Feb. 23, 1943. J. A. DORAN 2,311,647

SPARK PLUG AND METHOD OF MAKING

Filed May 6, 1940 2 Sheets-Sheet 1

Fig. 1.

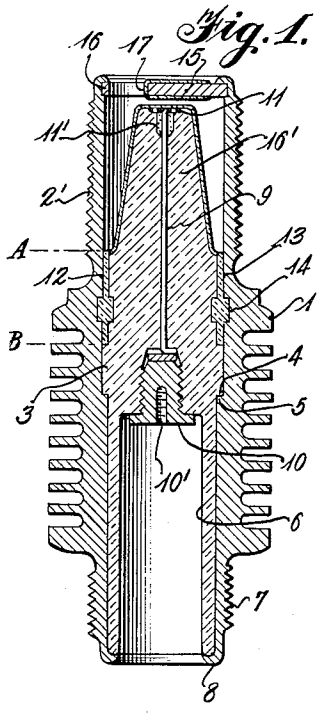


Fig. 2.

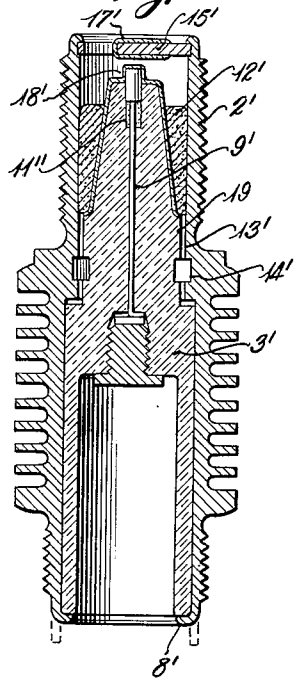


Fig. 3.

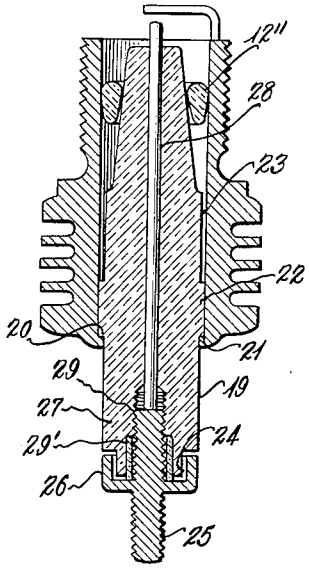


Fig. 4.

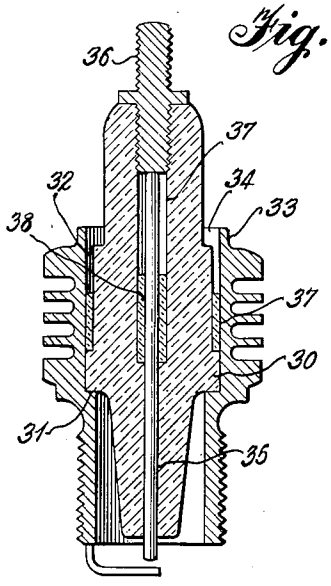
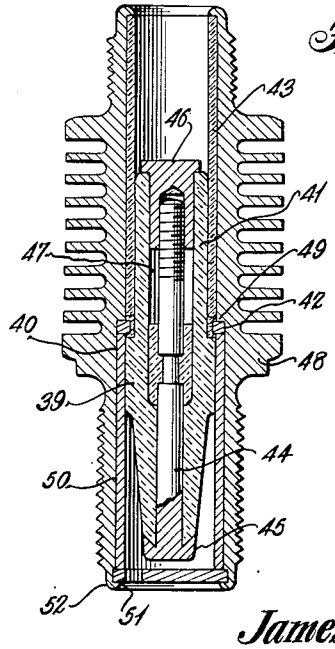


Fig. 5.



Inventor

James A. Doran

By Bacon & Thomas

Attorneys

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Fig. 6.

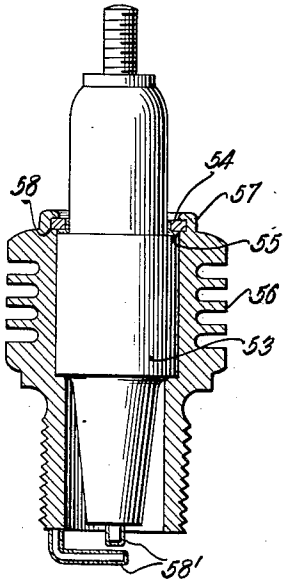


Fig. 7.

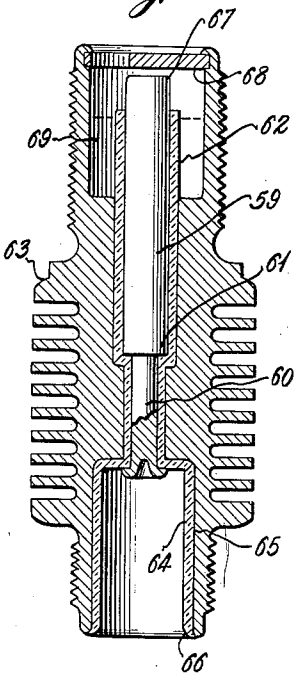


Fig. 8.

