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A Technical Study Evaluating the Three Major Brands of Spark Plugs

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A TECHNICAL STUDY EVALUATING THE THREE MAJOR BRANDS OF SPARK PLUGS

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by

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INTRODUCTION

The spark plug is the most needed part on an engine. It must withstand high temperatures and pressures, in addition to the high voltage, which must pass through it. Also, it must resist formation of carbon on its surfaces. Many years of engineering have been devoted to designing a spark plug which will perform well under all engine operating conditions.

Spark plug manufacturers recommend that spark plugs should be replaced every 10,000 miles. This is perhaps a good average; however, some spark plugs will last longer than this figure, and some will not last this long. A good rule to follow is this: whenever an engine starts missing and the problem cannot be contributed to something else, replace the spark plugs, if they have been used for 5,000 miles or more.

Statement of the Problem

In the consumer's world, there are three leading spark plug manufacturers. They are AC Spark Plug Company, Champion Spark Plug Company, and Motorcraft Corporation. In this research paper, the researcher will determine which brand of spark plug performs the best and is the best product of the three.

Research Goals

In this research study the researcher will prove which spark plug (of the major three) will perform the best in all operating conditions. These conditions are structural strength, anti-fouling characteristics, carbon tracking resistance, extended operational performance, high temperatures, high pressures, high voltage, seal ability, combustion performance, and the ability to resist detonation and pre-ignition.

Background and Significance

Spark plugs are a high consumption item for the American consumer. With the cost of professional mechanical help skyrocketing, the average consumer is turning to doing more of his own maintenance on his engines. Spark plugs are one of the main consumable items the consumer will be buying. To determine which brand of spark plug to buy, the consumer may be swayed by many different, but biased, ways of making a decision. Some of these ways are as follows: (1) He may watch television commercials produced by the manufacturer which say their product is the best; (2) he may be told by distributers of the product which think their product is the best but do not know why; (3) he may ask a mechanic who will recommend a favorite brand, but the chances are that the mechanic does not know why he likes a particular brand. These are a few ways the consumer has to determine which spark plug to buy; all of which are usually biased or unfounded.

In this research paper the researcher will perform an unbiased and scientific study to determine which brand of spark plug will be the one with the best all around performance for the consumer. Following are the limitations and assumptions of this research.

Limitations

The researcher's findings will be somewhat confined, due to the limitations of specific test equipment, and the inavailability of different types of operating situations. Some of the extended high temperature and high pressure operating conditions a spark plug may be subjected to, will be difficult to simulate because the researcher does not have the high compression racing engine. Due to the amount of time available to the researcher, extensively long operating conditions subjected on a spark plug during its normal life of 12,000 miles will be difficult to match in a testing situation.

Assumptions

The researcher believes that the data he obtains from his tests on the three brands of spark plugs will result in the following assumptions:

1. One spark plug will be structurally stronger.
2. One spark plug will perform better overall.
3. One spark plug will be the best buy.

Procedures

The researcher will submit the three leading brands of spark plugs to the same test conditions. The tests will use the same engines and pressure devices. All tests will be timed and documented the same. The engines used to simulate operating conditions will be new. They will be operated at the same RPM's and run for the same amount of time.

Overview of Remaining Chapters

In the previous statements, the researcher has shown the reason for determining the best brand of spark plug and the means of doing it. The consumer needs a reputable source of knowledge for determining which brand of spark plug will best fulfill his needs.

In chapter two the researcher will give a review of related literature on spark plug brands and their operation. In chapter three the researcher will tell of research procedures. In chapter four the researcher will give an analysis and results of tests. Finally, chapter five will be the summary and conclusion of this research.

Chapter II

REVIEW OF LITERATURE

Introduction

There is very little, if any, documented proof on which of the three major spark plug brands perform the best. In this review of literature on the manufacturing processes and innovations of spark plug design, the researcher will review those studies. The review will cover the history, the manufacture of, the operation, and the electrical characteristics of the spark plug.

Spark Plug History

For at least three centuries, man has been trying to use explosions to provide motive power. One of the earliest records is that of the 17th-century Dutch scientist Christian Huygens, who pumped water from the Seine using vacuum created in a cylinder by cooling gases after the explosion of a charge of gunpowder (ignition was by fuse). The first use of a spark plug is attributed to Lenoir, whose gas engine, patented in 1860, employed a high-tension Ruhmkorff coil ignition system and a ceramic insulated threaded spark plug, remarkably similar to those in one today.

Oddly enough, despite the lead given by Lenoir, early vehicle engines using electric ignition (which many did not) employed a low electric system in which a pair of make-and-break contact points located inside the combustion chamber were mechanically opened and closed, with ignition being accomplished by the spark which occurred when the contacts opened. However, this system had obvious limitations, and spark plugs soon became the standard device to "light the fire" within an engine's cylinders.

Though the original Lenoir spark plug carried its own thread, most early spark plug bodies were formed with massive flanges and held down against the low combustion pressures of the time with studs and nuts reminiscent of high-pressure steam joints. Around the turn of the century, however, plugs reverted to threaded mountings, some of which were tapered pipe threads and others straight-side threads with gaskets for sealing against the cylinder head. These early spark plugs employed porcelain clay-based ceramic insulators which were excellent electrically, when unstressed at room temperature and pressure, but very weak when subjected to mechanical and thermal shock. For reasons of strength, they were made in thick sections, which made them all the more susceptible to thermal shocks. These early insulators often cracked and the broken pieces would fly around inside cylinders, with disastrous results. Many engines, during the first decade of the twentieth century, were wrecked from this cause (Automotive Engineering, 1976, p.27).

These early spark plugs were generally large, making the threads have a bulky diameter. Since cylinders were then of comparatively large bore and low compression ratio, this did not matter much. However, subsequent trends toward smaller bores, larger valves, and higher compression ratios made it necessary to reduce the size of the plug proportionally, often to the despair of the plug designer, who was left with the impression that the engine designer had forgotten that he needed a spark plug at all. During the 1940's, sizes were reduced to the point at which certain American automobile manufacturers (among them Packard, Buick, and Chevrolet) used what may be termed "miniature" spark plugs with 10mm threads. However, modern practice has largely settled on 14mm and 18mm thread diameters as widespread industry standard sizes (Automotive Engineering, 1976, p.27).

Since the first introduction of the spark plug in the 1800's, the basic design of the spark plug has not changed. The spark plug's job then, as it is now, is to simply jump an air gap to ignite the air-fuel mixture inside the combustion chamber. The only major changes in the history of the spark plug is not in design, but in overall size, as mentioned above.

