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SPARK PLUGS AND METHODS OF PRODUCING SAME

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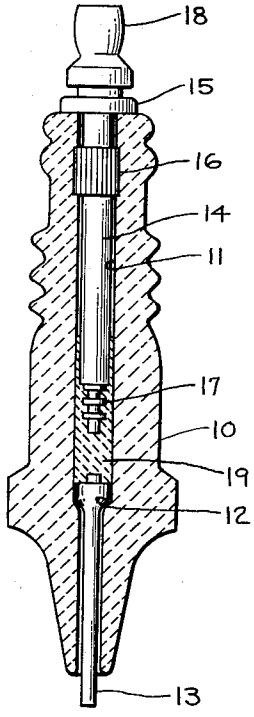


FIG. 1.

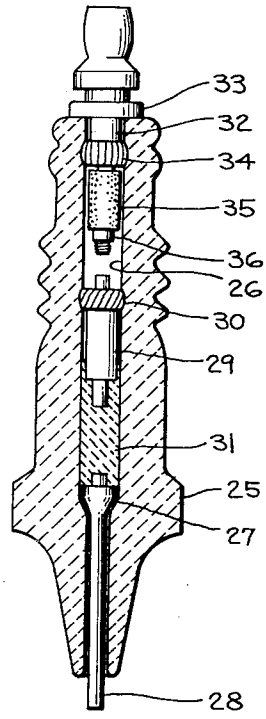


FIG. 3.

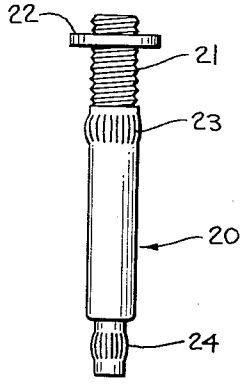


FIG. 2.

INVENTOR.
HARRY G. SCHURECHT
BY Owen & Owen
ATTORNEYS

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3,046,328

SPARK PLUGS AND METHODS OF PRODUCING SAME

Harry G. Schurecht, Detroit, Mich., assignor to Champion Spark Plug Company, Toledo, Ohio, a corporation of Delaware

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4 Claims. (Cl. 174—152)

This invention relates to spark plugs, and, more particularly, to spark plugs containing an improved, confined, electrically conducting, vitreous sealing means, and to a method for producing such spark plugs.

It has heretofore been proposed to seal the center bore in which the center electrode of a spark plug is disposed by fusing a layer of pulverized glass in the annular space between the electrode and the bore, or above a lower section of the center electrode, and, in the latter case, to make the seal of electrically conductive material.

In producing such known constructions, the parts to be sealed are usually assembled with the sealing material either in the form of a layer or mass of powdered glass with metal or other powders added, or with the composite sealing material in the form of a pellet. The material is then sufficiently softened by heating and the parts are brought into their final position by forcing an upper terminal electrode section into place against or through the molten glassy material. It is apparent that such a method requires individual heating of each spark plug and makes impossible the production of spark plugs on a mass scale by a method in which the formation of the seal by melting of the glassy material takes place during the passage of an assembled unit through a furnace. The seal produced by a method in which the glass is pressed while molten is a dense, inflexible mass which functions well as a seal only if no significant difference exists in the absolute thermal expansion of the seal parts.

In addition, the glassy material commonly employed in known constructions sometimes exhibits a tendency to boil out during the heating step when not confined and it has been proposed to reduce this tendency by adding to the glass a portion of the material of which the spark plug insulator is made, such material being finely powdered prior to its addition. Other attempts have been made to confine the glass sealing material during the melting step with all of the parts disposed in their final position, but these attempts have required the formation of screw threads within the insulator bore and have otherwise been cumbersome and expensive.

In a copending application, Serial No. 447,792, of Harry G. Schurecht, now United States Patent No. 2,898,395, a spark plug assembly is disclosed in which the vitreous sealing means is composed of a material which expands into a vesicular structure upon heating and occupies, after cooling, a volume greater than before such heating. It has been found that such a seal is flexible, having pockets of gas distributed therethrough, and that the pockets, because the gas is capable of contraction and expansion, serve, in essence, to cushion stresses to which the seal is subjected in service. Ordinarily, such stresses result from differences in coefficient of thermal expansion of the sealing material itself and of associated metallic and ceramic parts. The "pores" of the seal are, of course, separated by walls of the sealing material so that gas leakage from one end of the seal to the other is prevented.

