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T. G. McDOUGAL ET AL

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RESISTOR AND SPARK PLUG EMBODYING SAME

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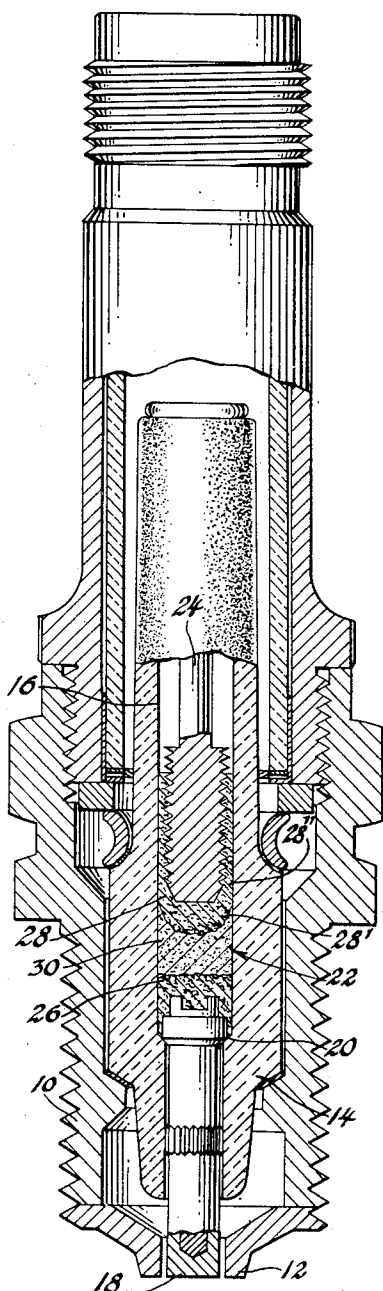


Fig. 1

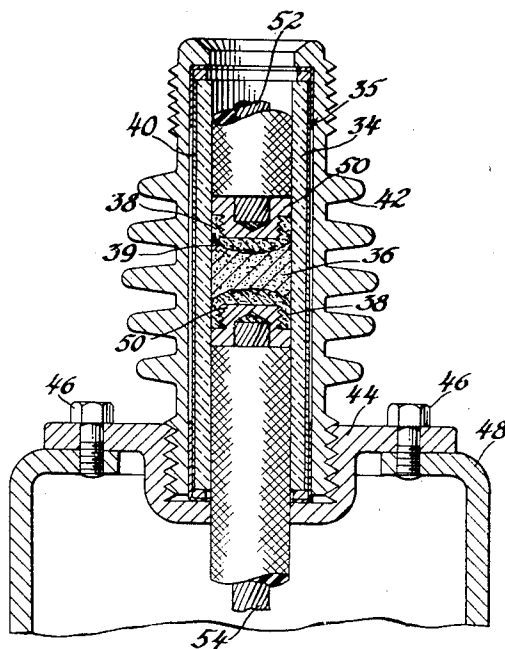


Fig. 2

Inventors
Taine G. McDougal,
Karl Schwartzwalder &
Alexander S. Kulka
By
Blackwood, Spencer & Flint
Attorneys

UNITED STATES PATENT OFFICE

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RESISTOR AND SPARK PLUG EMBODYING
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Taine G. McDougal, Flint, Karl Schwartzwalder,
Holly, and Alexander S. Rulka, Flint, Mich.,
assignors to General Motors Corporation, De-
troit, Mich., a corporation of Delaware

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22 Claims. (Cl. 315—58)

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This invention has to do with resistors particularly suitable for use in wiring harness and in spark plugs. Such resistors are commonly used to suppress the high frequency oscillations associated with spark discharge in ignition systems. Such oscillations sometimes cause rupture of the ignition cable and always cause increased erosion of the electrodes.

