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A Study of Air Cleaners and The Effect of Air Cleaner Design on Horsepower

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Abstract

It is the purpose of this study to investigate air cleaners and the effect of air cleaner housing design, intake snorkel tube design and filter media on engine horsepower. In doing the investigation, the writer will determine how horsepower is affected by: (1) the size and shape of the intake snorkel, (2) the placement of the intake snorkel in the engine compartment, (3) the size (volume) of the air cleaner housing, (4) the type of filtering media used, (5) the size of the filter element, (6) breather holes drilled in the filter housing, and (7) a partially clogged filter element.

A STUDY OF AIR CLEANERS

AND

THE EFFECT OF AIR CLEANER DESIGN ON HORSEPOWER

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

Many people study the modern automobile and its various systems. As a part of the intake system, the air cleaner assembly receives little publicity other than on filter element types and servicing fundamentals. Little information seems to be available on the topic of air cleaner design and how it affects engine performance.

I. THE PROBLEM

Statement of the problem. It is the purpose of this study to investigate air cleaners and the effect of air cleaner housing design, intake snorkel tube design and filter media on engine horsepower. In doing the investigation, the writer will determine how horsepower is affected by: (1) the size and shape of the intake snorkel, (2) the placement of the intake snorkel in the engine compartment, (3) the size (volume) of the air cleaner housing, (4) the type of filtering media used, (5) the size of the filter element, (6) breather holes drilled in the filter housing, and (7) a partially clogged filter element.

Importance of the study. Air cleaners of some sort have been used on automobile engines since their introduction. The auto industry today produces a variety of engines, based on displacement. When viewing this variety of engines, one finds the display of air cleaners to be quite different. They vary in housing size, intake snorkel size and shape, intake snorkel placement, filter element size and filtering media.

Textbooks designed for high school and college automotive classes offer little if any information on the subject of air cleaner design and its effects on engine performance. The writer has found that many high school students discard the entire filter assembly, alter its design or purchase a filter assembly designed for "better breathing" in an attempt to increase horsepower. The writer feels that in most cases there is little understanding connected with the changes implemented.

The writer believes there is a need to investigate the performance level of the factory equipment air cleaner assembly. The results of the investigation will give the writer a better understanding of performance of the engine as affected by the air cleaner design. This new knowledge and understanding will be valuable when teaching about automobile intake systems.

Limitations of the study. The writer is limiting this study to automobile air cleaner housings, intake snorkels and filter elements. The study is limited in that not all types of air cleaner housings or intake snorkels produced by the automobile industry are being tested.

The laboratory test is limited to only one level of engine speed and load. All tests are conducted with a stationary vehicle driving a chassis dynamometer. Some automobiles might perform differently in actual road tests because of the air flow patterns created by the moving vehicle.

The writer believes that published technical information related to the study is limited. The writer experienced difficulty in obtaining information from the automobile industry which has limited the technical section of the study.

II. DEFINITIONS OF TERMS USED

Chassis dynamometer. A chassis dynamometer is a testing device used to measure road horsepower. The unit consists of two metal rollers that are driven by the rear wheels of the car being tested. The revolving rollers drive a water turbine which acts as a loading device to increase the resistance of the rollers. This rolling resistance assimilates actual road operation for the car.

Combustion efficiency. Combustion efficiency is a test performed with an exhaust gas analyzer to determine how efficiently the fuel mixture is being burned in the cylinder. The analyzer indicates that as more oxygen enters the fuel mixture, the mixture becomes leaner and combustion efficiency increases. The test also gives an indication of the percentage of carbon monoxide in the exhaust. As combustion efficiency increases, the percentage of carbon monoxide decreases.

Intake manifold pressure. Intake manifold pressure indicates the pressure difference between the intake manifold and atmospheric pressure. A high intake manifold pressure indicates a high pressure difference.

Road horsepower. Road horsepower is a measurement of the power available at the rear wheels of an automobile to actually drive the car.

Water manometer. The water manometer is a test device used to indicate and measure pressure difference. It consists of two long plastic tubes held in an upright position. The tubes are connected with a "U" at the bottom and filled half full of water. A rubber hose is connected to the top of one tube and to the intake manifold of the test engine. The other tube is left open to atmospheric pressure. When the engine is running, a vacuum exists in the intake manifold and a suction is felt on the column of water. The atmospheric pressure pushes down on the other column causing an unbalanced water level. The difference between the water columns is measured and the "Inches of Water" is converted to manifold pressure.

CHAPTER II

REVIEW OF LITERATURE AND TECHNICAL INFORMATION

Many automotive text books have sections on air filter elements and service techniques. Little information is available in published form on the subject of air cleaner design and its effect on engine performance.

I. THE PURPOSE OF AIR CLEANERS

After World War II the automobile engine experienced design changes that made it more compact and increased the performance level over a wide range of operating conditions. In order for the engine to maintain its high performance over a long period of time, the skillfully designed components of the engine needed to be protected from wear. It was recognized that to protect the engine from wear, filters must remove contaminants from the fuel, oil and air.

During the early 1950's it was recognized that the present air filters had certain deficiencies that reduced their filtering efficiency. Since that time, the air filter has undergone research and change to improve its primary function, the cleaning of the intake air.

(Gruner and Forman, 1958, p. 1)

The second purpose of the air cleaner assembly is to reduce the volume of engine induction noise to an acceptable, safe, comfortable level. Guignard, in a paper presented to the Institution of Mechanical Engineers in 1967, established that the accoustical energy frequencies and pressure of unsilenced engines is disturbing to man. The resulting stress of audible noise contributes to "fatigue decreased proficiency." Impaired working efficiency can be a threat to safety. (Sherman, 1969, p. 1, 13)

The air cleaner also acts as a flame arrester if the engine backfires through the carburetor. If ignition should occur while the intake valve is open, the momentary flashback through the intake manifold and carburetor could ignite gasoline fumes outside the carburetor if the air cleaner was not used. (Crouse, 1967, p. 56)

The final purpose of the air cleaner is to control the intake air temperature. Ford first used the application of heated intake air on the 1957 Lincoln air cleaner. With heated intake air, engine warm-up is faster, the choke opens sooner, there is less mixture variation and carburetor icing is minimized.

When the automobile manufacturers were investigating ways to reduce the air pollution caused by exhaust gases, they found that the temperature control valve used in the air cleaner unit helped reduce the level of exhaust emissions. Many new cars today employ the temperature control air cleaner to help meet the federal standards for exhaust emissions. (Schofield, 1968, p. 26-27)

II. AIR CLEANER DESIGN

The air cleaner unit on an automobile is made up of three separate components: the air cleaner housing, the intake snorkel tube, and the filter element. Each of these components is designed to do a particular job as part of the air cleaner unit.

Air Cleaner Housing

When designing an air cleaner housing, many factors must be considered other than providing a means of connecting the filter element to the carburetor. Mr. W. W. McMullen, a staff engineer with AC Filters says that housing design is influenced by the space available, the cost of the housing and the acceptable level of silence for the intake system.

In a letter from Mr. R. M. Culbert, Project Engineer for Farr Company, manufacturers of air filters, the writer was told that the factors dealing with air cleaner housing design were quite complex. Culbert said:

> You are relating the dust-holding capacity of the air cleaner, which corresponds to the maintenance required and the efficiency needed for the engine involved, with the environment where it is expected to operate. For example, a 4-wheel drive vehicle to be used off the highway will need a much better air cleaner than the typical city car.

According to Mr. McMullen the size or volume of the air cleaner housing provides accoustical capacitance in silencing the intake system. The larger the volume of the air cleaner housing, the more efficient the silencing of the intake system will be.

Mr. W. J. Kovelan, Senior Engine Installation Engineer for White Truck Division of White Motor Corporation says that engine horsepower is influenced by pressure drop across the air cleaner assembly. Excessive pressure drop will cause the engine to be starved for air needed for efficient combustion and a horsepower loss will result.

