velocity in the chamber. The chamber is made up of plastic since to make your product look better longer, and in middle of the experimental set up one of the air cleaner was kept in the center and the fan is attached to one end of the box in order to calculate the air velocity and air flow measurements by using CFM anemometer. The experimental set up shown below:

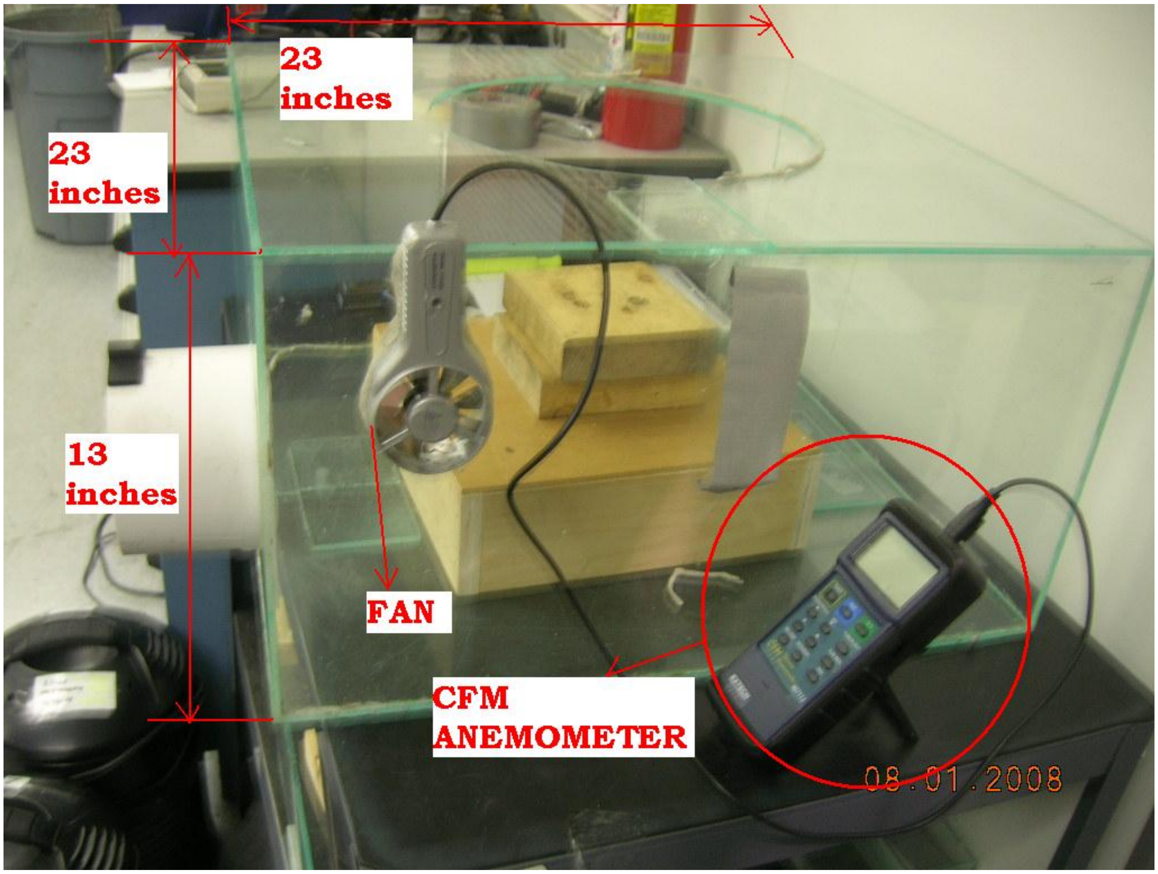


Figure 11. Experimental Set Up Courtesy: [HMI Industries]

The experimental set up is made in rectangular shape in order to get the airflow circulated whole through the box and the dimensions of the set up are given above like (23 inches *23 inches * 13 inches) and the surface area of the rectangular is also calculated with the formula

2 (lw+lh+wh) : Surface area of the rectangular: 2(lw+ lh+wh)

: 2(23*23+23*13+23*13)

: 2172.5 $inch^2$

: 15.08 Square feet

In this experimental set up there are some more parameters are measures like:

(i) RPM (rotations per minute),

(ii) Voltage

(iii) Frequency and

(iv) Power output was measured for the air cleaner in order to eligible for the energy star requirements. All these parameters are measured by different instruments and the instrumentation is discussed below and the parameters also explained.

3.2.1 RPM

Rpm expanded as rotations per minute, the number of full rotations completed in one around a fixed axis minute. It is most commonly used as a measure of rotational speed or angular velocity of some mechanical component and the rpm was measured by using photo contact tachometer.

3.2.2 Voltage

Voltage is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts. It is the measurement of the potential for an electric field to cause an electric current in an electrical conductor. Depending on the difference of electrical potential it is called extra low voltage, low voltage, high voltage or extra high voltage.

Specifically, voltage is equal to energy per unit charge. Voltage also measured by using digital power meter.

3.2.3 Frequency

Frequency is the number of occurrences of a repeating event per unit time. It is also referred to as temporal frequency. The period is the duration of one cycle in a repeating event, so the period is the reciprocal of the frequency and the frequency can also be controlled by using digital power meter. $T = 1/f$

3.2.4 Power output

Power output is calculated for the air cleaners in the standby mode and in the running mode by using Digital power meter and also by adjusting the frequency in the digital power meter.

All these parameters are measured by different apparatus and the instrumentation is discussed below:

3.3 Instrumentation

In order to qualify for the Energy star the above parameters should be measured and the instruments are:

(i) CFM Anemometer

(ii) Photo contact Tacho Meter

(iii) WT 200 Digital Power meter

(iv) 3KVA AC Power source

3.3.1 CFM Anemometer

This instrument measures air velocity , air flow (Volume) and temperature.

Figure 12. CFM Anemometer [12]

Sensor plug can be inserted in the sensor jack from only one direction. PC interface jack is provided in the kit and the sensor jack will be inserted into the van sensor in order to calculate the air velocity , air flow(volume) and temperature after turning on the air cleaner we can see these values on the LCD screen of the anemometer, and by using the kepad we can change the units from air velocity to airflow measurements and also the temperature units, and while taking the temperatures press the hold button in order to take the values of the air velocity and air flow measurements . By using this instrument we can note the maximum and minimum values.

3.3.2 Photo Contact Tacho Meter

Photo Contact Tacho Meter is used to measure the Speed of the motor in the lower, medium and in high speeds. Reflective tape will be placed on the motor of the air cleaner and after turning on of the motor the tachometer will be placed opposite to the reflective tape in order to take the motor speed at different speeds and the speed is constant at all points of the motor. Accurate to 0.05% with max resolution of 0.1rpm in either photo or contact mode.

Figure 13. Photo Contact Tacho Meter Courtesy: [HMI Industries]

3.3.3 WT 200 Digital Power meter

By using the power meter voltage , frequency and power output is measured in order to eligible for the Energy star qualifications, connect the cord of the air cleaner to the plug of the power meter and turn on the air cleaner and measure the voltage , frequency and Power output in the standby mode and in the running mode. The frequency range is 10Hz to 50 KHz and true Rms voltage is (20A, 1000v RMS)

Figure 14. WT 200 Digital Power Meter Courtesy: [HMI Industries14]

3.3.4 3KVA AC Power source

This instrument is used to control the frequency and voltage in order to match the speed of the motors at different speeds i.e; by controlling the voltage we can see the rpm's of the three air cleaners can be same at low, medium and high speed respectively, in order to measure the air velocity and airflow measurements at the same rpm's for the three air cleaners and compare between them. It also drives load from 0 to 1 power factor and the power range is 3kVA to 13.5kVA.

Figure 15. 3KVA AC Power source [15]

3.3.5 FDM Machine

This is rapid prototype machine that extrudes layers to build a model from an STP file layer by layer, most from 3D or CAD software system supports STL data exchange. The main advantage of using this machine is to test functionally with robust ABS models, cost reduction and time compression, better product development, vacuum forming moulds and sand casting patterns. The cost of the FDM rapid prototype is mainly depends on the time taken to produce the model.

Figure 16. Dimension FDM machine Courtesy: [HMI Industries]

3.4 Experimental Procedure

Defender Air Cleaner works 24 hours a day to remove air pollution in the indoor air filtration level that is higher than required in many hospitals. It also reduces more of the tiny, harmful particles HEPA cleaners leave behind. The experimental procedure is conducted in order to qualify for the Energy Star requirements, in this experimental procedure mainly we have to calculate Clean Air Delivery Rate (CADR), power output in the standby mode and in the running mode, voltage, temperature and relative humidity.

In the test we have taken 3 different types Defenders in order to test and take values of air velocity, flow rate, temperature and relative humidity by using different instruments. The three types of air cleaners are

(i) Nothing was modified in the Air cleaner(motor or volute)

(ii) Motor was modified

(iii) Volute and motor was modified.

The experiment is conducted in two cases in order to qualify for the Energy Star. They are:

(i) Different air cleaners with different rpm's and filters.

(ii) Different air cleaners with same rpm's and filters.

And the experiment is conducted in 3 stages for the above two cases they are:

(i) Without filter

(ii) With CQ screen

(iii) With Filter

3.4.1 Case I

In the first case of the test I we have 3 air cleaners with different rpm's and the air cleaners are tested is conducted in 3 stages as shown above.

3.4.1.1 Air Cleaner 1

In the first cleaner nothing was modified either the volute, motor nor the filter and also in this case the speed of the motor is measured at different levels i.e.; low, medium and high by using photo contact tachometer, and the test is conducted in three stages :

(i) Without Filter

(ii) With CQ screen

(iii) With Filter

Without Filter

In this case the air cleaner was kept in the test rig and the air cleaner will be running at least 5 minutes before taking the values of air velocity and flow rate and the values will be taken at different speeds (low, medium and high) and the figure is shown below:

Figure 17. Without Filter (Air Cleaner 1) Courtesy: [HMI Industries]

With CQ Screen

In this case also the air cleaner will be installed on the test rig and in the mean time while the air cleaner is running at different speeds, air velocity and flow rate reading will be noted and will be compared with the air cleaner 1. The figure shown below:

Figure 18. With CQ Screen (Air Cleaner 1) Courtesy: [HMI Industries]

With filter

In this case the air cleaner is tested in the test rig with the filter. First of all after installing in the test rig the air cleaner will be run for at least 5 minutes in standby mode in order to take the values of the air velocity, flow rate etc.., . The figure is shown below:

Figure 19. With Filter (Air Cleaner 1) Courtesy: [HMI Industries]

3.4.1.2 Air Cleaner 2

In the air cleaner 2 one change was made that is motor was modified compared to previous one which was used in the air cleaner1, speed of the motor is also measured in this case, and the same readings was taken as in the air cleaner 1. The test is also conducted in three stages they are:

Without Filter

In this case the air cleaner the test was conducted without filter in order to see how much air was flowing in the rest rig in terms of air velocity and flow rate in meter per second and cubic feet per minute and the results are compared with the first air cleaner.

Figure 20. Without Filter (Air Cleaner 2) Courtesy: [HMI Industries]

With CQ Screen

In this case the motor was modified, and the air cleaner was tested with CQ screen in order to see how much air it was leaking compared to the previous one and the remaining procedure is same as the previous one. The figure is shown below:

Figure 21. With CQ Screen (Air Cleaner 2) Courtesy: [HMI Industries]

With Filter

In this case air cleaner will be testing with filter and the values of air velocity and flow rate will be noted at different speeds in order to see the how much air was flowing when it was with filter. The figure was shown below:

Figure 22. With Filter (Air Cleaner 1) Courtesy: [HMI Industries]

3.4.1.3 Air Cleaner 3

In the third type of air cleaner in which volute and the motor was modified, like volute height was modified compared to the previous one, and the motor is the same as in the air cleaner 2, and the values are compared with previous two. In air cleaner 3 also test is conducted in 3 stages.

Without Filter

In this case also the air cleaner is tested on the test rig without filter and the same procedure is undergone as with the previous one in order to calculate the values of air velocity and flow rate and compare with the previous one. The figure in shown below:

Figure 23. Without Filter (Air Cleaner 3) Courtesy: [HMI Industries]

With CQ Screen

In this case the air cleaner is tested with cq screen in which we can say that how air was flowing within the test rig by using Cfm anemometer. The figure shown below:

Figure 24. With CQ Screen (Air Cleaner 3) Courtesy: [HMI Industries]

With Filter

In this case also procedure as in the previous one air cleaner will be tested with the filter in the test rig and the air velocity and flow rates will be noted at different speeds and compared with the previous 2 air cleaners. The figure is shown below:

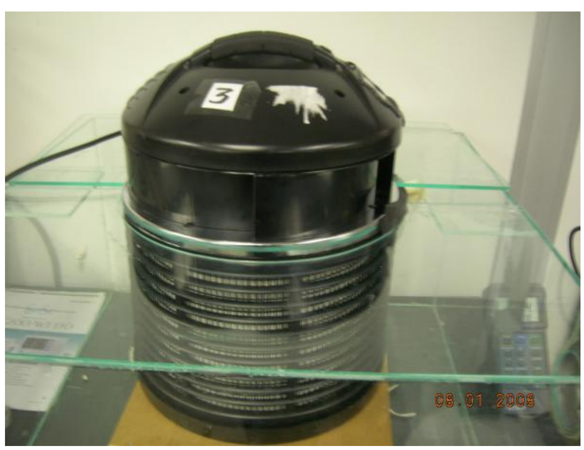


Figure 25. With Filter (Air Cleaner 3) Courtesy: [HMI Industries]

3.5 Case II

In the case ii also same procedure will be taking place, but in the first case we have used three different air cleaners with three different filters with different rpm's at low, medium and high speed, here in this case we will be using the same filter with the same speeds at low, medium and high and the speed of the rpm is controlled by digital power meter and power source in order to keep the air cleaners at same speeds. In this case also test is conducted with three air cleaner and in three stages as in the first case, and the figures are the same as in the first case.

The results in these two cases are compared within the air cleaners 1,2 and 3 and also with the second case, and in these two cases different parameters have taken into consideration like voltage, frequency current and the power output in the standby mode and in running model in order to qualify for the Energy Star requirements.

3.6 Modeling of the Modified Volute

In the above three cases we have used modified volute for calculating air velocity and flow rate for the air cleaner 3, in this case I have re-modeled the volute by using the modeling software called Pro-Engineer, and after modeling the model I have made the prototype of the model by using the FDM machine. For doing the model easy and comfortable I have cut the model into two pieces and sent to the FDM machine to make prototype.

The time taken for making the prototype is approximately 90 hours. The figure is shown below:

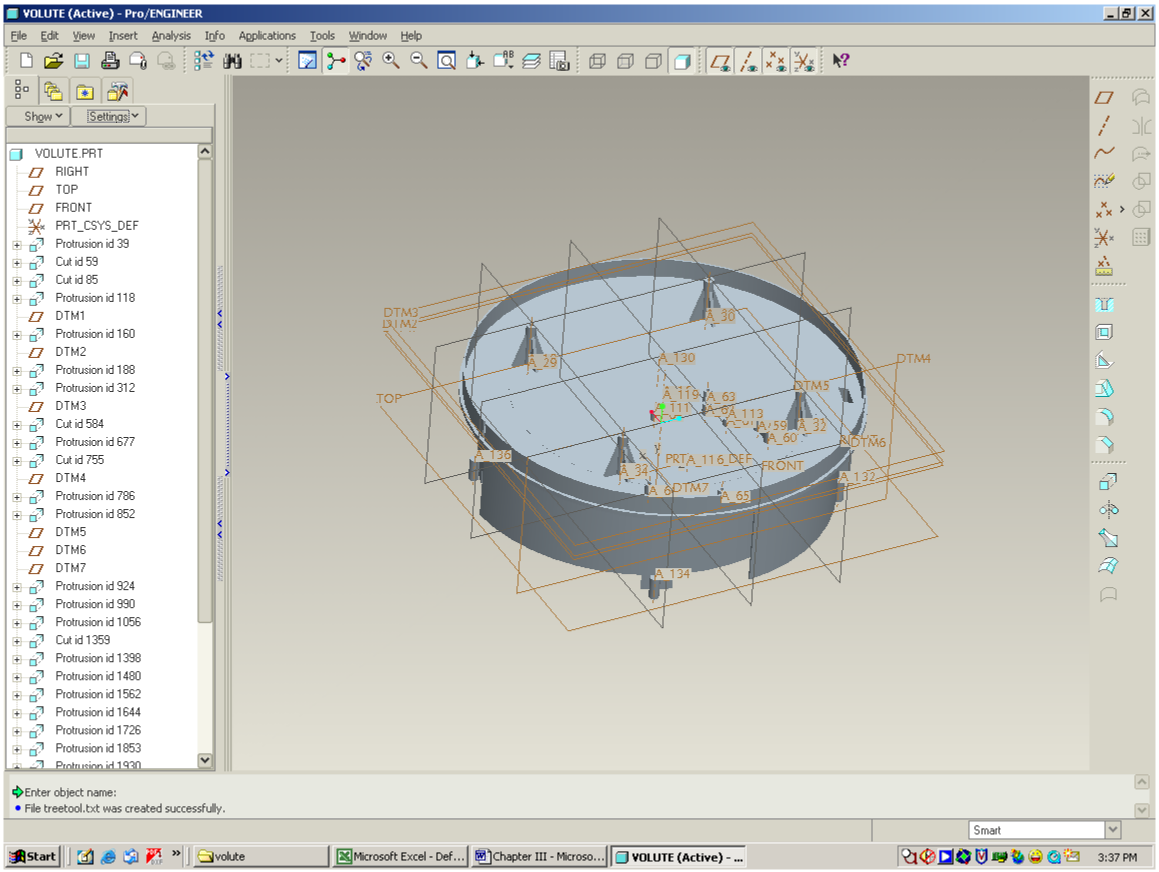


Figure 26. Pro-Engineer Model of the Modified Volute

3.7 Prototype model of the modified Volute

The prototype model is made up of on the Dimension FDM machine in order to make the model for testing the air cleaners and calculating the air velocity and flow rates in order to get the Clean Air delivery Rate (CADR) and this model made up of with the ABS mixtures by layer by layer in order to get the model easy and comfortable, after testing the prototype, If any changes need to be made a new model can be made and used to perfect the design thus making sure that the product will perform as expected before designing and purchasing costly molding tools. Here is the Prototype shown below:

Figure 27.Prototype model of modified volute Courtesy: [HMI Industries]

CHAPTER IV

NUMERICAL RESULTS

The results of the defender air cleaner for the two cases of the test was studied in this chapter and also the comparisons were made between the three defenders in the first case and in the second case in order to calculate the CADR (Clean Air Delivery Rate) values for the air cleaner in order to satisfy for Energy Star eligible requirements.

4.1 Case I [With different Filters and different rpm's]

4.2 Air Cleaner I

Table 1. Air Cleaners I with different Filters and different rpm's

WITHOUT FILTER						A= 1.40161m²
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CMM)**		
Low Speed (740 RPM)	Max	6.36	22.5	Low Speed (740 RPM)	Max	534
	Min	6.3	22.5		Min	531
Medium Speed (1360 RPM)	Max	11.47	22.9	Medium Speed (1360 RPM)	Max	945
	Min	11.29	22.8		Min	936
High Speed (1680 RPM)	Max	14.38	23	High Speed (1680 RPM)	Max	1190
	Min	14.19	23		Min	1187

WITH CQ SCREEN						A= 1.40161m²
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CMM)**		
Low Speed (740 RPM)	Max	6.48	22.7	Low Speed (740 RPM)	Max	545
	Min	6.31	22.7		Min	543
Medium Speed (1360 RPM)	Max	11.53	23.1	Medium Speed (1360 RPM)	Max	955
	Min	11.34	22.9		Min	954
High Speed (1680 RPM)	Max	14.21	22.9	High Speed (1680 RPM)	Max	1200
	Min	14.17	22.9		Min	1189

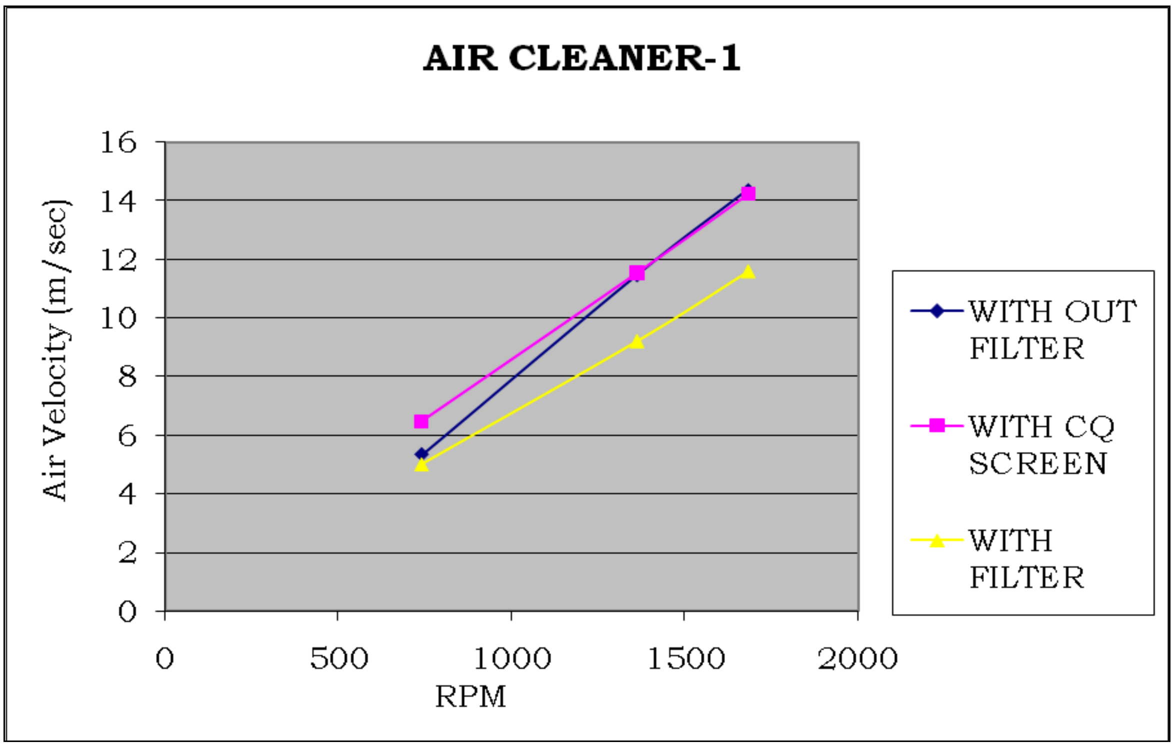
WITH FILTER						A= 1.40161m²
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CMM)**		
Low Speed (740 RPM)	Max	5.01	23	Low Speed (740 RPM)	Max	416
	Min	5	22.9		Min	408
Medium Speed (1360 RPM)	Max	9.21	22.9	Medium Speed (1360 RPM)	Max	773
	Min	9.13	22.9		Min	768
High Speed (1680 RPM)	Max	11.59	22.6	High Speed (1680 RPM)	Max	970
	Min	11.45	22.6		Min	962