Heretofore separate resistors have been used for this purpose. Difficulty has been encountered with them because of the tendency of the spark to flash over the outside of the resistance element, particularly at high altitudes, as well as because of large variations in resistance with the changes in temperature encountered during operation of the engine. We have overcome both of these difficulties with the constructions herein disclosed.

According to our invention the resistor comprises a sleeve of insulating material within which is secured the resistance element. The resistance element is sealed within the sleeve so as to exclude air and moisture which might adversely affect it.

The parts referred to are preferably made either wholly or partly of ceramic material so that they may be bonded or fused together by subsequent firing. The bonding of the resistance element to the sleeve makes it impossible for the current to flash over the outside of the resistor. The resistance element is preferably confined well within the sleeve so as to increase the length of the path by which flash-over might take place around the exposed surface of the sleeve, thereby rendering flash-over less likely.

The resistance element is preferably sealed within the sleeve by conducting material having a ceramic base so that it may be bonded to the resistance element as well as to the sleeve on the same firing.

In one form of the invention the sleeve is constituted by the insulator of the spark plug and the resistor forms part of the central electrode. In another form of the invention the sleeve, with its contained resistor, is adapted to be inserted in series with the high tension wires going to the spark plugs.

In the drawings:

Figure 1 is a section through a spark plug embodying our invention.

Figure 2 is a section through a resistor suitable for use in wiring harness embodying our invention.

Figure 1 is a section through a spark plug used in aviation engines. 10 indicates the spark plug

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shell provided with side electrodes 12 and having an insulator 14 suitably secured therein. In this form of the invention the insulator constitutes the sleeve previously referred to. The insulator is preferably of the sintered oxide type consisting either wholly of aluminum oxide or of a preponderance of aluminum oxide, together with other oxides, such as magnesium oxide, beryllium oxide or suitable silicates such as mullite. If preferred, the insulator may be a porcelain body characterized by a preponderance of mullite, zircon, zirconia or the like, together with glass.

The insulator is provided with the usual central aperture 16 to receive the electrode. The electrode comprises a lower section 18 which may be of any suitable material capable of withstanding high temperatures and possessing good heat conductivity, preferably nickel alloy filled with copper as described in Heller Patent 2,296,033. Section 18 is provided with a shoulder 20 resting on a shoulder provided in the bore in the insulator. 22 indicates generally the ceramic section of the electrode and 24 the upper section which is preferably of metal such as steel.

The ceramic section of the electrode comprises a lower seal 26, an upper seal 28, and an intermediate portion 30 constituting the resistance element.

The conducting seals may be made of any suitable material capable of being bonded to the insulator and to the resistance element and possessing relatively good electrical conductivity. We prefer to employ a mixture of glass and conducting material as described and claimed in Schwartzwalder and Kirk Patent No. 2,106,578 granted January 25, 1938, and in Schwartzwalder and Rulka Patent No. 2,248,415 granted July 8, 1941.

The lower seal 26 which is subjected to greater heating during operation of the plug is preferably made from a mixture consisting of 55 parts powdered copper, 45 parts Pyrex or borosilicate glass, together with 3 parts of a suitable binder such as Dritex, a hydrogenated cotton-seed oil.

The upper seal, which is less exposed to heat, is preferably made up of a lower portion 28' of the composition just described and an upper portion 28'' consisting of a similar mixture of copper, glass and binder, except that the glass employed possesses greater plasticity, preferably consisting of a lead borosilicate composition as described in said Schwartzwalder and Rulka patent.

A great deal of work has been done with different compositions of material for the resistance element in an effort to find one having the

least possible variation in resistance over the temperature range encountered during the use of the plug. We have had the most success with a resistor of the following composition:

	Percent
Borosilicate glass (Pyrex cullet)-----	62.4
Fluorspar (CaF ₂)-----	25.2
Magnesium borate glass-----	7.8
Thermax carbon-----	4.6

These materials are mixed together to give a uniform mixture. Water is added in proportion of 40 parts of water to 100 parts of material by weight. The wet mass is then dried to remove enough water to permit granulation of the material through a 20 mesh screen and then completely dried. This thoroughly dried material is then re-screened to pass a 20 mesh screen and is ready for use.