Spark Plug Manufacturing

Since the early days, dozens of materials have been used for spark plug insulators, including wood, rubber, mica, glass, and quartz. However, modern spark plug insulators are formed from ceramic materials consisting of about 93 weight alumina, one of the oxides of aluminum with a chemical composition of Al_2O_3. This material is received at the spark plug factory in granular form and placed into ceramic-lined ball mills for further grinding and mixing with other solids, one of which is silica. From the ball mill, the compound in very finely-powdered form is fed into large tanks where it is mixed with water, then screened and filtered to remove contaminants. From the blending tank, it is pumped to the top of a 60-foot tower similar to the "shot tower" used in the manufacture of spherical lead pellets. The compound is atomized into the heated atmosphere of the tower and, as the atomized particles fall, they lose their moisture content and become free-flowing spheres. The cooled compound must contain less than 0.2% moisture after this point (Automotive Engineering, 1976, p.29).

The dried compound is fed into rubber molds in presses, which automatically apply hydraulic pressure to form cylindrical blanks containing the electrode hole bore. These blanks (which are very fragile at this state) are placed on spindles and rotated against a contoured abrasive wheel, which grinds them to their final shape. Following grinding, they are placed upright in refractory trays, called "saggers", for the firing process.

In firing, the insulators are sent through gas-fired kilns of 150-200 feet length, which build up to a maximum temperature of about 3000 degrees Fahrenheit. During the 24-hour trip through the kiln, each insulator undergoes shrinkage of approximately 20 percent and emerges from the kiln with the same basic chemistry as a sapphire. After firing, a percentage of the insulators are quality-control tested for electrical integrity.

Following the firing operation, the insulators are placed onto spindles on a rotating platform and pass by stenciling equipment which applies the decoration (lettering, numbering, and color bands). As they progress on the platform, a spray nozzle applies glasing solution to the outer end of each insulator, and they are passed through a gas flame, which fires the glaze to the insulator body. Early spark plugs were glazed over the entire insulator surface, but they have not been made with glazed tips since the introduction of tetraethyl lead during the 1920's, which gave rise to the fouling problems when the lead reacted with the glaze on the insulator tip (Automotive Engineering, 1976, p.29).

Production techniques differ among manufacturers, when the center electrodes are installed in the insulators. One maker prefers to use a solid center electrode with a lower half made from nickel alloy and the upper half from basic steel. This electrode is placed in the bore of the insulator, together with a measured quantity of sealing cement. (In the case of a resistor plug, a small spring is placed in the insulator bore and carbon resistor of nominal 10,000 ohm value is placed on top of it.) The terminal is turned and cemented into the top of the insulator, and the insulator assembly is then complete (Automotive Engineering, 1976, p.32).

Another maker prefers center assemblies consisting of nickel alloy lower electrodes, which are placed into the bore of the insulator, then topped with a measured amount of "iron glass" — a powder consisting of glass mixed with iron (the amount of iron contained in the glass determines the plug's resistance). The upper portion of the electrode and the terminal are then placed in position and the whole assembly is run through a progressive hot press operation where it is gradually heated to about 1700 degrees Fahrenheit to liquefy the iron-bearing glass in the center--during which the glass fuses to the center and lower electrodes and forms a gas-tight, electrically conductive bond between them.

While the insulator assemblies are being completed, a separate shell manufacturing operation has been taking place. Rolls of steel from suppliers are run through straightening machines, then cut into "slugs" containing enough metal to form the finished shells. The slugs are fed into cold forming presses which, in a series of powerful blows, extrude the shells to a configuration close to their finished form. After secondary operations such as knurling, grinding, and cleaning, the shells run onto a conveyor system which passes under electric welding equipment. In a series of lightning moves, the side electrode is welded onto the shell and it is passed through a three-piece rotary thread-forming operation which rolls (i.e., squeezes rather than cuts) the threads onto the shells. Rolling is not only faster than machining, but also results in smoother threads with rounded, burr-free edges. The completed shells are then given a permanent finish, either by electroplating with zinc chromate or by immersion in a hot, highly alkaline solution containing strong oxidizers which react with the iron in the steel to form a black oxide finish.

The next step in manufacture is the joining of the insulator assembly and shell to form the completed spark plug. On another conveyor line, operators place the insulators inside the upright shells and the two pieces pass beneath welding and crimping machinery which rolls the upper shell flange inward over the insulator, with appropriate gasketing, sealing cement, and in some cases, electrical weld-stretching of the metal to fix the insulator permanently inside the shell. Following final assembly, the plugs go through additional complex machinery which automatically trims off excess wire from the side electrode and bends it to form the proper gap. The spark plugs then pass through a visual inspection station and proceed to automatic packaging machinery for final shipment to their destination.

One of the facts of life in the spark plug business is the knowledge that whatever plugs are offered for the cars of today will have to be available nearly indefinitely. A glance through the "Extra Range" catalog of one of the leading U.S. spark plug makers reveals that one can still purchase new plugs for his Auburn 12, Barley 6, Dagmar, Jordan Playboy, Kissel Kar, Locomobile Model 8-78, and Paramount Taxicab, among many other cars.

Perhaps the best testimony to the indestructibility of Henry Ford's Tin Lizzie is the fact that Champion Spark Plugs Company made 37,697 spark plugs for the Model T Ford during 1974 (Automotive Engineering, 1976, p.34).

In summary, the spark plug industry appears to be highly technological and innovative. These characteristics are aimed at meeting the high demands and varying operating conditions of modern day internal combustion engines.

Spark Plug Operation

The job of the spark plug is to receive electrical impulses from the ignition system and to discharge them across the electrode gap to ignite the air-fuel mixture. Its inner end operates near red heat, while its outer end operates in the atmosphere and may even at times be splashed with water. Throughout its lifetime it is exposed to high-temperature corrosive gases which, when combined with electrical volatization, tear apart its electrodes. Millions of cylinder explosions subject it to thermal and mechanical tortures which would destroy less hardy components within seconds. Yet, throughout it all, these "nails through pieces of china" function reliably and durably over the thousands of miles of service at low cost (Automotive Engineering, 1976, p.27).

The spark plug's ability to transfer heat from its firing end to the engine cylinder head is called "heat range". Heat range is primarily determined by the length of the plug's insulator tip. Hot plugs have long insulators with a consequent long heat flow path to the head, while cold plugs have shorter tips and flow paths. Traditionally, car owners could tailor the heat range of their spark plugs to the type of driving they did. Short-trip city drivers could use hotter plugs to prevent fouling, while highway drivers could use colder plugs to prevent electrode burning at higher-power-level operation. Nevertheless, the spark plug designer of today must create plugs with broader heat ranges than ever before. This is true because present-day legislature prohibits an automobile manufacturer or dealer from installing any other heat range spark plug than the one with which the vehicle was originally emissions-certified (Automotive Engineering, 1976, p.29).