4.2.1 Comparison of Air Cleaner I [With Air Velocity]

Table 2. Comparison of Air Cleaner I with Air Velocity

AIR VELOCITY (M/SEC)			
RPM	**Without filter**	**With CQ Screen**	**With Filter**
740	5.34	6.48	5.01
1360	11.47	11.53	9.21
1680	14.38	14.21	11.59

Figure 28. Comparison of Air Cleaner I with Air Velocity

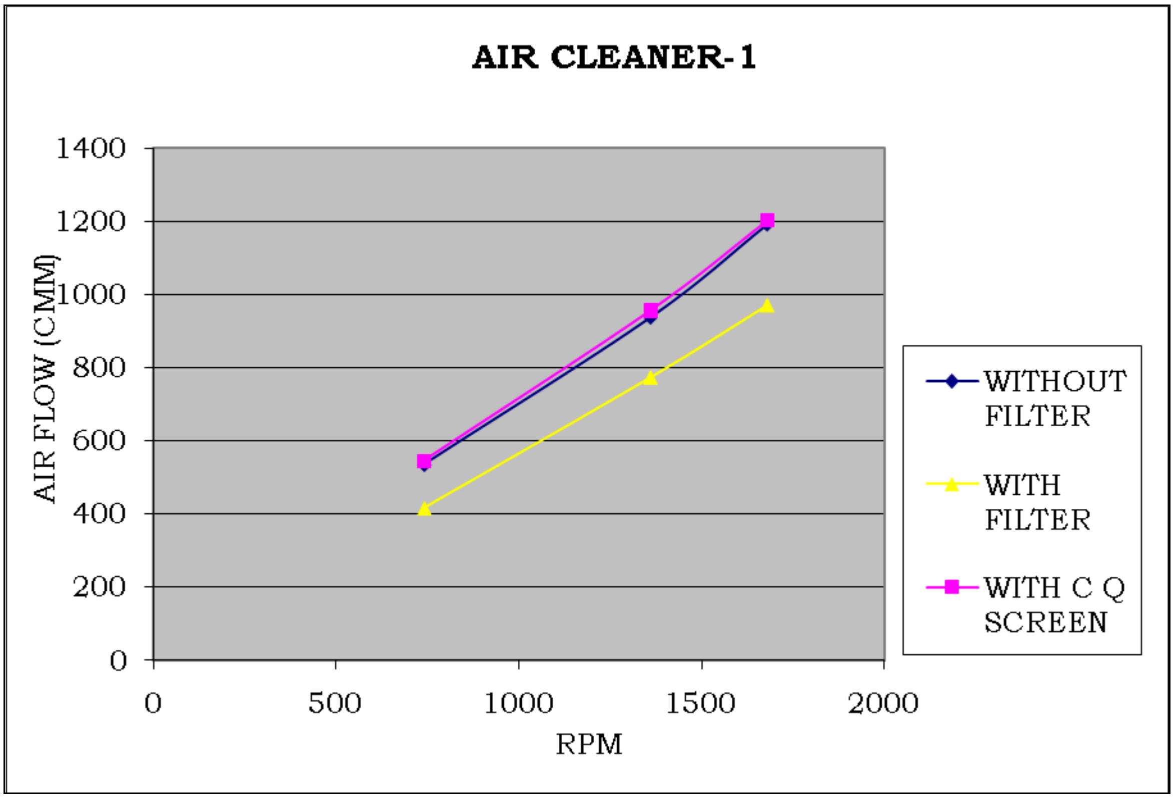


4.2.2 Comparison of Air Cleaner I [With Air Flow]

Table 3. Comparison of Air Cleaner I with Air Flow

AIR FLOW (CMM)			
RPM	**Without filter**	**With CQ Screen**	**With Filter**
740	534	545	416
1360	936	955	773
1680	1190	1200	970

Figure 29. Comparison of Air Cleaner I with Air Flow



4.3 Air Cleaner II

Table 4. Air Cleaners II with different Filters and different rpm's

WITH OUT FILTER						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (610 RPM)	Max	5.74	21.9	Low Speed (740 RPM)	Max	402
	Min	5.46	22.1		Min	395
Medium Speed (1260 RPM)	Max	11.16	22.2	Medium Speed (1360 RPM)	Max	860
	Min	11.01	22.4		Min	849
High Speed (1650 RPM)	Max	14.87	22.9	High Speed (1680 RPM)	Max	1215
	Min	14.7	22.8		Min	1200

WITH CQ SCREEN						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (610 RPM)	Max	5.59	22	Low Speed (610 RPM)	Max	510
	Min	5.51	21.8		Min	505
Medium Speed (1260 RPM)	Max	11.48	22.3	Medium Speed (1260 RPM)	Max	945
	Min	11.39	2.2		Min	930
High Speed (1650 RPM)	Max	14.86	22.6	High Speed (1650 RPM)	Max	1300
	Min	14.72	22.7		Min	1280

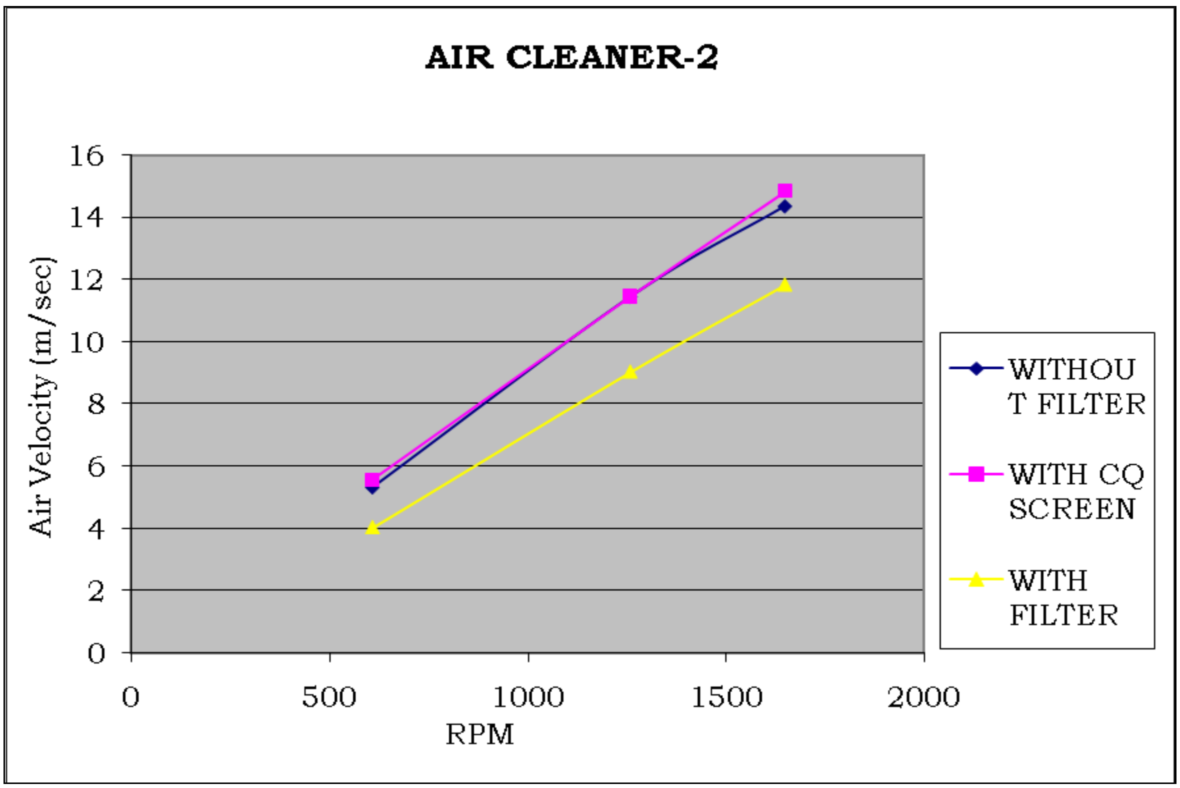
WITH FILTER						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (740 RPM)	Max	4.04	22.5	Low Speed (610 RPM)	Max	344
	Min	4	22.4		Min	338
Medium Speed (1360 RPM)	Max	9.04	22.2	Medium Speed (1260 RPM)	Max	750
	Min	8.89	22.4		Min	745
High Speed (1680 RPM)	Max	11.84	22.6	High Speed (1650 RPM)	Max	998
	Min	11.72	22.8		Min	983

4.3.1 Comparison of Air Cleaner II[With Air Velocity]

Table 5. Comparison of Air Cleaner II with Air Velocity

AIR VELOCITY (M/SEC)			
RPM	**Without filter**	**With CQ Screen**	**With Filter**
610	5.74	5.59	4.04
1260	11.16	11.48	9.04
1650	14.87	14.86	11.84

Figure 30. Comparison of Air Cleaner II with Air Velocity

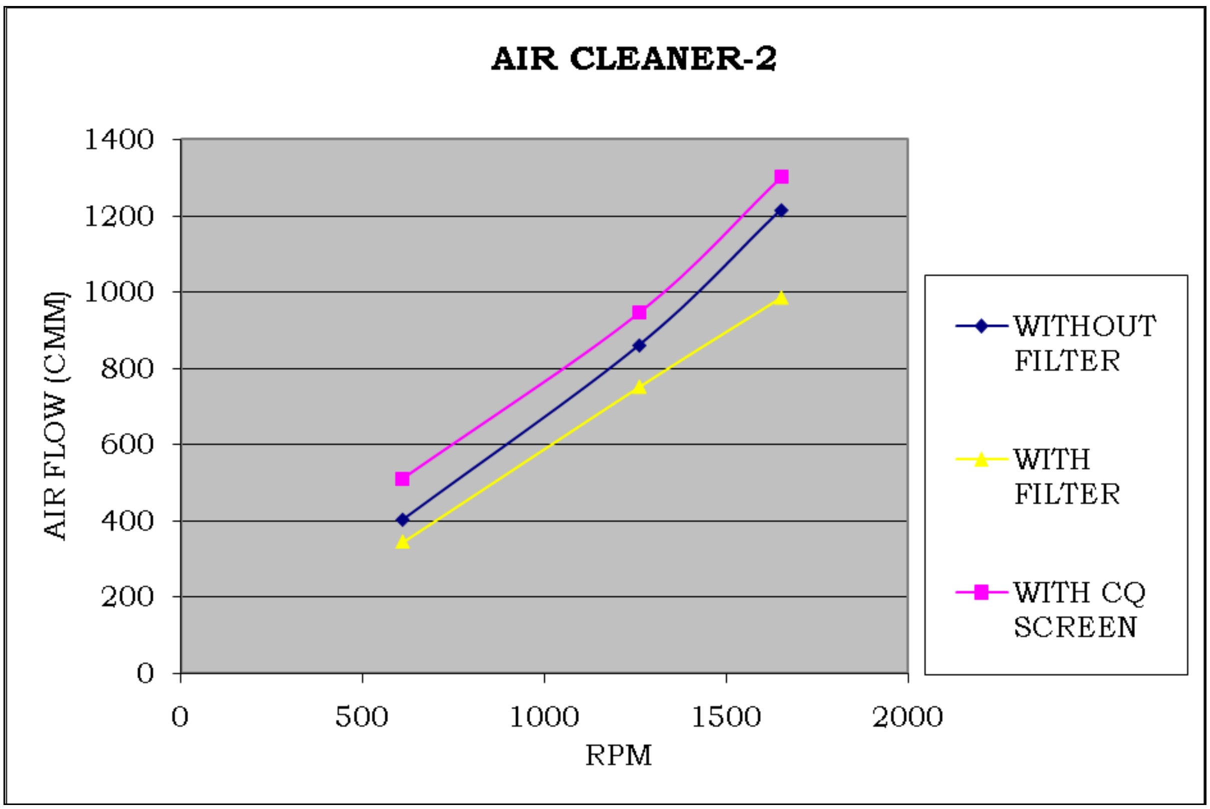


4.3.2 Comparison of Air Cleaner II [With Air Flow]

Table 6. Comparison of Air Cleaner II with Air Flow

AIR FLOW (CMM)			
RPM	**Without filter**	**With CQ Screen**	**With Filter**
610	402	510	344
1260	860	945	750
1650	1215	1300	983.5

Figure 31. Comparison of Air Cleaner II with Air Flow



4.4 Air Cleaner III

Table 7. Air Cleaners III with different Filters and different rpm's

WITH OUT FILTER						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (950 RPM)	Max	7.33	21.4	Low Speed (950 RPM)	Max	616
	Min	7.32	21.2		Min	610
Medium Speed (1445 RPM)	Max	12.28	22	Medium Speed (1445 RPM)	Max	1042
	Min	12.21	21.5		Min	1020
High Speed (1700 RPM)	Max	15.85	22.8	High Speed (1700 RPM)	Max	1336
	Min	15.7	22		Min	1300

WITH CQ SCREEN						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (950 RPM)	Max	7.25	22.7	Low Speed (950 RPM)	Max	628
	Min	7.2	22.7		Min	623
Medium Speed (1445 RPM)	Max	12.76	21.8	Medium Speed (1445 RPM)	Max	1072
	Min	12.66	21.8		Min	1065
High Speed (1700 RPM)	Max	15.67	21.9	High Speed (1700 RPM)	Max	1328
	Min	15.65	21.9		Min	1316

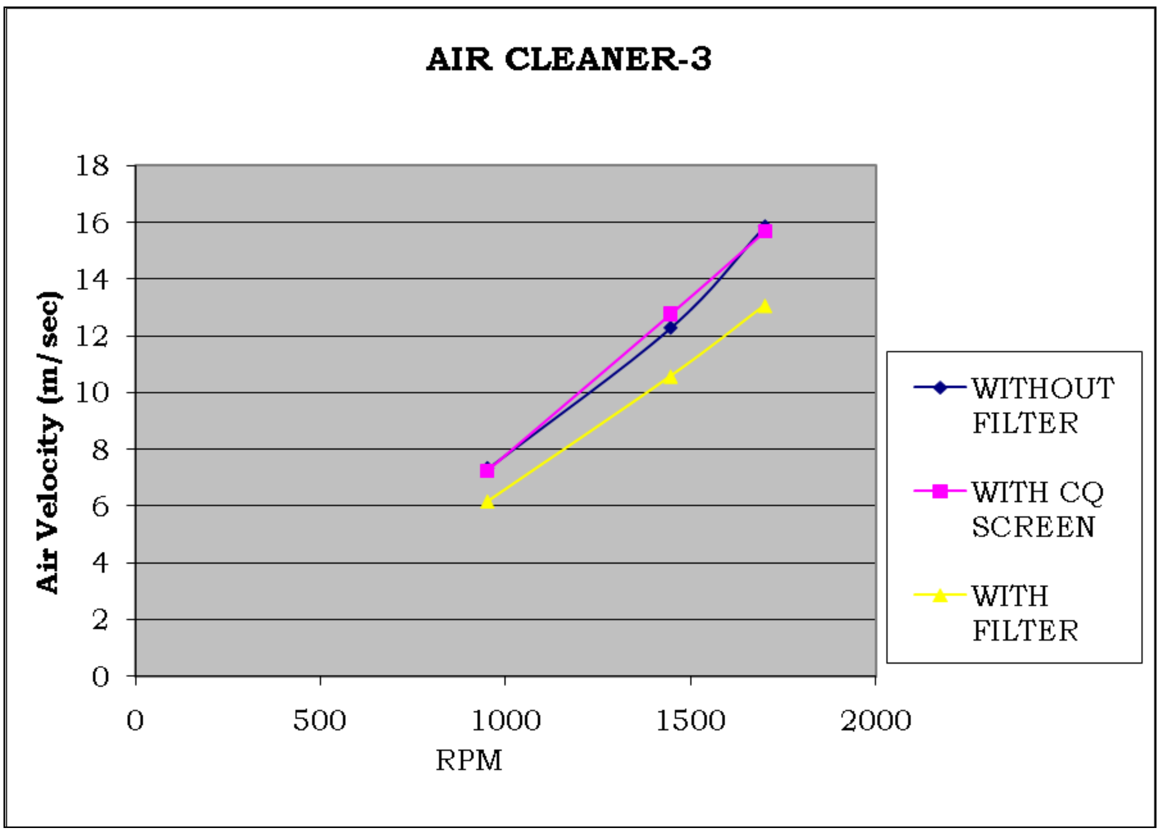
WITH FILTER						**A= 1.40161m²**
Air Velocity(m/sec)			**Temp (⁰C)**	**Air Flow Measurements (CMM)**		
Low Speed (950 RPM)	Max	6.19	22	Low Speed (950 RPM)	Max	506
	Min	6.17	21.9		Min	500
Medium Speed (1445 RPM)	Max	10.59	21.9	Medium Speed (1445 RPM)	Max	894.5
	Min	10.54	21.9		Min	887
High Speed (1700 RPM)	Max	13.08	22.1	High Speed (1700 RPM)	Max	1102
	Min	12.98	22.2		Min	1095

4.4.1 Comparison of Air Cleaner III[With Air Velocity]

Table 8. Comparison of Air Cleaner III with Air Velocity

AIR VELOCITY (M/SEC)			
RPM	**Without filter**	**With CQ Screen**	**With Filter**
950	7.33	7.25	6.19
1445	12.28	12.76	10.59
1700	15.85	15.67	13.08

Figure 32. Comparison of Air Cleaner III with Air Velocity

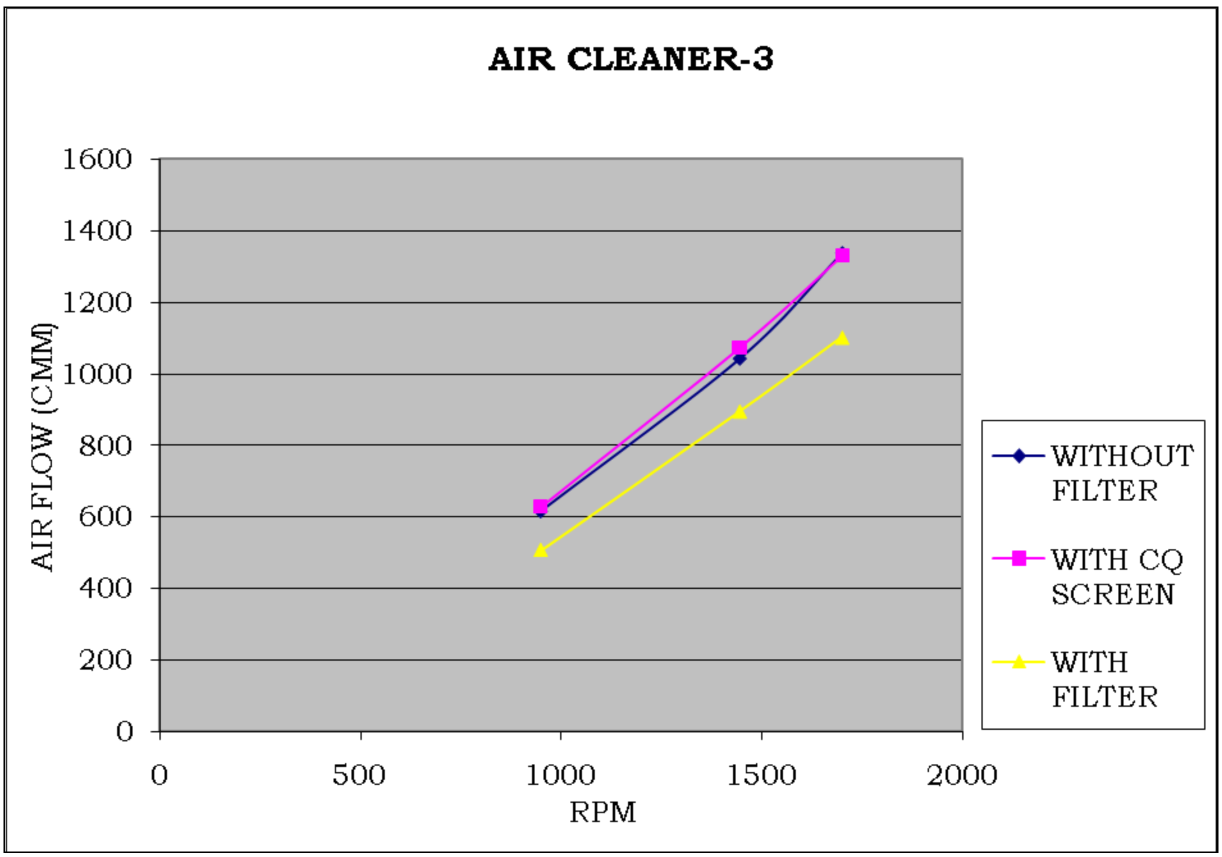


4.4.2 Comparison of Air Cleaner III[With Air Flow]

Table 9. Comparison of Air Cleaner III with Air Flow

AIR FLOW (M/SEC)			
RPM	Without filter	With CQ Screen	With Filter
950	616	628	506
1445	1042	1072	894.5
1700	1336	1328	1102

Figure 33. Comparison of Air Cleaner III with Air Flow



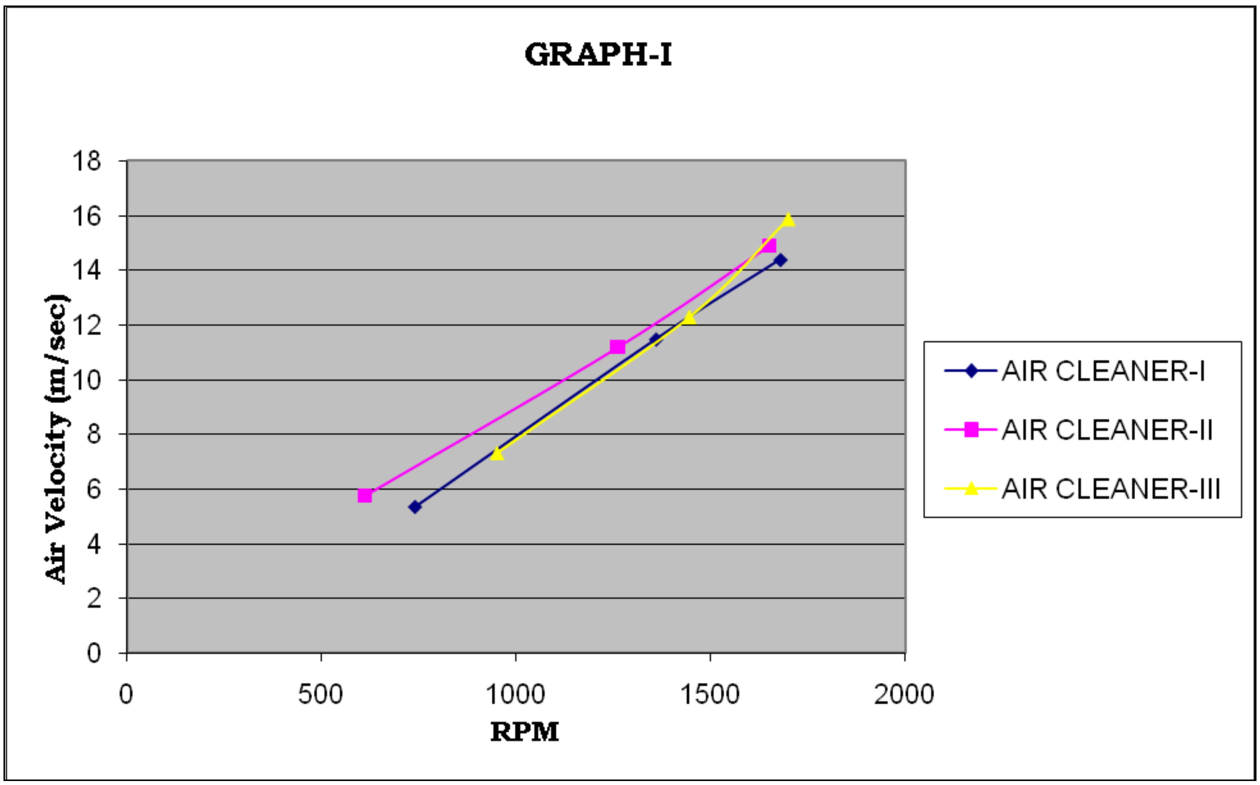
4.5 Comparison Between the three Air Cleaners [Case I]