In a letter from Mr. H. R. Johnson, Jr., Chief Engine Engineer for American Motors Corporation, the writer was told that insufficient space outside the filter can result in poor filter action. If the space is too small between the air cleaner housing and the filter element, the air flow can be restricted causing the pressure drop to be higher than desirable. This can cause a loss of horsepower.

Intake Snorkel Tube

The major intake noise of an internal combustion engine is caused by the intermittent change in velocity imparted to the gas in the intake manifold by the rapid opening and closing of the intake valves. In most cases, the inlet snorkel tube offers a major practical variable for controlling industion noise. (Sherman, 1969, p. 3-4)

Mr. McMullen of AC Filters expressed these opinions on intake snorkel tubes:

This tube is an important part of the accoustical system providing silencing. The cross-sectional area and its length affect the accoustical impedance, primarily inertance. The smaller the area and the greater the length, the greater will be the inertance. Therefore, for difficult silencing problems it is necessary to make this area small and the length as great as possible. However, as you can imagine, this will also be detrimental to power output. You will notice that in most cases the entrance to this tube is flared to reduce this effect as much as possible, and in many cases the tube is tapered in order to recover the energy as much as possible. Mr. McMullen further states: As I mentioned, it is necessary to compromise to provide adequate silencing to a level considered commercially acceptable without unduly affecting horsepower.

Since much of the intake noise is of a high enough frequency that it is to some extent directional, the best silencing is normally achieved by directing the tube straight forward. However, due to the necessity of clearing other components under the hood such as generator, power steering pump, air conditioner compressor, etc., this is not always possible.

Mr. Johnson of American Motors agrees with Mr. McMullen on snorkel design. He says that the design is generally determined by the degree of silencing desired for a particular air cleaner housing. This has a definite influence on air flow restriction and on horsepower.

Concerning the snorkel tube placement as an influence on horsepower, Mr. Johnson says, "If you were thinking about the possible ram effect if the inlet tube were placed straight ahead as opposed to side or rear location, the effect would be minimal."

In an interview with Mr. Ed Sanger, a salesman for a Cedar Falls Pontiac dealer, dirt track racer and drag strip participant, the writer asked about intake snorkels. Mr.

Sanger said that in his experience with air cleaners he has found the factory equipment to be slightly restrictive causing high fuel consumption. He has recommended to customers that they drill a series of six or eight holes, one inch in diameter, around the circumference of the air cleaner housing to admit more air. He reports that many achieve a one to two mile per gallon increase while many complain of the increased induction noise level.

Filter Elements

> The air filter devices used on today's passenger cars are classified according to the filtering media used. They are grouped under the following five types: oil-wetted mesh, oil bath, dry paper, oil-wetted paper and oil-wetted polyurethane foam. (Schofield, 1968, p. 25)

Oil-wetted mesh. The oil-wetted mesh filter element is one of the older types used on automobile engines. Dirt is collected as the air passes through a depth of oily copper or other metal mesh screen. This type of filter becomes clogged quite easily causing the air flow to become restricted.

> The oil-wetted mesh filter is not highly efficient in trapping small particles of dust because of the relatively large space between the metal strands.
>
> (Johnson and Toboldt, 1968, p. 241)

It has been observed by the writer that the oil-wetted mesh air cleaner has not been factory equipment on American cars for some time. It is sold through catalogs and suppliers of custom equipment.

Oil bath. The oil bath oil cleaner operates on the principal of reversing the direction of flow of the rapidly moving intake air over the surface of the oil bath. The heavier dirt particles can't make the directional change and are trapped by the oil. The smaller dust particles that escape the oil bath and continue in the air flow are filtered from the air by a mesh filter of steel wool, copper gauze, or loosely packed fibers or an animal hair filter.

(Schofield, 1968, p. 25)

The oil bath filter is more efficient than the oil-wetted mesh filter but not as efficient as the paper filter element. The mesh filter above the oil bath can't trap all of the small dust particles. Restriction to the air flow is caused by the sharp bends that the air must make in traveling through the filter. This could cause a horsepower loss.

(Schofield, 1968, p. 25-26)

The oil bath filter is more efficient at high engine speeds than at low speeds because the intake air is traveling at greater velocity and more dirt is thrown from the air stream by centrifugal force onto the oil bath. The following test results show how the efficiency of an oil bath filter varies with engine speed.

Engine Speed	Clearner Efficiency (%)
Maximum	96.3
Three Quarter	91.5
One Half	78.5
One Quarter	69.0
Minimum	60.0

(Forman and Gruner, 1958, p. 5)

The writer knows of no American automobile manufacturer that installs an oil bath air cleaner as standard equipment. When talking to a parts salesman at a local Ford dealership, the writer was told that oil bath air cleaners are available as optional equipment on pickups, trucks and taxi or police cars. The parts salesman said that some fleet owners feel it is more economical for them to service the oil bath cleaner than the paper element.

Dry paper element. The dry paper element is much newer than the oil bath or the oil-wetted mesh. The dry paper element is used extensively on today's new cars.

The paper section of the filter cartridge is formed of a circle of accordian pleated filter paper. The pleat shape of the paper maximizes dust holding capability against air pressure drop across the filter. To strengthen and control the porosity of the filter paper, it is usually impregnated with phenolic resin. The filter paper is flameproofed by treatment with a "phosphate". The edges of the pleated element are encased in soft plastic caps that act as seals when the element is installed in the air cleaner housing. The plastic caps are supported by perforated metal, which also protects the paper element. (Sherburn, 1969, p.5)

Efficiency of the dry paper filter is relatively consistant at all engine speeds and considerably higher than with an oil bath or oil-wetted mesh cleaner. The following shows the effect of engine speed on filter efficiency.

Engine Speed	Filter Efficiency (%)
Maximum	99.3
Three Quarter	99.2
One Half	99.0
One Quarter	98.9
Minimum	98.6

(Forman and Gruner, 1958, p. 5)

The horsepower of the engine can be affected by the paper filter element if it is too small to allow sufficient air flow or if it becomes restricted (dirty). Mr. Kovelan of White Motor Corporation says:

> Excessive pressure drop in the induction system of the engine will influence the engine power output by simply starving the engine of air required for efficient combustion. Gasoline engine air cleaners are considered restricted at between 8-15 inches of water.

Mr. McMullen of AC Filters says about filter size:

> As for the size of the filter element, this is generally made large enough to provide at least 24,000 miles of service before replacement under normal conditions. In some cases, the element diameter is larger than would otherwise be considered necessary so that it will drop down around the carburetor in order to make an installation within the limited space available between the carburetor and the hood of the vehicle.

The dry filter may be cleaned of dry dirt and dust by light tapping or with reverse air pressure. Shortened filter life may be experienced when the dry paper element is used in city conditions where smog is prevelant. The oily smog gums up the paper and when dust makes contact with the gummy paper the filter becomes restricted and can not be cleaned.

(Rickman, 1967, p. 110)

Oil-wetted paper element. The oil-wetted paper element, used mainly by General Motors, looks identical to the dry paper element. The difference lies in the service procedure. The oil-wetted paper element is more fragile and should never be oiled, washed, tapped or blown with compressed air. Service is limited to testing and replacement.

(Schofield, 1968, p. 25)

Oil-wetted polyurethane. The oil-wetted polyurethane filter element is relatively new in the auto industry. Its dimensions are similar to the paper filter and usually they are interchangeable. The polyurethane filter element is a ring of polyurethane foam supported by a perforated metal ring. (Schofield, 1968, p. 26)

When comparing the efficiency of the paper filter element to the polyurethane foam element, Schofield (1968, p. 26) says, "One evidently does as good a job as the other, because cars will come through from the same factory with both kinds of elements."

Mr. Ed Sanger feels the polyurethane filter does a more efficient job of filtering dust if properly serviced. He considers the polyurethane element more economical than the paper element because it will do a highly efficient job of filtering after 50,000 miles if serviced regularly. According to Mr. Sanger, the paper element starts to loose its efficiency after 5,000 miles and can't be adequately cleaned.

Some engines that employ closed crankcase ventilation experience oil vapors going past the PCV valve under low manifold vacuum conditions. These oil vapors tend to clog and ruin a paper filter element. Under these conditions, the polyurethane foam element would be a wise replacement for the paper element since the oil can't harm the foam.