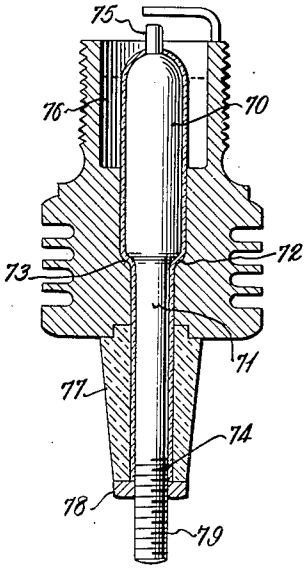


Fig. 9.



Fig. 10.



Fig. 11.

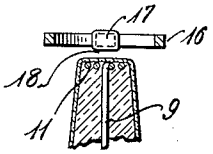


Fig. 12.

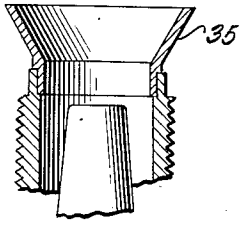
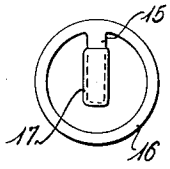


Fig. 13.



Inventor

James A. Doran

By Bacon & Thomas

Attorneys

Patented Feb. 23, 1943

2,311,647

UNITED STATES PATENT OFFICE

2,311,647

SPARK PLUG AND METHOD OF MAKING

James A. Doran, Providence, R. I.

Application May 6, 1940, Serial No. 333,681

19 Claims. (Cl. 123—169)

This invention relates to spark plugs and method of making and more particularly to a novel method of sealing the electrode in the insulator, and the insulator in the shell and also the spark plug produced thereby.

In making spark plugs by conventional methods, great difficulty is experienced in preventing gas leakage between the members. Gas leakage occurs in the majority of new spark plugs and, during use in an engine, leakage generally increases due to contractions and expansions from sudden and frequent changes in the operating temperatures. The damaging effects of such gas leakage are well known.

In spark plugs used on aircraft engines, gas leakage is especially serious, and is generally expected owing to the severe strains set up by abnormally high temperatures, severe vibration and large cylinder diameters. To overcome such leakage difficulties, and to obtain more efficient cooling of spark plugs, this invention provides a novel construction involving sealing of the members by fusing them together with molten glass or glass like compounds having definite characteristics. The sealing structure of the present invention also provides an improved and controllable path for heat dissipation from the plug in order to avoid, in a large degree, sudden changes in temperature of the elements of the plug and furthermore provides improved insulator surfaces and electrode sparking surfaces to reduce fouling of the plug and disintegration of the sparking surfaces.

One object of this invention is to provide spark plugs free from gas leakage.

Another object is to obtain more rapid and controlled dissipation of heat from spark plug electrodes.

Another object is to provide spark plugs with a complete heat range, in which a definitely controlled thermal path is employed to extract heat from the insulator tip and in which fouling of the plug is prevented.

Another object is to furnish spark plugs that operate at full efficiency over an unusually long period of time.

Another object is to provide a spark plug having safety and reliability over a long life, particularly in aircraft use.

Another object is to provide means for preventing deposits of carbon and lead oxide on the portion of the insulator exposed to combustion.

Another object is to prevent wear and erosion of spark plug electrodes.

Another object is to provide an electrical resistance at the spark gap to serve as a radio suppressor.

Another object is to provide an electrical resistance at the spark gap of sufficient amount to serve as a means for decreasing the "tail of the spark."

Another object of the invention is to provide an improved method of sealing either the inner electrode or the shell to the insulator to produce a gas tight plug and improved heat dissipation.

A further object of the invention is to provide a method of producing a spark plug by which the various members are secured together with a fused bond in order to prevent gas leakage while at the same time improved insulator and electrode surfaces can be produced.

A still further object of the invention is to provide a method and structure in which all members of a spark plug can be simultaneously fused together by a single continuous operation resulting in markedly reducing cost of production.

These and other objects and advantages will be apparent from the following description and accompanying drawings wherein:

Figure 1 is a sectional view of my preferred embodiment of a shielded spark plug, wherein the insulator is assembled into the firing end of the shell.

Figure 2 is a sectional view of a spark plug, prior to sealing, of the type where the mounting screw thread is of small size and in which the insulator is assembled into the outer or terminal end of the shell.

Figure 3 is a view similar to Figure 2 illustrating a conventional unshielded spark plug wherein the insulator is assembled from the firing end of the shell.

Figure 4 is a sectional view of a modified form of unshielded spark plug where the insulator is assembled into the outer end of the shell.

Figure 5 illustrates a modified form of shielded plug having a seal between the insulator and shell consisting of a metal collar fused to the insulator.

Figure 6 illustrates an unshielded spark plug having a sealing collar fused to the insulator.