The composition above given is susceptible of considerable modification. The resistance may be reduced by increasing the amount of carbon and may be increased by decreasing the amount of carbon.

We have used various forms of carbon black but have had best results with carbon black known as "Thermax," employing the coarsest particle size obtainable, this being on the order of 1.12 microns as determined by the ultra-microscopic method. Thermax is a carbon black produced in an oxygen free atmosphere by thermal decomposition of natural gas.

Pyrex or borosilicate glass possesses a low coefficient of expansion as well as ability to resist heat. The magnesium borate glass likewise possesses a low coefficient of expansion and appears to give an elastic quality to the resulting glass which reduces strains. Fluorspar is added to increase the thermal expansion of the resulting seal.

Resistances of the above composition have been made having values on the order of from 60 to 100 ohms. If higher resistances of substantially the same size are desired it may be found desirable to modify the compositions as indicated below:

Composition	Resistance of Order of 500 Ohms	Resistance of Order of 5,000 Ohms	Resistance of Order of 10,000 Ohms
Ground Pyrex cullet-----	63.8	63.5	64.0
Magnesium borate glass-----	8.0	9.0	9.0
Fluorspar-----	25.6	11.0	11.0
Whiting-----		15.0	
Beryl-----			15.0
Thermax carbon-----	2.6	1.5	1.0

The values of resistance given are, of course, for resistors of the same cross-section. The increase in resistance is, of course, obtained by reducing the carbon content.

We have also had success with resistors of the following composition where the temperatures encountered are not as high as those for which the preferred composition of resistance element is adapted:

	Percent
Pyrex glass-----	27.5
Glass, preferably consisting of 95% B ₂ O ₃ and 5% MgO-----	25
Boron carbide-----	37.5
Tungsten carbide together with 3.0% of a suitable binder such as Dritex-----	10.0

Boron carbide and tungsten carbide act as conducting materials and when used together

seem to have the effect of reducing variation of resistance with passage of time. Boron metal may be used in place of tungsten carbide if desired. Other heat resisting conducting materials may be used with the glass or other ceramic material to make the resistor, for example, various metallic carbides or oxides with or without the additions of metals. Carbon may be incorporated in the glass either alone or in combination with the other resistance materials mentioned. The carbon used is preferably in the form of carbon black.

In the manufacture of the spark plug the insulator is made in the usual manner. The temperatures required in firing the insulator will be within the range of from approximately 1450° to 1750° C. depending upon the composition employed.

In assembling the center electrode in the insulator, the lower section 13 is dropped in place, a measured amount of copper-glass seal in powdered form is fed into the bore and tamped in place. Any loose powder is blown out of the insulator to prevent contamination of the resistor. The desired amount of powdered resistance material is then placed in the bore and tamped, followed by a measured portion of powdered copper glass seal and more tamping; and then by a small quantity of the powdered mixture of copper and lead-borosilicate glass. The upper electrode section 24 is then inserted in the bore and the whole assembly is heated to approximately 1600° F. When the glass is sufficiently softened pressure is applied to the upper electrode section to force it down into the bore, thereby compressing the softened material and causing the more fluid copper lead-borosilicate sealing material to surround and grip the part 24.

In Figure 2 the invention is shown embodied in a resistor 35 adapted for use in a wiring system, for example in the high tension leads of the ignition system of an aircraft engine.

The resistor 35 is illustrated as enclosed in a metal sleeve 42 provided with cooling fins as shown. The sleeve 42 has threaded engagement at one end with cap 44 secured by bolts 46 to the distributor housing cover 48.