(Schofield, 1968, p. 26)

The effects of the polyurethane filter element on horsepower would be similar to that of the dry or oil-wetted paper elements. If the filter becomes clogged enough to restrict the air flow, horsepower will decrease. In a case where a polyurethane element was the stock filter on a Chevrolet Tri-Power carburetor, a power loss was experienced at wide open throttle. The soft foam had a tendency to press together at the high engine speed and restrict the air flow.

(Scritchfield, 1968, p. 57)

Heavy duty dual stage cleaners. A heavy duty filter element consists of a paper filter element surrounded by a polyurethane foam or washable wrapper for an outer filter or pre-cleaner. (Schofield, 1968, p. 25-26)

The foam outer filter acts as an effective pre-cleaner when operating in extremely dirty conditions or when oil might ruin the paper element. Tests show that while the dual stage filter does a more efficient job of removing dirt than the paper element, the two filters combined restrict the air flow more than the paper element used separately.

(Sherburn, 1969, p. 6)

The effect of the polyurethane foam and paper filter combination on horsepower would depend on the amount of restriction. If the filter causes a pressure drop, the horsepower would decrease along with gas mileage.

CHAPTER III

TEST APPARATUS AND TEST CONDITIONS

I. TEST APPARATUS

Test automobile. The automobile used for the dynamometer tests is a 1967 Ford, Galaxie 500, with a 289 cubic inch engine rated at 200 brake horsepower at 4400 RPM. It is equipped with a Ford two barrel carburetor. The transmission is a three speed Cruise-O-Matic.

Dynamometer. The unit is a Clayton Chassis Dynamometer Model C-200-1-OTD. The meter registering road horsepower is calibrated from 0-200 horsepower in 2 horsepower units. The speed indicating meter has low and high scales, the low scale reading from 0-60 MPH in 1 MPH units and the high scale reading from 0-120 MPH in 2 MPH units. For all the dynamometer tests the meter will be on the high scale.

Tachometer. The tachometer is a unit of a Sun 1120 Electronic Diagnosis Engine Tester. For the dynamometer tests the 0-5000 RPM scale, which is graduated in 100 RPM units, will be used.

Exhaust analyzer. The exhaust analyzer used to measure the combustion efficiency of the test engine is a unit of a Sun 1120 Electronic Diagnosis Engine Tester. The meter is calibrated from 60% to 100% combustion efficiency in 1% units. For all the tests the exhaust analyzer pickup tube will be installed in the laboratories exhaust pickup line approximately five feet behind the tail pipe at a "Y" connection. This arrangement is necessary to get the combustion efficiency reading while at the same time exhausting the exhaust gases from the laboratory.

Water manometer. The water manometer used for the tests consists of two vertical plastic tubes connected at the bottom with a "U". The tubes are mounted on a vertical board with two 60" tape measures attached to the board outside of and parallel to each tube. The manometer has the capacity for providing readings up to 60 inches of water in 1/8" units. For all the tests the manometer will be connected to the vacuum line leading from the intake manifold to the automatic transmission. The hose from the intake manifold to the manometer will be clamped shut except when the engine is fully loaded and the manifold vacuum is low. This will prevent the water in the manometer from being drawn from the manometer tube by the high intake manifold vacuum that exists at idle and less than full load conditions. After the manometer reading has been taken, the hose will again be clamped shut to prevent manifold vacuum from drawing the water from the manometer during deacceleration.

The manometer readings will be taken as total inches of water (H_2O), obtained by subtracting the low reading from the high. The difference will be converted into pounds per square inch, which represents the difference between the atmospheric pressure and the intake manifold pressure, by multiplying the inches of water times 0.03613. The inches of water reading can be converted to inches of mercury, which represents the manifold vacuum reading, by multiplying the inches of water times 0.07355.

(Pease, 1967, Table of Conversion Factors)

II. TEST CONDITIONS

The tests were run on January 12, 1970. On that morning, the humidity was 62 per cent and the barometric pressure was 30.22 inches of mercury or 14.84 pounds per square inch. All tests were made with the engine at operating temperature with the hood closed and latches in the safety position. The intake system was required to draw in the warm under-the-hood air which averaged about 115 degrees Fahrenheit during the tests.

CHAPTER IV

LABORATORY TESTS

This chapter deals with eighteen laboratory tests and their results which are used to study the effects of air cleaner housing design, intake snorkel design and filter media on road horsepower. While testing the effects of different housings, snorkels and filter elements on horsepower, the writer will observe their effect on combustion efficiency and intake manifold pressure.

The test data will be used to evaluate the efficiency of the factory equipment air cleaner unit of the test engine by comparing its test results to those obtained using other combinations of equipment on the same engine, under the same test conditions.

I. TEST I

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and manifold pressure of the test engine when equipped with the factory equipment air cleaner housing, intake snorkel tube and a replacement paper filter element designed for the factory equipment filter housing. The results of Test I will be used as a standard for comparison with all other tests.

Special Test Apparatus

The special test apparatus for Test I are the factory air cleaner housing, intake snorkel tube and a replacement filter element designed for the test engine.

Air cleaner housing. The following is a list of specifications pertaining to the factory equipment air cleaner housing shown in Figure 1.

1. Diameter equals 14 inches.
2. Height equals 4 3/4 inches.
3. Depth outside the filter equals approximately 2 3/4 inches.
4. Volume outside the filter equals approximately 470 cubic inches.

Figure 1. Factory Equipment Air Cleaner Housing For Ford 289 Cubic Inch Engine

Filter element. The following are specifications for a paper filter element made to fit the factory equipment air cleaner housing.

1. Diameter equals 8 3/8 inches.
2. Height equals 3 1/4 inches.
3. Height of the pleats equals 2 5/8 inches.
4. Depth of the pleats equals 11/16 inches.
5. Number of pleats equals 175.
6. Surface area of filter material equals 632 square inches.

Intake snorkel. The following are specifications for the intake snorkel tube that was factory equipment on the test engine.

1. Length equals 7 3/4 inches.
2. Opening at the air cleaner housing equals 2 3/8 inch diameter.
3. Intake opening is formed like an arch, 2 1/2 inches high and 3 inches wide.
4. Intake opening has a slightly flared end.
5. Snorkel mounts at 60 degrees from straight ahead in the engine compartment.

Test Method

With the factory equipment air cleaner unit in place, the test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle. The engine will be at operating temperature so the thermostatic valve in the snorkel will be open to admit under-the-hood air rather than hot air off the exhaust manifold.

Test Data

Road Horsepower - 62 Combustion Efficiency - 75.5*

Inches of Water - 19.75 Manifold Pressure - .714

* All combustion efficiency readings are in per cent.

II. TEST II

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and manifold pressure of the test engine with the factory air cleaner unit removed. The unfiltered air will be drawn directly into the carburetor air horn. The test results will be compared to those of Test I to determine if the factory air cleaner system restricts air flow and limits horsepower.

Special Test Apparatus

No special test apparatus is needed for this test.

Test Method

The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 59.5   Combustion Efficiency - 84.0

Inches of Water - 16.375   Manifold Pressure - .592

Observations

The test data shows a much lower manifold pressure for Test II which indicates the stock assembly is restrictive to air flow. Combustion efficiency increased indicating more air entered the cylinders to produce a leaner mixture. The horsepower decreased indicating that the mixture was too lean for maximum power or that the air was not in a form conducive to maximum horsepower. When talking with Dr. Luck of the University of Northern Iowa Industrial Arts and Technology Department and with Mr. Sanger, the writer was told that sometimes the air cleaner housing gives the air turbulence that improves vaporization of the gasoline to give higher horsepower than obtained with unfiltered air.

III. TEST III

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and manifold pressure of the test engine using the factory equipment air cleaner housing and the replacement paper filter element but with the intake snorkel tube removed, as shown in Figure 2. The test results will be compared to the test results of Test I to determine the effect of the intake snorkel tube on road horsepower, combustion efficiency and manifold pressure.

