

[54] SPARK PLUG

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[58] Field of Search .. 313/118, 11.5, 131, 130, 128, 313/137

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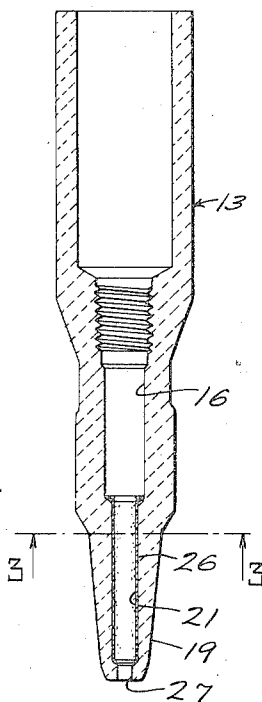
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[57]

ABSTRACT

In a spark plug including an insulator mounted in a tubular shell and an electrode assembly mounted within a bore through the insulator and projecting from a nose portion of the insulator to define a spark gap with a ground electrode, a method for improving the resistance of the nose portion to cracking caused by thermal stresses. The electrode assembly includes a high heat conducting portion in close proximity with the wall of the portion of the bore extending through the nose portion of the insulator. The method comprises applying a coating of a glaze slip to the interior wall of the portion of the insulator bore which will be in proximity with the heat conducting portion of the electrode and then firing the glaze at a controlled time and temperature to form an uninterrupted glassy coating on at least the portion of the nose bore adjacent the end of the insulator. The fired glaze must have a lower coefficient of thermal expansion than the insulator, an appreciably lower thermal conductivity than the insulator and a softening temperature above the highest operating temperature encountered by the glazed bore wall.