Spark plug fouling is caused by a wide variety of conditions ranging from worn cylinders and rings (poor oil control) to cold engine operation. Carbon fouling, one of the more common varieties, was significantly reduced by the introduction of tetraethyl lead in gasoline during the 1920's (a deposit of lead and carbon will burn off spark plug electrodes at about 700 degrees Fahrenheit, while deposits of plain carbon will require about 850 degrees for burnoff). The recent removal of lead from gasoline has caused carbon fouling to become a problem again. Some new cars may presently be turned over to their purchaser with partially carbon-fouled plugs. This condition results from the many start-and-stop low-temperature engine operations which occur during the process of the car's manufacture, transportation to dealer destination, and customer preparation. However, this carbon fouling problem is counterbalanced by the extended electrode life which has resulted from the removal of lead from gasoline, since lead (and, to a lesser extent, sulfur) in fuel are the principal factors which create the chemically corrosive atmosphere which erodes electrodes. All spark plug designs are a compromise between long life, anti-fouling requirements, and cost. For long life, large electrodes are desirable. All manufacturers would like to make electrodes as large as possible, except that the electrodes would then occupy a large percentage of tip volume with consequent loss of clearance volume necessary for scavenging of deposits. Thus, large electrodes are built at the cost of fouling protection (Automotive Engineering, 1976, p.28).

With engine manufacturers using ever-leaner mixtures to reduce the unburned hydrocarbons in the exhaust, the ability of the ignition system to ignite lean mixtures is becoming imperative. Tests at Champion Spark Plug Company suggest that increased gap spacings and projections and longer duration spark improve ability to ignite lean mixtures (Automotive Engineering, 1976, p.29).

Tests on five sets of spark plugs at a simulated 30-mph road-load operating condition show that gap location affects engine performance at lean fuel-air ratios. The ability to ignite a lean fuel-air mixture improves as the gap is projected farther into the combustion chamber. The 0.531-in. gap projection gives the best results. A 0.215-in. gap projection is, however, the practical limit in today's engines. Larger gap projections cause higher electrode temperatures and rapid electrode erosion.

Another factor affecting spark is the ignition system discharge characteristic. In 30-mph simulated tests of four widely different ignition systems, the spark discharge characteristic had no appreciable effect on engine output with spark advances of 23-33 degrees and on fuel-air ratio of 0.072. At spark advance settings above 33 degrees, the longer duration discharge improves engine output. At the lean fuel-air ratio of 0.061, the engine output at the same throttle setting has dropped from 10 to 7.5 hp. Unlike previously, engine output is now highly dependent on spark duration. The longer duration discharges are again advantageous.

It is now clear that with high spark advance and little turbulence around the plug, a long spark is required to initiate combustion and minimize misfiring. With a more turbulent and homogeneous fuel charge, such as occurs with the piston near top dead center, a short discharge can provide satisfactory ignition.

Some of the performance lost at lean fuel-air ratios by extremely short duration sparks may be recovered by using larger spark plug gaps. For instance, with the 300 micro-second duration system and a fuel-air ratio of 0.061, substituting a 0.05-in. spark plug gap for a 0.035-in. gap considerably improves performance at spark advances above 33 degrees. There is a measurable, but less significant performance improvement when fuel-air ratio is 0.072. With a 1600 micro-second duration system, performance improvements are negligible. The performance gained with larger spark plug gaps does not bring the overall output up to that available with longer duration systems. Additionally, the larger spark plug gaps require greater spark plug voltages. (SAE Journal, 1970, p.95).

A plasma-jet spark plug developed in Britain by Associated Engineering is claimed to provide greatly improved ignition reliability when operating with weak fuel mixtures for maximum economy and reduced emissions. It is triggered from a standard contact breaker and coil, and produces a turbulent, high-velocity jet from the gas compressed in the cylinder. This penetrates deep into the combustion chamber to create a large expanding flame. The plug has a third electrode in addition to the usual two. One of the "hot" electrodes is connected to its own external condenser on a separate charging circuit. When the other electrode fires in the normal way, it ionizes the gas inside the plug body. This electrically-conductive gas envelops the second electrode, causing the external condenser to discharge through the pocket of ionized gas. A high-energy arc results, and the plug chamber is specially shaped to inject it into the cylinder.

Aside from increased flame speeds, advantages cited for the new spark plug concept are greater combustion efficiency, reduced hydrocarbon emissions and improved fuel consumption. It is said to be particularly suitable for Wankel and aerospace engines. Associated Engineering in Britain has made patent applications in all major countries, but does not intend to manufacture the plug itself. Detailed information on the development will be made available to potential licensees (Automotive Engineering, 1974, p.27).

The operation of the modern day spark plug demands that it be designed to reduce combustion chamber fouling, carbon tracking, excessive tip temperatures, insulation cracking, corrosion, and cost. It is evident that the spark plug gap, the fuel-air ratio, and the spark duration affect the performance of the spark plug.

Electrical Characteristics

To produce a spark across a plug gap requires a particular voltage, which varies very widely, depending upon the size of the gap, shape of its electrodes, temperature of the electrodes, and compression pressure at the instant of firing. The maximum voltage available is, of course, the highest voltage level the ignition system can put out. The maximum voltage actually developed is usually quite different from the maximum available, since the voltage across a spark plug does not rise beyond that required to fire the gap initially. In practice, this covers a range from approximately 3000 volts at light throttle or idling to more than 25,000 volts at full load acceleration.

The higher the current (amperage) through the spark gap, the greater the rate of electrode erosion. Consequently, to get high energy through the gap, it is usually desirable to raise voltage. However, the higher the voltage applied, the more prone to fouling the plug becomes (i.e., the higher voltage seeks a shunt path which short-circuits the gap). Since the voltage applied to the spark plug starts at zero and gradually increases in value until the plug sparks through the gap, a partially fouled plug is draining some current across its fouled coating, while this voltage buildup is taking place. This loss of current (which represents a loss of energy) cuts down on the peak voltage to which the ignition system can build and the process becomes a race between the ignition system, which tries to build enough voltage to fire the plug, and the fouling coating which tries to drain off energy as fast as it builds up. For this reason, extremely fast rise times are desirable in ignition systems due to their ability to maintain sparking through the gaps of badly fouled plugs.

Although the alternator sometimes produces radio frequency interference (RFI), as well as the tires acquiring a static charge and causing interference, the ignition system of a vehicle is the source of the highest amplitude of RFI and is the most difficult to control. The spark plug may be considered a coaxial capacitor, with the center electrode on one side of the capacitor and the steel shell on the other side. When the spark occurs, this capacitance is very rapidly discharged, resulting in high amplitude (rapidly alternating current which is responsible for the major portion of the radiated RFI). Some years ago, engineers discovered that placing a resistor in series with the center electrode of the spark plug would, essentially, split the capacitance in half. The lower portion of the capacitance would discharge just as before, but the upper capacitance must discharge through the resistor, reducing the current and the amount of RFI emitted. Also, the resistor acts as a damper to prevent the electrical oscillations set up at the plug gap from passing backward through the ignition harness, where they would be radiated easily. Resistor ignition cables were later developed to supplement the spark plug's suppression capabilities, and resistor plugs are now nearly universal equipment at the OEM level (Automotive Engineering, 1976, p.29).