Special Test Apparatus

The same air cleaner housing and replacement paper filter as used in Test I will be used in this test.

Figure 2. Factory Equipment Air Cleaner Without Snorkel

Test Method

The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64   Combustion Efficiency - 79
Inches of Water - 19.25   Manifold Pressure - .696

Observations

It appears that the factory equipment snorkel restricts air flow since manifold pressure is lower than in Test I. Combustion efficiency is higher indicating more air flow, and road horsepower increased indicating the mixture isn't too lean for good horsepower output.

IV. TEST IV

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine equipped with the factory equipment air cleaner housing, intake snorkel tube and a polyurethane foam filter element. The test results will be compared to those of Test I to determine if the polyurethane foam element offers more or less restriction to the air flow, resulting in different horsepower output.

Special Test Apparatus

The only special test apparatus needed for this test is a polyurethane foam filter element that will fit the factory equipment air cleaner housing.

Filter element. The following are specifications for the polyurethane foam filter element shown in Figure 3.

1. Diameter equals 9 inches.
2. Height equals 3 inches.
3. Depth of foam equals 3/8 inch.
4. Surface area equals 87 square inches.

Figure 3. Polyurethane Foam Filter Element

Test Method

The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle. The engine will be at operating temperature so the thermostatic valve in the snorkel tube will be open to admit under-the-hood air rather than the hot air off the exhaust manifold.

Test Data

Road Horsepower - 63	Combustion Efficiency - 77.5
Inches of Water - 19.5	Manifold Pressure - .705

Observations

The results indicate that the polyurethane foam filter element is less restrictive than the paper element used in Test I. The manifold pressure is lower and the combustion efficiency is higher indicating less restriction and more air flow. The horsepower is slightly higher which could be the result of the additional air in the cylinder.

V. TEST V

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine equipped with the factory equipment air cleaner housing, intake snorkel tube and a heavy duty, dual element filter. The heavy duty filter element is a combination of the polyurethane foam element over the replacement paper element. The test results will be compared to those of Test I and Test IV to determine if the double filter element restricts air flow causing a lower horsepower output.

Special Test Apparatus

The special test apparatus needed for this test are the factory equipment air cleaner housing, intake snorkel tube, replacement paper filter element used in Test I and the polyurethane filter element used in Test IV.

Figure 4. Heavy Duty Filter Element

Test Method

The polyurethane foam filter element will be placed over the paper filter element, as shown in Figure 4, and the combined unit fitted into the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency, and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle. The engine will be at operating temperature so the thermostatic valve in the snorkel will be open to admit under-the-hood air rather than the hot air off the exhaust manifold.

Test Data

Road Horsepower - 63   Combustion Efficiency - 75.0

Inches of Water - 20.25   Manifold Pressure - .732

Observations

The test results indicate that the dual element, heavy duty filter is more restrictive than the paper filter element used in Test I or the polyurethane filter element used in Test IV. The manifold pressure is higher and the combustion efficiency is slightly lower than in Test I or in Test IV. The horsepower is slightly higher than the output in Test I, which could be the result of a slightly richer mixture or due to error in reading the horsepower output meter.

VI. TEST VI

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine using the factory equipment air cleaner housing, replacement paper filter element and a snorkel tube of different dimensions than the factory equipment snorkel. The test results will be compared to the results of Test I to determine the effect of snorkel tube design on horsepower and combustion efficiency.

Special Test Apparatus

The special apparatus for this test are the factory equipment air cleaner housing, replacement paper filter element and an intake snorkel manufactured by General Motors which is shown in Figure 5.

Intake snorkel. The following specifications are for the intake snorkel used for Test VI.

1. Length equals 8 inches.
2. Oblong opening at the air cleaner housing is 1 3/8 inches by 2 inches.
3. Round opening at the intake end is 1 inch in diameter with a flare diameter of 1 3/8 inches.

Figure 5. General Motors Test Snorkel

Test Method

The test snorkel will be attached to the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshifting. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 50

Combustion Efficiency - Approximately 55, the meter was off the calibrated scale

Inches of Water - 27.125

Manifold Pressure - .980

Observations

The test results indicate that this snorkel is very restrictive. Compared to Test I, the manifold pressure is higher and combustion efficiency is very low. The horsepower decreased, probably from the lack of air.

VII. TEST VII

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine using the factory equipment air cleaner housing, replacement paper filter element and a snorkel tube of different dimensions than the factory equipment snorkel. The test results will be used to determine the effect of snorkel tube design on horsepower and combustion efficiency in comparison with Test I and Test VI.

Special Test Apparatus

The air cleaner housing and replacement paper filter element are the same as those used in Test I. Figure 6 shows the intake snorkel tube which is manufactured by General Motors.

Intake snorkel. The following specifications are for the intake snorkel tube used in Test VII.

1. Length equals 10 5/8 inches.
2. Oblong opening at the air cleaner housing is 1 5/8 inches by 4 1/4 inches.
3. Round opening at the intake end is 1 1/2 inches in diameter with a flare diameter of 2 7/16 inches.

Figure 6. General Motors Test Snorkel

Test Method

The test snorkel will be attached to the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshifting. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64	Combustion Efficiency - 79.5
Inches of Water - 18.25	Manifold Pressure - .659

Observations

The test results indicate this snorkel is less restrictive than the snorkel in Test VI or the factory equipment snorkel used in Test I. The manifold pressure is lower than in Test I or Test VI and the combustion efficiency is higher, indicating a greater volume of air. Horsepower is high from what must be a well balanced fuel mixture.

VIII. TEST VIII

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine using the factory equipment air cleaner housing, a replacement paper filter element and a snorkel tube of different dimensions than the factory equipment snorkel tube. The test results will be used to determine the effect of snorkel tube design on horsepower and combustion efficiency in comparison to Test I and Test VII.

Special Test Apparatus

The air cleaner housing and the paper filter element are the same as those used in Test I. The intake snorkel tube manufactured by General Motors is shown in Figure 7.

Intake snorkel. The following at the specifications of the intake snorkel tube used in Test VIII.

1. Length equals 8 inches.
2. Oblong opening at the air cleaner housing is 1 5/8 inches by 4 1/4 inches.
3. Oblong opening at the intake end is 1 1/2 inches by 2 inches, flared to 2 3/8 inches by 2 3/4 inches.

Figure 7. General Motors Test Snorkel

Test Method

The test snorkel will be attached to the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 63.5	Combustion Efficiency - 80.5
Inches of Water - 17.875	Manifold Pressure - .646

Observations

The tests indicate that the snorkel is less restrictive than the snorkels used in Tests I and VII, since the manifold pressure is lower and the combustion efficiency is higher. The additional air flow improved horsepower over Test I but very little difference is indicated between Test VII and VIII. The induction noise level is higher than in Tests, I, VI, and VII.

IX. TEST IX

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine using the factory equipment air cleaner housing, a replacement paper filter element and an intake snorkel of different dimensions than the factory equipment snorkel. The test results will be used to determine the effect of snorkel tube design on horsepower and combustion efficiency compared to Tests I, VII and VIII.

Special Test Apparatus

The air cleaner housing and paper filter element are the same as those used in Test I. The intake snorkel tube manufactured by General Motors is shown in Figure 8.

Intake snorkel. The following specifications are for the intake snorkel used in Test IX.

1. Length equals 9 1/4 inches.
2. Oblong opening at the air cleaner housing is 1 5/8 inches by 4 1/2 inches.
3. Oblong opening at the intake end is 1 1/2 inches by 3 inches, flared to 2 3/8 inches by 3 7/8 inches.

Figure 8. General Motors Test Snorkel

Test Method

The test snorkel will be attached to the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 63   Combustion Efficiency - 82.0

Inches of Water - 18.0   Manifold Pressure - .650

Observations

The test results show less snorkel restriction than in Tests I and VII as the manifold pressure is lower. The results show slightly more restriction than in Test VIII but the writer feels this inaccurate since the combustion efficiency is higher indicating a greater air flow. The pressure difference indicates only one-eighth inch of water difference which the writer feels could be attributed to error. The horsepower output is higher than in Test I, apparently because of the additional air flow. It is slightly lower than in Tests VII and VIII apparently because the mixture is leaner and just past the point of the ideal balance for power with the carburetor jetting used.