Figure 7 shows a partly completed shielded plug constructed without use of a conventional insulator; but with a fused coating of insulating material between the center electrode and the shell sealing the electrode and shell together.

Figure 8 shows a construction similar to Figure 7, applied to an unshielded plug.

Figure 9 is an enlarged perspective view of the electrode of Figure 1.

Figure 10 is a plan view of the electrode of Figure 9.

Figure 11 is an enlarged sectional view of the electrodes shown in Figure 1, illustrating the glazed surfaces of these electrodes.

Figure 12 illustrates a special funnel required when the combustion space between insulator and shell is not of sufficient volume to accommodate the supply of unfused flux material.

Figure 13 is a plan view of the electrode used in Figure 1 and similar to the electrodes used in Figures 2, 5 and 7.

Figure 1 illustrates a spark plug provided with a shell 1 having the customary screw thread 2 for mounting in the cylinder of a combustion engine. An insulator 3 is mounted from the firing end of the shell and has a shoulder 4 abutting the ledge 5 in the shell 1. The insulator 3 has a well 6 in the outer end thereof designed to receive the terminal fitting of the cable. The outer end of the shell 1 has a screw thread 7 for receiving the locking nut of a standard shielded terminal elbow. The outer end 8 forms a protecting ledge for the insulator wall, but the insulator wall should preferably have clearance at this point in view of the fact that the shoulder 4 abuts the ledge 5.

An electrode 9, preferably made of platinum, although other heat resistant metal or allow having a coefficient of expansion similar to that of the material of the insulator 3 may be employed, and may be fused into the insulator 3 when it is vitrified as shown in my copending application Serial No. 317,795.

In the present construction, I prefer, however, to produce a vitrified insulator with a small bore therethrough to receive a small diameter wire, which wire may be sealed into the plug simultaneously with other sealing operations as hereinafter described. If sealed during this sealing operation with glazing material, the stem of the electrode 9 may be of copper or any other suitable metal with a tip 11 of electrode metal such as nickel or stainless steel welded thereto. The stem may, however, be of the same material as the electrode tip and may be of unitary construction requiring no welding. If the tip is to be covered with a protective glazed coating the entire electrode may be of any metal having a melting point above the fusing temperature of the sealing material.

Abutting the inner end of electrode 9 is a terminal block 10 with screw thread engagement in the insulator. This terminal block may be provided with a screw threaded bore 10' to receive a conducting pin for certain types of connectors. The firing end 11 of the electrode is preferably made as a spiral, shown in enlarged detail in Figures 9 and 10, although any other type of firing tip may be employed.

The insulator 3 is preferably secured to and sealed to the shell 1 by a body of solidified fusible material 12 positioned in a clearance space 13, which material adheres to both the metal of the shell and the ceramic material of the insulator. If desired registering locking grooves 14 in the shell and insulator may be employed to provide a locking ring of solidified fusible material. The sealing material 12 is preferably a glass or glass like material having a melting point lower than the material of the insulator or the metal of the shell and electrode but higher than temperatures encountered in the use of the spark plug.

In one embodiment of my novel method of sealing the insulator in the shell, the insulator is first assembled in the shell, then the combustion space between the firing tip and the shell is filled or partly filled with powdered fusible material, either dry or in a volatile carrier liquid. The partly completed plug of Figure 2 illustrates fusible material at 12' prior to fusing. The assembly of Figure 1 is then heated to a temperature sufficient to liquify the fusible material and cause it to flow by gravity into the clearance space 13 and locking groove 14. The volume of fusible material is preferably such as to fill the clearance space 13 without any surplus resting in the combustion chamber between insulator tip and shell after fusing. The assembly is then allowed to cool slowly so as not to fracture the fused material.

Before the fusing process it is preferable to position a ground electrode 15 in a recess 16 in the firing end of the shell 1 along with a small amount of a suitable breezing or welding material such as silver solder and a flux between the electrode 15 and the walls of the recess. Also, before the fusing process it is preferable to coat the tip 16' of the insulator and the firing end of the electrode therein with a glazing material of such composition that when fused it will be alkaline at the operating temperatures of the spark plug. Likewise, the firing portion 17 of the ground electrode is preferably coated with a fusible material. One way to accomplish the coating of the electrodes and insulator is to spray or otherwise apply a coating of powdered fusible material carried by a suitable binder, for example, a solution of an organic gum such as gum arabic of gum tragacanth. After fusing, the exposed surfaces 18 and 19 of the electrodes 15 and 9, illustrated in Figure 11, should preferably have a thickness of fused material, such as about .002" or .003". If the type of fusible material applied to the electrode surfaces is of a type having relatively low resistance under operating conditions in an engine, this thickness may be and is preferably increased.