4.5.1. Air Velocity Values (M/Sec) of Air Cleaners I, II & III without Filter

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**Without filter**	**RPM**	**Without filter**	**RPM**	**Without Filter**
740	5.34	610	5.74	950	7.33
1360	11.47	1260	11.16	1445	12.28
1680	14.38	1650	14.87	1700	15.85

Table 10. Comparison Between the three Air Cleaners with Air velocity without Filter)

Figure 34. Comparison Between the three Air Cleaners for Air velocity (without filter)

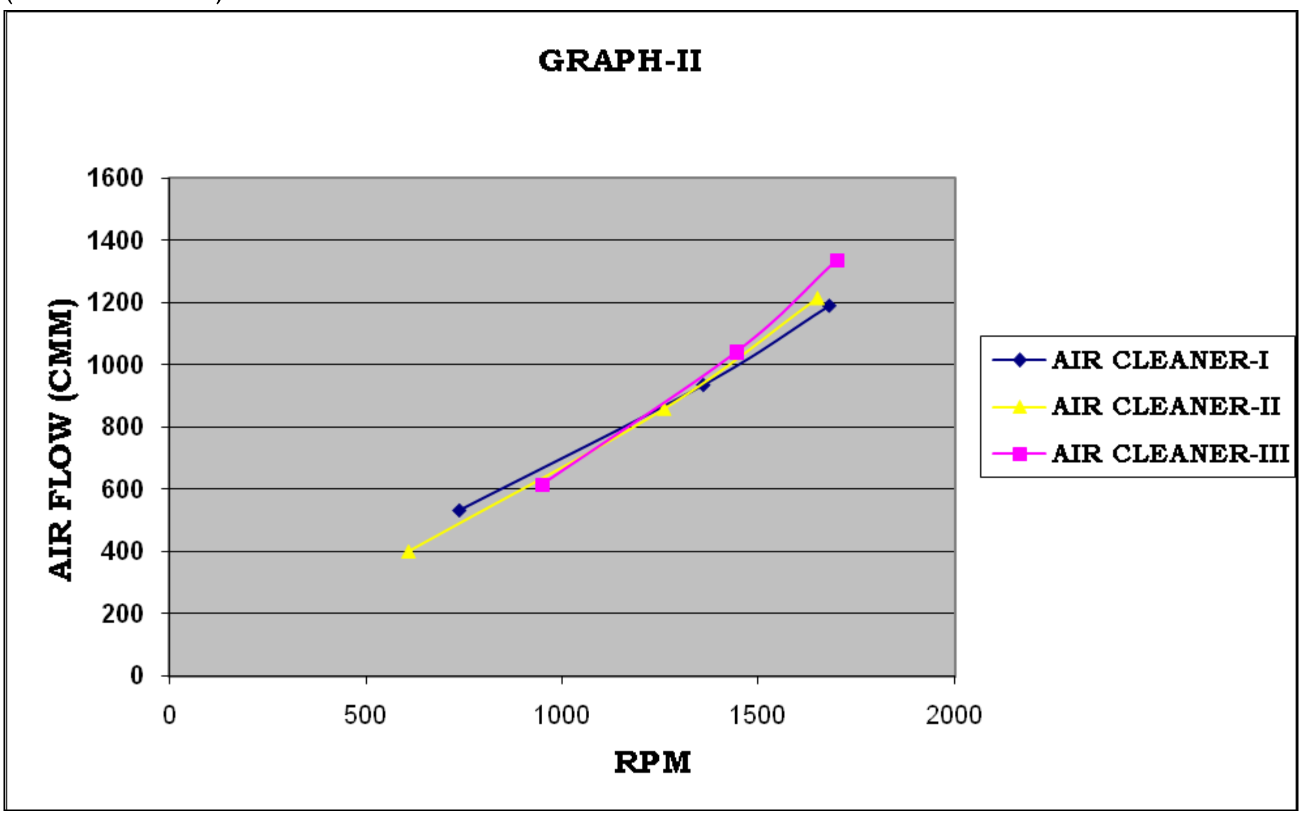


4.5.2. Air Flow Values (CMM) of Air Cleaners I, II & III Without Filter

Table 11. Comparison Between the three Air Cleaners for Air Flow (without filter)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**Without filter**	**RPM**	**Without filter**	**RPM**	**Without Filter**
740	534	610	402	950	616
1360	936	1260	860	1445	1042
1680	1190	1650	1215	1700	1336

Figure 35. Comparison Between the three Air Cleaners for Air Flow (without filter)

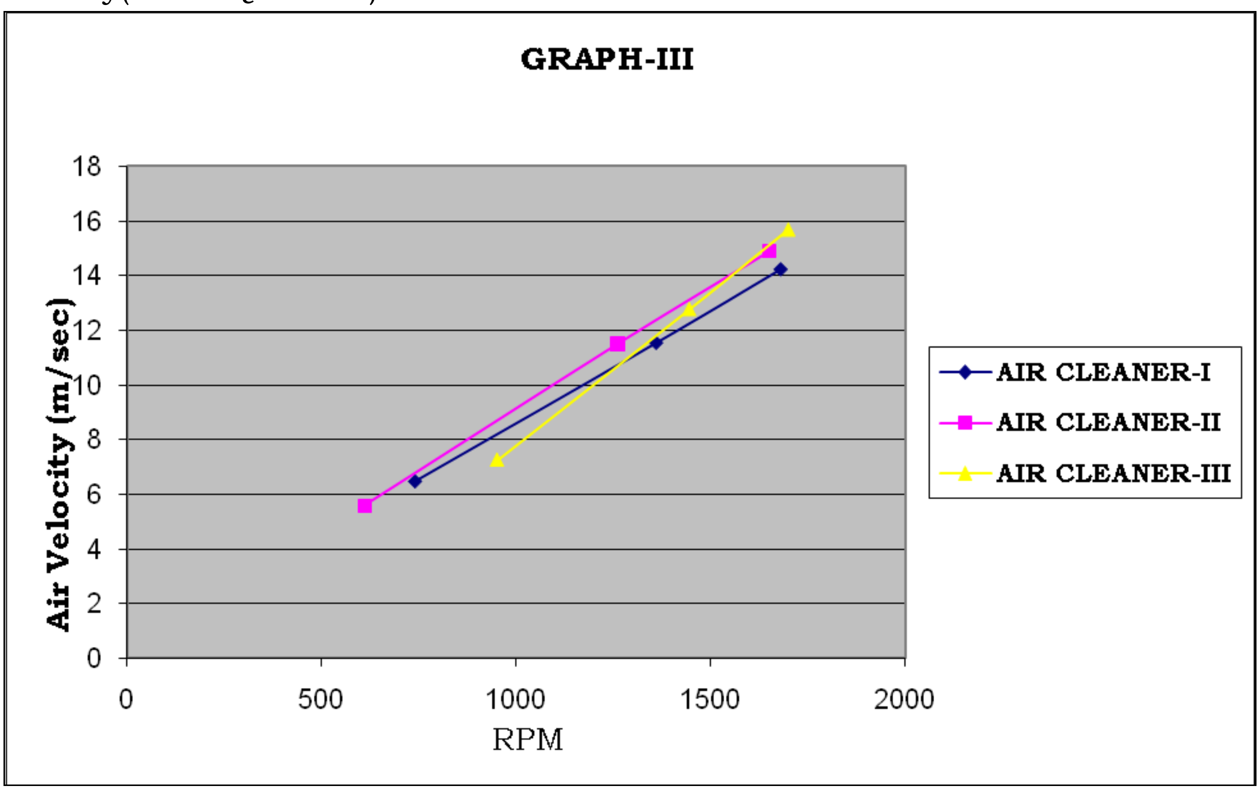


4.5.3. Air Velocity Values (M/Sec) of Air Cleaners I, II & III With CQ Screen

Table 12. Comparison Between the three Air Cleaners for Air velocity (with CQ screen)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**With CQ SCREEN filter**	**RPM**	**With CQ SCREEN filter**	**RPM**	**With CQ SCREEN filter**
740	6.48	610	5.59	950	7.25
1360	11.53	1260	11.48	1445	12.76
1680	14.21	1650	14.86	1700	15.67

Figure 36. Comparison Between the three Air Cleaners for Air velocity(with CQ screen)

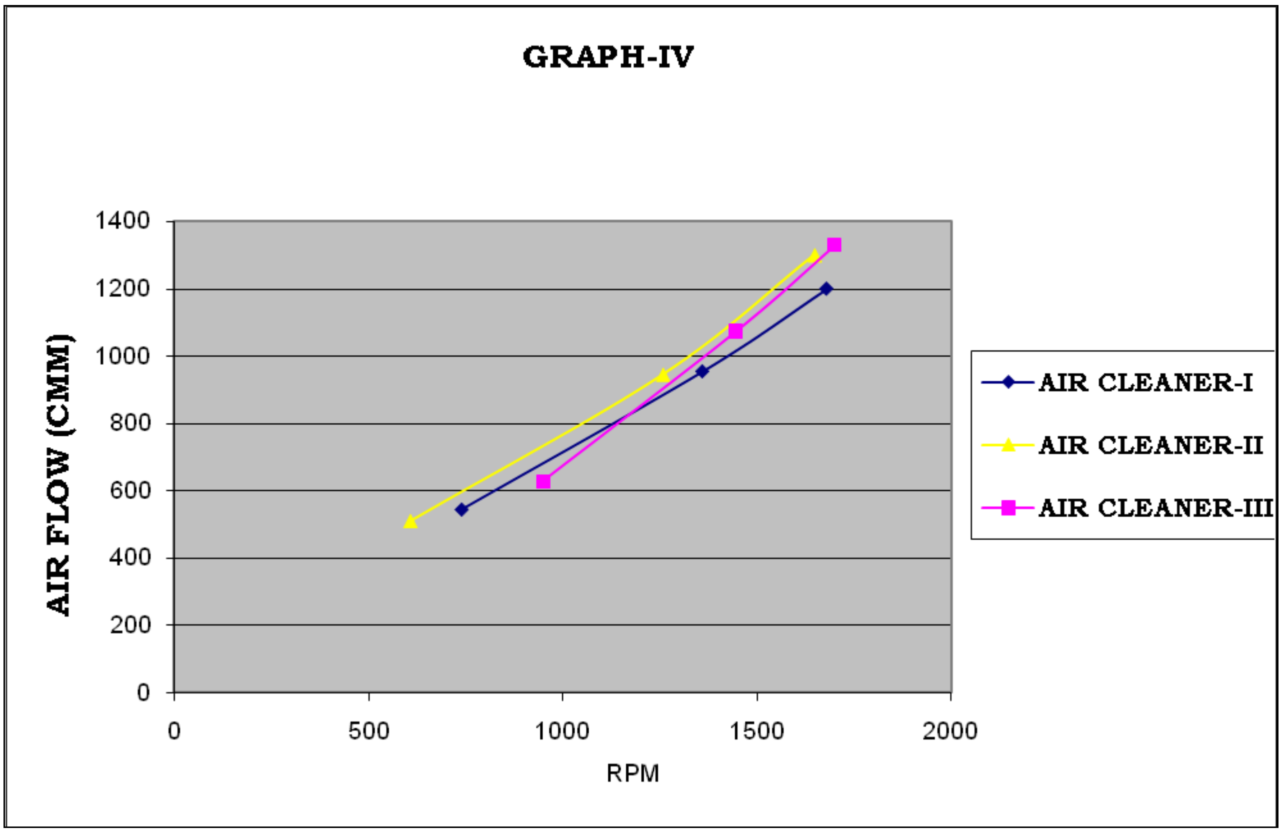


4.5.4 Air Flow Values (CMM) Of Air Cleaners I, II & III With CQ Screen

Table 13. Comparison Between the three Air Cleaners for Air Flow (with CQ screen)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	With CQ SCREEN filter	RPM	With CQ SCREEN filter	RPM	With CQ SCREEN filter
740	545	610	510	950	628
1360	955	1260	945	1445	1072
1680	1200	1650	1300	1700	1328

Figure 37. Comparison Between the three Air Cleaners for Air Flow (with CQ screen)

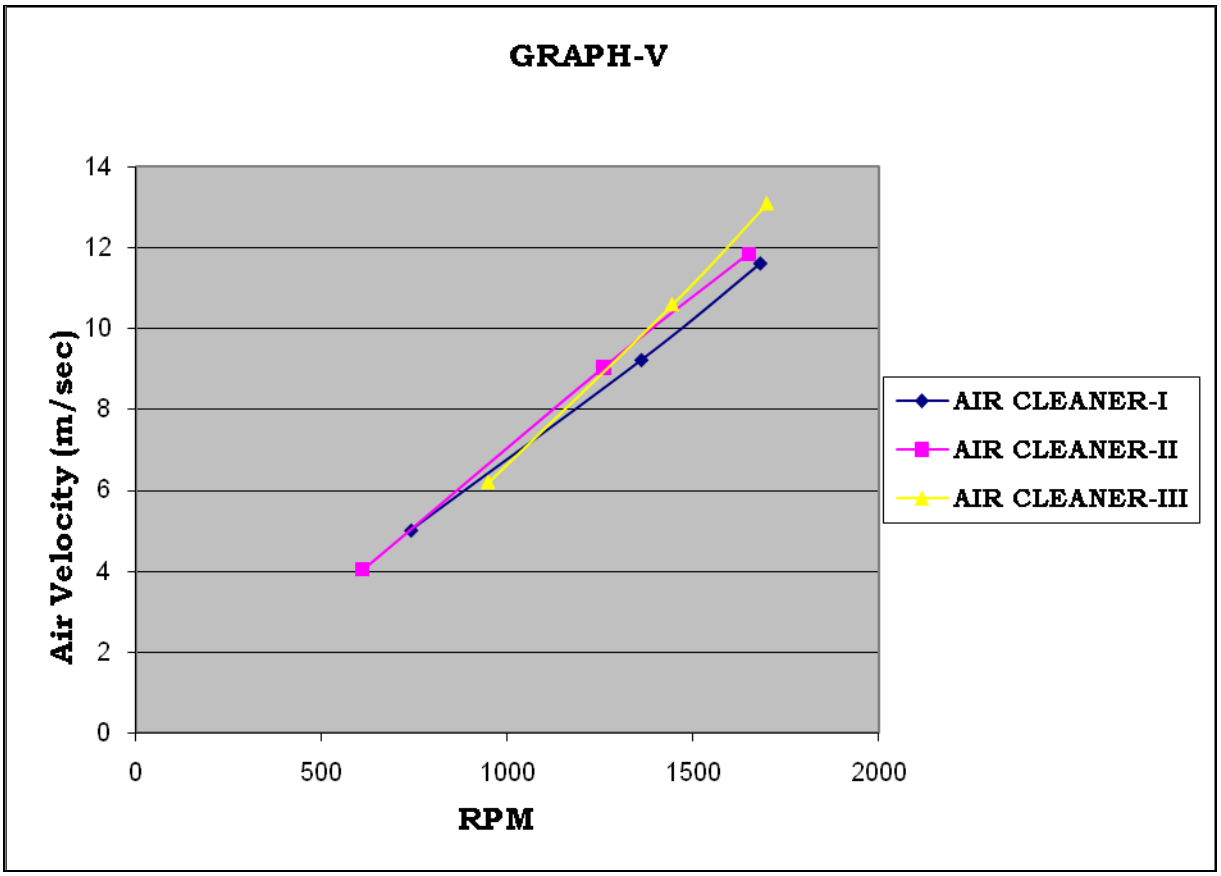


4.5.5 Air Velocity Values (M/Sec) of Air Cleaners I, II & III With Filter

Table 14. Comparison Between the three Air Cleaners for Air velocity(with filter)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**With Filter**	**RPM**	**With Filter**	**RPM**	**With Filter**
740	5.01	610	4.04	950	6.19
1360	9.21	1260	9.04	1445	10.59
1680	11.59	1650	11.84	1700	13.08

Figure 38. Comparison Between the three Air Cleaners for Air Flow (with filter)

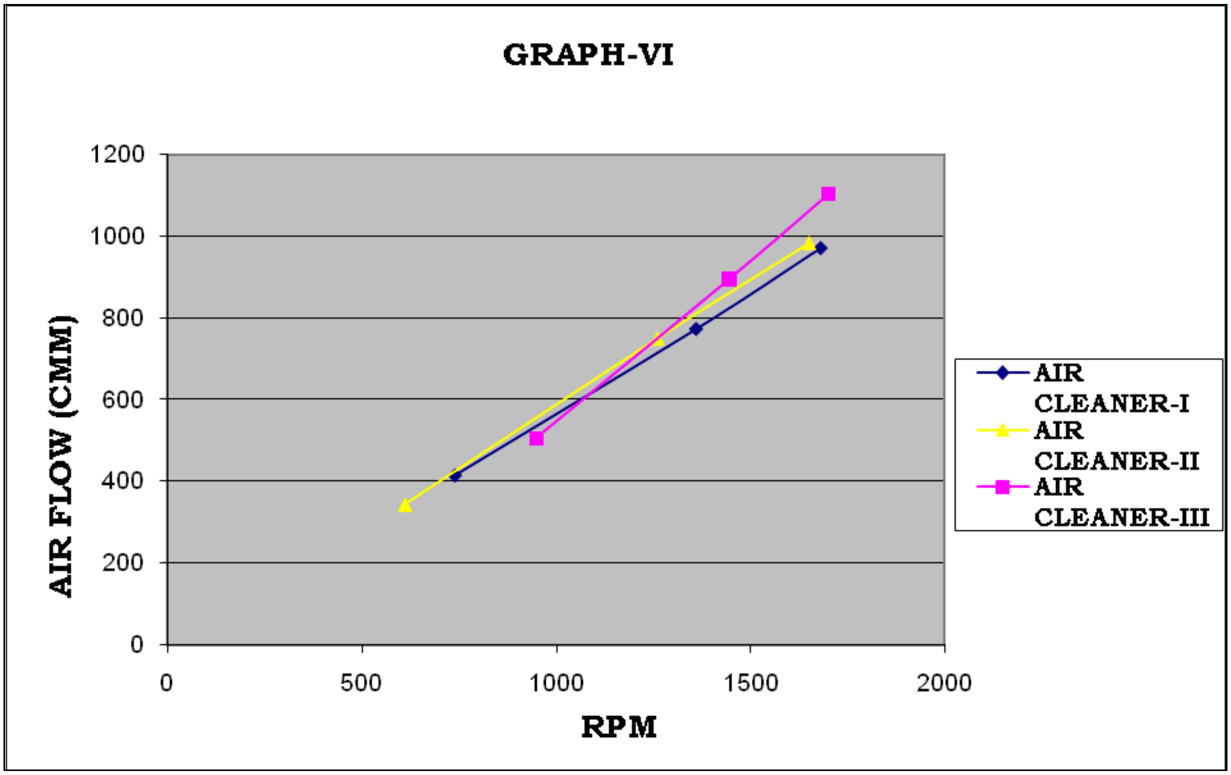


4.5.6. Air Flow Values (CMM) Of Air Cleaners I, II & III With Filter

Table 15. Comparison Between the three Air Cleaners for Air Flow (with filter)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**With filter**	**RPM**	**With filter**	**RPM**	**With Filter**
740	416	610	344	950	506
1360	773	1260	750	1445	894.5
1680	970	1650	983.5	1700	1102

Figure 39. Comparison Between the three Air Cleaners for Air Flow (with filter)



4.6 Case II [With Same Filters and Same Rpm's]

Table 16. Air Cleaners I with same Filters and same rpm's

WITHOUT FILTER				V= 120 Volts, F= 60 Hz Current Limit= 19.9A A= 15.08 ft^2		
Air Velocity(m/sec)			**Temp (^0C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	6.59	21.6	Low Speed (780 RPM)	Max	19380
	Min	5.37	21.4		Min	-
Medium Speed (1370 RPM)	Max	11.21	21.9	Medium Speed (1370 RPM)	Max	33990
	Min	9.42	21.7		Min	-
High Speed (1685 RPM)	Max	14.13	22.4	High Speed (1685 RPM)	Max	42000
	Min	11.77	22		Min	-

WITH CQ SCREEN						
Air Velocity(m/sec)			**Temp (^0C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	6.76	22	Low Speed (780 RPM)	Max	19950
	Min	6.74	21.9		Min	-
Medium Speed (1370 RPM)	Max	11.61	22.3	Medium Speed (1370 RPM)	Max	34490
	Min	11.55	22.4		Min	-
High Speed (1685 RPM)	Max	14.26	21.8	High Speed (1685 RPM)	Max	41770
	Min	14.02	22		Min	-