Amperage, voltage, static electricity, capacitance, and resistance are factors that need to be understood in the manufacture of the spark plugs and associated components that allow desirable operating performance. Such components are the ignition coil, ignition points, distributor, distributor cap, rotor, ignition wires, wire connections, and individual spark plug components.

Summary

Spark plugs--often taken for granted, like many other automotive components--have a development history full of ingenuity, innovation, and experiment. Without these reliable and durable automotive engineers, the Otto-cycle engines we use and enjoy in our everyday life could not exist.

CHAPTER III

METHODS AND PROCEDURES

Introduction

In this comparison study of the three leading brands of spark plugs manufactured, the researcher, through various tests, will determine which one is the best product for the consumer to buy. These methods and test procedures will be described in this chapter.

Discussion of Research Methods

The spark plugs will be subjected to three types of tests. The spark plugs will be subjected to component strength tests. The components being tested for strength are the porcelain insulator, the metal shell, the center electrode, and the ground electrode. These are the components of the spark plugs that are affected by external pressures requiring strength. The external pressures occur when the spark plug is being handled, adjusted for proper electrode gap, and installed by the mechanic.

The strength tests will be performed by a controlled and calibrated pressure exerted upon each brand of spark plug. The component will be subjected to the pressure until the exact point of component breakage.

The second type of testing will be the ability of the spark plug to function under adverse conditions; these conditions being high operating temperatures, corrosion, and electrode fouling.

A spark plug has to withstand extremely high operating temperatures. An oil-fouled electrode requires about 850 degrees Fahrenheit to burn the oil off. To test the amount of heat a spark plug electrode can withstand without deterioration, the following test will be made: The three spark plug brands will be submitted to an open flame for the same lengths of time. This flame will simulate combustion chamber temperatures. The flame time will be recorded and the amount of electrode deterioration observed and recorded.

Spark plug components have to be able to resist corrosion. The metal and porcelain parts are subjected to acidic conditions in the combustion chamber, and corrosive conditions from being exposed to the atmosphere. To determine which spark plug brand can best withstand corrosion, the following tests will be given. The spark plugs will be submerged in strong acid for extended lengths of time and their deterioration observed. The spark plug brands will be subjected to moisture and exposed to the atmosphere to test for rust resistance.

Electrode fouling occurs when the path of voltage is not across the provided spark gap. When the spark does not jump this gap, a missing or dead cylinder condition exists in the engine. The causes of spark plug fouling are excessive amount of oil in the cylinders and cold engine operation. To test the abilities of the spark plug brands to resist fouling, the following test will be made. Three new Briggs and Stratton four-cycle, horizontal shaft engines will be used in the test. Three new spark plugs of the three brands being studied will be installed in each new motor. Oil will be mixed in a container with gasoline. This gasoline will then be equally divided among the three engines, and they will be run for the same length of time. Any fuel remaining will be drained. At the completion of the running of the engine, the spark plugs will be removed and the cleanliness of the electrodes observed. When the findings are documented, both written and photographed, another mixture of fuel and oil will be used, but a greater amount of oil than the first test. This increase of oil and testing will continue until the amount of oil in the fuel is so great the engines will not run. At this point, a valid decision can be made on which brand can resist fouling the best.

The third type of test will be for overall length of time performance. The test will be accomplished by installing in engines three new spark plugs of the brands being tested. These engines, identical Briggs and Stratton four-cycle, will then be run long periods of time and the spark plugs' operating condition observed at periodic intervals.

These three test procedures will give the researcher the necessary data to determine which of the three brands of spark plugs are the best.

Research Design

This research on spark plug brands is of the experimental type. The tests, upon which the three different brands of spark plugs are subjected, are the same. All possible precautions are being taken to avoid any variables in the study, which would make the finding invalid. The testing procedures enable the researcher to test components and draw valid conclusions from the results of the tests.

Data Collection and Recording

Information collected in this study will be recorded in two ways. Time and outcomes will be recorded graphically. Operating conditions will be photographed and placed with associated graphs.

Summary

The researcher, using the testing methods and documentation as previously described, will be able to make a valid research conclusion. This conclusion, when decided, will tell the consumer which of the three major spark plug brands will give him/her the best performance.

Chapter IV

FINDINGS

Introduction

The tests which will determine which of the three leading brands of spark plugs is the best product for the consumer are described in this chapter.

The tests will be broken down into three major units. These units are spark plug physical strength, the ability of the spark plug to function under adverse conditions, and overall length of time performability.

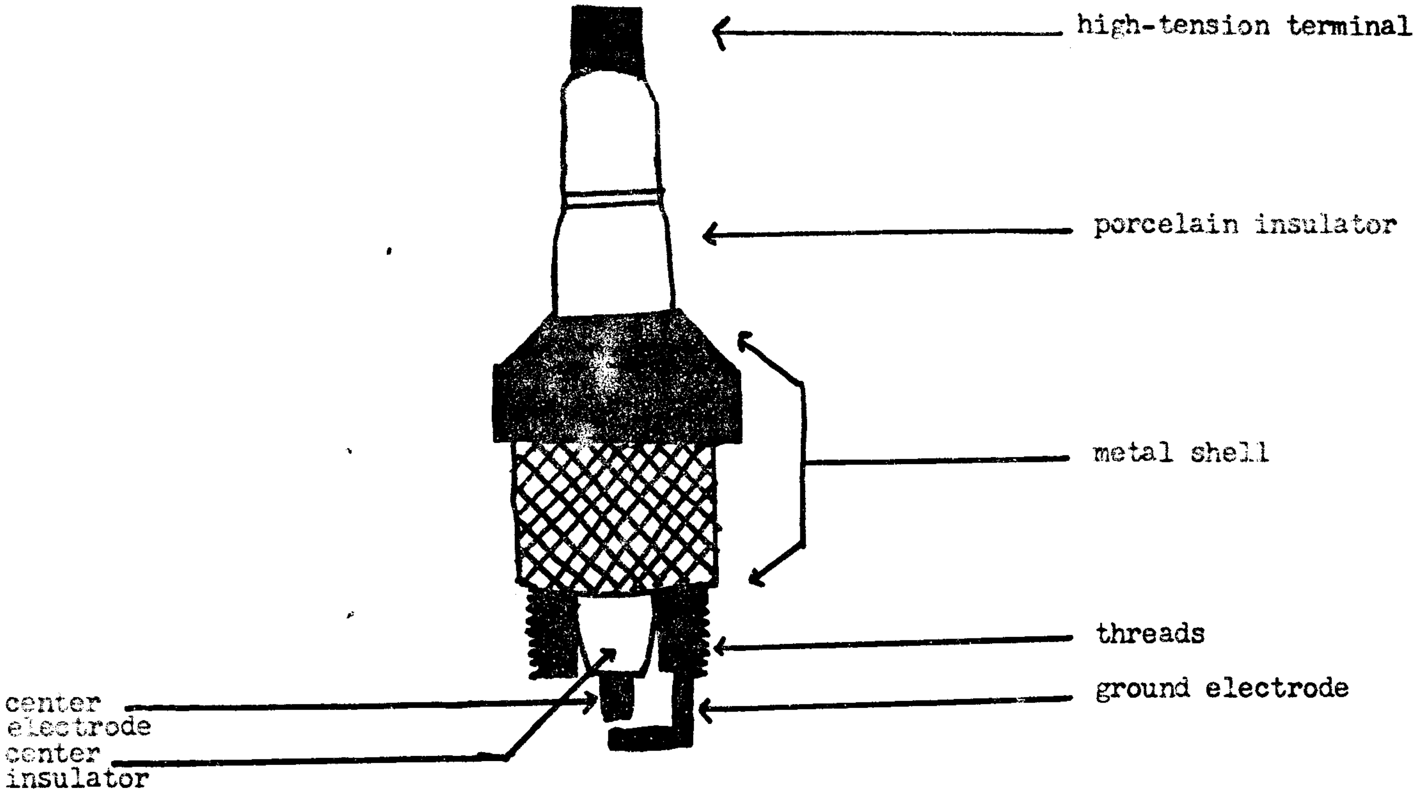
These test units gave the researcher the necessary data to draw a valid conclusion.