In the fusing process the insulator is sealed to the shell, the alkaline glaze coating is fused to the insulator firing tip, and also to the ground electrode; and the electrode is brazed or soldered into the shell. The power electrode 9 may likewise be sealed or fused to the insulator at the same time. Since the sealing fusible material may become mixed with the glazing material for the insulator tip in certain embodiments of the present invention, it is preferred at least in said embodiments, to employ a sealing fusible material which is also alkaline. It is many times advantageous to glaze the portion of the insulator exposed to combustion and the portion of the insulator adjacent the sealing space with the alkaline glaze by a heating operation applied to the insulator prior to assembling it with the other portions of the plug. This can usually be done during the sintering of the insulator during manufacture thereof. The glaze on the insulator causes the sealing material to more readily bond with the insulator and to more readily flow into the clearance space provided for the sealing compound. Also, when powdered fusible sealing material either dry or in a carrier liquid is employed, sufficient space must be provided to hold a considerable volume of the

material since fusing the same causes a marked decrease in volume.

In this process of fusing I prefer to use an electric furnace with controlled temperature, equipped with a conveyor belt on which the spark plugs are placed so as to be moved through the heating zone. By this method of fusing the entire plug assembly is gradually brought up to the fusing temperature, is held at the fusing temperature a controlled period of time to insure the proper liquifying and flowing of the fusible sealing and glazing compounds, and the cooling period is prolonged and carefully controlled to prevent damage to the sealing compound. Slow cooling anneals the fused material and thus eliminates future breakage. This method of sealing an insulator in a shell gives a leak-proof spark plug which remains free from leakage under all engine operating conditions. An important insuring factor consists in the fact that the shell upon cooling contracts a substantial amount while the insulator contracts a negligible amount. Thus, the contraction of the shell compresses the sealing compound in its semi-plastic condition, and insures the absolute sealing of the two members.

When this novel spark plug is operating in an engine the temperature of the sealing compound is approximately 600° to 800° F. at which point the sealing compound preferably becomes slightly softened and more elastic. This fact insures that engine vibration and cylinder pressures cannot injure or crack the fused sealing material.

The fusible sealing material may be made of any desired refractory compound having the necessary fusion point and characteristics of adhering to metal and the ceramic material of the insulator. I find it preferable to use a siliceous material, such as silica or alkaline earth silicates containing from 5 to 15% cobalt oxide and having sufficient alkali metal or alkaline earth metal content to reduce the melting temperature to such a point that the material will liquify below the melting or softening temperatures of the various members of the spark plug structure. Thus, glass or glass-like compositions containing cobalt oxide and having a melting point between approximately 1000° and 1700° F. may be employed.

As to the glazing material on the insulator tip and the electrodes, it is preferable to use material which will be alkaline when fused. This is extremely desirable because, if such glazed surfaces should be of an acid nature, lead oxide (when using ethyl gasoline) tends to form objectionable deposits. However, I find that when the glazing material has a sufficient quantity of sodium or other alkali metal or alkaline earth metal and/or boron compounds, such as borax, the glazed surface will be alkaline and will discourage the depositing of lead oxide. If the electrode **9** is to be sealed to the insulator after the insulator has been vitrified, a recess **11'** may be provided for a supply of fusible material.

It has been thought impossible to extrude spark plug blank with an extremely small hole for the reception of a power electrode. A hole about .070" has been considered to be about the minimum possible. I have found that insulator blanks with holes as small as .005 can be produced in order to permit the use of a very small size wire of precious or other metal. Thus, wires varying from .001 to .007 in holes ranging from .005 to .015 can be employed.

The core pins of an extruding die to produce such holes must be of extremely small diameter. Ordinary metals will not withstand the large forces due to the high compressing under which the ceramic materials are extruded to obtain sufficient density of the blank. These pressures are measured in tons per square inch and the tensile stress on the core pin is enormous. It has been found that core pins made of tungsten or tungsten alloys stand up under such stresses without breakage. Obviously, another metal having tensile strength approaching that of tungsten may likewise be employed.

As previously explained, Figure 2 is a modified form of the construction shown in Figure 1, desirable when the screw thread **2'** may be of very small diameter. In such case the insulator **3'** has its sealing section **19** of smaller diameter than its body section. Clearance space **13'** is provided to receive the fused sealing compound. In this figure, the plug is shown prior to the heating required for the sealing operation. A quantity of unfused compound **12'** of such volume to fill the sealing space when fused is shown positioned in the combustion space of the plug. The recess **11"** also contains a supply of fusible material. In this modified form the electrode wire **9'** has a tip **18** preferably welded thereto which tip may be of any suitable electrode material. The center electrode tip **18** and the ground electrode tip **17'** of the grounded electrode **15'** are preferably coated with a fused material. The electrode **15'** is preferably brazed into the shell **2'** at the same time as the sealing material is being fused, as described with reference to the similar electrode of Figure 1. In this form it is desirable to have locking grooves **14'** to support the stresses from cylinder pressures. In this construction the outer end of the shell **8'** is formed in open position as indicated by the dotted lines, to permit entering the insulator into the shell; while after the assembling in the shell the upper edge is curled over to retain the insulator in the shell.