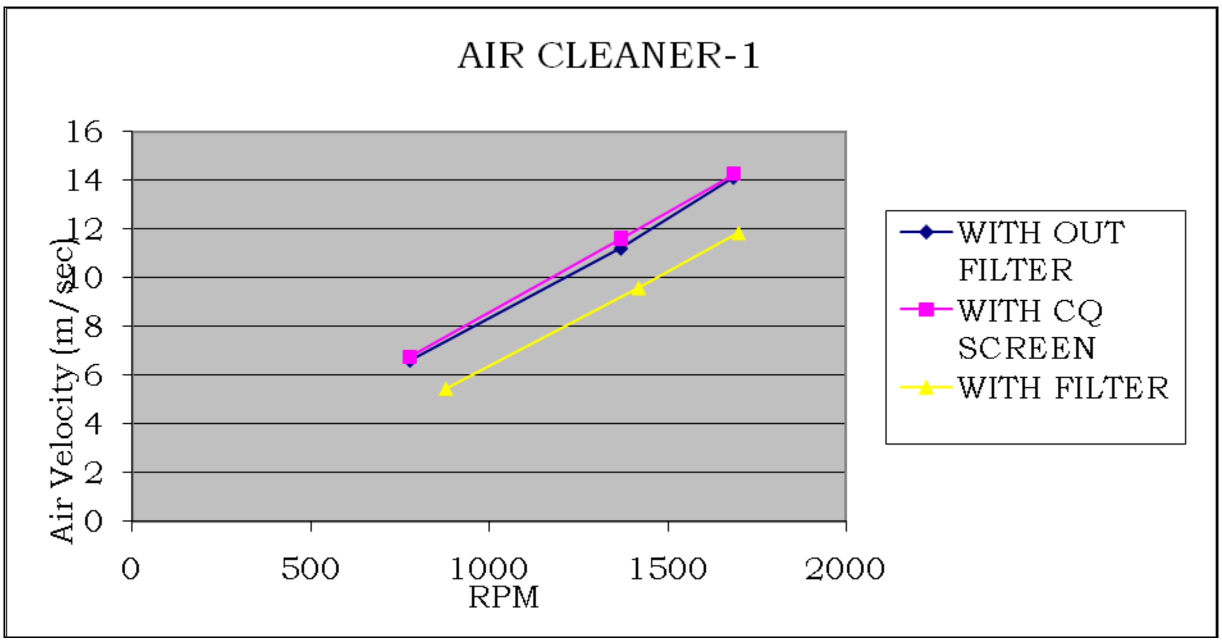
WITH FILTER						
Air Velocity(m/sec)			**Temp (^0C)**	**Air Flow Measurements (CFM)**		
Low Speed (880 RPM)	Max	5.45	21.6	Low Speed (880 RPM)	Max	15970
	Min	5.37	21.4		Min	-
Medium Speed (1420 RPM)	Max	9.6	21.9	Medium Speed (1420 RPM)	Max	28320
	Min	9.42	21.7		Min	-
High Speed (1700 RPM)	Max	11.86	22.4	High Speed (1700 RPM)	Max	34640
	Min	11.77	22		Min	-

4.6.1 Comparison of Air Cleaner I [With Air Velocity]

Table 17. Comparison of Air Cleaner I with Air Velocity in case II

RPM		AIR VELOCITY (M/SEC)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	6.59	6.76	5.45
1420	1370	11.21	11.61	9.6
1700	1685	14.13	14.26	11.86

Figure 40. Comparison of Air Cleaner I with Air Velocity in case II

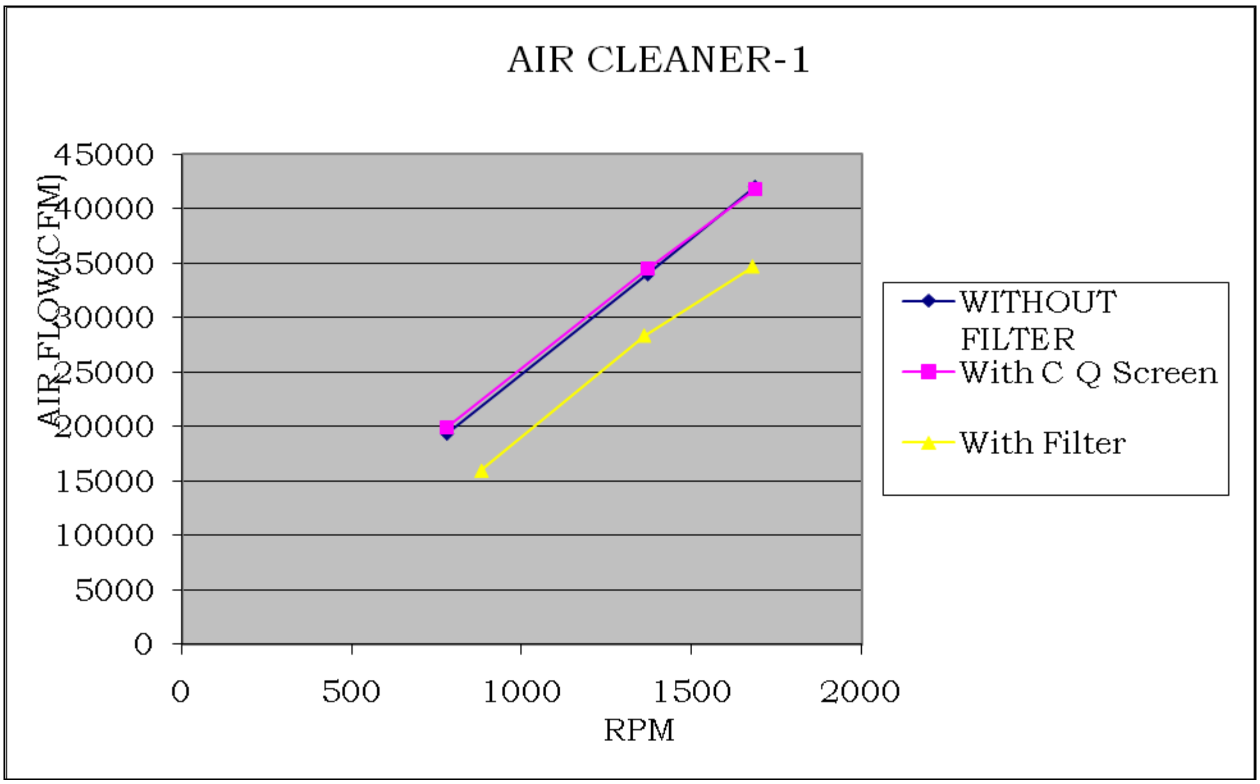


4.6.2 Comparison of Air Cleaner I [With Air Flow]

Table 18.Comparison of Air Cleaner I with Air flow in case II

RPM		AIR FLOW (CFM)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	19380	19950	15970
1360	1370	33990	34490	28320
1680	1685	42000	41770	34640

Figure 41.Comparison of Air Cleaner I with Air Flow in case II



4.7 Air Cleaner 2

Table 19. Air Cleaners II with same Filters and same rpm's

WITHOUT FILTER				**V= 126 Volts, F= 60 Hz** **Current Limit= 19.9A** **A= 15.08 ft²**		
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	6.69	22	Low Speed (780 RPM)	Max	19950
	Min	6.68	22		Min	-
Medium Speed (1370 RPM)	Max	12.1	22	Medium Speed (1370 RPM)	Max	35890
	Min	11.9	22		Min	-
High Speed (1685 RPM)	Max	14.8	23	High Speed (1685 RPM)	Max	43900
	Min	14.7	22		Min	-

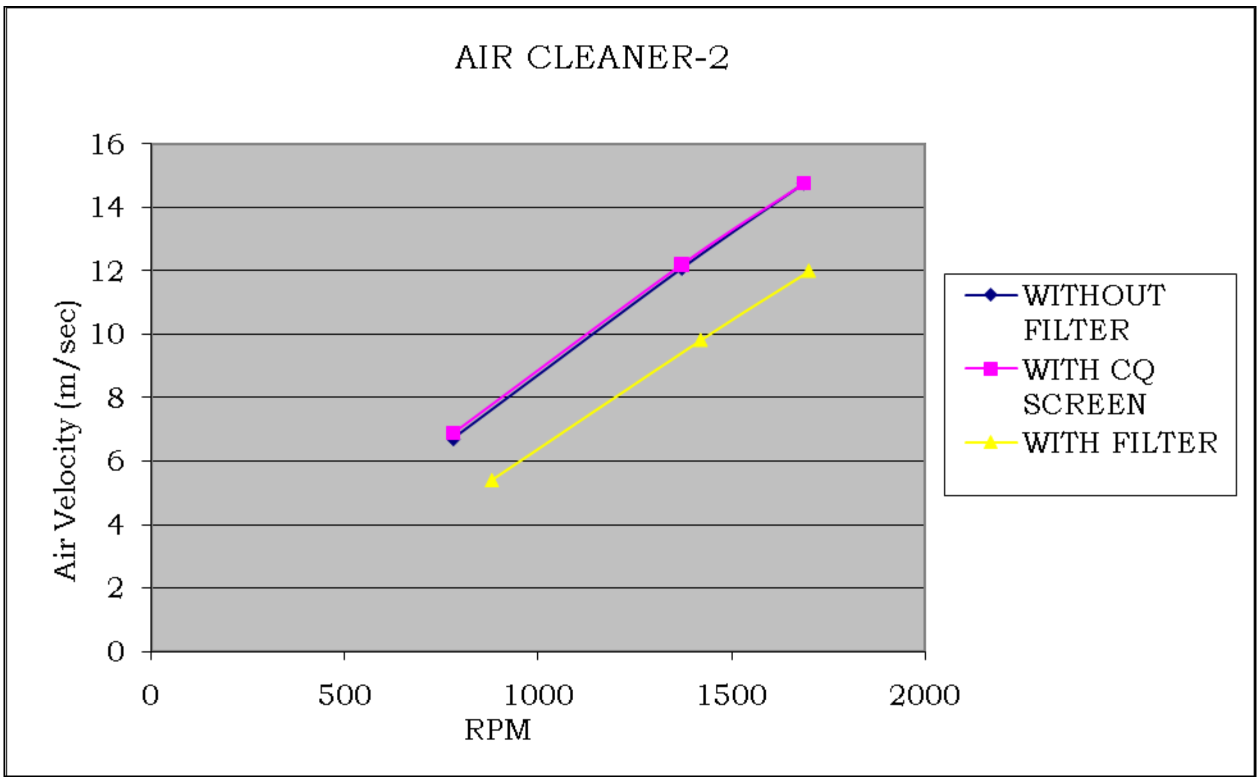
WITH CQ SCREEN						
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	6.89	22	Low Speed (780 RPM)	Max	20190
	Min	6.85	22		Min	-
Medium Speed (1370 RPM)	Max	12.2	22	Medium Speed (1370 RPM)	Max	36250
	Min	12.2	22		Min	-
High Speed (1685 RPM)	Max	14.8	23	High Speed (1685 RPM)	Max	43730
	Min	14.7	22		Min	-
WITH FILTER						
Air Velocity(m/sec)			**Temp (°C)**	**Air Flow Measurements (CFM)**		
Low Speed (880 RPM)	Max	5.41	22	Low Speed (880 RPM)	Max	15940
	Min	5.3	22		Min	-
Medium Speed (1420 RPM)	Max	9.83	22	Medium Speed (1420 RPM)	Max	28940
	Min	9.65	22		Min	-
High Speed (1700 RPM)	Max	12	21	High Speed (1700 RPM)	Max	35860
	Min	11.8	22		Min	-

4.7.1 Comparison of Air Cleaner II [With Air Velocity]

Table 20. Comparison of Air Cleaner II for Air velocity in case II

RPM		AIR VELOCITY (M/SEC)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	6.69	6.89	5.41
1420	1370	12.07	12.2	9.83
1700	1685	14.75	14.75	12.01

Figure 42. Comparison of Air Cleaner II for Air velocity in case II

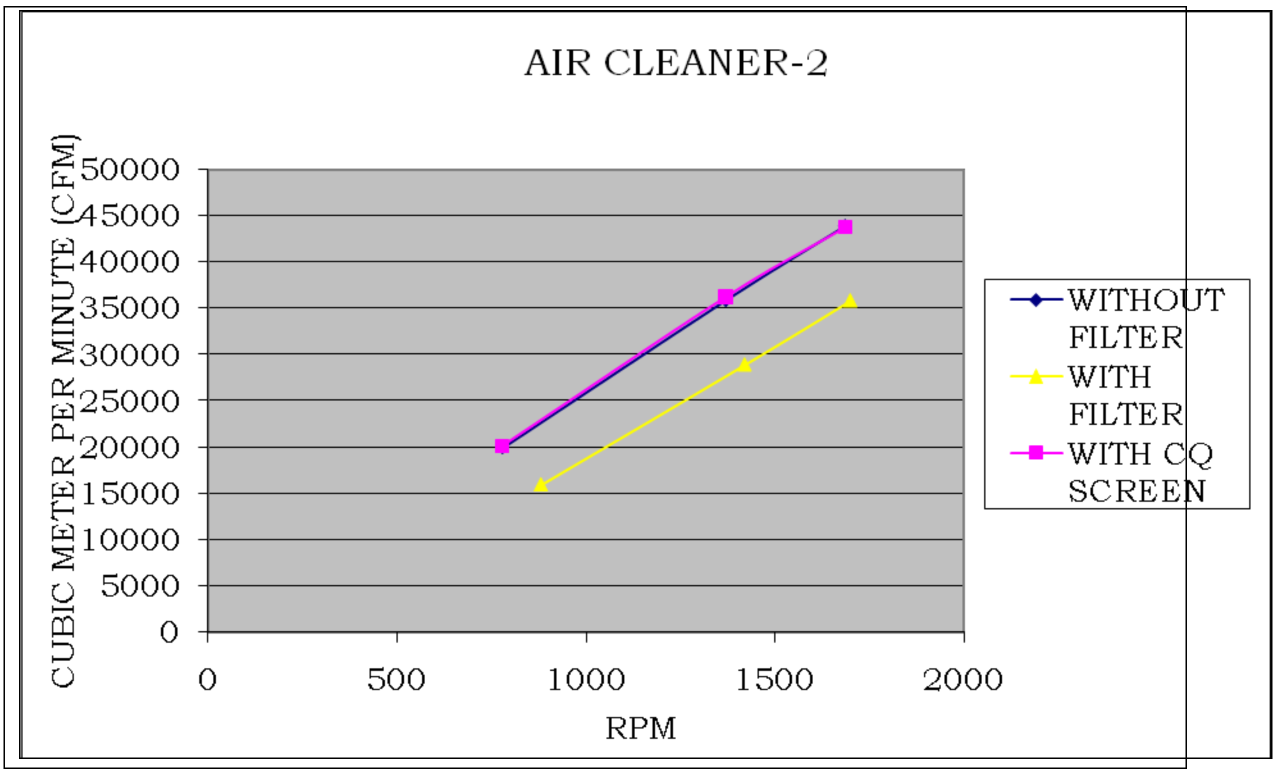


4.7.2 Comparison of Air Cleaner II [With Air Flow]

Table 21.Comparison of Air Cleaner II for Air flow in case II

RPM		AIR FLOW (CFM)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	19950	20190	15940
1420	1370	35890	36250	28940
1700	1685	43900	43730	35860

Figure 43. Comparison of Air Cleaner II for Air flow in case II



4.8 Air Cleaner 3

Table 22. Air Cleaners III with same Filters and same rpm’s

WITHOUT FILTER				**V= 115 Volts, F= 60 Hz** **Current Limit= 19.9A** **A= 15.08 ft^2**		
Air Velocity(m/sec)			**Temp (^{0}C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	7.3	21.9	Low Speed (780 RPM)	Max	21280
	Min	7.22	22		Min	-
Medium Speed (1370 RPM)	Max	12.6	22.2	Medium Speed (1370 RPM)	Max	37430
	Min	12.5	22.1		Min	-
High Speed (1685 RPM)	Max	15.8	22.3	High Speed (1685 RPM)	Max	46280
	Min	15.6	22		Min	-

WITH CQ SCREEN						
Air Velocity(m/sec)			**Temp (^{0}C)**	**Air Flow Measurements (CFM)**		
Low Speed (780 RPM)	Max	7.35	22.2	Low Speed (780 RPM)	Max	21700
	Min	7.3	22.1		Min	-
Medium Speed (1370 RPM)	Max	12.5	22.2	Medium Speed (1370 RPM)	Max	37050
	Min	12.4	22.1		Min	-
High Speed (1685 RPM)	Max	15.6	22.2	High Speed (1685 RPM)	Max	46640
	Min	15.5	22		Min	-

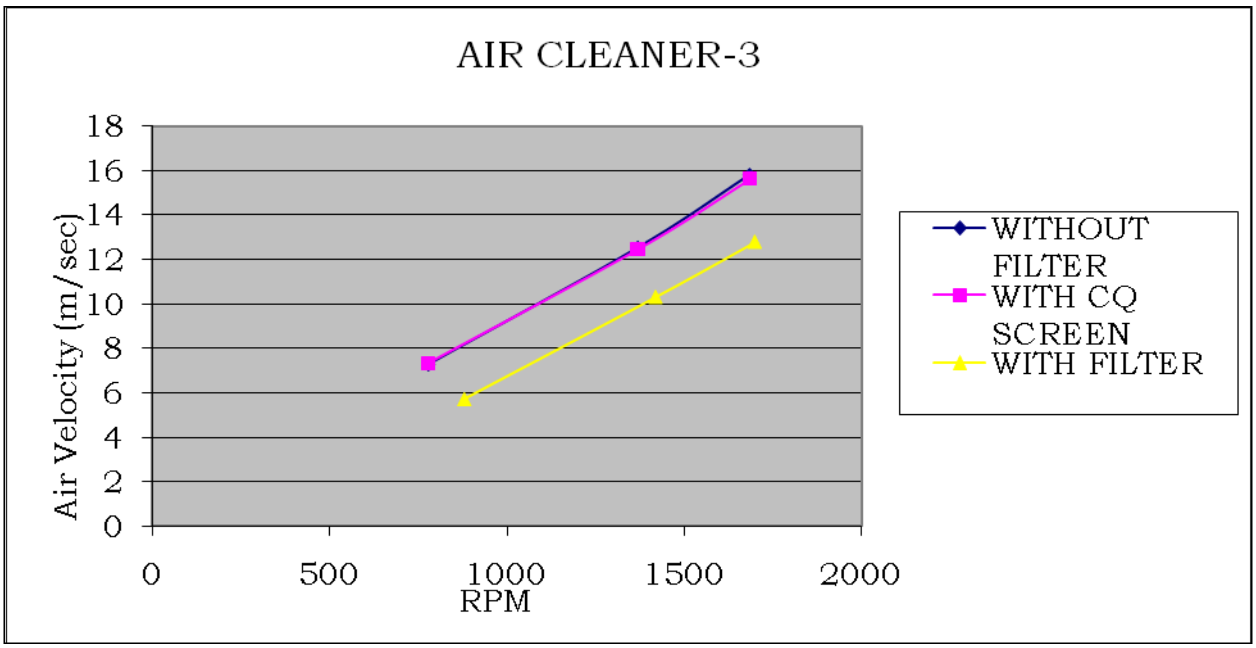
WITH FILTER						
Air Velocity(m/sec)			**Temp (^{0}C)**	**Air Flow Measurements (CFM)**		
Low Speed (880 RPM)	Max	5.72	21.7	Low Speed (880 RPM)	Max	17040
	Min	5.67	21.7		Min	-
Medium Speed (1420 RPM)	Max	10.3	22	Medium Speed (1420 RPM)	Max	30930
	Min	10.3	21.9		Min	-
High Speed (1700 RPM)	Max	12.8	22	High Speed (1700 RPM)	Max	38120
	Min	12.8	22.2		Min	-

4.8.1 Comparison of Air Cleaner III[With Air Velocity]

Table 23. Comparison of Air Cleaner III for Air Velocity in case II

RPM		AIR VELOCITY (M/SEC)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	7.3	7.35	5.72
1420	1370	12.55	12.48	10.33
1700	1685	15.82	15.63	12.81

Figure 44. Comparison of Air Cleaner III for Air Velocity in case II

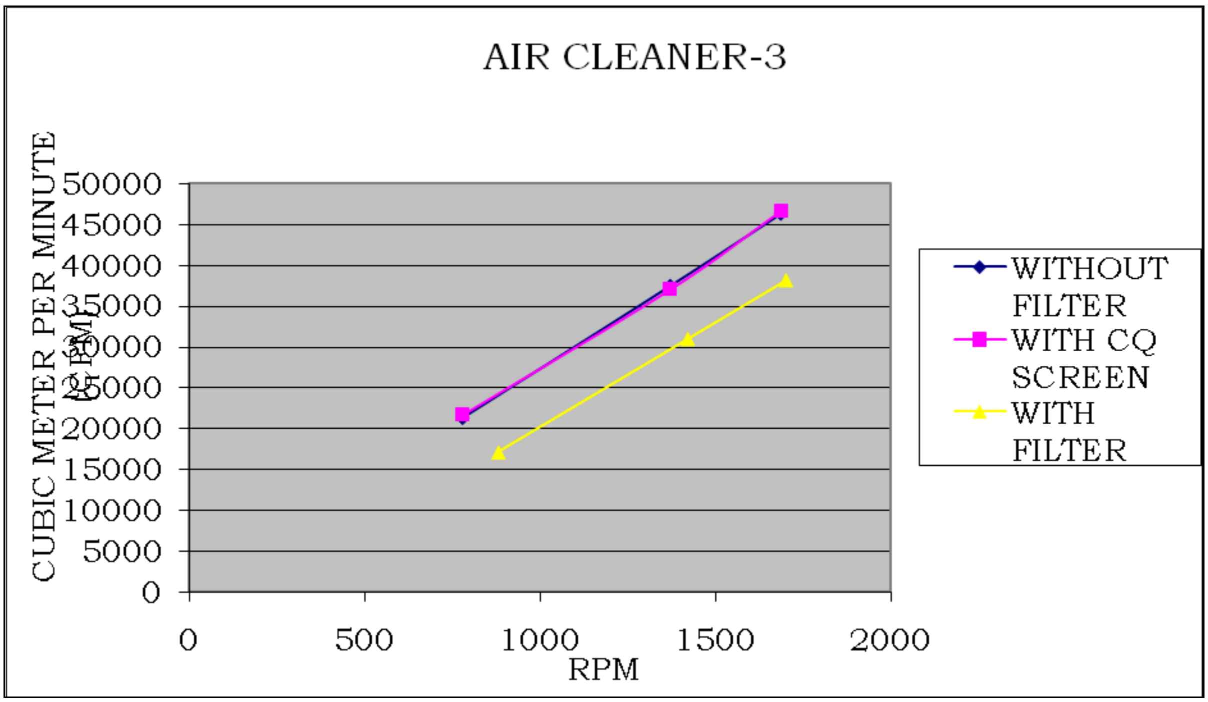


4.8.2 Comparison of Air Cleaner III [With Air Flow]

Table 24. Comparison of Air Cleaner III for Air flow in case II

RPM		AIR FLOW (CFM)		
With Filter	**With CQ Screen and Without Filter**	**Without filter**	**With CQ Screen**	**With Filter**
880	780	21280	21700	17040
1420	1370	37430	37050	30930
1700	1685	46280	46640	38120