The spark plugs used in this study are new. They have a 13/16 inch shell, and are all of the same style and heat range.

Test Unit I

Spark Plug Physical Strength

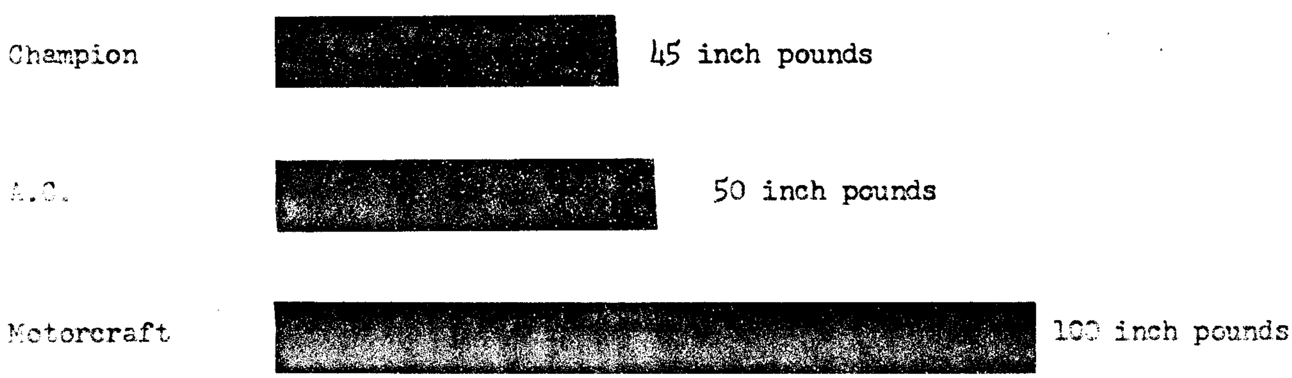
The components of a spark plug being tested in this unit are the porcelain insulator, the metal shell, the center electrode, the ground electrode, the threads, and the center insulator.



Test One - Strength of porcelain insulators

The spark plugs were mounted in a holding fixture, and pressure was applied at the uppermost point until the porcelain broke. The pressure was measured in inch-pounds of torque and recorded at breakage.

The findings are as follows: the Champion spark plug insulator broke at forty-five inch-pounds of pressure, the AC spark plug broke at 50 inch-pounds of pressure, and the Motorcraft spark plug broke at 100 inch-pounds of pressure.

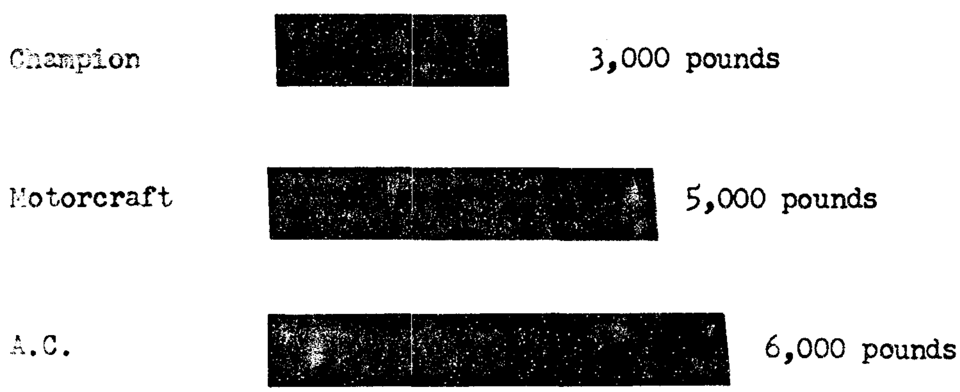


Linear graph showing the pressure in inch pounds at the point of breakage of the spark plug porcelain insulator.

Test Two - Strength of the metal shell

The spark plugs were placed in a $17\frac{1}{2}$ ton press with a calibrated pressure gauge. Pressure was applied to the metal shell until enough distortion occurred to crack the porcelain insulator it holds.

The findings are as follows: the Champion spark plug shell distorted at 3,000 pounds of pressure, the Motorcraft spark plug shell distorted at 5,000 pounds of pressure, and the AC spark plug shell distorted at 6,000 pounds.

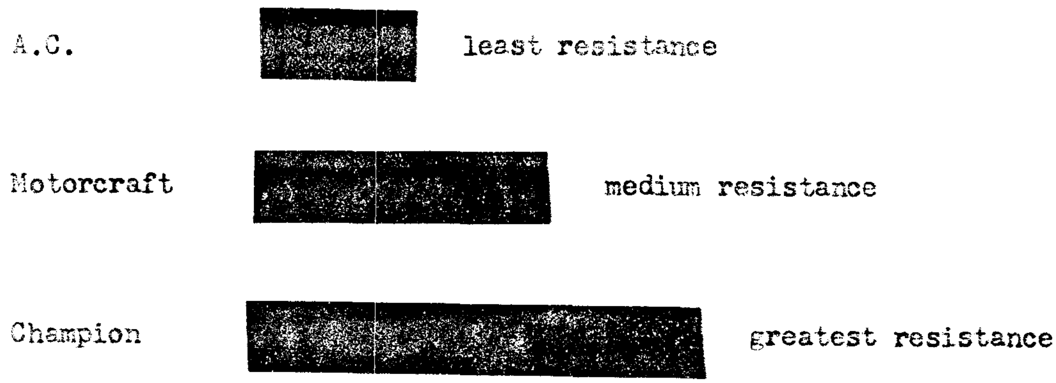


A linear graph showing pressure in pounds at point of distortion of spark plug shells.