3 Claims, 6 Drawing Figures



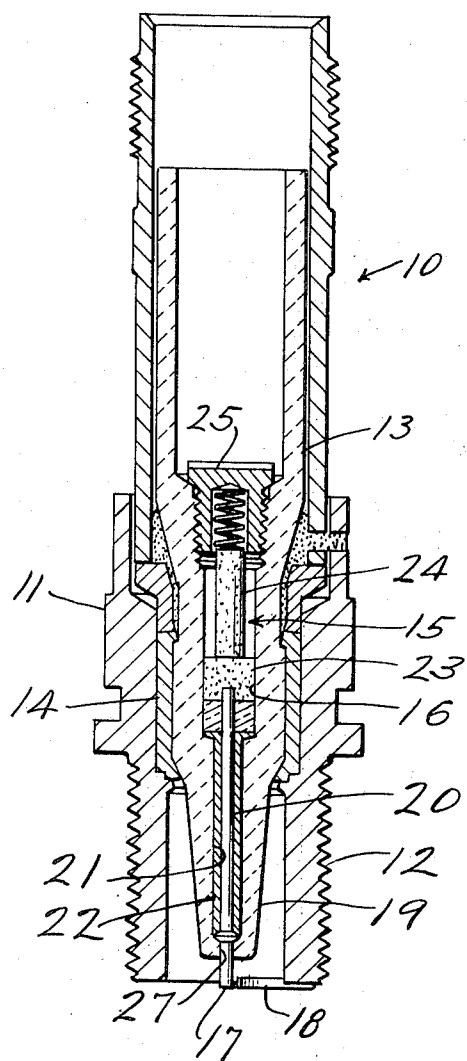


FIG-1 -

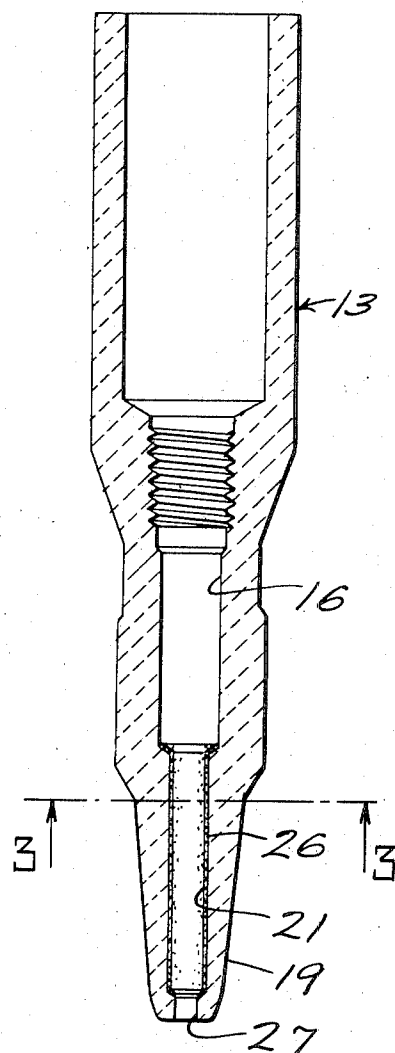


FIG-2 -

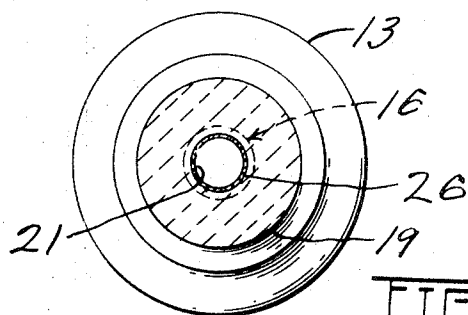


FIG-3 -

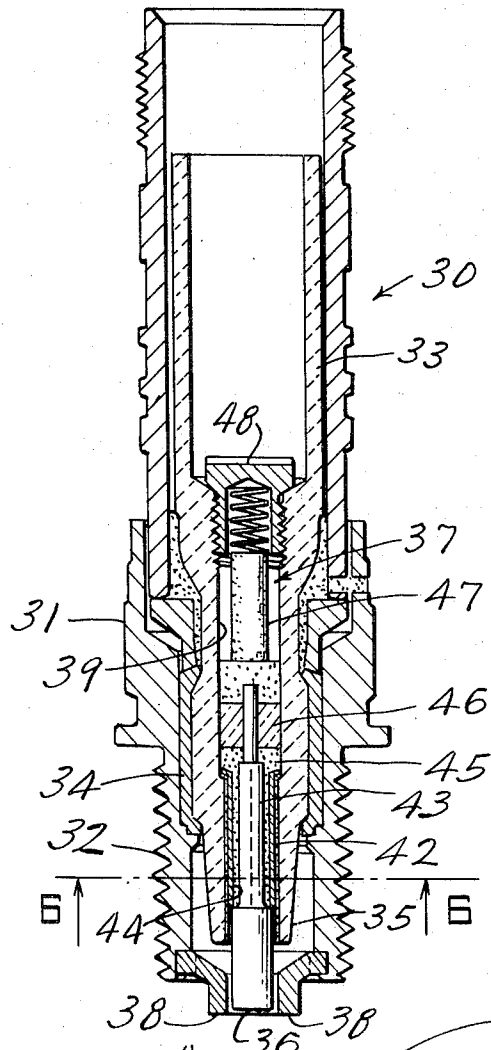


FIG-4-

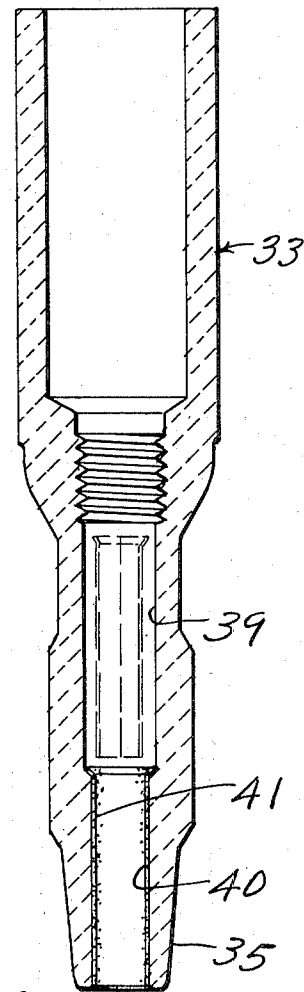


FIG-5-

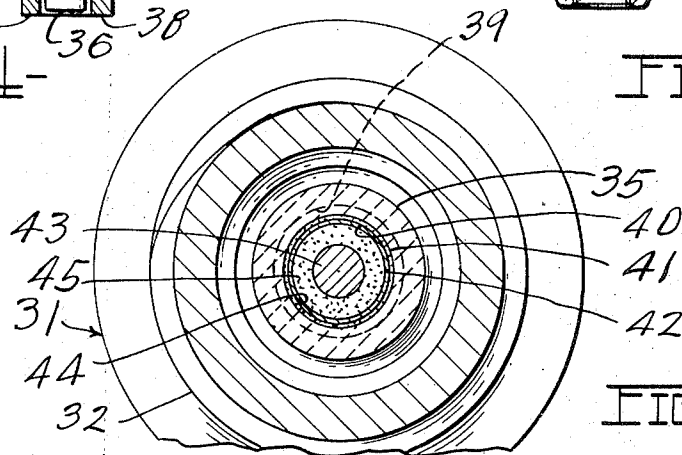


FIG-6-

SPARK PLUG

This is a division of application Ser. No. 224,456 filed Feb. 8, 1972.

BACKGROUND OF THE INVENTION

This invention relates to spark plugs and, more particularly, to a method for improving the cracking resistance of the nose portion of insulators in spark plugs of a type having high thermally conducting center electrode assemblies.

Although the specific design and operating characteristics of spark plugs for internal combustion engines vary with the requirements of each particular engine, spark plugs generally include a hollow tubular shell having a threaded end for engaging the engine, a ceramic insulator rigidly mounted in the shell and a center electrode assembly mounted in a bore through the insulator. The center electrode assembly includes a terminal end and a firing end. The firing end of the electrode assembly is positioned to define a spark gap with a ground electrode which is attached to the shell. The insulator includes a nose portion which extends from adjacent the firing end of the electrode assembly to an enlarged diameter intermediate insulator portion which is seated against a shoulder within the shell. A gasket is usually used on the seat. The seat functions as a gas seal and as a heat transfer path for conducting heat away from the center electrode and the nose portion of the insulator.

In the use of ceramic insulated spark plugs in high performance internal combustion engines, and in particular in aircraft engines, substantial difficulty has been encountered because the insulator nose has a tendency to crack. The cracking tendency is particularly acute in spark plugs having a high thermally conductive center electrode assembly. This type