Figure 45. Comparison of Air Cleaner III for Air flow in case II



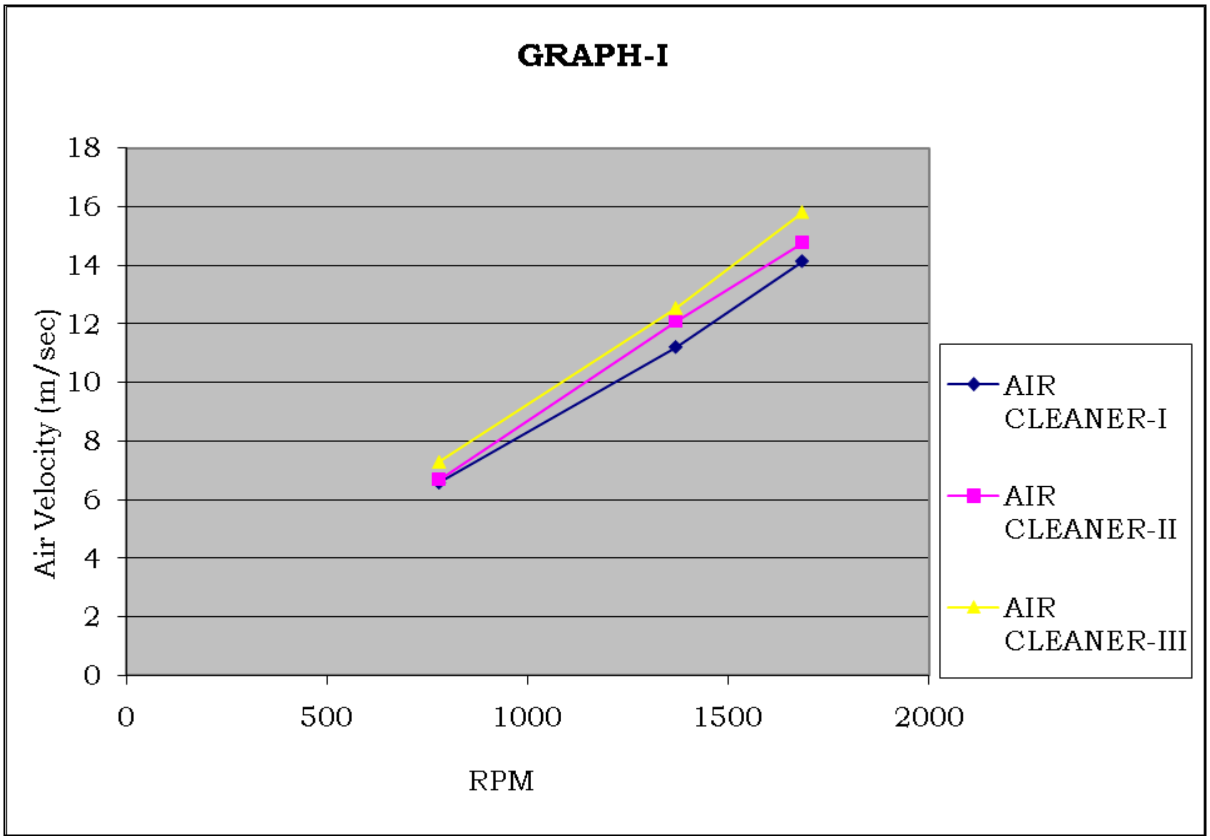
4.9 Comparison between the three Air Cleaners in Case II

4.9.1 Air Velocity Values (M/Sec) Of Air Cleaners I, II & III Without Filter

Table 25. Comparison Between the three Air Cleaners for Air velocity(without filter

Air Cleaner I		Air Cleaner I		Air Cleaner III	
RPM	**Without filter**	**RPM**	**Without filter**	**RPM**	**Without Filter**
780	6.59	780	6.69	780	7.3
1370	11.21	1370	12.07	1370	12.55
1685	14.13	1685	14.75	1685	15.82

Figure 46. Comparison Between the three Air Cleaners for Air velocity(without filter

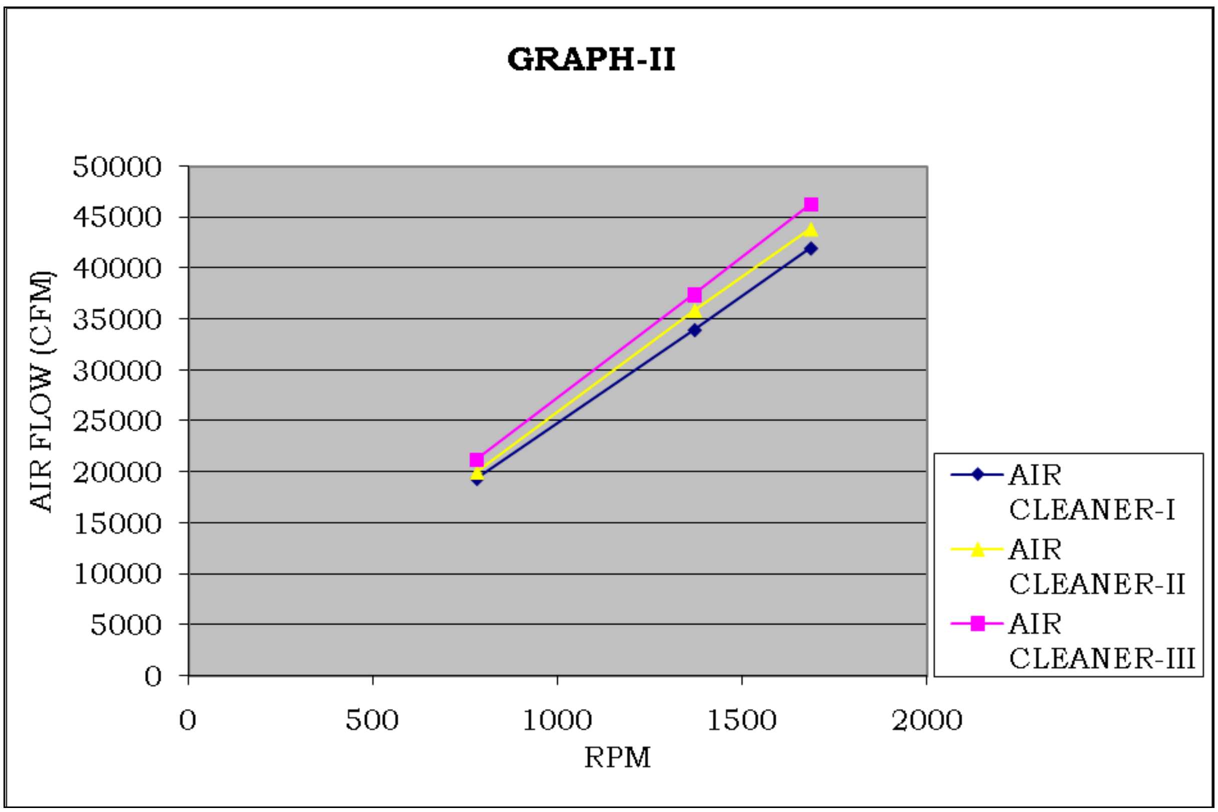


4.9.2 Air Flow Values (CMM) Of Air Cleaners I, II & III Without Filter

Table 26.Comparison between the three Air Cleaners for Air flow (without filter)

Air Cleaner I		**Air Cleaner II**		**Air Cleaner III**	
780	19380	780	19950	780	21280
1370	33990	1370	35890	1370	37430
1685	42000	1685	43900	1685	46280

Figure 47.Comparison between the three Air Cleaners for Air Flow (without filter)

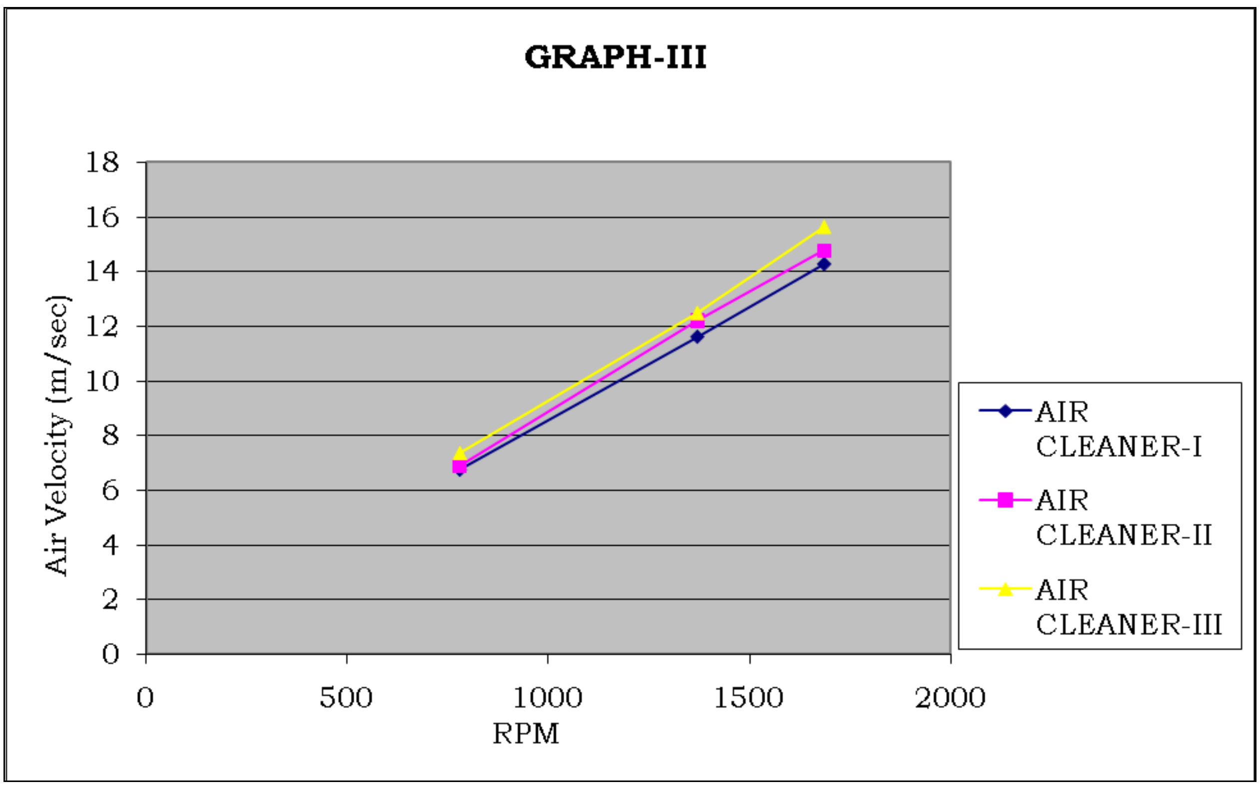


4.9.3 Air Velocity Values (M/Sec) Of Air Cleaners I, II & III With CQ Screen

Table 27.Comparison Between the three Air Cleaners for Air velocity (with CQ screen)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
780	6.76	780	6.89	780	7.35
1370	11.61	1370	12.2	1370	12.48
1685	14.26	1685	14.75	1685	15.63

Figure 48.Comparison Between the three Air Cleaners for Air velocity(with CQ screen)

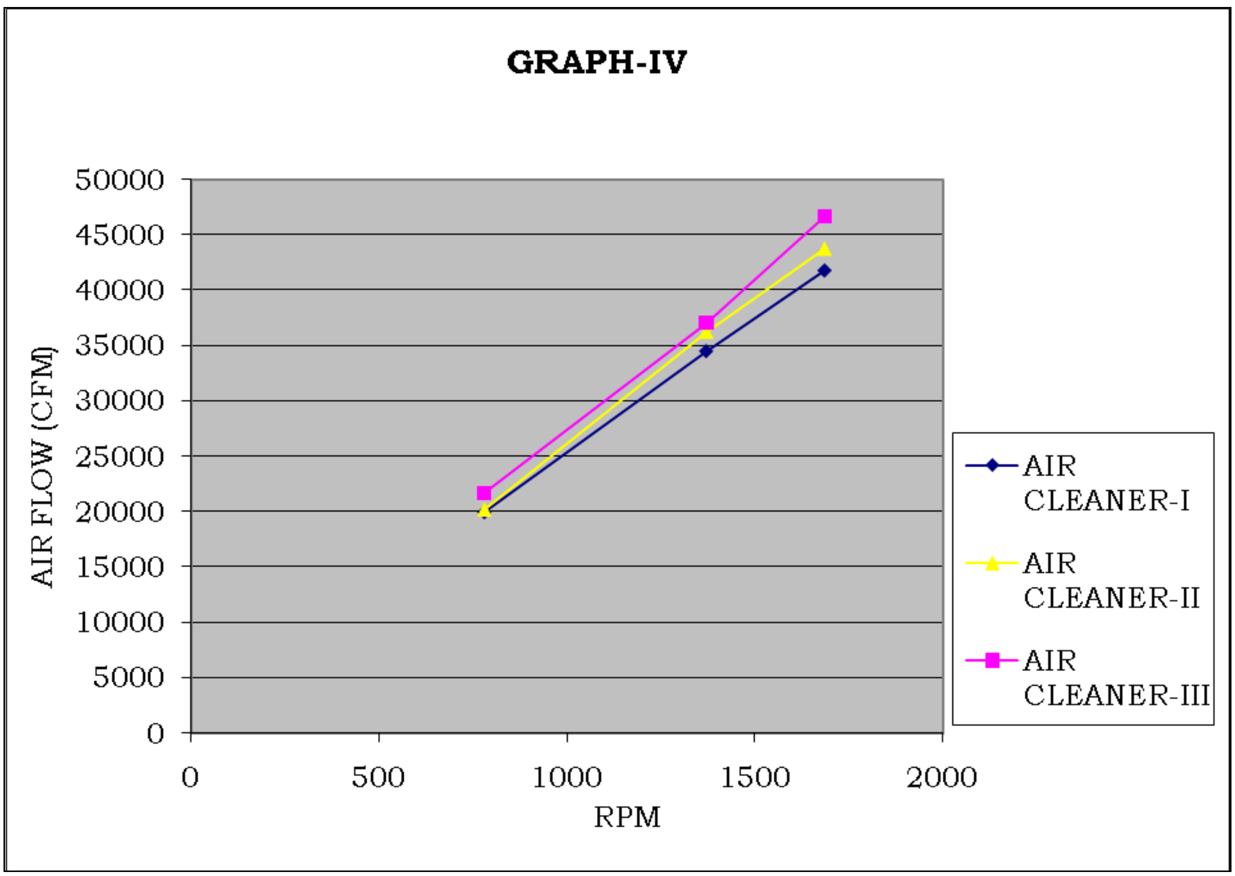


4.9.4 Air Flow Values (CMM) Of Air Cleaners I, II & III With CQ Screen

Table 28. .Comparison Between the three Air Cleaners for Air flow(with CQ screen)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**With CQ SCREEN**	**RPM**	**With CQ SCREEN**	**RPM**	**With CQ SCREEN**
780	19950	780	20190	780	21700
1370	34490	1370	36250	1370	37050
1685	41770	1685	43730	1685	46640

Figure 49. Comparison Between the three Air Cleaners for Air flow (with CQ screen)

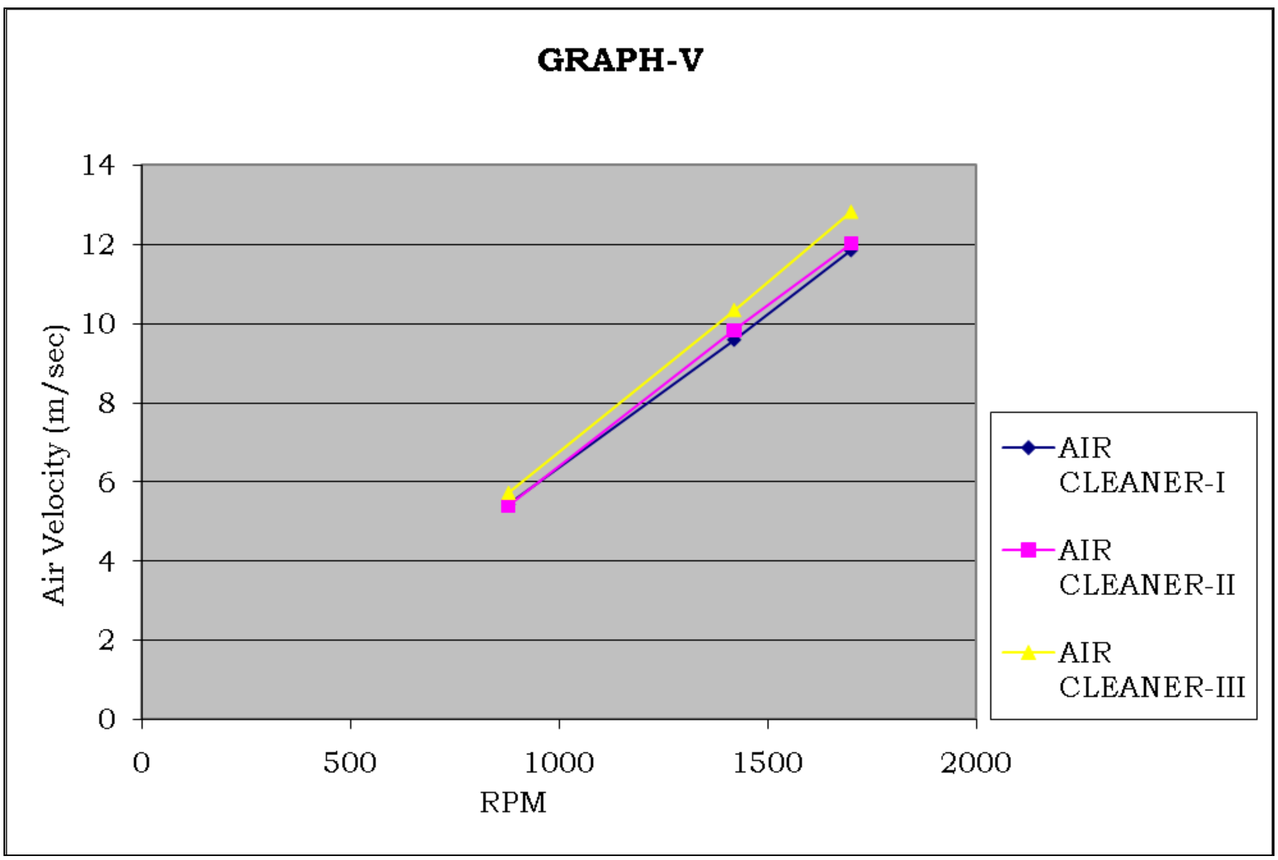


4.9.5 Air Velocity Values (M/Sec) Of Air Cleaners I, II & III With Filter

Table 29.Comparison between the three Air Cleaners for Air velocity (with filter)

Air Cleaner I		Air Cleaner II		Air Cleaner III	
RPM	**With filter**	**RPM**	**With Filter**	**RPM**	**With Filter**
880	5.45	880	5.41	880	5.72
1420	9.6	1420	9.83	1420	10.33
1700	11.86	1700	12.01	1700	12.81

Figure 50.Comparison between the three Air Cleaners for Air velocity (with filter)

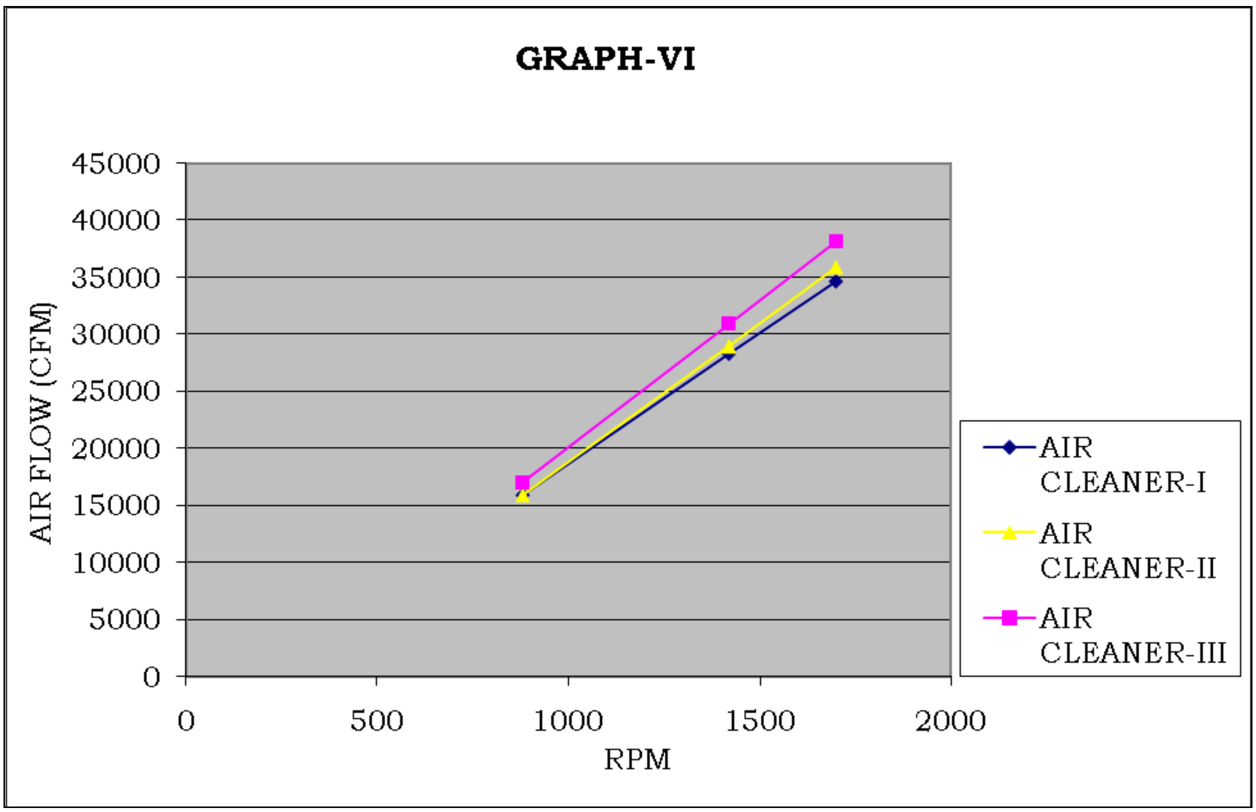


4.9.6 Air Flow Values (CMM) Of Air Cleaners I, II & III With Filter

Table 30.Comparison between the three Air Cleaners for Air flow (with filter)

Air Cleaner I		**Air Cleaner II**		**Air Cleaner III**	
RPM	**With FILTER**	**RPM**	**With FILTER**	**RPM**	**With FILTER**
880	15970	880	15940	880	17040
1420	28320	1420	28940	1420	30930
1700	34640	1700	35860	1700	38120

Figure 51. Comparison between the three Air Cleaners for Air flow (with filter)