Test Three - Strength of center electrode

The spark plugs were installed in a fixture with the ground electrode removed. A flat file was then drawn across the center electrode and the resistance to the file was evaluated by the researcher.

The findings are as follows: the Champion spark plug gave the greatest resistance, the Motorcraft spark plug gave the next greatest resistance, and the AC spark plug gave the least resistance.

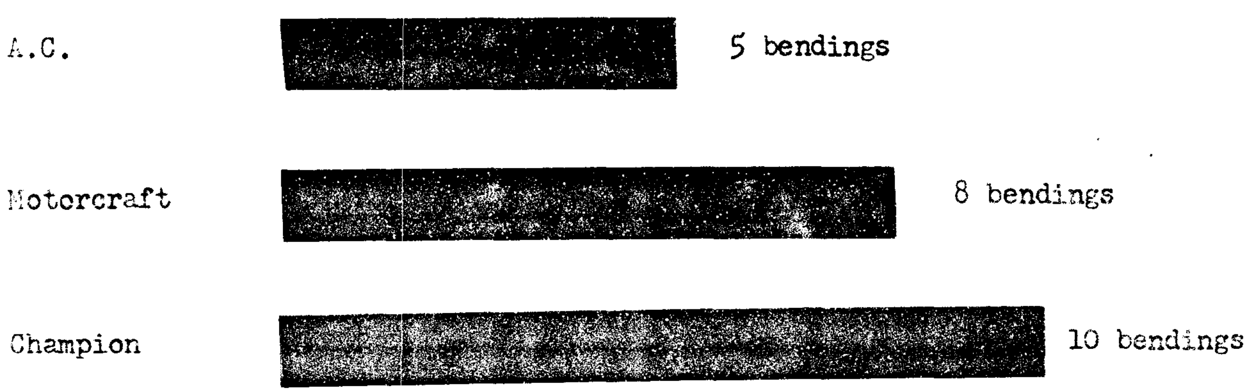


A linear graph showing hardness in resistance of center electrodes expressed in resistance.

Test Four - Strength of ground electrode

The spark plugs were mounted in a holding fixture and a small clamp was applied to the ground electrode. The ground electrodes were then straightened out and returned to their normal position until point of breakage. This is the type of stress the ground electrode will be submitted to by the mechanic while adjusting it for proper gap.

The findings are as follows: the AC ground electrode broke after five bendings, the Motorcraft broke after eight bendings, and the Champion broke after ten bendings.

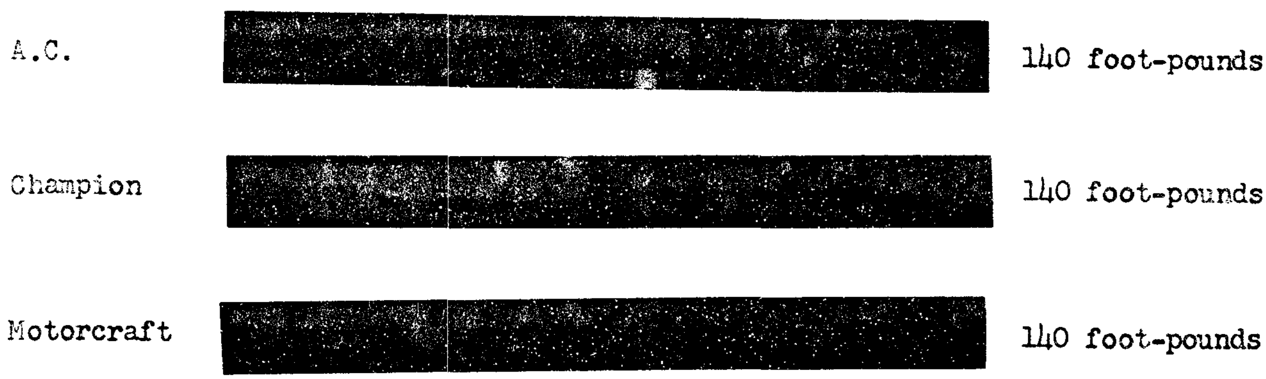


A linear graph showing point of spark plug ground electrode breaking expressed in number of breakings of ground electrode.

Test Five - Strength of threads

The spark plugs were inserted into a cylinder head. Force was then applied to the threads with a foot-pounds torque wrench for the purpose of stripping the threads and recording the pressure at point of strippage.

The researcher applied 140 foot-pounds of force to all three brands, this being the greatest amount of force the researcher was able to apply, and none of the spark plugs stripped at this force.



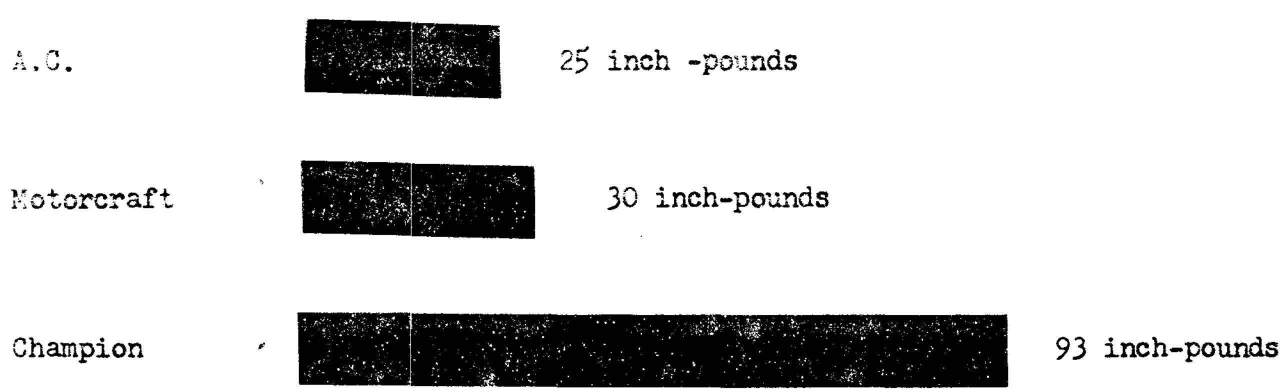
A linear graph showing pressure in foot-pounds in an attempt to strip the threads on the three spark plug brands. No strippage occurred at this pressure.

Test Six - Strength of the center insulator

This test was conducted using three new spark plugs of the brands being researched.