Figure 3 represents an unshielded spark plug with the insulator having an exposed portion **19**. The insulator has a shoulder **20** supporting it against a ledge **21** in the shell. The portion **22** fits the shell snugly while the portion **23** is smaller than the interior diameter of the shell to give the necessary clearance for the sealing compound. I have found that a clearance space ranging from approximately .015" to .020" is preferable in all forms of the spark plug herein illustrated as this thickness provides room for the entrance of the fused material and does not result in cracking due to too great thickness of the sealing material. This figure also illustrates a similar sealing of the center electrode to the shell. As indicated at **24**, a sealing space is provided by the construction of the terminal head **25**, which has a cup flange **26** loosely fitting on a reduced neck **27** of the insulator. The electrode stem **28** is welded or otherwise attached to the head **25**. The inner end **29** of the terminal head is preferably in screw threaded engagement with the insulator bore in order to facilitate assembly and to cooperate with the fused seal formed in the space **24**, in carrying the thrust from cylinder pressures. Instead of using powdered fusible material, a formed ring of fusible material **12"** may be placed in the combustion chamber of the plug. This ring preferably contains the correct amount of fusible material to just fill the sealing space **23** after the fusing operation. A similar formed ring **29'** of fusible material may be placed in a space provided between the terminal head and

the insulator 19. In the fusing operation the sealing of the insulator to the shell and of the terminal head to the insulator are accomplished simultaneously by fusing the rings 12'' and 29' and allowing the fused material to flow into the sealing spaces 23 and 24 respectively. Similar rings instead of powdered fusible material may also be employed in fabricating any of the spark plugs shown herein. During cooling, after fusing the sealing compound, the flange 26 contracts to a greater extent than the insulator to form a tight seal.

In Figure 4 is illustrated another modified form of an unshielded spark plug. In this case the insulator is assembled into the outer end of the shell. The insulator has a shoulder 30 resting on a ledge 31 in the shell. A clearance space 32 is provided, the lower end of which contains the sealing compound. The upper end of the shell 33 before being curled over provides a chamber 34 in which the unfused material is placed. This chamber may be too small to hold sufficient fusible material so that a funnel similar to 35 in Figure 12 may be employed in order to provide a container for sufficient fusible material. After fusing the funnel is removed from the plug. The center electrode 35 is welded or otherwise secured to the terminal head 36. An enlarged bore 37 provides a clearance chamber which is to be filled with fusible material when assembling the electrode in the insulator and shell. The assembly is heated to the required temperature, causing the fusible material to liquefy and flow by gravity into the lower portions of the sealing spaces 37 and 38.

Figure 5 illustrates a shielded spark plug of modified construction in which the insulator 39 has a shoulder 40 and a neck 41. A metal collar 42 having a coating of fusible material on its inner surface is placed against the shoulder 40. An insulation sleeve 43 is placed over the neck 41 abutting the collar 42. The electrode construction in this form consists of the electrode 44 with a head 45, secured in the insulator by threaded engagement with a terminal nut 46. When entering the electrode 44 into the insulator 39 a supply of fusible material is placed in the clearance space 47. The terminal nut 46 is then applied to hold the parts in assembled position. The fusible material on the metal collar 42 between the shoulder 40 and sleeve 43, and the fusible material between electrode 44 and insulator 39, is then fused by subjecting the assembly of the electrode and insulator parts to the fusing temperature, in order to form a unitary composite body of all said members. This composite assembly is then placed in the shell 48 with the collar 42 supported against the ledge 49 and securely sealed thereon by a metal sleeve 50 under pressure from electrode 51 and the curled over edge of the shell 52.

A similar construction for an unshielded plug is shown in Figure 6. The insulator 53 has a metal collar 54 fused against the shoulder 55 and the neck 56. After being fused in the manner previously described the assembled insulator and collar is inserted into the upper end of the shell 56 and the upper edge 57 is curled over to maintain sealing pressure of the collar 54 against the ledge 58 in the shell 56. A conventional electrode construction in which the electrodes have been coated with a glaze 58' is indicated in this figure.

The insulator of the spark plugs above described may be of any material conventionally employed, for example, various types of porcelain made of siliceous materials, or of powdered refractory oxides such as aluminum or magnesium oxide or mixtures thereof with a siliceous bonding material. Glass insulators have not heretofore been commercially employed, one reason being the difficulty of exerting sufficient pressure upon glass to enable a tight contact seal to be made with metal. By the present invention, insulators of high melting point glass can be successfully sealed to metal by means of a lower melting point glass-like fusible material as mechanical seals requiring high pressure upon the glass are not employed.

Figure 7 illustrates another modified form of a shielded spark plug which does not require the use of a ceramic or other insulator of conventional size and shape. The electrode 59 is made of any suitable electrode material, such as manganese, nickel or the like. It has a neck 60 at its outer end with a shoulder 61, to facilitate securing it in position. The electrode 59 is coated with a heavy film 62 of insulating fusible material which provides the electrical insulation between the electrode 59 and the shell 63. This coating of insulating material is continued beyond the electrode neck 60 to form the walls of the well 64 in the shell 63. Well 64 is formed by the bore 65 in the shell 63. The walls of the well extend to the end of the shell 66. The firing face of the electrode 67 forms a gap with the ground electrode, both of such gap surfaces being preferably coated with a thin film of the fused material.