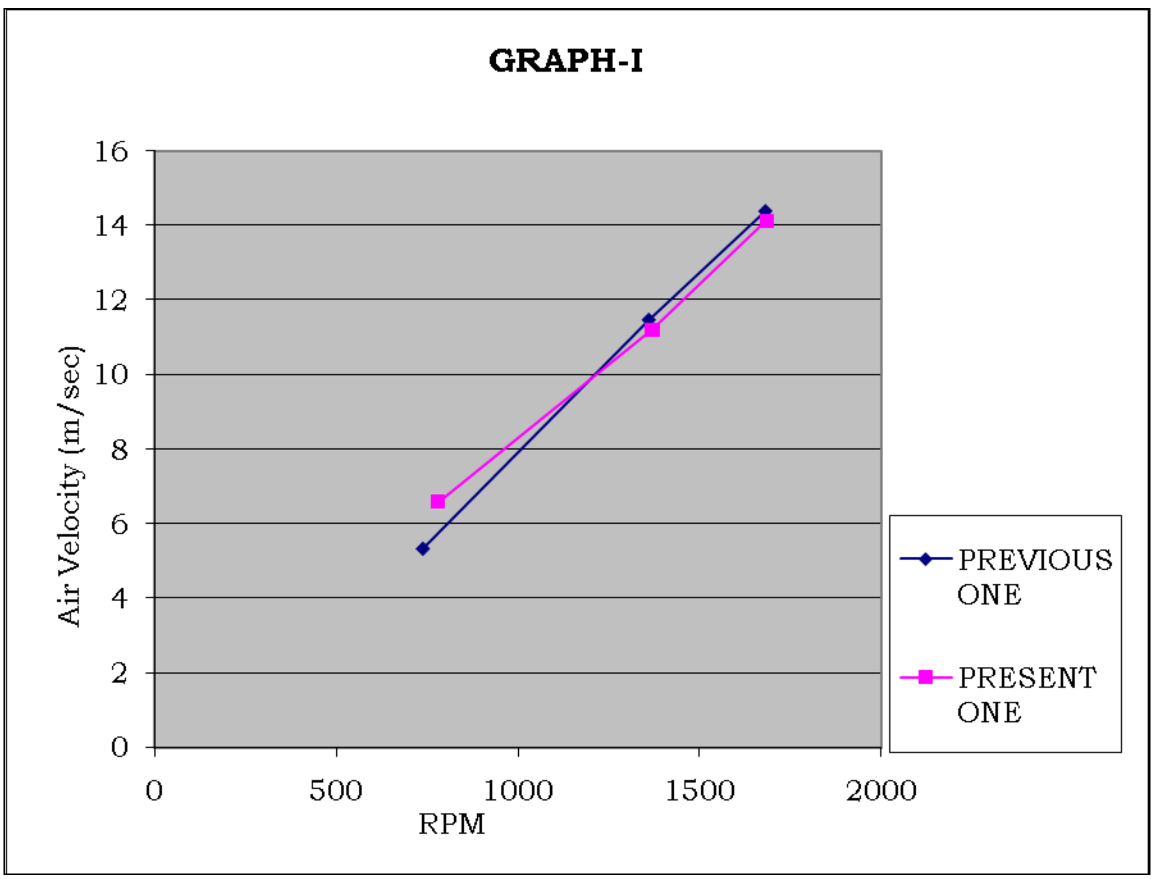
4.10 Comparison between Case I and Case II

4.10.1 Air Cleaner-I (without filter)

Table 31. Comparison between Case I and Case II for Air Velocity (Air cleaner-I without filter)

AIR VELOCITY (M/SEC)			
PREVIOUS ONE		PRESENT ONE	
RPM	Without filter	RPM	Without filter
740	5.34	780	6.59
1360	11.47	1370	11.21
1680	14.38	1685	14.13

Figure 52. Comparison between Case I and Case II for Air velocity (Air Cleaner I -without filter)

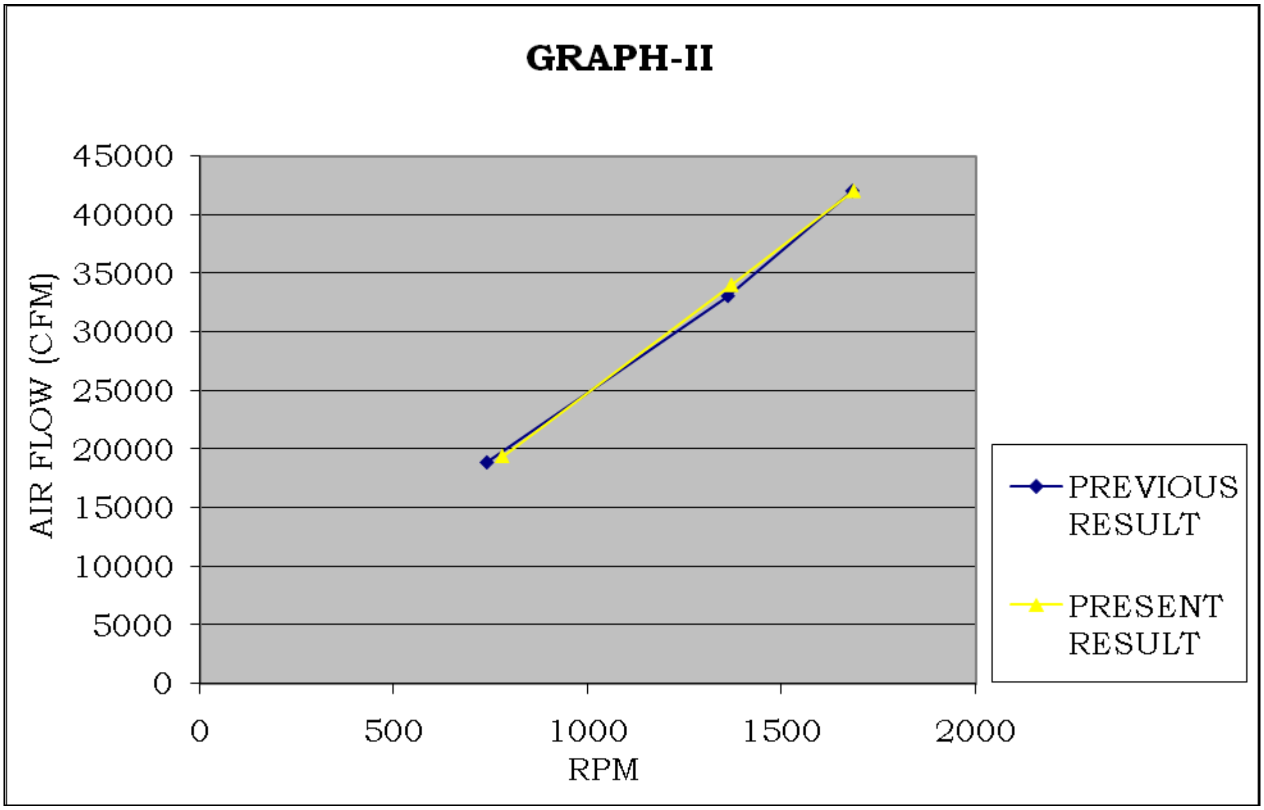


4.10.2 Air Cleaner-I (without filter)

Table 32. Comparison between Case I and Case II for Air flow (Air cleaner-I without filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	Without filter	RPM	Without filter
740	18858	780	19380
1360	33055	1370	33990
1680	42025	1685	42000

Figure 53. Comparison between Case I and Case II for Air flow (Air cleaner-I without filter)

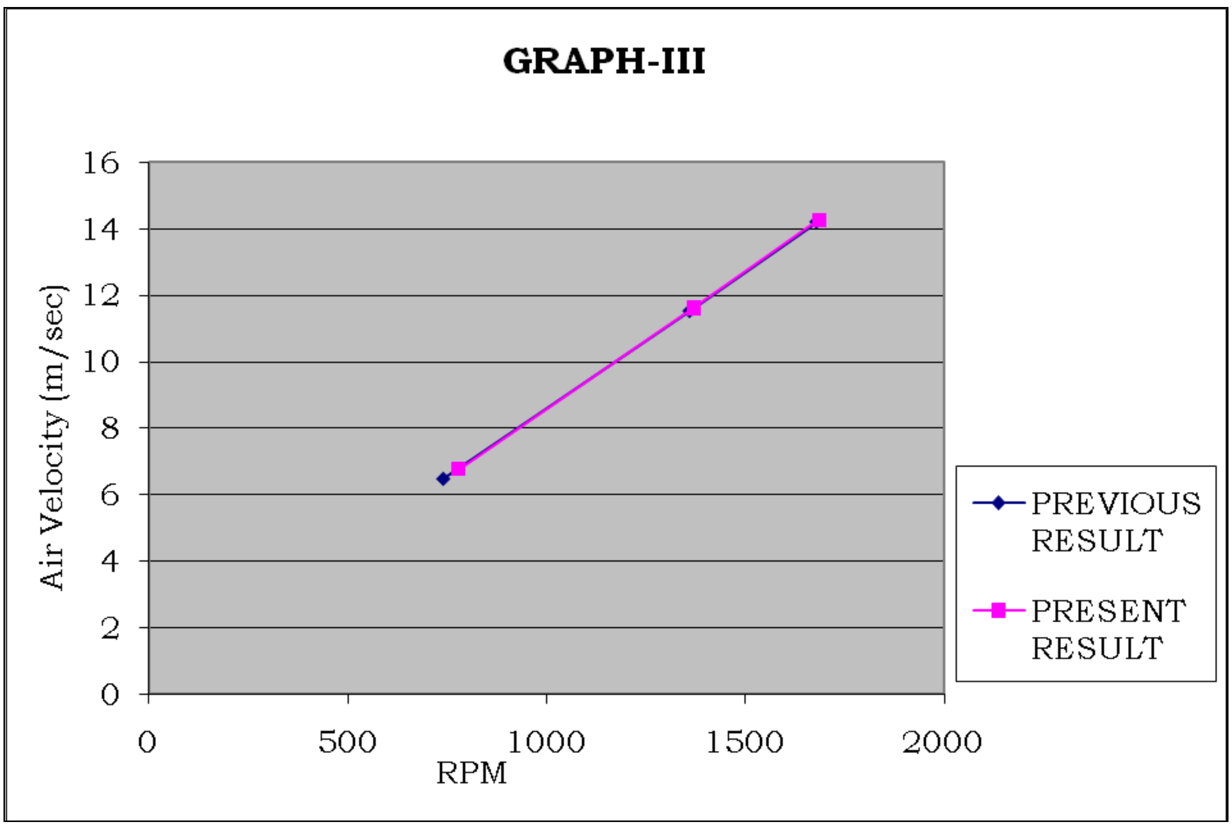


4.10.3 Air Cleaner-I With CQ Screen

Table 33. Comparison between Case I and Case II for Air Velocity (Air cleaner-I with CQ screen)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With CQ SCREEN	RPM	With CQ SCREEN
740	6.48	780	6.76
1360	11.53	1370	11.61
1680	14.21	1685	14.26

Figure 54. Comparison between Case I and Case II for Air Velocity (Air cleaner-I with CQ screen)

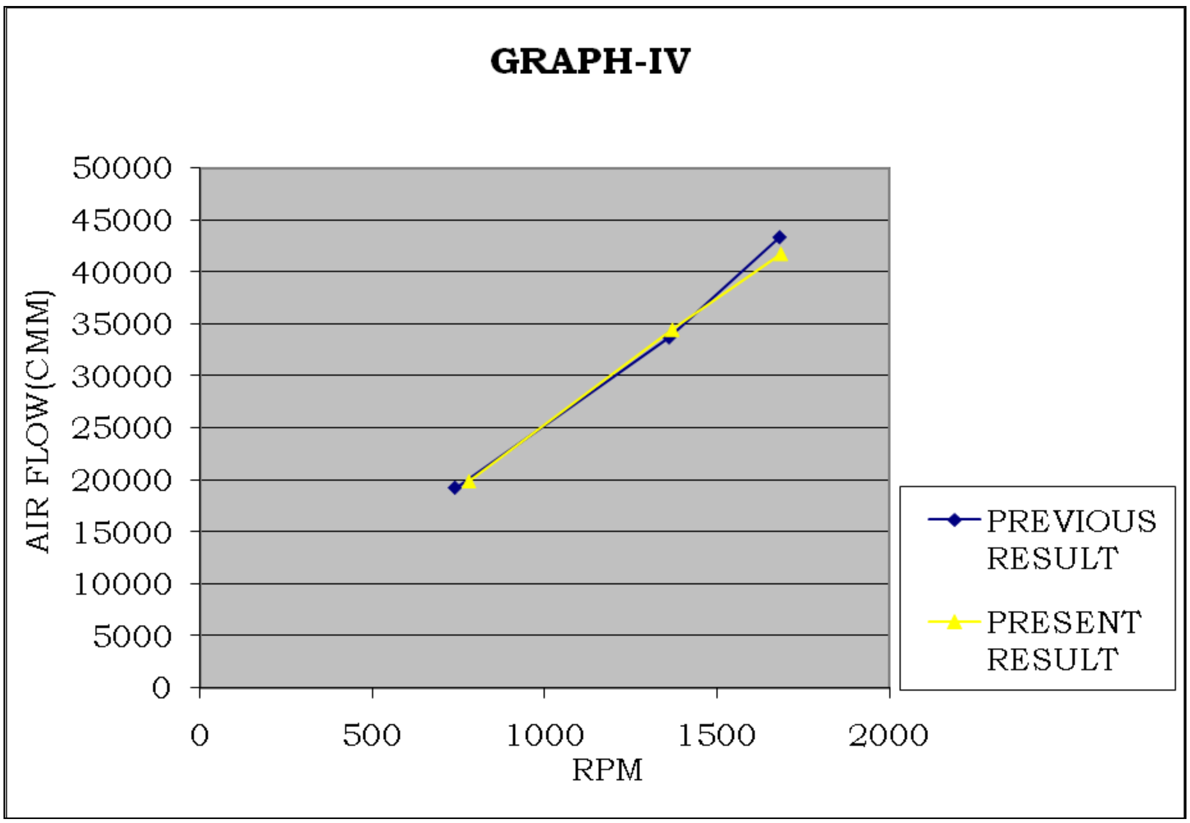


4.10.4 Air Cleaner-I With CQ Screen

Table 34. Comparison between Case I and Case II for Air flow (Air cleaner-I with CQ screen)

AIR FLOW MEASUREMENT (CMM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With CQ SCREEN	RPM	With CQ SCREEN
740	19247	780	19950
1360	33726	1370	34490
1680	43378	1685	41770

Figure 55. Comparison between Case I and Case II for Air flow (Air cleaner-I with CQ screen)

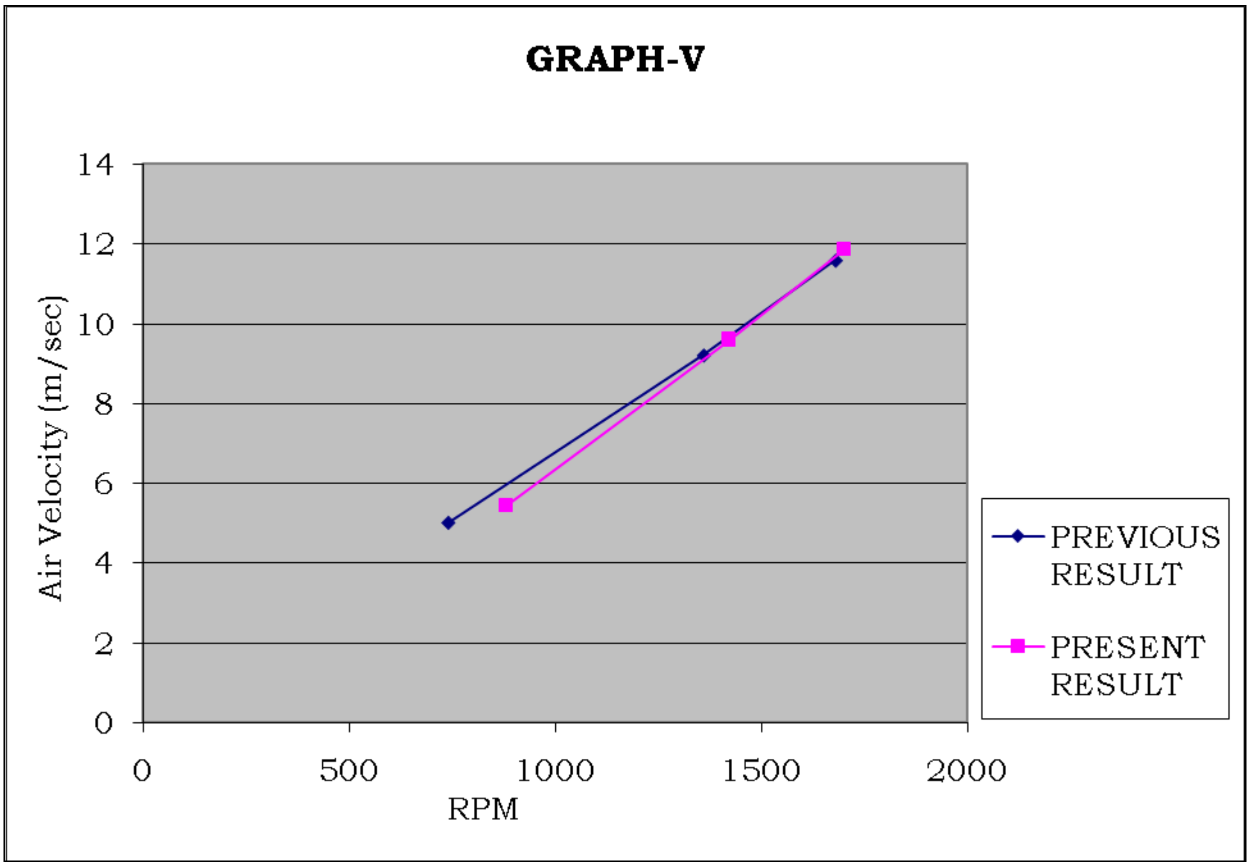


4.10.5 Air Cleaner-I With Filter

Table 35. Comparison between Case I and Case II for Air velocity (Air cleaner-I with filter)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With filter	RPM	With Filter
740	5.01	880	5.45
1360	9.21	1420	9.6
1680	11.59	1700	11.86

Figure 56. Comparison between Case I and Case II for flow (Air cleaner-I with filter)

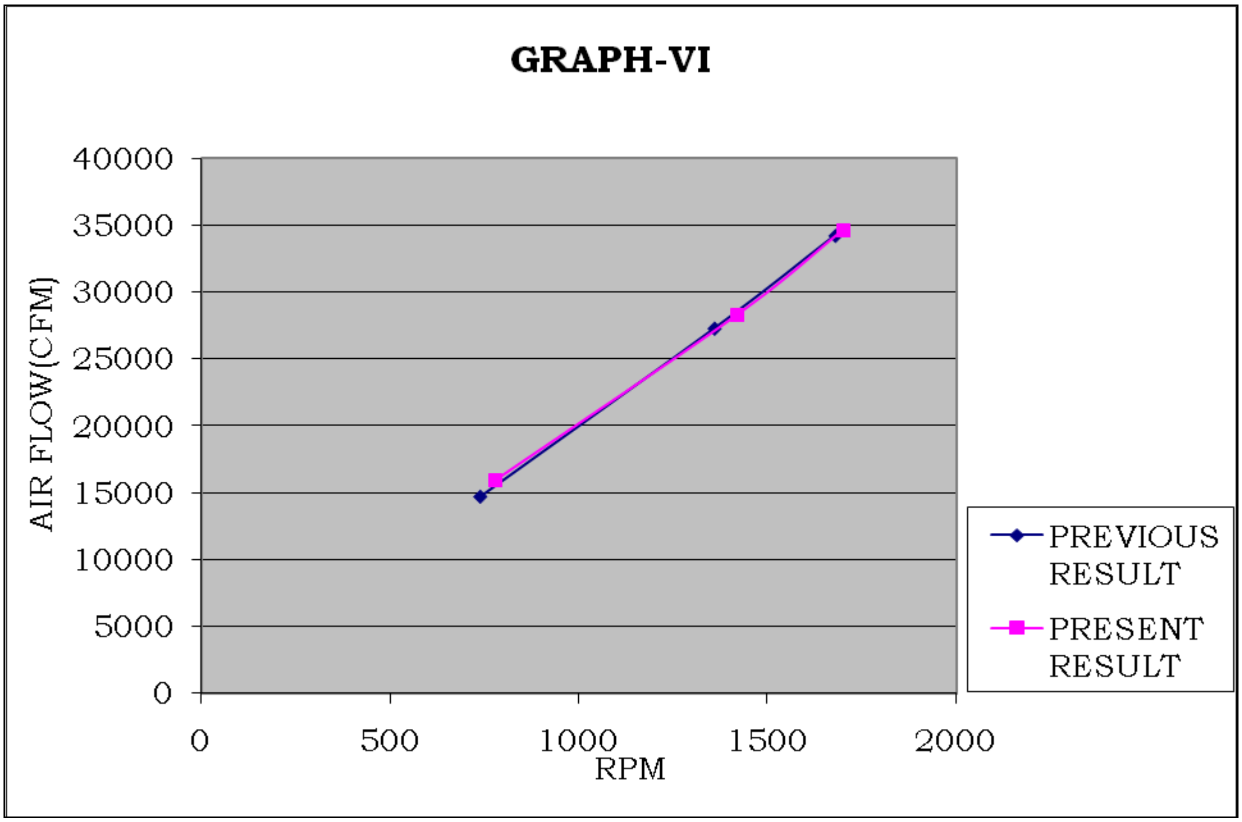


4.10.6 Air Cleaner-I With Filter

Table 36. Comparison between Case I and Case II for Air flow (Air cleaner-I with filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With FILTER	RPM	With FILTER
740	14691	780	15970
1360	27298	1420	28320
1680	34256	1700	34640

Figure 57. Comparison between Case I and Case II for Air flow (Air cleaner-I with filter)



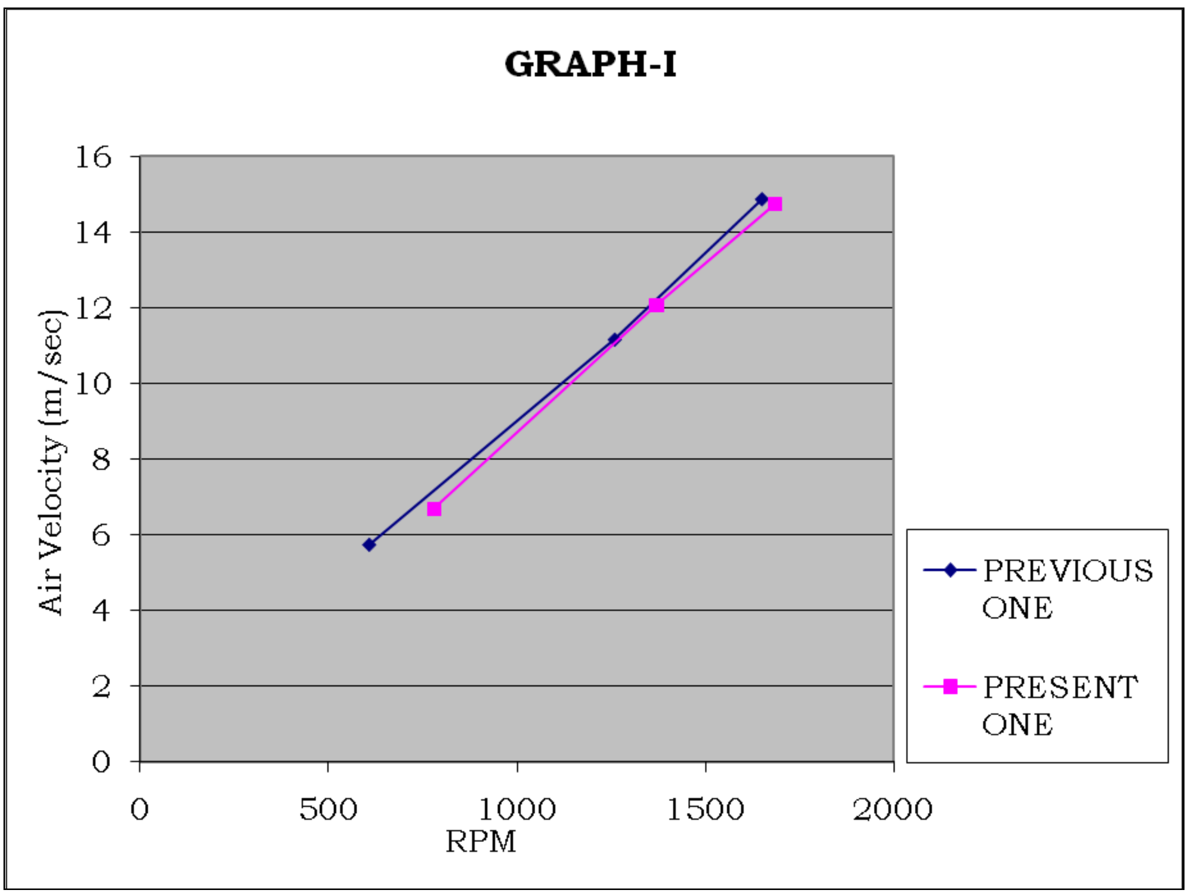
4.11 Air Cleaner II

4.11.1 Air Cleaner-II Without Filter

Table 37. Comparison between Case I and Case II for Air velocity (Air cleaner-II without filter)