The resistor consists of a sleeve 34 of either sintered oxide or porcelain composition, the same as the insulator 14 of Figure 1. However, if desired, some other suitable insulator composition may be employed as the sleeve 44 is not subjected to the same thermal and electrical stress as a spark plug insulator. Within the sleeve and integrally bonded thereto is a resistance element 36 preferably of the same composition as the resistance element 36 of Figure 1. The resistance element is sealed within the sleeve 34 by glass seals 38 which may be of the same composition as the seals disclosed in Figure 1, the outer portion of the glass seals, if desired, being formed of a more fusible glass such as indicated at 28' in Figure 1. The glass seals secure within the sleeve 34 metal terminals 50, one of which is in electrical contact with cable 52 coming from the ignition coil while the other is in conducting relation with cable 54 leading to the distributor. Suitable means, not shown, will be provided to hold the cables in the position indicated. The glass seals form a good bond with the terminals 50 and 52 just as they do with the metallic sections of the electrode illustrated in Figure 1.

The method of manufacture of this resistor is substantially the same as that of the plug. One of the terminals 50 is inserted in the sleeve, the

glass seal material in powdered form is inserted, followed by the powdered resistance material and the powdered ingredients of the second seal. The other terminal is then inserted and the assembly is heated to soften the glass, thereupon pressure is applied to the terminals to cause them to seat in the glass as shown. In this operation suitable stops are provided to insure the centering of the resistance element in the sleeve.

It may be found desirable to provide the resistor of Figure 2 with a silver coating on the outside as illustrated at 40 to permit better heat transfer to the metal housing in which the resistor and the ignition cable are usually mounted, the housing shielding the cable and preventing interference with radio communication. Obviously the resistor can be used wherever it is desired to employ a fixed resistance unaffected throughout a considerable range of temperature.

The described construction has many advantages. Owing to the integral assembly of resistor and insulator or shell, there is no possibility of the high tension current flashing over the sides of the resistor as sometimes happens when independent resistors are employed at high altitudes. The resistance element is sealed from attack by gases and vapors by the conducting seals. The resistance elements provide a constant resistance over a wide temperature range. This range is the greatest in the case of the preferred composition containing carbon black.

The resistance may be varied by increasing the proportion of glass or other ceramic base material. It is also possible to decrease the resistance by increasing the pressure employed in the assembly operation or by increasing the temperature during assembly thereby producing better contact between the particles making up the seal.

While glass is preferred as the ceramic base for the resistance element and conducting seals, especially borosilicate glass because of its low expansion and resistance to heat, as well as its relative low softening temperature, it may in some instances be found desirable to employ material having greater heat resistance such as sintered oxides or mixtures of sintered oxides and silicates. The ceramic material employed should not soften within the range of temperature to which the resistor is subjected in use, for it has been found if that is the case the resistance increases with time.

The preferred form of resistance material expands less upon heating than does the usual alumina base insulator, so that when contraction takes place after the assembly operation the insulator or shell tends to grip the resistance element and seals insuring tightness.

This is a continuation in part of application Serial No. 407,844, filed August 22, 1931 by the same inventors.

We claim:

1. The combination of a sleeve of ceramic insulating material, a resistance within and closing the passage through the sleeve and comprising a mixture of glass and carbon black fused in place and thermally bonded to the sleeve, and a seal comprising a mixture of glass and conducting material overlying one end of the resistance element fused in place and thermally bonded to the resistance and to the sleeve and protecting the element from the atmosphere.

2. The combination of a sleeve of ceramic insulating material, a resistance within and closing the passage through the sleeve and comprising a

mixture of glass and carbon black fused in place and thermally bonded to the sleeve, and seals comprising a mixture of glass and conducting material overlying the ends of the resistance element and fused in place and thermally bonded to the resistance and to the sleeve and protecting the element from the atmosphere.

3. A resistor comprising a sleeve of insulating material, a resistance element within and closing the passage through the sleeve and thermally bonded thereto, and seals overlying the ends of the resistance element and thermally bonded thereto and to the sleeve, the ends of said sleeve overhanging the ends of said resistance element thereby providing a long leakage path to prevent flash-over.