The spark plugs were put into a holding fixture and pressure was applied at the uppermost point of the center insulator. An indicator was used to measure the force in inch-pounds at time of breakage.

The findings are as follows: the AC spark plug center insulator broke at 25 inch-pounds, the Motorcraft spark plug center insulator broke at 30 inch-pounds of pressure, and the Champion spark plug center insulator broke at 93 inch-pounds of pressure.



Linear graph showing pressure in inch-pounds at point of breakage of the spark plug center insulator.

Test Unit II

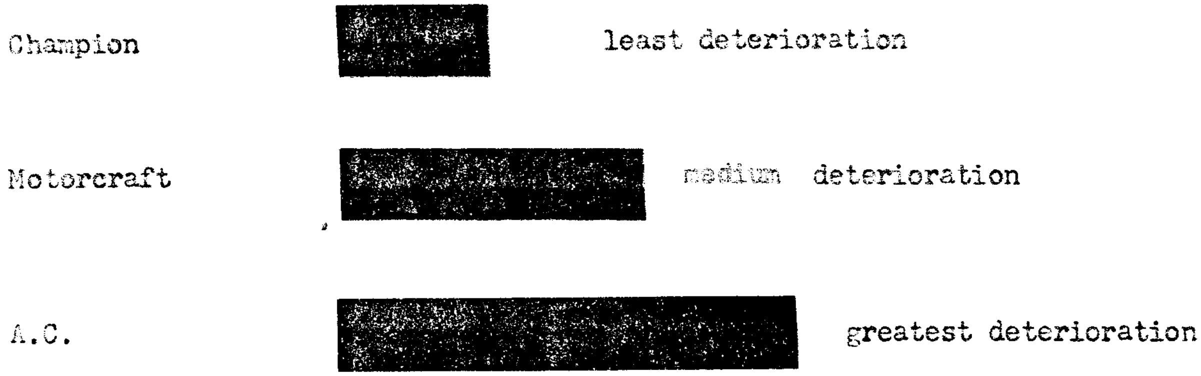
Ability To Function Under Adverse Conditions

The capabilities of the spark plugs being tested in this unit are their ability to withstand high temperatures, corrosion resistance, and the ability of electrodes to resist oil and electrical fouling.

Test One - Ability to withstand high temperatures

The spark plugs were inserted into a fixture one at a time and exposed to a propane flame for three minutes. The propane flame was directed toward the center and ground electrode area.

The findings are as follows: the Champion spark plug ground and center electrode deteriorated the least under the heat, the Motorcraft spark plug showed the next amount of deterioration, and the AC spark plug showed the most deterioration.

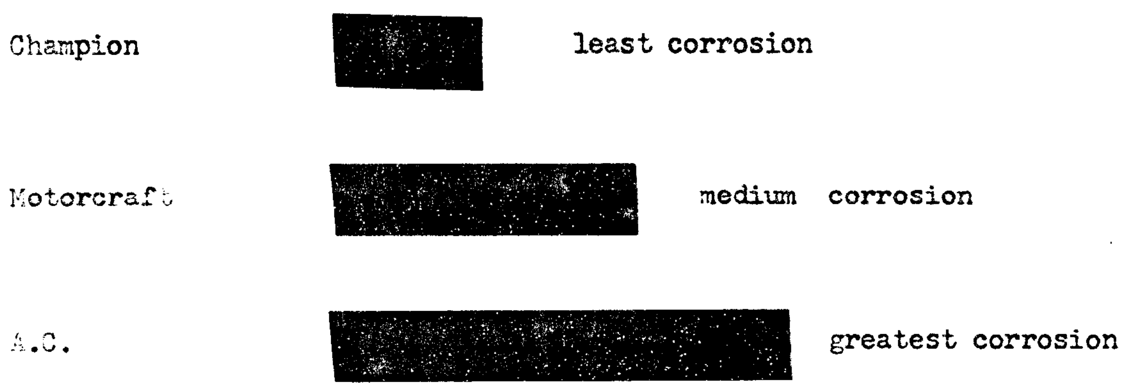


A linear graph showing a deterioration of the center and ground electrode area exposed to open flame.

<u>Test Two</u> - <u>Corrosion resistance</u>

The spark plugs were inserted into a holding fixture and elevated about one inch above a tray of muratic acid for two days. This is the same acid as used in cleaning bricks.

The findings are as follows: the Champion spark plug corroded the least in the acid, the Motorcraft showed the next greater amount of corrosion, and the AC corroded the most.

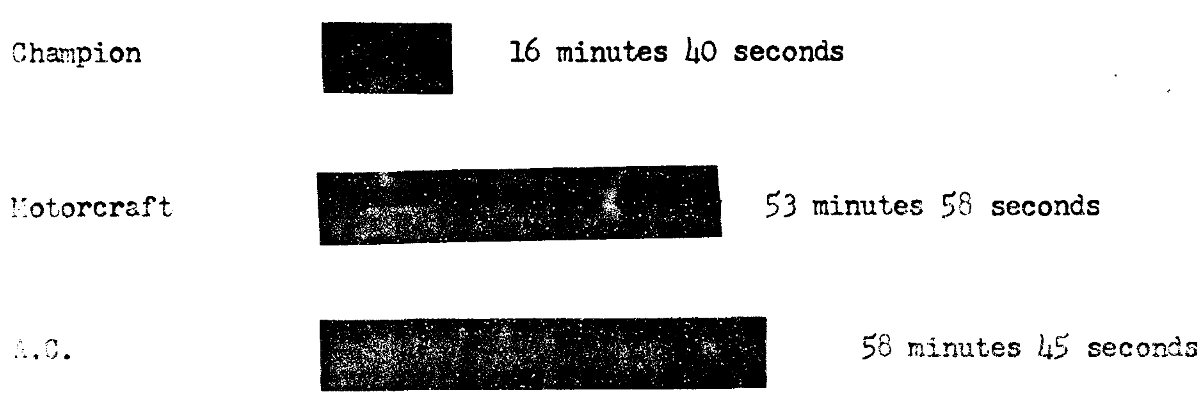


A linear graph showing the amount of corrosion of spark plug metal parts when exposed to the atmosphere and muratic acid.

Test Three - Oil fouling resistance

Three new Briggs and Stratton three horsepower engines were used in this test. The engines were run for a one hour break-in period. The engine's operating speed was adjusted to 700 RPM with a tachometer. The engines were then run until they consumed all their fuel and stopped running. The fuel tanks were then filled with one quart of carefully measured regular grade gasoline fuel; a metering device which held 35 cc of oil was mounted to the engines to meter oil into the fuel system through the gas tank. The amount of metering was 2.5 cc of 30 weight Pennzoil per minute. The engines were started and run until the ratio of oil and fuel was rich emough to oil foul the spark plug, causing the engine to stop running.