AIR VELOCITY (M/SEC)			
PREVIOUS ONE		PRESENT ONE	
RPM	Without filter	RPM	Without filter
610	5.74	780	6.69
1260	11.16	1370	12.07
1650	14.87	1685	14.75

Figure 58 . Comparison between Case I and Case II for Air velocity (Air cleaner-II without filter)

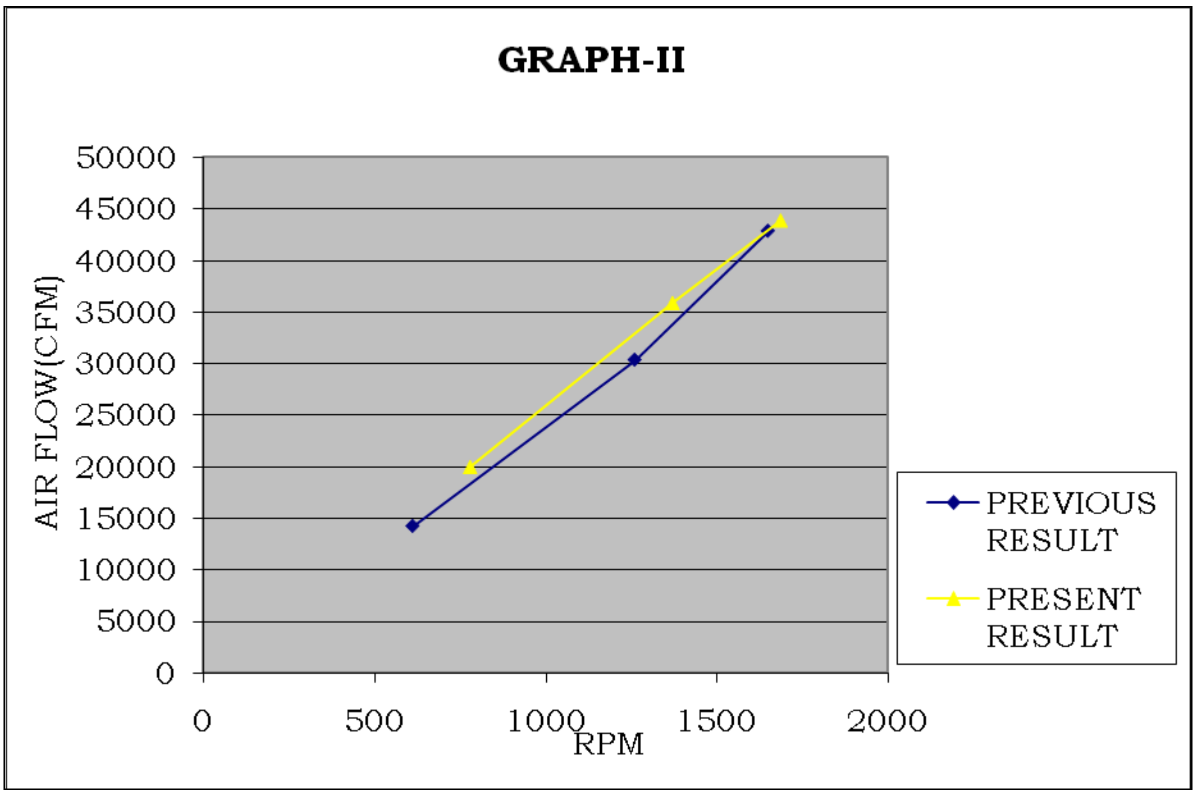


4.11.2 Air Cleaner-II Without Filter

Table 38. Comparison between Case I and Case II for Air flow (Air cleaner-II without filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	Without filter	RPM	Without filter
610	14197	780	19950
1260	30371	1370	35890
1650	42908	1685	43900

Figure 59. Comparison between Case I and Case II for Air flow (Air cleaner-II without filter)

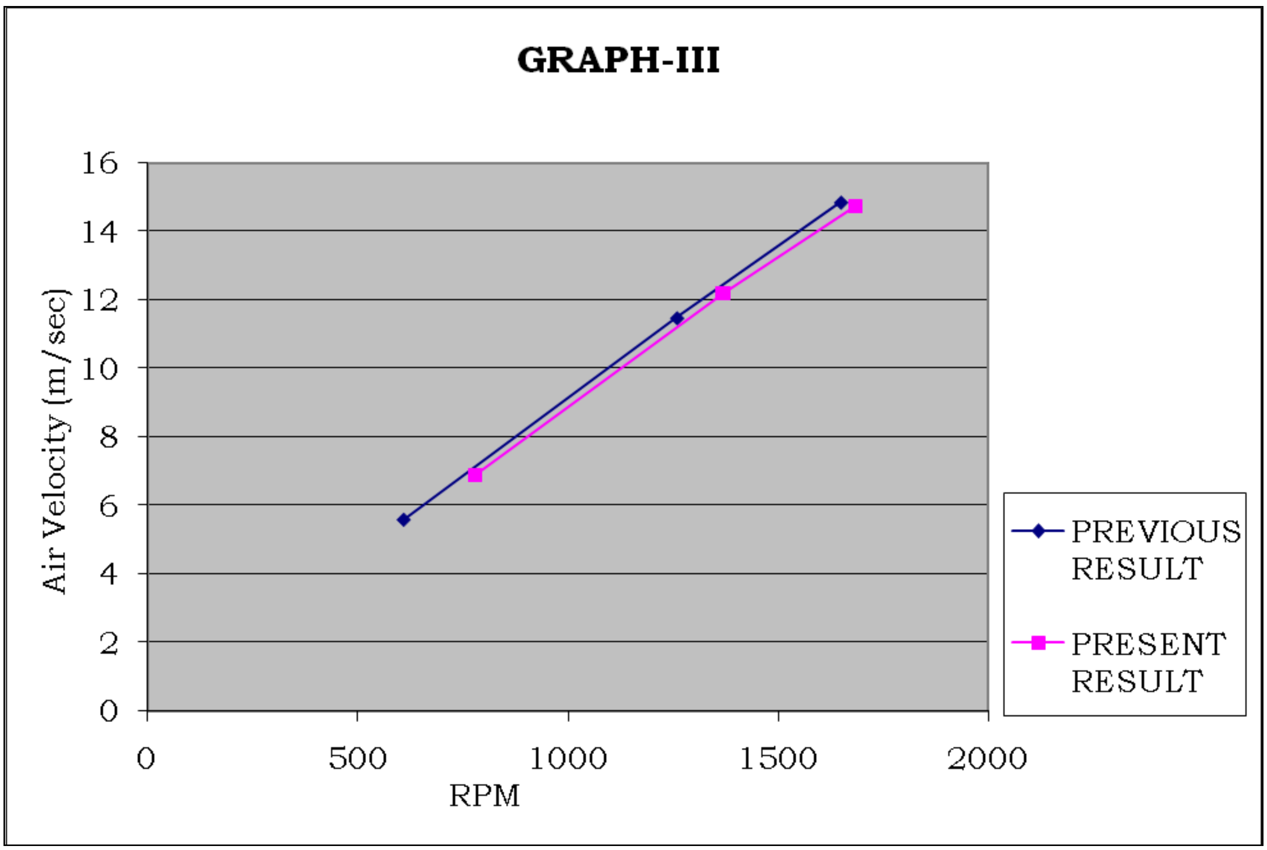


4.11.3 Air Cleaner-II With CQ Screen

Table 39. Comparison between Case I and Case II for Air velocity (Air cleaner-II with CQ screen)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With CQ SCREEN	RPM	With CQ SCREEN
610	5.59	780	6.89
1260	11.48	1370	12.2
1650	14.86	1685	14.75

Figure 60. Comparison between Case I and Case II for Air velocity (Air cleaner-II with CQ screen)

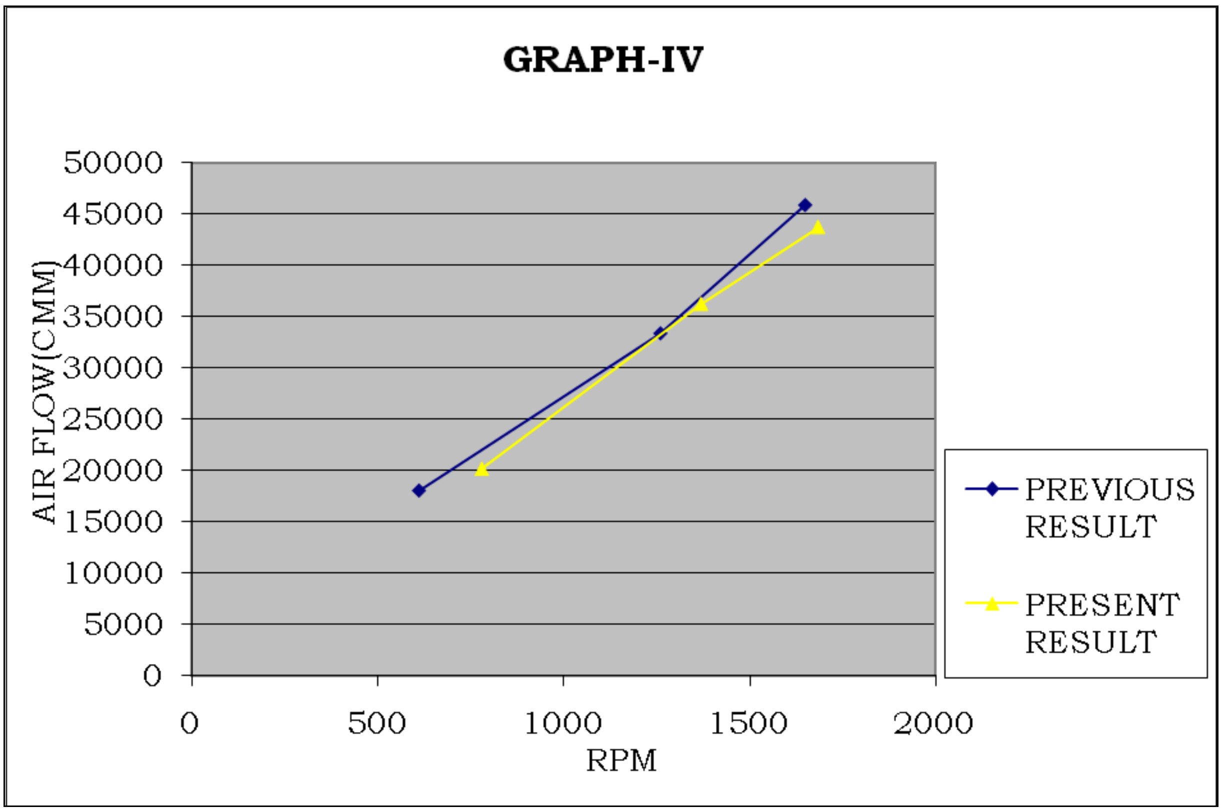


4.11.4 Air Cleaner-II With CQ Screen

Table 40. Comparison between Case I and Case II for Air flow (Air cleaner-II with CQ screen)

AIR FLOW MEASUREMENT (CMM)			
PREVIOUS RESULT		**PRESENT RESULT**	
RPM	**With CQ SCREEN**	**RPM**	**With CQ SCREEN**
610	18011	780	20190
1260	33373	1370	36250
1650	45910	1685	43730

Figure 61. Comparison between Case I and Case II for Air flow (Air cleaner-II with CQ screen)

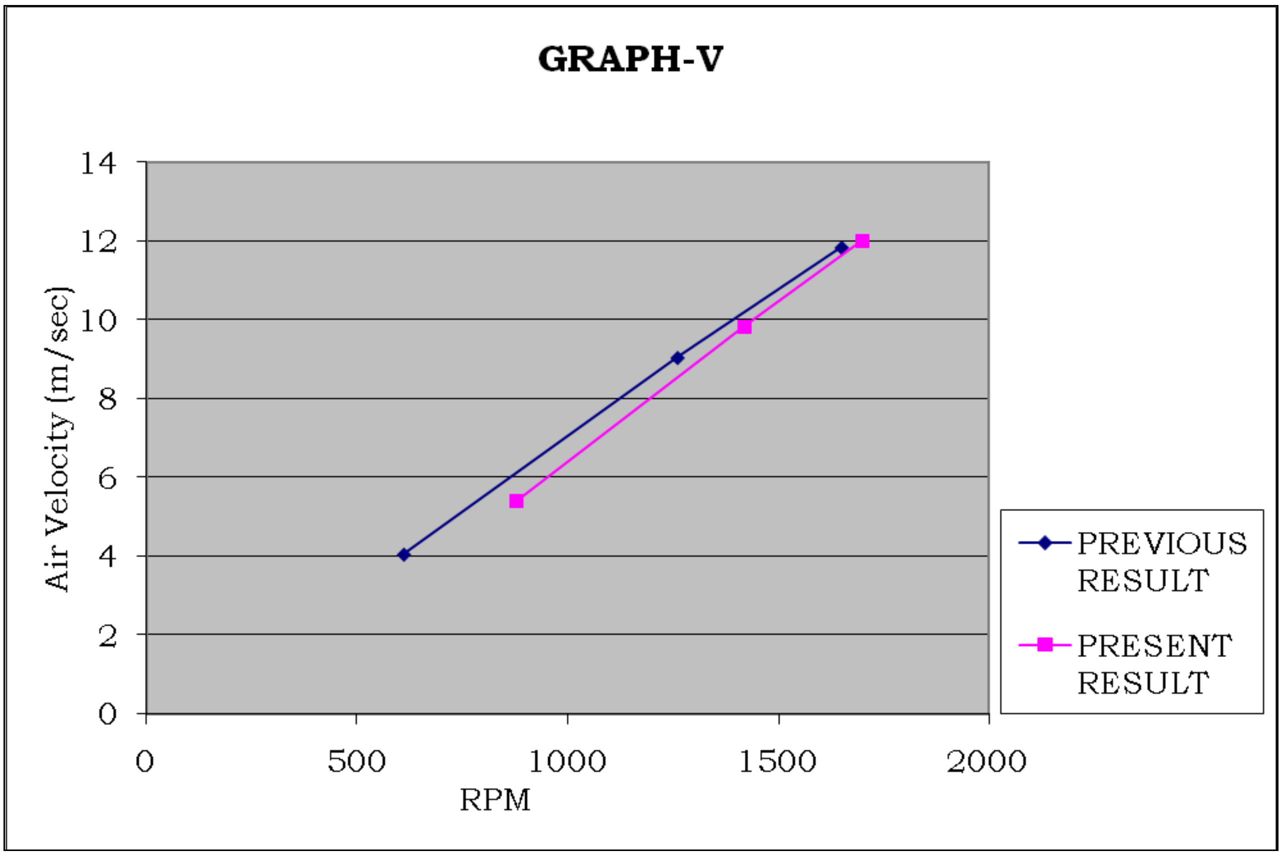


4.11.5 Air Cleaner-II With Filter

Table 41. Comparison between Case I and Case II for Air velocity (Air cleaner-II with filter)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		**PRESENT RESULT**	
RPM	**With filter**	**RPM**	**With Filter**
610	4.04	880	5.41
1260	9.04	1420	9.83
1650	11.84	1700	12.01

Figure 62. Comparison between Case I and Case II for Air velocity (Air cleaner-II with filter)

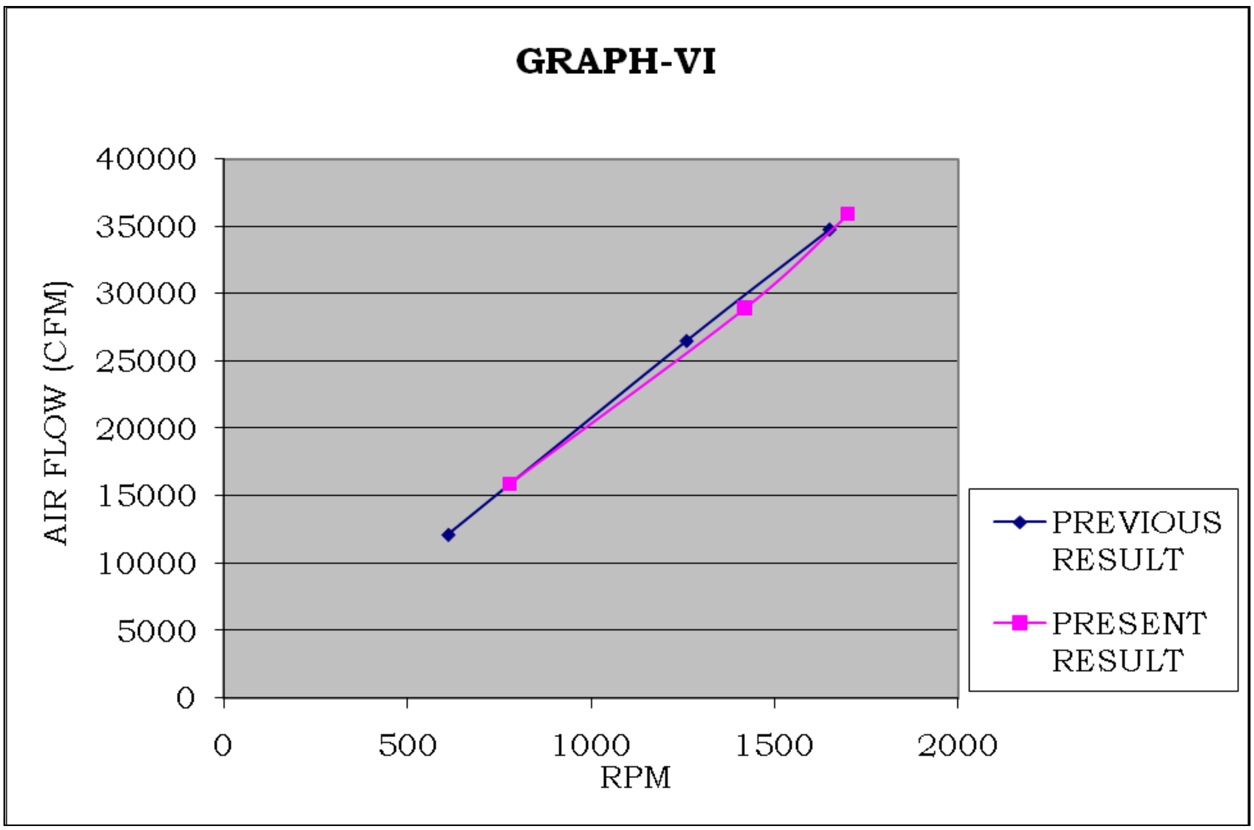


4.11.6 Air Cleaner-II With Filter

Table 42. Comparison between Case I and Case II for Air flow (Air cleaner-II with filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		**PRESENT RESULT**	
RPM	**With FILTER**	**RPM**	**With FILTER**
610	12148	780	15940
1260	26486	1420	28940
1650	34732	1700	35860

Figure 63. Comparison between Case I and Case II for Air flow (Air cleaner-II with filter)



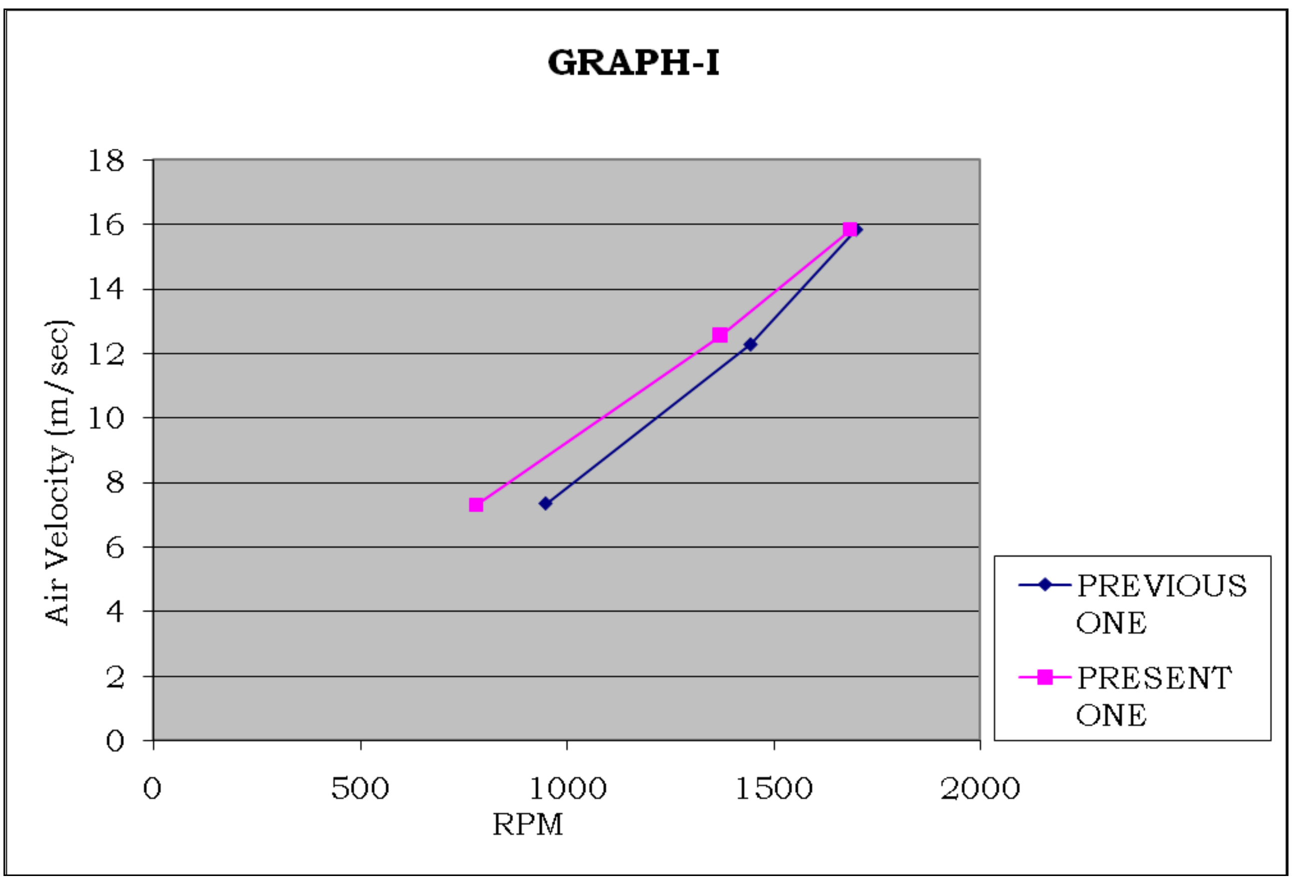
4.12 Air Cleaner III

4.12.1 Air Cleaner-III Without Filter

Table 43. Comparison between Case I and Case II for Air velocity (Air cleaner-III without filter)