There are several methods of manufacturing the construction shown in Figure 7. However, I prefer to first apply a coating of the fusible material to the electrode 59 by spraying the fused material or by applying it in any other convenient manner. The inner wall of the well 65 is also coated with the fused material preferably by a nozzle spraying device. However, if desired, this coating may be applied by having the fusible material in liquid form containing a gum binder which will permit the unfused coating to adhere to the wall 65 of the shell. After application of the fusible material to the electrode and to the interior of the well the electrode is assembled in the shell and placed in a furnace in inverted position so that an additional supply of unfused material may be placed in the combustion chamber as indicated at 69. Upon being subjected to the necessary temperature the fusible material will fuse in position and the surplus material at 69 will liquefy and flow by gravity to fill all void space between the electrode and the shell.

Figure 8 is a sectional view showing an unshielded spark plug similar to that shown in Figure 7. The electrode 70 has a reduced portion 71 in order to form a shoulder 72 which rests on the ledge 73 in the shell. The outer end of the electrode 70 is threaded at 74. The electrode 70 is first coated by spraying or otherwise, with a heavy coating of fusible insulating material on the entire length thereof excepting an exposed firing tip portion 75 and the terminal threaded portion 74. The electrode is assembled into the shell with the shoulder 72 supported on the ledge 73. Additional fusible material 76 is placed in the combustion chamber. Then the assembly is subjected to the proper fusing temperature, the additional supply 76 liquefying and flowing into the crevices between the insulator 70 and the shell. A protective collar 77 made of ceramic, glass, synthetic resins or any suitable insulating

material is preferably mounted above the shell in order to protect the fusible coating on the electrode 71. A locking nut 78 is now screwed down solidly against the protecting head 77, leaving the exposed screw thread 79 to receive a terminal binding nut.

With further reference to the thin coating of glazing material on the firing portions of the electrodes, great importance must be attached to the thickness and the ohmic resistance of these films. A minimum thickness of film is sufficient to encase the electrodes and protect them against corrosion, erosion, and burning away. However, for additional electrical purposes, the thickness of this film must be such as to obtain the desired ohmic resistance. Furthermore, the composition of this glazing material may be governed by having a compound sufficiently metallic to obtain the required ohmic resistance. This film on the center electrode may be utilized as a radio suppressor and for this purpose should have an electrical resistance of about 15,000 to 20,000 ohms to provide protection against the high-tension circuit affecting adjacent radio apparatus.

The insulating film on the electrodes may also be utilized to improve the intensity of the spark itself by minimizing or eliminating the "tail of the spark." For this purpose the ohmic resistance should be between 6,000 and 10,000 ohms. To obtain the desired resistance, the composition of the fusible material applied to the electrode surfaces may be varied, as indicated above.

In standard spark plugs, various metals, such as nickel, alloyed steel, platinum, tungsten, etc. are used, in the effort to prevent, (1) corrosion from the gases; (2) erosion by action of incoming and outgoing gases; (3) burning away of the metal by the arcing effect of the spark. All of these troubles are eliminated by this device whereby the electrode gap surfaces are sealed by a glazed film that protects the sparking surfaces from all the above destructive factors. Thus less expensive metals may be employed and are protected so as to have an indefinitely long life.

It has already been explained above that the fusible material may be so compounded that it will weld to the steel walls of a conventional shell, and then simultaneously impregnate and bond to the insulator. Other types of shells such as shells of non-ferrous metals can be employed in the present invention and the fusible material modified to produce an effective welded seal therewith. Furthermore, the sealing material should have approximately the same expansion under varying temperatures as the metal of the shell or at least an intermediate expansion between that of the metal of the shell and the insulator. For such purpose a silicious material containing 5 to 15% of cobalt oxide proves to be practicable and satisfactory for welding to steel or iron as well as non-ferrous metals. However, any other type or compound of fusible material may be substituted providing it will maintain the sealed and welded relation between the members, and will maintain such relation under all engine operating conditions of the spark plug.

An important feature of this invention resides in the actual welding of the insulator to the shell. The welding material acts as a flux for the forming of the weld. The method of sealing and welding an insulator in a shell, including the filling of a chamber with unfused material, enables the unfused material to serve as a protection against oxidizing of the surfaces to be welded until the unfused material becames a molten flux.

In all standard spark plug constructions great difficulty has been experienced in assembling the members so as to obtain a satisfactory thermal flow by conduction between these members. As spark plugs are subjected to high temperatures and pressures, particularly in aircraft engines, standard methods of obtaining thermal flow all prove insufficient for dissipating heat away from the insulating firing point with the result that such engines cannot safely operate with open throttles and maximum supercharging pressure. This invention, therefore, is valuable in the respect, that it provides control of heat dissipation which can be varied to provide for spark plug operation under any desired conditions without preignition. This degree of heat resistance is controllable by selecting a suitable area of sealing surface such as the circumferential area in the distance from A to B in Figure 1. As a specific example, a plug of the type shown in Figure 1 having a distance from A to B of ⅜ inch and a diameter of insulator of ½ inch will not preignite in engines of 1500 horsepower with 6½ to 1 compression and a high pressure of supercharging operating under full open throttle. In an engine of 300 horsepower at 6½ to 1 compression without supercharging the distance from A to B need be only ⅛ inch. It is apparent that such a controllable area can be employed to produce plugs capable of operating an engine with open throttle at any desired compression ratio and with any desired supercharging pressure without preignition.