X. TEST X

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine using the factory equipment air cleaner housing, a replacement paper filter element and a snorkel tube with the flare on the intake end removed. The test results will be compared to the results of Test VII to determine the value of the flared end on the General Motors intake snorkel tube.

Special Test Apparatus

The special test apparatus for this test is the same as that used for Test VII except the flare at the intake end of the snorkel tube has been removed at the position indicated in Figure 9.

Intake snorkel. The following are the new specifications for the intake snorkel tube after alterations.

1. Length equals 9 3/4 inches.
2. Round intake end opening is 1 1/2 inch diameter.

Figure 9. General Motors Test Snorkel With Flare Removed

Test Method

The test snorkel will be attached to the factory equipment air cleaner housing. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 60	Combustion Efficiency- Approximately 55, the meter was off the calibrated scale
Inches of Water - 29.5	Manifold Pressure - 1.066

Observations

The test results indicate the flare on the end of the intake snorkel has a great influence on air intake. The manifold pressure showed a marked increase and combustion efficiency dropped a great deal from the readings obtained in Test VII. Horsepower decreased, apparently from the lack of air. It seems that the flare on the end of the intake snorkel tube must have a venturi effect on the air which increases its velocity. This permits a greater volume of air to enter the snorkel tube with the flare.

XI. TEST XI

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine equipped with an air cleaner housing, paper filter element and dual intake snorkels, all having different dimensions than the factory equipment. The test results will be compared to the results of Test I to determine the effects of a filter element with a greater surface area and the dual snorkels on road horsepower and combustion efficiency.

Special Test Apparatus

The air cleaner housing with the dual snorkels and the paper filter element as shown in Figure 10 are manufactured by General Motors.

Air cleaner housing. The following specifications are for the air cleaner housing used in Test XI.

1. Diameter equals 14 inches.
2. Height equals 3 3/4 inches.
3. Depth outside the filter element equals 1 3/8 inches.
4. Volume outside the filter element is approximately 188 cubic inches.

Figure 10. General Motors Dual Snorkel Air Cleaner Housing

Filter element. The following specifications are for the paper filter element used in Test XI.

1. Diameter equals 11 1/2 inches.
2. Height equals 3 inches.
3. Height of pleats equals 2 5/8 inches.
4. Depth of pleats equals 1 1/4 inches.
5. Number of pleats is 118.
6. Surface area of filter material is 775 square inches.

Intake snorkels. (2) The following specifications are for the intake snorkel tubes on the air cleaner housing used in Test XI.

1. Length equals 7 1/4 inches.
2. Oval openings at the air cleaner housing are 1 7/8 inches by 4 1/8 inches.
3. Oval openings at the intake end are 1 1/2 inches by 4 1/4 inches, with slight flares.
4. Snorkels are placed approximately 105 degrees apart.

Test Method

The test air cleaner assembly will be mounted on the test engine so that each snorkel is about 52 1/2 degrees from the straight ahead position. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 61   Combustion Efficiency - 83.5

Inches of Water - 17.875   Manifold Pressure - .646

Observations

The test results indicate that the dual snorkel air cleaner assembly is less restrictive than the factory equipment filter assembly in Test I. The combustion efficiency is higher and manifold pressure is lower, indicating a greater volume of air flow. The horsepower is lower than in Test I indicating that the fuel mixture is leaner and some power has been sacrificed. Induction noise is higher than in Test I.

XII. TEST XII

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and the intake manifold pressure of the test engine equipped with an air cleaner housing, paper filter element and single intake snorkel tube, all with different dimensions than the factory equipment tested in Test I. The test results will be compared to Test I for a comparison of road horsepower and combustion efficiency. The results will be compared to Test VII to determine the influence of housing and filter element design on horsepower and combustion efficiency when using identical intake snorkel tubes. The results will be compared to Test XI to determine the value of dual snorkels over the single snorkel on identical housings using the same filter element.

Special Test Apparatus

The air cleaner housing and paper filter element shown in Figure 11 have the same dimensional values as those used in Test XI. The intake snorkel is identical to the one used in Test VII except this one is factory equipment on an air cleaner housing used by General Motors.

Figure 11. General Motors Air Cleaner Housing With Large Filter Element

Test Method

The air cleaner assembly will be mounted on the test engine with the snorkel tube positioned at a 45 degree angle from the straight ahead position, on the left side of the engine (passenger side). The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64   Combustion Efficiency - 78.5

Inches of Water - 19.75   Manifold Pressure - .714

Observations

When compared to the results of Test I, the test results indicate that the amount of restriction is the same since the manifold pressures are equal. The results also indicate that more air is entering the cylinders since horsepower and combustion efficiency both increased. The increased air flow could be attributed to the larger filter surface area or the design of the intake snorkel tube.

When compared to Test VII, which used the Ford factory equipment air cleaner housing with the same snorkel tube used in Test XII, the test results indicate an increase in restriction in Test XII. Combustion efficiency decreased slightly and horsepower stayed the same. It appears that the lower manifold pressure and higher combustion efficiency registered in Test VII can only be attributed to the greater housing volume outside the filter element since the snorkels were the same and the Ford filter element had less surface area.

Since Test VII showed lower manifold pressure and higher combustion efficiency than Test XII, it seems the horsepower and combustion efficiency increase of Test XII over Test I can be attributed to the different snorkel tube used in Test XII.

When compared to the results of Test XI, the results of Test XII show a horsepower increase and a decrease in combustion efficiency. This indicates that the air flow with the dual snorkel air cleaner is greater but that there is a sacrifice in horsepower. The dual snorkel air cleaner assembly would probably give more economical engine operation with a sacrifice in horsepower.

XIII. TEST XIII

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and manifold pressure of the test engine equipped with the same air cleaner assembly used in Test XII except that seven, 7/8 inch holes will be drilled at points equally spaced around the circumference of the air cleaner housing. The test results will be compared to the results of Test XII to determine the value of "venting" the air cleaner housing.

Special Test Apparatus

The air cleaner housing, paper filter element and intake snorkel tube are the same General Motors units used in Test XII. The only change is that seven, 7/8 inch holes have been drilled in the air cleaner housing, spaced forty-five degrees around its circumference starting with the center line of the intake snorkel as shown in Figure 12.

Figure 12. General Motors Air Cleaner Housing With Breather Holes

Test Method

The air cleaner assembly will be mounted on the test engine with the intake snorkel tube placed at a 45 degree angle from the straight ahead position, on the left side of the engine. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshifting. Readings of road horsepower, combustion efficiency and manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 63 Combustion Efficiency - 81.5

Inches of Water - 17.5 Manifold Pressure - .632

Observations

The test results indicate less restriction to air flow with the holes drilled through the air cleaner housing. Manifold pressure decreased and combustion efficiency increased over the readings obtained in Test XII. There was a slight horsepower loss, probably caused by the leaner fuel mixture.

XIV. TEST XIV

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure of the test engine equipped with the same air cleaner housing and intake snorkel tube as used in Test XII but with a paper filter element having less surface area than the filter element used in Test XII. The test results will be compared to the results of Test XII to determine the effects of the surface area of filter material on horsepower and combustion efficiency.

Special Test Apparatus

The air cleaner housing and intake snorkel tube shown in Figure 13 have the same specifications as those used in Test XII.

Figure 13. General Motors Air Cleaner Housing With Small Filter Element

Filter element. The following specifications are for the paper filter element used in Test XIV.

1. Diameter equals 11 1/2 inches.
2. Height equals 2 1/2 inches.
3. Height of paper pleats equals 2 inches.
4. Depth of pleats equals 1 1/4 inches.
5. Number of pleats is 118.
6. Surface area of filter material is 590 square inches.