AIR VELOCITY (M/SEC)			
PREVIOUS ONE			*PRESENT ONE*
RPM	Without filter	RPM	Without filter
950	7.33	780	7.3
1445	12.28	1370	12.55
1700	15.85	1685	15.82

Figure 64. Comparison between Case I and Case II for Air velocity (Air cleaner-III without filter)

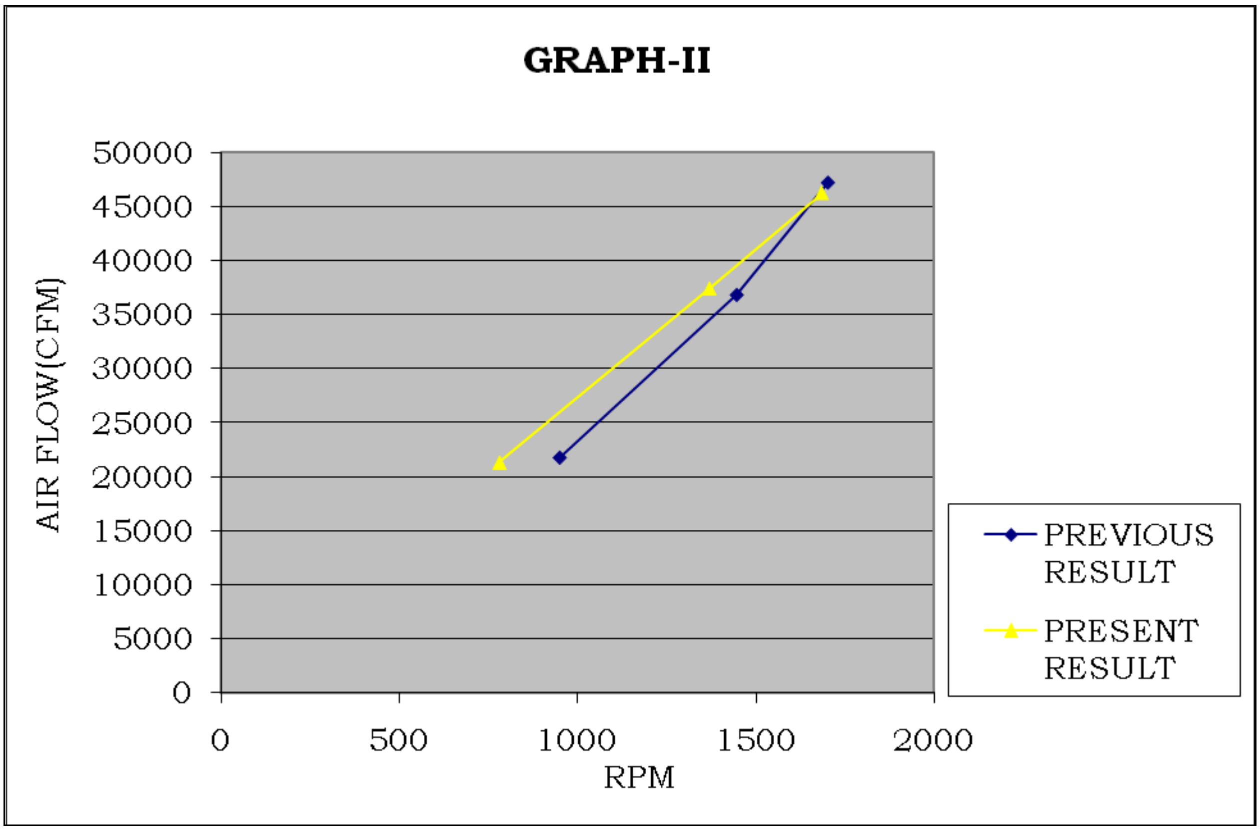


4.12.2 Air Cleaner-III Without Filter

Table 44. Comparison between Case I and Case II for Air flow (Air cleaner-III without filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	Without filter	RPM	Without filter
950	21754	780	21280
1445	36798	1370	37430
1700	47181	1685	46280

Figure 65. Comparison between Case I and Case III for Air flow (Air cleaner-III without filter)

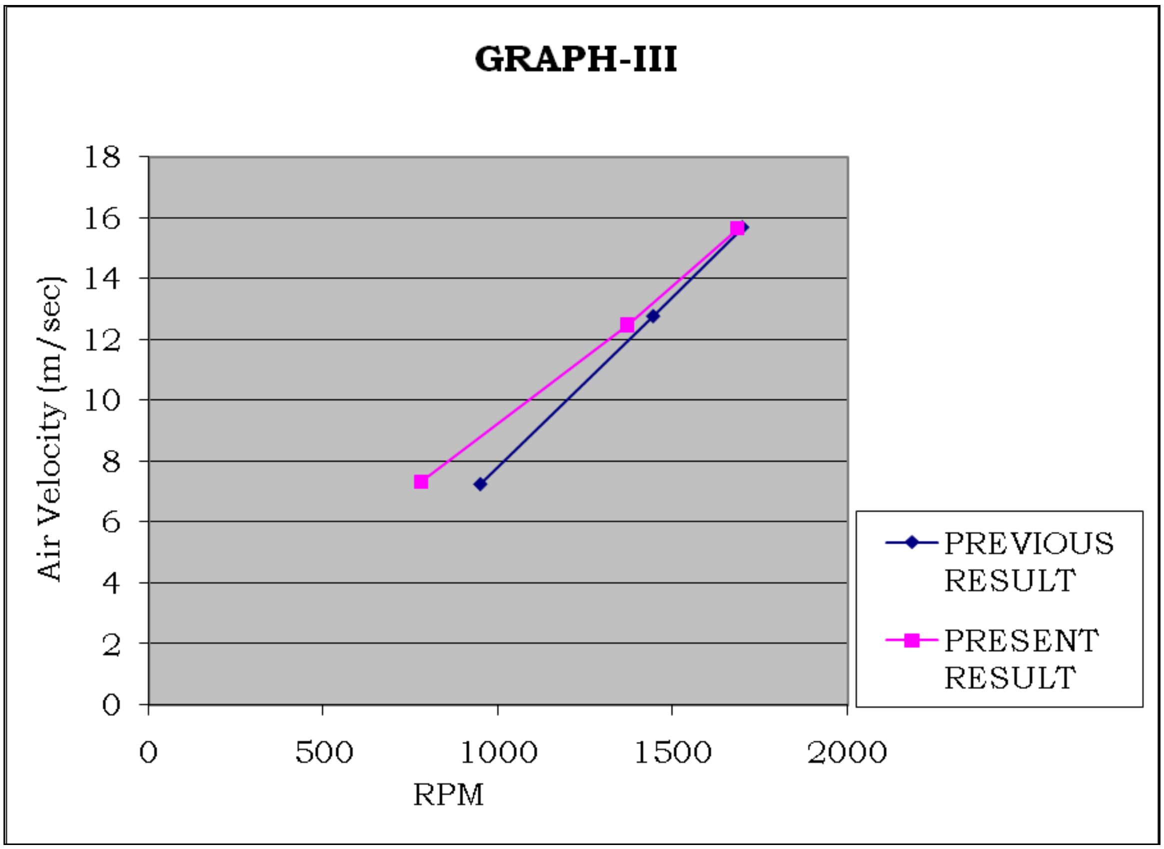


4.12.3 Air Cleaner-III With CQ Screen

Table 45. Comparison between Case I and Case II for Air velocity (Air cleaner-III with CQ screen)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With CQ SCREEN	RPM	With CQ SCREEN
950	7.25	780	7.35
1445	12.76	1370	12.48
1700	15.67	1685	15.63

Figure 66. Comparison between Case I and Case II for Air velocity (Air cleaner-III with CQ screen)

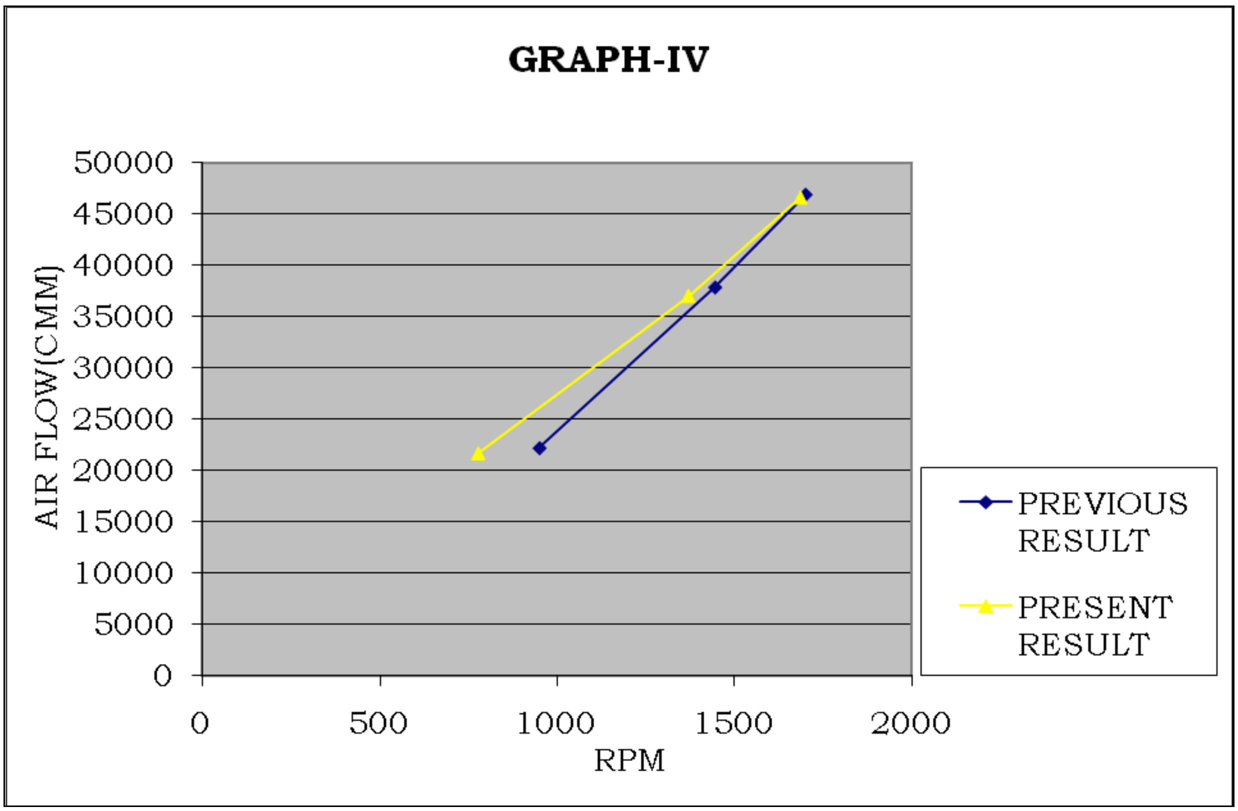


4.12.4 Air Cleaner-III With CQ Screen

Table 46. Comparison between Case I and Case II for Air flow (Air cleaner-III with CQ screen)

AIR FLOW MEASUREMENT (CMM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With CQ SCREEN	RPM	With CQ SCREEN
950	22178	780	21700
1445	37858	1370	37050
1700	46898	1685	46640

Figure 67 . Comparison between Case I and Case II for Air flow (Air cleaner-III with CQ screen)

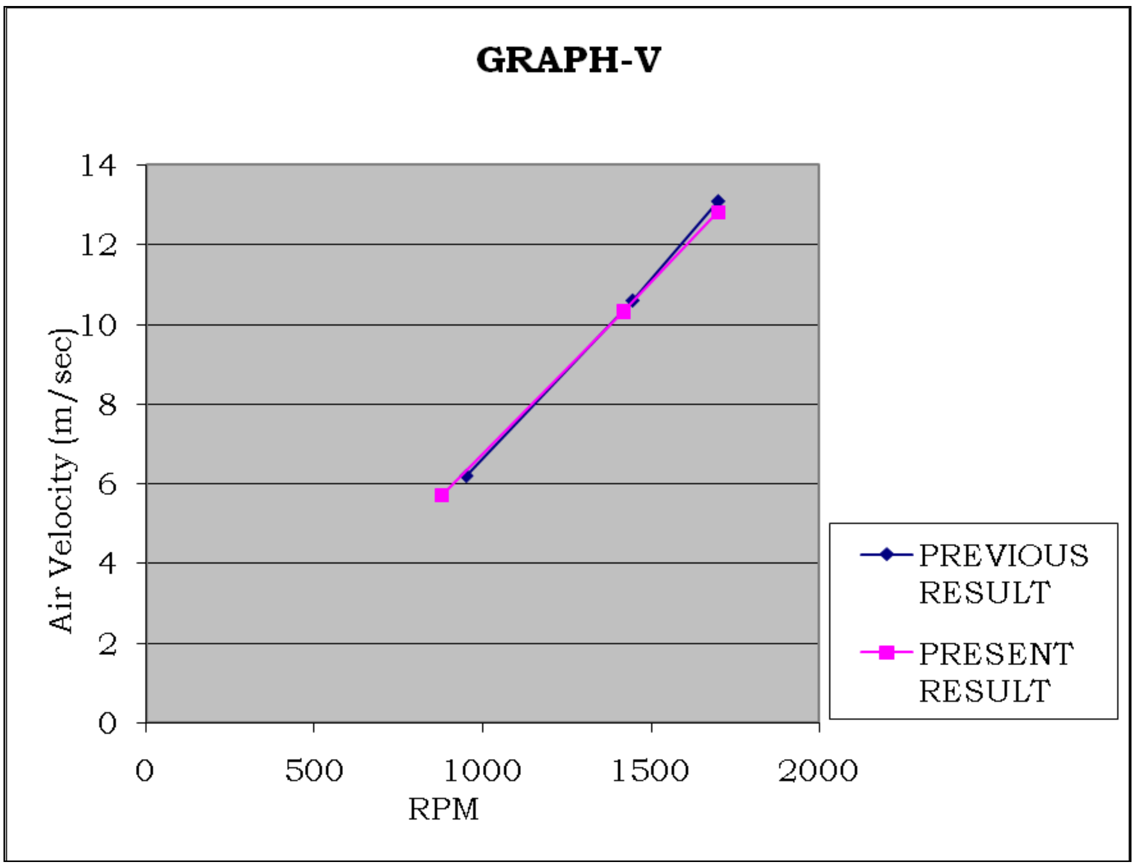


4.12.5 Air Cleaner-III With Filter

Table 47. Comparison between Case I and Case II for Air velocity (Air cleaner-III with filter)

AIR VELOCITY (M/SEC)			
PREVIOUS RESULT		**PRESENT RESULT**	
RPM	**With filter**	**RPM**	**With Filter**
950	6.19	880	5.72
1445	10.59	1420	10.33
1700	13.08	1700	12.81

Figure 68. Comparison between Case I and Case II for Air velocity (Air cleaner-III with filter)

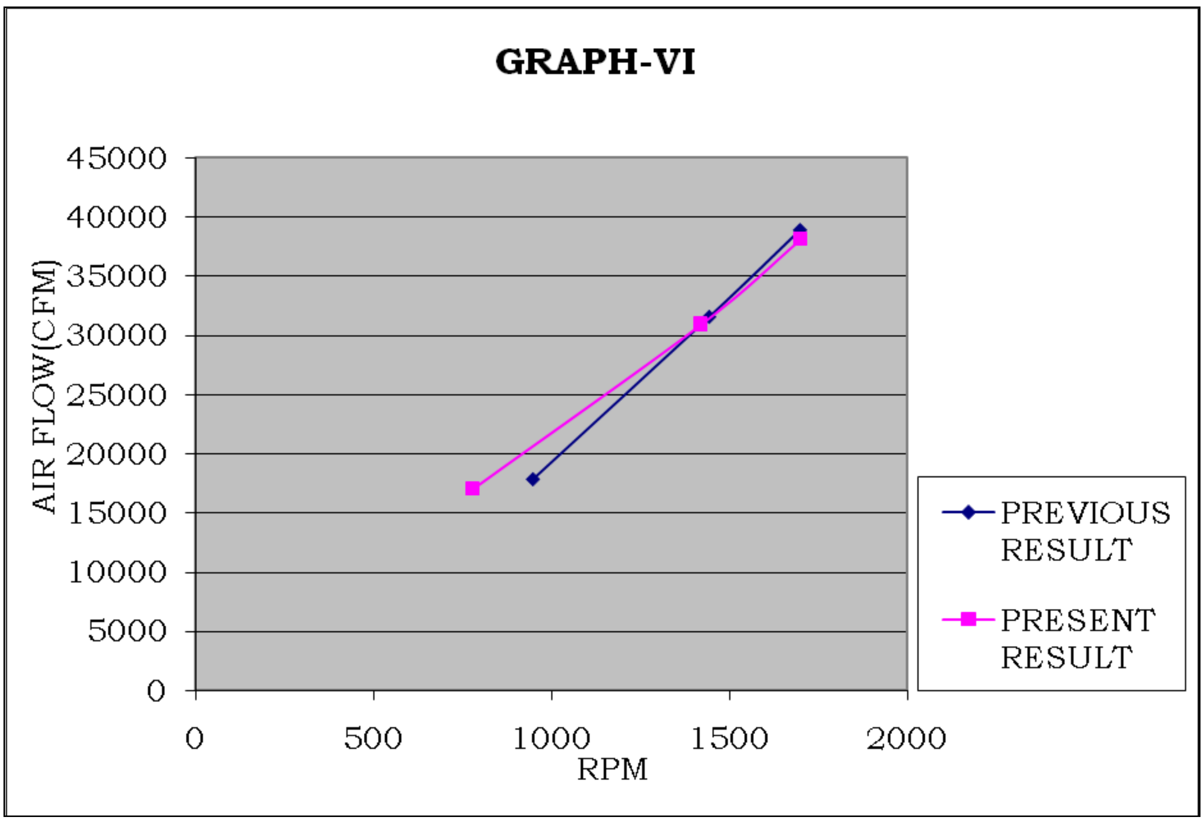


4.12.6 Air Cleaner-III With Filter

Table 48. Comparison between Case I and Case II for Air flow (Air cleaner-III with filter)

AIR FLOW MEASUREMENT (CFM)			
PREVIOUS RESULT		PRESENT RESULT	
RPM	With FILTER	RPM	With FILTER
950	17869	780	17040
1445	31589	1420	30930
1700	38917	1700	38120

Figure 69. Comparison between Case I and Case II for Air velocity (Air cleaner-III with filter)



CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

An overview of the air cleaners, a discussion and modeling of the modified volute which includes the experimental testing and performance of the air cleaner. This paper explains about a new performance technique – energy performance based on the power usage per air flow rate to characterize the energy efficiency of the air cleaner. A low energy performance indicated the low consumption of power and more energy efficient of air flow delivery system and also discussion of the numerical results and calculation of the air velocity and flow rates for the modified model have been made.

The following conclusions can be drawn from the results of this study which evaluate the effect of modeling a volute for the present air cleaner and test rig to calculate the air flow rates related to conservation of mass which takes in the experimental setup:

1) By calculating the value of the clean air delivery rate of the air cleaner we can say that the certain air cleaner is qualified for the energy star requirements.

2) The average value of the clean air delivery rate was almost 145cfm than the predicted one. If the value is 145cfm we can say that we are saving the energy than the previous use in the household system.

3) The temperature and air flow rates of different air cleaners recorded by cfm anemometer vary, depending on the speed and the volute height and the motor specifications.

4) Pro-Engineer predicts the new model of the volute in order to get the uniform air velocity and flow rated in order to qualify for the Energy star.

5) In going from the old model of the volute to the new model of the volute air velocity was varying from one air cleaner compared with the second one.

6) The graphs between rpm and air velocity look similar for the three air cleaners.

7) Plotting of the results and comparing the results are qualitatively similar with minimal difference of the result.

8) The comparison of the three different air cleaners results with the experimental data and other numerical results from the literature showed good qualitative agreement between predictions and the experimental data, however there are some disagreements in the air

velocity, flow rate and temperature in the test rig. Overall the air velocity calculations showed good promise.

9) The inclusion of the new modeled volute resulted in reduction in the minimum and maximum values of flow rates and work-input in the test rig.

10) Addition of different components evaluates the air cleaner values at stationary points especially at the maximum and minimum clearance value of the volute i.e.; from 4.515inches to 3.265inches.

11) The addition of the modified motor and the modified volute helps to improve the air cleaner profile correspondence with the help of Pro-Engineer to reduce the height and the motor specifications.

12) The effect of the air velocity and flow rates values is clearly noticed when the maximum and minimum values are calculated when the air cleaner is in testing mode.

13) In both the cases the model of the air cleaner is same but the speed of the motor and the filter are changed in order to see the filter efficiency.

14) A new design which addresses the above issues, and is politically acceptable to all parties, is unlikely.

15) The cheaper the purifier, the more important the AHAM air delivery rate becomes, relative only to other units in its price class.

16) High quality air purifiers with real carbon filtration and tight gasket filters are at a big disadvantage in the clean air delivery game. Quality machines operate at higher internal pressures; CADR favors a strong fan generating high throughput at low pressure.

17) For those concerned about health, the clean air delivery rate should be considered a primary standard to measure air purifier effectiveness.

18) If you are living in an area with high background particle concentrations, as present in most metropolitan areas of United States and European countries, the purchase of portable air cleaners is recommended to permanently improve indoor quality and will simultaneously get protection of temporary haze.

19) For families with children or members with respiratory or cardio-vascular diseases - thus more susceptible persons to suffer haze related health impacts and particle exposure – the benefit of should considered with higher priority.

20) It should be noted that air cleaning devices (portable air cleaners or upgrading air-conditioning) are only effective if applied in sound relation of the device' removal rate and the room used. Reducing indoor haze pollution in all rooms of your house/apartment will need high investments. The most practicable will be to reduce indoor pollution in one or two rooms only, most suitable parents and children's sleeping

rooms and two spend also most of the daytime in this room during high outdoor pollution levels.

20) When purchasing an air cleaner, please be aware of the fact that there exists no international standard for testing their efficiency. Efficiency given should refer to the scientifically based and approved the DOP method in Military Standard 282, the ANSI/AHAM Standard AC-1-1988 based Clean Air Delivery Rate (CADR) or the atmospheric dust spot test ASHREA Standard 52-7.

21) High Efficient Particulate Air (HEPA)-Filter air cleaning devices scientifically proven the highest efficiency in removing particles. Ion generators seen and the based ASHREA testing method of -HEPA-devices will significantly reduce indoor air pollution and the ensuing haze risk if operated properly. However, those devices are cost-intensive not only in purchase but also in maintenance (power, filter change).

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