of spark plug is often used in high performance engines. When the insulator nose cracks, the discontinuity in the heat transfer path causes a drastic temperature rise, with the result that the tip of the spark plug may become heated to the point that preignition occurs in the associated cylinder. Preignition is a serious difficulty in a high performance internal combustion engine. If such an engine is operated under preignition for more than a few seconds, the extreme heat generated will damage both the spark plug and the engine. In severe cases of preignition, both the piston and the spark plug may melt. If preignition does not occur after formation of a crack in the insulator nose, the crack may still become a complete fracture and a part of the insulator may be dislodged. The dislodged part may itself cause severe mechanical damage in the combustion chamber.

The prior art has generally explained cracking of the nose portion of spark plug insulators on the difference in thermal expansion of the metallic electrode and the ceramic insulator. There is a theory that the high rate of expansion of the electrode causes it to expand against the interior wall of the insulator and exert a tensile force thereon. This theory cannot, of course, account for cracking in those spark plugs where the center electrode is a body of heat conductive metal, silver for example, cast directly in the insulator bore. If the cast metal has a higher coefficient of expansion than the insulator, it is obvious that it can never expand to a dimension as great as the dimension it had when it was molten and that the cast metal must always be no larger than the bore of the insulator. A study of the ac-

tual temperatures existing during operation has indicated that the cracking probably results from thermal stresses within the insulator caused by the interior of the nose portion of the insulator running colder than the exterior surface of the nose portion by reason of heat transfer into the relatively cooler metallic center electrode.