Test Method

The air cleaner assembly will be mounted on the test engine with the intake snorkel positioned 45 degrees from the straight ahead position on the left side of the engine. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64   Combustion Efficiency - 76.0

Inches of Water - 19.75   Manifold Pressure - .714

Observations

The test results indicate no difference in restriction to the air flow since the manifold pressure remained the same. Combustion efficiency decreased in Test XIV which seems to indicate that the volume of air passing through the filter was less than with the larger filter used in Test XII. Horsepower was unaffected by the smaller filter surface area.

XV. TEST XV

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure using the same air cleaner assembly as used in Test XII but with the snorkel tube positioned at different angles in the engine compartment. The test results will be used to determine the effect of snorkel tube placement on road horsepower and combustion efficiency.

Special Test Apparatus

The air cleaner housing, paper filter element and intake snorkel tube have the same specifications as those used in Test XII.

Test Method

The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the intake snorkel in the following positions: (a) straight ahead, (b) 30 degrees, (c) 45 degrees, (d) 60 degrees, and (e) 90 degrees. The engine will be operating at 2500 RPM and at full throttle.

Test Data

(a) Road Horsepower - 64 Combustion Efficiency - 72.5
Inches of Water - 20.5 Manifold Pressure - .741

(b) Road Horsepower - 64.5 Combustion Efficiency 77.5
Inches of Water - 19.5 Manifold Pressure - .705

(c) Road Horsepower - 64 Combustion Efficiency - 78.5
Inches of Water - 19.75 Manifold Pressure - .714

(d) Road Horsepower - 64 Combustion Efficiency - 77
Inches of Water - 19.5 Manifold Pressure - .705

(e) Road Horsepower - 64 Combustion Efficiency - 76
Inches of Water - 19.5 Manifold Pressure - .705

Observations

The test results indicate some variations in manifold pressure and combustion efficiency in the various positions tested. The factory recommended position of 45 degrees resulted in the best combustion efficiency although the manifold pressure was not lowest at this position. The differences in combustion efficiency at the various positions seem to be due to the air flow patterns under the hood. The low combustion efficiency recorded in the straight ahead position (a) could possibly be attributed to air turbulence from the fan actually interferring with air entry into the snorkel tube. Horsepower was influenced little by the various positions of the intake snorkel.

XVI. TEST XVI

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and manifold pressure of the test engine equipped with a factory equipment air cleaner assembly designed for a 352 cubic inch Ford engine. The results of this test will be compared to the results of Test I to determine if the air cleaner assembly from an engine of larger displacement would offer an increase in horsepower, improved combustion efficiency and less restriction to air flow.

Special Test Apparatus

The air cleaner assembly shown in Figure 14 is a Ford unit designed for use on a 352 cubic inch engine with a four barrel carburetor.

Air cleaner housing. The following specifications are for the air cleaner housing used in Test XVI.

1. Diameter equals 19 1/4 inches.
2. Height equals 4 inches.
3. Depth outside the filter equals 3 1/2 inches.
4. Volume outside the filter equals approximately 705 cubic inches.

Filter element. The following specifications are for the paper filter element used in Test XVI.

1. Diameter equals 11 1/2 inches.
2. Height equals 2 1/8 inches.
3. Height of paper pleats equals 1 3/4 inches.
4. Depth of pleats is 9/16 of an inch.
5. Number of pleats is 247.
6. Surface area of filter material is 487 square inches.

Intake snorkel. The following specifications are for the intake snorkel on the air cleaner housing used in Test XVI.

1. Length equals 3/4 of an inch.
2. Rectangular opening is 1 1/4 inches by 5 3/4 inches.

Figure 14. Factory Equipment Air Cleaner Housing For Ford 352 Cubic Inch Engine

Test Method

The air cleaner housing will be installed on the test engine according to the manufacturer's recommendation with the intake snorkel positioned 90 degrees to the right of straight ahead. The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64.5 Combustion Efficiency - 75.5

Inches of Water - 20.0 Manifold Pressure - .723

Observations

When compared to the results of Test I, the test data shows the air cleaner assembly was more restrictive to air flow than the factory equipment for the 289 Ford engine. The combustion efficiency was the same, indicating the volume of air entering the cylinders was the same. The horsepower output increased on the same fuel mixture. The writer speculates that this might be the result of the different air cleaner housing design. It seems possible that the air might achieve more or less turbulence in the housing thus vaporizing the gas to a more combustable form.

XVII. TEST XVII

Objective

The objective of this test is to measure the road horsepower and combustion efficiency of the test engine using a "free breathing" air cleaner. This unit has no outside housing or intake snorkel tube. The test results will be compared to those of Test I and Test XVI to determine if this air cleaner unit offers any advantages over the two Ford factory equipment units.

Special Test Apparatus

The "free breathing" air cleaner unit shown in Figure 15 is constructed from a Ford 352 cubic inch engine air cleaner assembly. The paper filter element is the same element used in the factory equipment air cleaner housing in Text XVI.

Figure 15. Free Breathing Air Cleaner

Test Method

With the air cleaner assembly mounted on the test engine, the test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the engine operating at 2500 RPM and at full throttle.

Test Data

Road Horsepower - 64   Combustion Efficiency - 80.0

Inches of Water - 18.5   Manifold Pressure - .668

Observations

The test results show advantages over the factory equipment for the 289 cubic inch engine air cleaner assembly as there is less restriction, improved combustion efficiency and increased horsepower. Compared to the air cleaner in Test XVI, the unit is less restrictive and supplies more air with little effect on horsepower.

It is interesting to note that this unit, without a snorkel or outside housing, was more restrictive than some units with snorkel equipped housings. This might be caused by the paper filter element which has less surface area of filter material than the other paper filter elements tested.

XVIII. TEST XVIII

Objective

The objective of this test is to measure the road horsepower, combustion efficiency and intake manifold pressure using the factory equipment air cleaner housing and intake snorkel tube but with a paper filter element altered to assimilate a partially clogged filter element. The test results will be used to determine the effect of filter obstruction on horsepower and combustion efficiency. The writer hopes to determine to some extent the margin of performance protection built into the filter element.

Special Test Apparatus

The factory equipment air cleaner housing, paper filter element and intake snorkel tube used in Test I will be used in this test. Masking tape will be used to assimilate the clogged filter.

Test Method

The test automobile will drive the chassis dynamometer in high gear (drive) with the mechanical downshift linkage removed to prevent mechanical downshift. Readings of road horsepower, combustion efficiency and intake manifold pressure will be taken with the filter element in the following conditions: (a) new, no obstruction, (b) 25 per cent obstructed, (c) 50 per cent obstructed, and (d) 75 per cent obstructed. The filter obstruction will be assimilated by wrapping masking tape around the outside of the filter element.

Test Data

(a) Road Horsepower - 62 Combustion Efficiency - 75.5
Inches of Water - 19.75 Manifold Pressure - .714

(b) Road Horsepower - 64 Combustion Efficiency - 77.5
Inches of Water - 20.0 Manifold Pressure - .723

(c) Road Horsepower - 63 Combustion Efficiency - 73.5
Inches of Water - 20.0 Manifold Pressure - .723

(d) Road Horsepower - 62.5 Combustion Efficiency -71.5
Inches of Water - 20.0 Manifold Pressure - .723

Observations

After studying the test data, the writer feels that the data for this test is not fully reliable but an approximate indication of what the results might be in actual operation if the filter became plugged with foreign matter.

The test results indicate an increase in restriction when 25 per cent of the filter area was covered and an increase in combustion efficiency and horsepower. At 50 per cent and 75 per cent restricted conditions, the manifold pressure remained constant while combustion efficiency and horsepower decreased indicating that the volume of air was decreasing. The writer feels that the combustion efficiency and manifold pressure should have shown more marked changes than indicated when the per cent of obstruction was increased.

If this test has any amount of validity, it indicates that this filter element has a high reserve capacity for dirt and dust before performance would be seriously affected.

The writer suggests that this test might be more reliable if four filter elements of the same brand were used and some type of sealant was sprayed onto the filter paper to seal the pores to represent the different percentages of obstruction.