The area of welded bond is selected to give any desired rate of heat dissipation in order to provide a definite point at which preignition will occur in any given engine. At the present time no plug will operate satisfactorily under a compression ratio much above 6½ to 1. The present plug can be provided with a bond area sufficient to extract heat fast enough to operate at any desirable higher compression ratios. The bond in combination with adequate radiating fins is capable of dissipating extremely large amounts of heat. This was not true in prior plugs since the construction was such that the thermal path was obstructed by varying contact between various layers of material between the center electrode and the radiating fins. The fins could not effectively function as radiators since the resistance to heat flow to the fins was excessive. In the present plug a definite controllable continuous heat path of high heat conductivity is established by welding or fusing the unlike materials together so that the heat is delivered to the fins at any desired rate and radiated thereby.

Ordinarily, when a plug is as cold as described in the above paragraph, great fouling trouble is experienced particularly when starting, because the insulator tip is at a low temperature. In order to overcome such fouling tendency I provide an insulator with a wire electrode of small diameter, which is glazed into the insulator. Such insulator is virtually a solid mass. Being solid, the firing tip is not susceptible to breakage. With such construction the insulating tip may safely be of very small exterior diameter and of considerable length and still have a high safety factor. This produces an abnormally large chamber between the insulating tip and the shell. Such a large chamber causes the exhaust gas to be readily scavenged. The chamber, thereby, constantly fills with fresh gas and live flame which acts to consume carbon and lead in suspension

and thus prevent deposition thereof upon the insulator tip. The large volume of flame would ordinarily overheat any insulator tip; but with my welded connection between insulator and shell, such heat is dissipated so rapidly that the insulator tip remains cool while being cleansed with flame.

Another most important advantage of maintaining a cool insulator is that the insulation qualities of the insulator are always maintained. It is a well known fact that when an insulator is at a high temperature, its electrical resistance is greatly reduced thereby causing electric leakage with consequent impairment of spark strength. Also, the method of constructing spark plugs in accordance with the present invention absorbs variation and irregularities in the insulator and enables larger tolerances in the metal members, thus reducing rejects as well as costs due to close tolerances ordinarily required in spark plugs.

In the above description I have confined the subject matter of the present invention to the construction of spark plugs, and I have disclosed a novel and practicable method for bonding and welding a ceramic surface to a metal surface without any leakage therebetween. This method is applicable to a great many uses in the electrical and other arts wherever it may be advantageous to bond a metal member in the interior of a ceramic member or to weld a ceramic member to the interior of a metallic member. It is understood that the invention is not to be limited to the specific embodiments described and shown but that the details of the invention may be varied within the scope of the following claims.

I claim as my invention:

1. In a spark plug, a core of ceramic insulating material, a metallic shell around said core, said core and shell having formed therebetween stepped annular cavities freely communicating with one end of said plug to provide a clearance space therebetween, and a fusible compound having a lower melting point than the material of said core and said shell, having been applied via said one end of said plug and positioned in at least one of said cavities and fused to said core and said shell.

2. In a spark plug, a core member of ceramic insulating material, a metallic electrode member extending through said core, a metallic shell around said core, said members being formed to provide clearance spaces therebetween communicating with one end of said plug, a glass-like fusible compound having a lower melting point than the materials of said members positioned in said clearance spaces via said one end and fused to said members to provide a gas tight seal between said members.

3. In a spark plug, a core of ceramic insulating material, a longitudinal hole in said core having an enlarged recess formed therein near the tip thereof, a metallic electrode extending therethrough, said electrode and shell being formed to provide a clearance space therebetween, and a fusible glass-like material having a lower melting point than the materials of said electrode and core positioned in said recess and in said clearance space and fused to said electrode and said core to provide a gas tight seal between said electrode and said core.

4. In a spark plug for internal combustion engines a metallic shell and a core of ceramic insulating material sealed therein, the portion of said core exposed to the combustion chamber of said engine being provided with a glazed coating of material which is alkaline at the operating temperature of said spark plug.

5. In a spark plug, a shell, an inner electrode insulated from said shell and a ground electrode carried by said shell, said electrodes having the sparking portions thereof covered by a thin layer of glazed insulating material having a lower melting point than the material insulating said electrode from said shell.

6. In a spark plug, a shell, an insulator, an inner electrode mounted in said insulator and a ground electrode carried by said shell, at least one of said electrodes having the sparking portion thereof covered by a thin layer of glazed insulating material having a lower melting point than said insulator and said glazed insulating material being alkaline at the operating temperature of said spark plug.