Several factors have been shown, theoretically, to effect nose cracking in spark plug insulators. These factors include the following: (1) the modulus of elasticity of the nose ceramic; (2) the thermal coefficient of expansion of the nose ceramic; and (3) the tensile strength of the ceramic material comprising the nose portion. In general, factors (1) and (2) should be as low as possible in order to minimize the thermal stress on the insulator and factor (3) should be as high as possible.

When a spark plug is operated in a high performance engine, and the output of the engine is gradually increased, an engine output is eventually reached at which that particular spark plug causes preignition. The "indicated mean effective pressure" of an engine at which a particular spark plug will cause preignition when operating within the engine is commonly denominated as the "I.M.E.P." rating for that spark plug. It has been found that the I.M.E.P. rating of a spark plug can be increased by shortening the insulator nose and thus lowering the temperature of the firing tip. However, such an expedient is relatively undesirable because the deviations from an average I.M.E.P. rating, for any given lot of plugs, are high, and because spark plugs of this type are particularly subject to carbon fouling when operated in an engine at a low output level.

Another expedient that has been found to be effective to increase the I.M.E.P. rating of a spark plug is to position a thermally conducting center electrode part, such as a cast silver electrode part, in the bore through the nose portion of the spark plug insulator. The thermally conducting center electrode part lowers the temperature of the firing tip to increase the I.M.E.P. rating. Several types of thermally conducting electrode parts have been used in, for example, aircraft spark plugs. In one thermally conducting center electrode design, a rivet or rod formed from an erosion and corrosion resistant material such as an alloy of platinum or iridium is positioned to project from the bore through the insulator nose to form a spark tip and silver is then cast in the nose bore. In another design, a longitudinally split nickel alloy tube is positioned in the insulator nose bore either around a portion of a relatively massive electrode which extends from the insulator for defining a spark gap with a ground electrode or to hold a rivet tip which defines the spark gap with the ground electrode. Silver is cast in the open space within the tube. In each electrode design, the purpose of the thermally conducting portion of the electrode is to increase the conduction of heat from the firing tip of the electrode, thereby reducing the temperature of the firing tip and increasing the I.M.E.P. rating of the spark plug. Other known designs for thermally conducting electrodes, of course, may also be used in spark plugs of this type.

SUMMARY OF THE INVENTION

According to the present invention, a method is provided for reducing the incidence of thermal stress cracking of the nose portion of insulators in spark plugs of the type in which the center electrode assembly has

a high thermally conducting portion within the insulator nose bore. It has been discovered that such thermal stress cracking is greatly reduced or even eliminated by applying a glaze to the portion of the insulator nose bore which is in close proximity with the thermally conducting portion of the center electrode assembly. The glaze may be applied to the insulator by flowing a suitable glaze tip through that portion of the bore which is to be glazed. The insulator is then fired at a controlled time and temperature to fuse the glaze into a continuous glassy coating. The glaze slip is preferably applied such that the thickness of the fired glaze is at least 0.0005 inch and, preferably, is within the range of 0.0010 inch and 0.0025 inch.

Four glaze compositions have been found satisfactory for reducing the incidence of cracking in spark plug insulator noses caused by thermal stresses. The four compositions include various amounts of K_2O , Na_2O , Li_2O , CaO , MgO , B_2O_3 , PbO , Al_2O_3 and SiO_2 . After firing, each of the glaze compositions has a lower coefficient of thermal expansion than the spark plug insulator, an appreciably lower thermal conductivity than the insulator and a softening temperature above the highest operating temperature encountered at the glazed surface.

Accordingly, it is a primary object of this invention to provide a method for reducing cracking of the nose portion of insulators in spark plugs of the type used in high performance internal combustion engines.

Another object of the invention is to provide a method for reducing thermal stress cracking of the nose portion of spark plug insulators.