The findings of this test are as follows: the engine fired by a Champion CJ-8 spark plug ran for 16 munites 40 seconds before the spark plug oil fouled, the engine fired by a Motorcraft A7NXLM spark plug ran for 53 minutes 58 seconds, and the engine fired by a AC CS45 spark plug ran for 58 minutes 45 seconds.

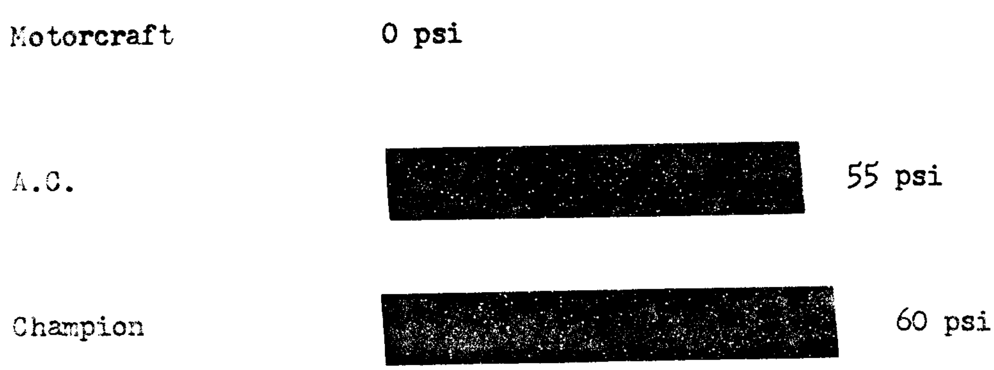


A linear graph showing the length of operation in minutes of Briggs and Stratton three horsepower engines before stoppage of engines due to oil fouling of the spark plugs.

Test Four - Electrical fouling resistance

A spark plug testing machine, which visually shows electrical characteristics of spark plugs under compression, was used in this test. The spark plugs were gapped at .040 of an inch. A carbon rod was then inserted between the spark plug shell and level with the tip of the center insulator. The positioning of this carbon rod gave the electrical charge going into the center electrode a short path to ground rather than jumping the gap to the ground electrode. The compression in the chamber was slowly increased until the electrical charge being sent to the spark plug was forced to jump to the carbon rod rather than across the .040 inch gap.

The results of this test are as follows: the Motorcraft spark plug fouled at 0 psi of compression, the AC spark plug fouled at 55 psi of compression, and the Champion spark plug fouled at 60 psi of compression.



A linear graph showing the point of electrical fouling when spark plugs were operated under compression expressed in pounds per square inch.

Test Unit III

Overall Length of Time Performability

The capabilities of the spark plugs being tested in this unit are their ability to function under operating conditions over extended lengths of time.

Test One - Electrical length of time performability

This test was conducted using spark plugs gapped at .040 of an inch. A four cylinder distributor was used. This distributor subjected the spark plugs to the same set of points and ignition circuit to give equal firing voltages. The spark plugs were new and of equal heat ranges; all connections were new and of the same type; spark plug wires were new and exactly the same length; firing voltages were all set equal by a Marquette engine analyzer scope; firing voltage was 22,000 volts D.C.; distributor speed was 1,725 RPM, the equivalent of 3,450 engine RPM or an approximate automobile speed of 65 MPH. The running time in hours for the test was 185 hours, or the equivalent of 12,025 miles. The accepted life of a spark plug is 12,000 miles.

The findings are as follows. The firing pattern of the Champion spark plug was from the center electrode to the side of the ground electrode. There was a definite transfer through electrolytic action from the center electrode to the ground electrode. This is the major reason for spark plug wear, due to the transfer of materials. The insulator burned extensively. There was fouling between center electrode and porcelain insulator.

The AC spark plug showed unusual fouling between the center electrode and the ground electrode. There was slight metal transfer between electrodes. Irregular firing patterns and no burning of the insulator were observed.

The Motorcraft spark plug had a straight firing pattern from the center electrode to the ground electrode. There was no indication of metal transfer.

no fouling, and little burning of the insulator.

Test Two - General in-engine operating performability

This test was conducted by installing the three different brands of spark plugs in a 302 Ford engine with 82,000 miles of usage. The engine was then operated for 6,517 miles under all operating conditions. Those conditions were driving from Poquoson, Virginia to Calgary, Canada and back to Poquoson, Virginia in three weeks. Some of the conditions the spark plugs were subjected to were driving across Glacier National Park, Yellowstone Park, Black Hills of South Dakota, and across the prairies of Montana and South Dakota at temperatures reaching 105°.

The findings of this test are as follows: the Champion spark plug showed burning and metal transfer; the AC spark plug showed slight transfer of metal and slight burning; and the Motorcraft showed no metal transfer, no burning, and light tan color indicating proper combustion.

Summary

The researcher, using the data gathered in the tests from the three units, will be able to draw a valid research conclusion. This conclusion will tell the consumer which of the three major spark plug brands will give him/her the best performance.

Chapter V

SUMMARY AND CONCLUSIONS

In this research paper the researcher has thoroughly tested the three leading brands of spark plugs available to the consumer. The three leading brands are AC, Champion, and Motorcraft (also called Auto-Lite). The purpose of this research is to determine which of the brands will give the consumer the best product for his money, inasmuch as all three brands are priced nearly the same.

The research was broken down into three units: spark plug physical strength, the ability of the spark plug to function under adverse conditions, and overall length of time performability.

Of the three units, the most important to the consumer is the ability of the spark plug to function for a long length of time. Unit one, which is spark plug physical strength, is important, but not to the consumer because very seldom do spark plugs fail because of physical strength. Unit two, which is the ability of the spark plug to function under adverse conditions is important, but not to the average consumer because they are usually not driving worn out, oil burning cars or driving in the Sahara Desert, where severe temperatures are present. Unit three, which is overall length of time performability, is the unit which deteremines which spark plug performs the best for the longest period of time, thus being the best product for the consumer.

The main factor which limits the life of the spark plug under normal operating conditions is the non-transfer of metal from the ground electrode or the center electrode.

The unit three tests clearly showed that there was less metal transfer and deterioration with Motorcraft (Auto-Lite) spark plugs than the other two brands. Thus, the best spark plug for the consumer is Motorcraft.

RECOMMENDATIONS

The tests indicate that the spark plug brand which will give the best overall performance is the Motorcraft Spark Plug. The reason is that it showed the least amount of metal deterioration and transfer from the ground and center electrode. This transfer and deterioration is the major factor which determines spark plug life.

The tests show that, if the consumer has an automobile which is burning oil, the best brand to use would be A.C. This is true because the A.C. spark plug has the ability to resist fouling under oily conditions.

None of the spark plug brands showed to be the physically strongest in all areas. The Motorcraft had the strongest porcelain insulator which is important because this insulator is susceptible to breakage during installation.

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