7. In a spark plug, a ceramic insulating core, an electrode extending through said core, the portion of said core exposed to the combustion chamber of an engine and the sparking portion of said electrode being covered by a thin layer of glazed material having a lower melting point than said ceramic and which is alkaline at the operating temperature of said engine.

8. In a spark plug for internal combustion engines, a metallic shell provided with heat radiating fins, a core of ceramic insulating material positioned within said shell, a controlled circumferential cavity formed partially within said shell and partially within said core and communicating with the firing end of said plug, and a body of insulating material introduced via said firing end after said core and shell are assembled fused to said shell adjacent said firing end by heating said assembled plug, thereby providing a continuous thermal path from said core to said radiating fins.

9. In a spark plug for internal combustion engines, a metallic shell, a core of ceramic insulating material positioned within said shell and having its firing end of small diameter relative to the inside diameter of said shell and of substantial length, thereby providing a large combustion chamber in said plug, an electrode of small diameter relative to the diameter of said portion of said core extending through said core to provide clearance therebetween, said core being fused to said electrode and having a controlled circumferential area thereof adjacent said portion fused to said shell in order to provide a continuous thermal path from said electrode to said shell.

10. The method of assembling a spark plug having an insulator of ceramic material and a metallic shell around said insulator, which comprises positioning said insulator within said shell, providing annular communicating clearance spaces between said shell and said core, one to form a compartment for containing fusible sealing material before the same is fused and the other to receive the fused material from said compartment, and the final step of heating said core, shell and fusible material to a temperature sufficiently high to melt said fusible material and cause it to flow into said clearance space and weld with said core and shell.

11. The method of making a spark plug having a core of ceramic insulating material and an electrode extending therethrough, which comprises, positioning said electrode in said core, providing a clearance space between said electrode and said core, providing a compartment above said clear-

ance space and communicating therewith introducing a fusible material into said compartment, and heating said electrode, core and fusible material to cause said fusible material to melt and flow into said clearance space and weld with said core and said electrode.

12. The process of making spark plugs, which comprises, extruding a core of ceramic material under high pressure and with a small central bore, inserting an electrode of small diameter into said bore and inserting said core into a shell, an annular pocket being provided between said core and said shell communicating with one end of said shell, providing a supply of glass-like fusible sealing material between said core and said shell and in said end of said shell and on said electrode at the end of said core, heating the resulting assembly to a temperature above the fusing point of said fusible material to cause the same to weld to said electrode, said shell and said core together, and slowly cooling the heated assembly to form an annealed gas tight seal of solidified glass-like material between the elements of said assembly.

13. In a spark plug, a core of ceramic insulating material, a metallic shell around said core, an electrode extending through said core, an annular pocket formed partially in said shell and partially in said core a fused insulating material in said pocket and bonded to both the core and the shell, a sealing medium bonded to said shell and to said electrode to provide a gas tight seal therebetween, a ground electrode carried by said shell, the portion of said core adapted to be exposed to the combustion chamber of said engine being provided with a glazed coating of material which is alkaline at the operating temperature of said spark plug and at least one of said electrodes having the sparking portion thereof covered by a substantially thin layer of glazed material of a constituent different from said ceramic.

14. In a spark plug, an elongated core member formed of ceramic material and having stepped annular grooves formed in a zone therein, a shell member having a stepped bore therein and having a portion of its length fitting a portion of the length of said core for holding the stepped portions of said members in concentric relation to each other, and fused insulating material lying within at least one of said grooves and bonded with both said members, said fused material having entered its groove via an adjacent groove while molten and while said members were heated to a temperature approximate to that of the melting point of said material.

15. In a spark plug, an elongated ceramic core having a longitudinal hole therethrough, said hole having a portion of its length enlarged near one end thereof to form a recess, a metallic electrode rod extending through said hole, and a non-metallic bonding material fused in said recess by heat applied to said core and electrode after assembly.

16. A spark plug according to claim 14, in which said fused insulating material includes between 80 and 90% of silicious material and between 5 and 15% cobalt oxide.

17. A spark plug according to claim 14, in which said fused insulating material includes approximately 11% of cobalt oxide.

18. In the manufacture of spark plugs, the method of sealing a ceramic core member in the bore of a shell member, which comprises the steps of: forming matchel annular spaces in said members, supporting said core member in fixed relation to said bore, heating said plug and causing molten vitreous material to flow into said annular spaces and form bonds with both said members, and the final step of slowly cooling said plug to a normal temperature, thereby annealing said vitreous material.

19. In the manufacture of spark plugs, the method of sealing a ceramic core member in the bore of a shell member, which comprises the steps of; forming matched annular spaces in said members freely communicating with one end of said plug, supporting said core member in fixed relation to said bore, heating said plug and causing molten vitreous material to flow into said annular spaces via said one end and form bonds with both said members, and the final step of slowly cooling said plug to a normal temperature, thereby annealing said vitreous material.

JAMES A. DORAN.