Other objects and advantages of the invention will become apparent from the following detailed description, with reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an enlarged vertical section of an aircraft spark plug manufactured in accordance with the principles of the present invention;

FIG. 2 is an enlarged vertical section of the insulator from the spark plug shown in FIG. 1;

FIG. 3 is a cross-sectional view taken along line 3—3 of FIG. 2;

FIG. 4 is an enlarged vertical section of a modified design of a spark plug manufactured in accordance with the principles of the present invention;

FIG. 5 is an enlarged vertical section of the insulator from the spark plug of FIG. 4; and

FIG. 6 is a cross-sectional view taken along line 6—6 of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As previously stated, spark plugs of the type used in high performance internal combustion engines such as aircraft engines are commonly provided with a center electrode assembly having a highly heat conducting portion located within and in close proximity with at least a portion of the wall of a bore extending through the nose portion of the spark plug insulator. This portion of the electrode assembly may include a mass of silver cast either directly in contact with the insulator nose bore wall or cast in a metal tube positioned within the nose bore. As used herein, "close proximity" is used to describe the position of the highly conductive

portion of the center electrode with respect to the insulator nose bore for both types of electrode assemblies. The cast silver functions to conduct heat away from a firing tip at the end of the electrode assembly and away from the insulator nose to increase the I.M.E.P. rating for the spark plug. However, problems have occurred with insulator nose cracking in spark plugs of this type. The insulator nose cracking apparently is caused by thermal stresses resulting from a temperature gradient within the insulator nose.

According to the present invention, the incidence of nose cracking may be greatly reduced by applying to the bore through the insulator nose a glaze having a lower coefficient of thermal expansion than the insulator, and appreciably lower thermal conductivity than the insulator and a softening temperature above the highest operating temperature encountered by the glaze.

Several theories have been advanced as to why the glaze reduces the incidence of thermal cracking. According to a first theory, the glaze acts as a thermal barrier to reduce the rate of heat transfer between the insulator and the center electrode assembly. Under this theory, the glaze reduces heat stresses occurring in the insulator nose at the interface with the cooler center electrode assembly and reduces the temperature gradient within the insulator nose. According to a second theory, the glaze functions as a strengthening mechanism. The glaze will be under a high compressive load since the glaze has a lower coefficient of expansion than the insulator. The compressive load is applied to the glaze on the bore surface as the insulator and glaze are cooled after the glaze is fired. On the other hand, the glaze may strengthen the insulator by healing over surface flaws and micro-fissures occurring in the nose bore surface of the ceramic insulator. To date, there has been no adequate showing as to which of the theories is correct. Of course, more than one of these theories may apply.

Only certain glaze compositions have been found satisfactory for reducing the incidence of thermal stress cracking in spark plug insulator noses. The reason that many glazes do not work is probably because the softening temperatures of such glazes are too low. If the glaze softens during high temperature operation of the spark plug, the center electrode may move into contact with the insulator, preventing the glaze from functioning as a thermal barrier. The softened glaze would also cease to function as a strengthening mechanism for the insulator. Four glazes which have been found to be satisfactory consist essentially of the compositions shown in Table I. These glaze compositions may include minor amounts of ingredients which do not materially affect the strengthening and thermal barrier properties of the glaze and do not lower the melting temperature of the glaze appreciably.

To be effective, glazes having the composition shown in Table I must be fired for a controlled time and at a controlled temperature. The firing time and temperature are controlled to produce a glaze having a glassy appearance. A given glaze, for example, may be effective if fired at 2,500° F. to 2,750° F. for 6 minutes and be ineffective if fired at the same temperature for 10 hours or if fired at a higher temperature for only 6 minutes. If the glaze is properly fired, it will be fused into a continuous coating, but it will not have had sufficient time or be heated to a sufficient temperature to flow.

Either an excessively high firing temperature for a relatively short time or an excessively long firing time at a lower temperature will permit the glaze to flow, resulting in a dull appearance similar to the unglazed insulator. Such a glaze will not be effective to reduce the incidence of insulator nose cracking.