4. A resistor comprising a sleeve of insulating material, a resistance element within and closing the passage through the sleeve and thermally bonded thereto, and seals overlying the ends of the resistance element and thermally bonded thereto and to the sleeve, the ends of said sleeve overhanging the ends of said resistance element, said sleeve having an exterior coating of conducting material.

5. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode section in the bore, a seal having good electrical conductance securing and sealing said section in the bore and rendering said bore impervious to gases, and a resistance element in the bore in series with the section and seal and bonded to the insulator and to the seal, the resistance of said element being sufficient to substantially reduce erosion of the electrode by spark discharge.

6. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode section in the bore, a seal having good electrical conductance securing and sealing said section in the bore and rendering said bore impervious to gases, and a resistance element in the bore in series with the section and seal and bonded to the insulator and to the seal, the resistance of said element being sufficient to substantially reduce erosion of the electrode by spark discharge, and a second conducting seal bonded to the other end of the resistance element and to the insulator, said conducting seals protecting said resistance element, while the bonding of the resistance element to the insulator prevents flash-over.

7. A spark plug comprising a shell, a ceramic insulator in the shell having a bore therein, an electrode section in the bore, a ceramic base seal having good electrical conductance overlying one end of said section and securing and sealing said section in the bore, said seal being bonded to the insulator and rendering said bore impervious to gases, and a ceramic base resistance element in the bore bonded to the insulator and to the seal and constituting a part of the electrode in series with said section and seal, the resistance of said element being sufficient to substantially reduce erosion of the electrode by spark discharge.

8. A spark plug comprising a shell, a ceramic insulator in the shell having a bore therein, an electrode section in the bore, a ceramic base seal having good electrical conductance overlying one end of said section and securing and sealing said section in the bore, said seal being bonded to the insulator and rendering said bore impervious to gases, and a ceramic base resistance element in the bore bonded to the insulator and to the seal and constituting a part of the electrode in series with said section and seal, the resistance of said element being sufficient to substantially reduce

erosion of the electrode by spark discharge, and a second ceramic base seal having good electrical conductance overlying and bonded to the other end of the resistance element and to the insulator, and sealing the resistance element therein.

9. A spark plug comprising a shell, a ceramic insulator in the shell having a bore therein, an electrode section in the bore, a ceramic base seal having good electrical conductance overlying one end of said section and securing and sealing said section in the bore, said seal being bonded to the insulator and rendering said bore impervious to gases, and a ceramic base resistance element in the bore bonded to the insulator and to the seal and constituting a part of the electrode in series with said section and seal, the resistance of said element being sufficient to substantially reduce erosion of the electrode by spark discharge, and a second ceramic base seal having good electrical conductance overlying and bonded to the other end of the resistance element and to the insulator, and sealing the resistance element therein, and a second electrode section secured in said bore in good conducting relation with the second seal.

10. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a section having its end normally exposed in the combustion chamber, a conducting seal securing and sealing said section in the bore and a non-porous resistance element in the bore bonded to the insulator and to the seal under heat and pressure, the resistance of said element being on the order of at least 60 ohms so as to reduce erosion of the electrodes by the spark.

11. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a section having its end normally exposed in the combustion chamber, a conducting seal securing and sealing said section in the bore and a non-porous resistance element in the bore bonded to the insulator and to the seal under heat and pressure, the resistance of said element being on the order of at least 60 ohms so as to reduce erosion of the electrodes by the spark, and a conducting seal in the bore beyond the resistance element and bonded thereto and to the seal.

12. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a section having its end normally exposed in the combustion chamber, a conducting seal securing and sealing said section in the bore and a non-porous resistance element in the bore bonded to the insulator and to the seal under heat and pressure, the resistance of said element being on the order of at least 60 ohms so as to reduce erosion of the electrodes by the spark, a conducting seal in the bore beyond the resistance element, a conductor in the bore beyond the last named seal, said seal being bonded to the resistance element, and to the insulator and having a substantially gas-tight union with the said conductor.

13. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a section having its end normally exposed in the combustion chamber, a conducting ceramic seal securing and sealing said section in the bore, and a non-porous resistance element in the bore bonded to the insulator and to the seal under heat and pressure, said resistance element comprising a fused mixture of glass and carbonaceous material, the resistance of said element being on the order of

at least 60 ohms so as to reduce erosion of the electrodes by the spark.

14. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a section having its end normally exposed in the combustion chamber, a conducting ceramic seal securing and sealing said section in the bore, and a non-porous resistance element in the bore bonded to the insulator and to the seal under heat and pressure, said resistance element comprising a fused mixture of glass, boron carbide and tungsten carbide, the resistance of said element being on the order of at least 60 ohms so as to reduce erosion of the electrodes by the spark.

15. A spark plug comprising a shell, an insulator in the shell having a bore therein, an electrode in the bore comprising a section having its end normally exposed in the combustion chamber and having a core of metal of good heat conductivity, a conducting ceramic seal securing and sealing said section in the bore, and a non-porous resistance element in the bore comprising a fused mixture of ceramic insulating material and resistance material bonded to the insulator and to the seal under pressure, the resistance of said resistance material being on the order of at least 60 ohms so as to substantially reduce erosion of the electrodes by the spark.

16. A heterogeneous electrically conducting structure comprising a skeleton of continuous substantially non-conducting glass bond in which are embodied in sequence along its length finely divided copper, finely divided carbon and finely divided copper.

17. A spark plug comprising a shell, an insulator in the shell having a bore therein and an electrode in the bore comprising a resistance element consisting of a non-porous vitrified mixture of heat resistant glass and carbon black of coarse particle size bonded and compacted in the bore under heat and pressure, the resistance of said element being sufficient to substantially reduce erosion of the electrode by spark discharge.

18. The combination of a sleeve of insulating material, a heat and pressure compacted resistance element within and closing the passage through the sleeve and thermally bonded thereto, and seals having good electrical conductance, overlying the ends of the resistance element and thermally bonded thereto and to the sleeve and protecting the element from the atmosphere, said element and seal having a ceramic base, the melting point of said resistance element and said seal being substantially below the melting point of said sleeve to permit bonding of said element and seal thereto without deforming said sleeve.

19. The combination of a sleeve of ceramic insulating material, a resistance element within and closing the passage through the sleeve and having a ceramic base, said element being sintered and thermally bonded to the sleeve, and a seal having a ceramic base and having good electrical conductance overlying the resistance element and thermally bonded thereto and to the sleeve and protecting the element from the atmosphere, the melting point of said resistance element and said seal being substantially below the melting point of said sleeve to permit bonding of said element and seal thereto without deforming said sleeve.

20. The combination of a sleeve of ceramic insulating material, a sintered resistance element within and closing the passage through the sleeve and having a ceramic base, said element being

thermally bonded to the sleeve, and seals having a ceramic base and good electrical conductance overlying the ends of the resistance element and thermally bonded thereto and to the sleeve and protecting the element from the atmosphere, the ceramic base of said resistance element and said seals being of glass having a melting point substantially below the melting point of said sleeve to permit bonding of said element and seal thereto without deforming said sleeve.

21. A resistance element consisting of a dense, vitrified homogeneous mixture consisting of from 7.8 to 9% magnesium borate glass; from 11 to 25.6% fluorspar; from 1 to 4.6% carbon black; from 0 to 15% whiting; from 0 to 15% beryl, and the balance borosilicate glass.

22. A resistance element comprising a skeleton of continuous substantially non-conducting glass bond in which are distributed in sequence along its length finely divided good conducting metal, finely divided carbon and finely divided good conducting metal.

TAINÉ G. McDOUGAL.
KARL SCHWARTZWALDER.
ALEXANDER S. RULKA.

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