CHAPTER V

THE SUMMARY AND CONCLUSIONS

I. THE SUMMARY

Air cleaner units are designed to do four jobs in the modern automobile: (1) to keep dirt and dust from entering the engine with the intake air, (2) to reduce the level of induction noise to an acceptable and comfortable level, (3) to act as a flame arrester in case of backfire, and (4) to provide heated air to the carburetor for quicker warm-up and reduced levels of exhaust emissions.

The literature the writer received from industry seems to indicate that the most concern in air cleaner design centers around the induction noise level. This is controlled through the size or volume of the air cleaner housing, the opening of the snorkel tube, the cross sectional shape of the snorkel tube and the length of the snorkel tube.

If the air cleaner housing or intake snorkel tube restricts the air flow in an attempt to control the induction noise, the horsepower of the engine could be decreased. Appendix B, page 69, shows the relationship between road horsepower and manifold pressure. As air flow becomes restricted, manifold pressure increases. The writer interprets the information from industry as saying that the air cleaner unit is in many cases a compromise between horsepower performance and noise control. A little power is sacrificed for a quieter passenger compartment.

To protect the engine from harmful dirt and dust, the auto industry has used six types of filter elements: (1) oil-wetted mesh, (2) oil bath, (3) dry paper, (4) oil-wetted paper, (5) oil-wetted polyurethane foam, and (6) a heavy duty element combining the paper and a foam wrapper.

The efficiency of filtration varies with the different types of filters. Reports show that the dry paper, oil-wetted paper, the polyurethane foam and the heavy duty, dual element filters, do the most efficient job in removing dirt and dust.

If a filter element is too small to allow a sufficient air supply to pass through or if the material is restrictive in nature, the horsepower of the engine can be affected. A polyurethane foam filter is rated by some to be slightly less restrictive than a paper element. The combination foam and paper element is more restrictive than either filter used separately.

Some filter elements give more economical performance in adverse conditions such as in extreme dust or smog laden air. The choice of filter element depends upon initial cost, ease of maintenance, cost of maintenance and engine performance. In some cases the filter used may be a compromise with some loss of engine performance considered acceptable.

II. CONCLUSIONS

After reviewing literature and technical information, talking to individuals with a knowledge of induction systems and conducting tests with air cleaner housings, intake snorkel tubes and filter elements, the writer feels that engine performance is definitely affected by air cleaner design.

The air cleaner unit is a very essential component of the automobile engine. Not only does it protect the engine from harmful foreign materials, it also can help the engine develop maximum horsepower. The writer observed that the test engine developed higher horsepower in all tests except one, Test II, when test results with the use of an air cleaner were compared to horsepower developed without the air cleaner unit.

Appendix A, page 68, is a composite of all test data and may be used as a quick reference for comparing a specific test result to the results of other tests.

Using the Ford factory equipment air cleaner housing and Test I as a standard, the writer found very little difference between horsepower developed using this housing and horsepower developed using housings of a different volume.

The component of the air cleaner unit that showed the most effect on horsepower was the intake snorkel tube. The laboratory tests support the statement that snorkel tube design is a compromise between induction noise control and engine performance.

The factory equipment with a straight snorkel tube developed lower horsepower than the same filter and housing equipped with tapered snorkel tubes.

Horsepower differences were not as noticeable as the changes in combustion efficiency when using different snorkels. As with horsepower output, the tapered snorkel tubes recorded higher combustion efficiency than the straight factory equipment snorkel. Those snorkels that developed higher combustion efficiency and lower manifold pressure than the straight snorkel also had a higher induction noise level. It was observed that as the intake opening increased in size, the combustion efficiency and induction noise increased. Appendix C, page 70, shows the relationship between combustion efficiency and manifold pressure as recorded by the writer in all tests performed.

The dual snorkel housing had very high combustion efficiency, a high noise level and one of the lower horsepower readings. The writer feels this shows that the additional air flow can produce a leaner fuel mixture at the sacrifice of some horsepower.

To some persons economy is more important than maximum horsepower. The writer feels the tests show that higher combustion efficiency can be obtained with snorkels different from the Ford snorkel tube. This should show some increase in gas mileage. Appendix A, page 68, shows the Air-Fuel Ratio that corresponds to the combustion efficiency of each test. In some cases the economy gain may realize a slight horsepower increase while others will show a loss. With the economy gain, one may have considerably higher induction noise levels during acceleration and wide open throttle.

The manufacturer's recommendation for snorkel tube placement seemed to produce the best overall performance for the particular unit tested.

Many automotive supply houses advertise little screen inserts that can be fitted into holes drilled into the circumference of the air cleaner housing. They advertise that this will increase engine performance. This test did not show a horsepower gain but it did show a combustion efficiency increase which could mean better gas mileage.

The writer found the polyurethane foam filter element to be less restrictive than the paper element when tested in the same housing, with the same intake snorkel. The heavy duty filter was more restrictive than the paper element and, though not affecting horsepower, may decrease gas mileage.

The assimilation of an obstructed filter element may not be reliable but it did show an indication of decreased combustion efficiency which could result in poor gas mileage.

The writer feels the auto industry does compromise to give acceptable performance at all three levels: horsepower, economy and noise control. By changing one or more levels for gain, the others may be sacrificed.

It should be recognized that the test results in this study can not be taken as a general rule for all air cleaners on passenger cars today. To assume that the efficiency or horsepower output of an engine can be changed by changing intake snorkels or drilling some holes in the air cleaner housing is not necessarily true. Only through laboratory tests or extensive road tests can individual situations be evaluated.

BIBLIOGRAPHY

BIBLIOGRAPHY

Crouse, William. *Automotive Fuel, Lubricating and Cooling Systems*, New York: McGraw-Hill Book Company, 1967.

Forman, H. L. and Gruner, F. R. "Application and Performance of Dry Type Air Cleaners on Farm, Construction and Industrial Machinery." A Report Presented at the SAE National Farm, Construction, and Industrial Machinery Meeting, Milwaukee, Wisconsin, September 8-11, 1958.

Johnson, Larry and Toboldt, William K. (editors) *Automotive Encyclopedia*. Homewood, Illinois: Goodheart-Willcox Co., 1968.

Pease, Dudley A. *Basic Fluid Power*. Englewood Cliffs, N. J.: Prentice-Hall Inc., 1967.

Rickman, Eric. "Keep It Clean." *Hot Rod*. (October, 1967) p. 110.

Schofield, Miles. *Basic Carburetion and Fuel Systems*. Los Angeles: Peterson Publishing Co., 1968.

Scritchfield, Dick. "Segal's Total Performance Air Cleaner," *Rod and Custom*. (August, 1968), p. 56-57.

Sherburn, Peter E. "Air Cleaner Design - Present and Future." An SAE Report, Presented at the International Automotive Engineering Congress, Detroit, Michigan, January 13-17, 1969.