TABLE I

Composition:	Percent					
	K ₂ O Na ₂ O Li ₂ O	CaO MgO	B ₂ O ₃	PbO	Al ₂ O ₃	SiO ₂
1.-----	1-5	2-7	-----	-----	10-20	70-80
2.-----	1-5	20-30	-----	-----	40-50	20-30
3.-----	1-5	2-7	15-20	1-5	5-15	60-70
4.-----	1-5	-----	-----	-----	30-40	55-65

Referring now the drawings, two embodiments are shown of spark plugs manufactured for high performance internal combustion engines and made in accordance with the principles of the present invention. In FIGS. 1-3, a spark plug 10 is shown including a hollow tubular shell 11 having a threaded end 12 for engaging the head of an internal combustion engine. A ceramic insulator 13 is mounted within the shell 11 and is seated against a thermally conducting tubular sleeve 14. The sleeve 14 provides a seal and a good heat transfer path between the insulator 13 and the shell 11. A center electrode assembly 15 is mounted within a bore 16 through the insulator 13. The center electrode assembly 15 terminates in a tip 17 which defines a spark gap with a ground electrode 18. The ground electrode 18 is attached to the threaded end 12 of the shell 11. The insulator 13 has at its lower end a nose portion 19 which is positioned between the exposed tip 17 and the seat formed by the sleeve 14. The tip 17 is of a corrosion resistant material and may consist of a headed rivet or of the end of a rod 20 which extends upwardly through a portion 21 of the insulator bore 16 within the nose 19. A heat conductive metal 22, such as silver, is cast in the annular space between the rod 20 and the nose bore 21. In operation of the spark plug 10, heat is conducted from the tip 17 and from the insulator nose portion 19 upwardly through the heat conducting material 22 through the insulator 13 and the sleeve 14 to the shell 11. The remainder of the electrode assembly 15 is of a conventional design and may include a conductive glass seal 23, a resistor 24 and a terminal 25.

As stated above, the lower portion 21 of the insulator bore 16 is in contact with the heat conducting material 22 which is cast directly in the insulator 13. According to the present invention, the lower insulator bore 21 within the nose portion 19 is coated with a glaze 26 having a composition consisting essentially of one of the four compositions shown in Table I. The glaze is initially applied to the insulator nose bore 21 in the form of a liquid glaze slip. The glaze slip is applied by any suitable method, such as by flowing the slip through the nose bore 21 to completely and uniformly coat the bore 21. The insulator is then fired for a controlled time and at a controlled temperature to fuse the glaze into a glassy coating 26. The glaze slip is applied such that the finished glaze will have a thickness of at least 0.0005 inch and preferably a thickness within the range of 0.0010 inch and 0.0025 inch. The insulator bore 16 may also have a constricted portion 27 at its lower end for closely engaging the firing tip 17 as it protrudes from the insulator 13 to retain the tip 17 within the in-

insulator bore 16. The constricted portion 27 may be unglazed so that a close fit may be obtained with the tip 17. If the glaze 26 is applied to the constricted portion 27, it may be difficult to obtain an accurate fit with the tip 17 to prevent erosion and corrosion of the heat conducting material 22 by hot combustion gases.

It has been found that the occurrences of bare spots in the glaze 26 affects the performance of the glaze 26 in reducing cracking of the insulator nose 19. As used herein, the term "bare spot" shall include spots where the glaze is thin in addition to spots completely void of glaze. Bare spots are not present where the glaze is "continuous." If bare spots occur in the glaze 26, particularly near the lower end of the nose 19 adjacent the firing tip 17, the glaze 26 will be ineffective for reducing thermal stress cracking of the insulator nose 19. However, bare spots occurring in the glaze 26 in the upper portion of the nose bore 21 adjacent the sleeve 14 do not appreciably reduce the effectiveness of the glaze 26. As a result of this, care must be taken in applying the liquid glaze slip to prevent bare spots or bubbles in the glaze 26 near the lower end of the nose bore 21.