SUPPLEMENTARY INFORMATION

I. LETTERS

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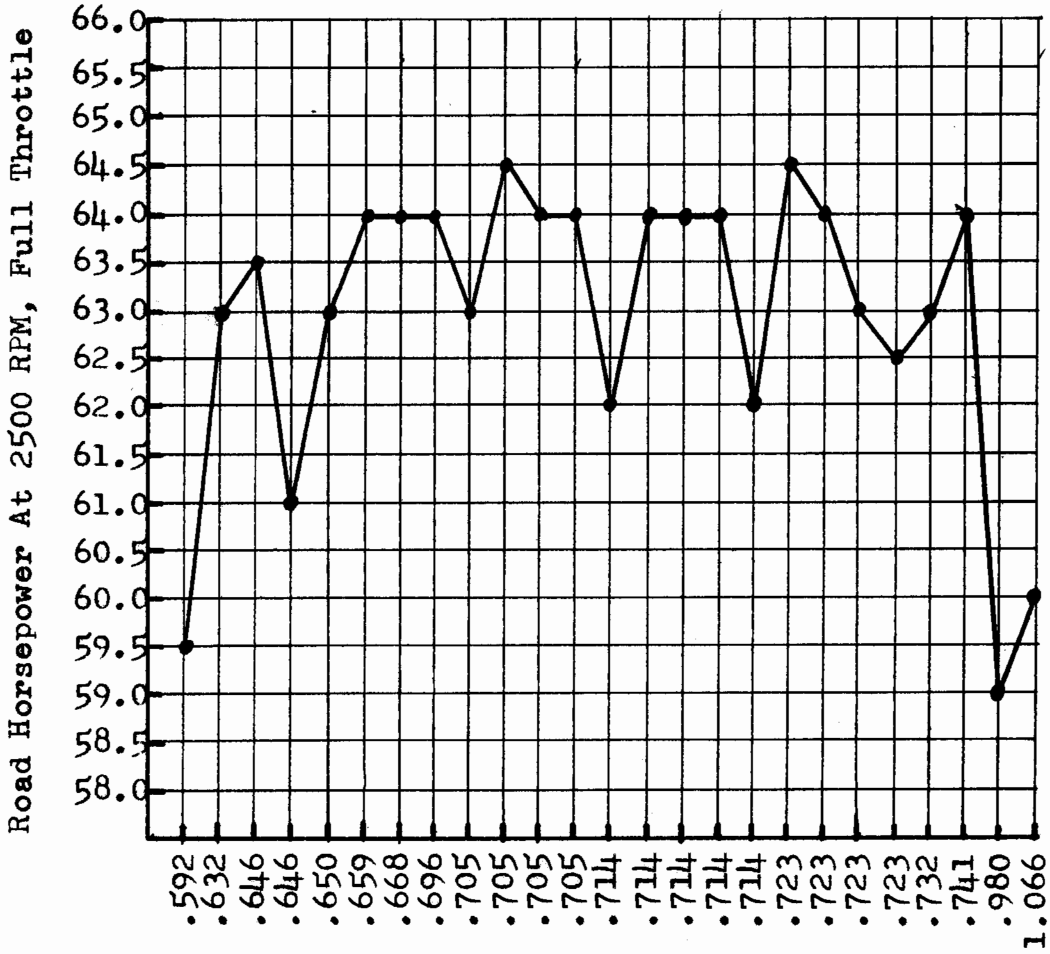
APPENDIX

APPENDIX A.

Number of Test	Road Horsepower	Combustion Efficiency	Air-Fuel Ratio	Inches of Water *	Manifold Pressure	Manifold Vacuum
I	62	75.5	12.67:1	19.75	.714	1.45
II	59.5	84.0	13.85:1	16.375	.592	1.20
III	64	79.0	13.15:1	19.25	.696	1.41
IV	63	77.5	12.95:1	19.5	.705	1.43
V	63	75.0	12.60:1	20.25	.732	1.49
VI	59	55.0	9.80:1	27.125	.980	2.00
VII	64	79.5	13.22:1	18.25	.659	1.34
VIII	63.5	80.5	13.37:1	17.875	.646	1.31
IX	63	82.0	13.60:1	18.0	.650	1.32
X	60	55.0	9.80:1	29.5	1.066	2.17
XI	61	83.5	13.77:1	17.875	.646	1.31
XII	64	78.5	13.07:1	19.75	.714	1.45
XIII	63	81.5	13.52:1	17.5	.632	1.28
XIV	64	76.0	12.75:1	19.75	.714	1.45
XV(a)	64	72.5	12.22:1	20.5	.741	1.51
(b)	64.5	77.5	12.95:1	19.5	.705	1.43
(c)	64	78.5	13.07:1	19.75	.714	1.45
(d)	64	77.0	12.90:1	19.5	.705	1.43
(e)	64	76.0	12.75:1	19.5	.705	1.43
XVI	64.5	75.5	12.67:1	20.0	.723	1.47
XVII	64	80.0	13.30:1	18.5	.668	1.36
XVIII(a)	62	75.5	12.67:1	19.75	.714	1.45
(b)	64	77.5	12.95:1	20.0	.723	1.47
(c)	63	73.5	12.37:1	20.0	.723	1.47
(d)	62.5	71.5	12.07:1	20.0	.723	1.47

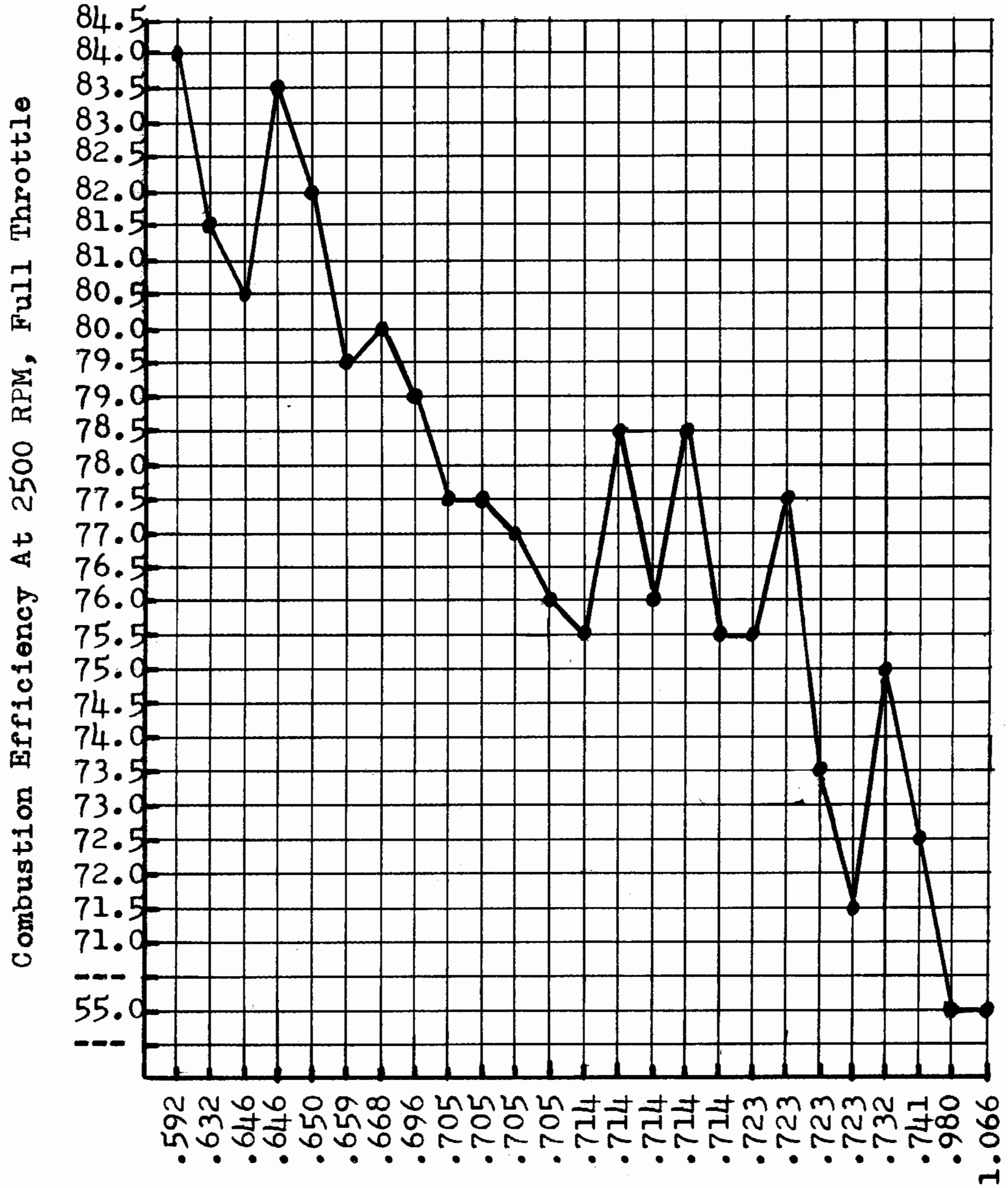
* Conversion Formula On Page 19

APPENDIX B.



PSI. **Manifold Pressure At 2500 RPM, Full Throttle Operation, With Different Housings, Snorkels and Filter Elements.**

APPENDIX C.



PSI. Manifold Pressure At 2500 RPM, Full Throttle Operation, With Different Housings, Snorkels and Filter Elements.