Turning now to FIGS. 4-6, a second embodiment is shown of a spark plug 30 manufactured in accordance with the present invention. Again, the spark plug 30 includes a tubular shell 31 having a lower end 32 threaded for engaging an internal combustion engine. An insulator 33 is positioned within the shell 31 and is seated in place by means of a tubular sleeve 34 which forms a gas seal and a good heat transfer path between the insulator 33 and the shell 31. The lower end of the insulator 33 defines a nose 35 which is located between a firing tip 36 at one end of a center electrode assembly 37 and the sleeve 34. In this embodiment of the spark plug 30, the tip 36 is relatively massive and is surrounded by a plurality of ground electrodes 38 which are attached to the threaded end 32 of the shell 31.

The insulator 33 is provided with a central bore 39 having a lower portion 40 which extends through the insulator nose 35. In manufacturing the insulator 33, the lower portion of the bore 40 is coated with a glaze slip having one of the compositions shown in Table I. The glaze slip is applied such that the glaze, when fused, will have a thickness of at least 0.0005 inch and preferably a thickness within the range of 0.0010 inch and 0.0025 inch. Again, the fused glaze 41 should not have bare spots near the lower end of the nose bore 40 which is located adjacent the tip 36. After the glaze 41 is fused onto the insulator 33, the center electrode assembly is formed by initially positioning a split metal tube 42 within the nose bore 40. The center electrode tip 36 is then positioned to project from the nose bore 40. The tip 36 has an integral reduced diameter portion 43 which extends upwardly through the split tube 42 to define an annular space 44. A heat conducting material 45, such as silver or a silver alloy, is then cast within the annular space 44. Casting of the material 45 may be accomplished by any conventional method. The center electrode assembly 37 is then completed and may include a glass seal 46, an ignition noise suppression resistor 47 and a terminal 48.

EXAMPLE

A number of spark plugs were manufactured according to the design shown in FIGS. 1-3. During manufacturing of the spark plugs, the nose bores of ceramic in-

insulators for fifteen spark plugs were coated with a glaze slip having a composition consisting essentially of 1.29 percent K_2O , 0.7 percent Na_2O , 4.22 percent CaO , 0.03 percent MgO , 14.96 percent Al_2O_3 , and 78.72 percent SiO_2 . The insulators coated with the glaze slip were then fired for 10 minutes at $2,700^\circ F$. A test on a glaze of this composition indicated that the glaze had a coefficient of thermal expansion of 2.87×10^{-6} in./in./ $^\circ C$. The insulator, on the other hand, was found to have a coefficient of thermal expansion of 5.8×10^{-6} in./in./ $^\circ C$. When the assembled spark plugs were tested in an internal combustion engine and subjected to preignitions, none of the fifteen spark plugs in which the insulator bore had been glazed failed after a test including twenty-five preignitions while 100 percent of the unglazed spark plugs failed through insulator nose cracking.

It will be readily apparent that insulator nose cracking may be reduced in spark plug designs other than those described above and shown in the attached drawings. It will also be appreciated that various changes and modifications may be made in the above-described invention without departing from the spirit and the scope of the appended claims.

What is claimed is:

1. A spark plug for an internal combustion engine which is resistant to insulator cracking caused by ther-

mal stresses comprising, in combination, a shell having a threaded end for engaging an internal combustion engine, an elongated insulator mounted within said shell, said insulator having a nose portion forming an end adjacent the threaded end of said shell, a terminal end and a bore extending through said insulator between said nose portion and said terminal end for mounting an electrode assembly, a glaze forming a continuous glassy coating on at least the wall of the bore within and adjacent the exterior end of said insulator nose portion, said glaze having a thickness within the range of 0.0005 inch and 0.0025 inch and having a softening temperature above the highest operating temperature encountered by said glaze during operation of said spark plug in such engine, and an electrode assembly mounted within said insulator bore, said electrode assembly including a high thermally conducting portion cast directly within said insulator nose bore.

2. A spark plug, as defined in claim 1, wherein said high thermally conducting portion of said center electrode assembly is cast from silver.

3. A spark plug, as defined in claim 2, wherein said cast silver portion of said center electrode assembly is in contact with said glaze on the wall of said insulator nose bore.

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