In producing such structures as are disclosed in the above mentioned application, it is essential that the expansible sealing material be at least partially confined during the heating step due to the inherent propensity of such a sealing material to foam and boil during the time that it is heated in producing a seal. Unless confined, the resulting seal may be of such high porosity that it leaks because a continuous path of bubbles has formed, and remains after hardening of the seal, or may actually boil from the space to be sealed. The confinement can be by a tamped layer of refractory metals or metal oxides, or mixtures thereof, or by a separate cup-shaped metal member as disclosed in the said Patent No. 2,898,395. The confinement has two distinct advantages, namely, of overcoming the tendency to foam and boil, and of increasing the capability of a sealing material to wet the metal of the electrode parts, but the pressure on the seal material is not sufficient to produce an undesirably dense, inflexible seal, such as results in the known processes previously described from the application of high mechanical pressure.

It has now been discovered, and the instant invention is based upon such discovery, that excellent spark plugs can be produced on a mass scale during the passage of an assembled unit through a furnace when utilizing an expansible, electrically conducting, vitreous sealing material therein by providing at least one frictionally anchored electrode part in the insulator bore. More particularly, the instant invention provides a method which comprises seating a first electrode part in a central bore of a spark plug insulator, inserting a quantity of the expansible sealing material into the bore, and then urging a second electrode part into the insulator bore and into a predetermined position where it is frictionally anchored relative to the insulator with at least a portion of the said sealing material being confined between, and in contact with, each of the electrode parts, so that upon heating the sealing material to a temperature sufficient to cause its expansion, it is pressed into sealing relationship with the insulator bore and upon cooling, is effective to prevent the flow of a gas therethrough.

It has been found that a frictionally anchored electrode part in the bore serves as a packing or confining member for the glass sealing material, and, further, can eliminate the need for threading an insulator and an electrode part since the frictional engagement prevents such electrode part from being moved by the boiling and expansion of the vitreous sealing material. Not only is such an assembly inexpensive to manufacture, but, also, there are various other significant advantages. For example, since the portion of the insulator in frictional engagement with the electrode part is held in compression therewith, such portion of the insulator is more resistant to impact. Further, assembly of the spark plug parts is made simpler as the glass sealing material, e.g., in the form of a pellet, is upset as a result of the force exerted thereon by the urging of the second electrode part into frictional engagement with the insulator bore, thus eliminating the need for a separate tamping operation to upset the pellet. The seal produced is fine grained but is a porous or vesicular structure in which essentially all voids are surrounded completely by an adequate layer of a homogenous, strong material. As a result of the vesicular structure, or closed porosity, the seal is sufficiently flexible to yield without rupture under the stress caused in service by unequal thermal expansion of metallic and ceramic parts with which it is associated.

It is, therefore, an object of the invention to provide an improved spark plug assembly.

It is a further object of the invention to provide a novel method of retaining the glass seal within the bore of a ceramic part of a spark plug in such a manner that the glass seal material is not displaced during the formation of the seal, which formation takes place with the glassy material under a pressure produced only by its confinement.

Another object of the invention is to provide an expedient method for producing spark plug seals on a mass

scale in which the firing of the seal takes place during the passage of an assembled unit through a furnace.

Other objects of the invention will in part be apparent, and in part appear hereinafter.

For a better understanding of the nature of the objects of the invention, reference should be had to the following detailed description and to the attached drawings, in which:

FIG. 1 is a central vertical sectional view of an insulator and center electrode assembly according to the invention, including a knurled upper electrode part;

FIG. 2 is a fragmentary view in elevation of a modified form of an upper electrode confining means for use in producing an assembly according to the invention; and

FIG. 3 is a central vertical sectional view of an insulator and electrode assembly according to the invention for use in an auxiliary gap spark plug.

Referring now to FIG. 1 of the drawings, reference numeral **10** indicates a ceramic insulator having a longitudinal bore **11** extending therethrough. The bore is provided with an internal shoulder **12** adjacent the lower end of the insulator to provide a seat for a lower, nickel sparking electrode part **13**. An upper or terminal electrode part **14** of cold rolled steel is positioned in the upper insulator bore and provided with a shoulder **15** limiting the extent of insertion of the electrode part into the bore, and a raised portion comprising a vertical knurl **16**. The various projections provided on the electrode part **14** by the knurl **16** effect a plurality of frictional supports whereby the electrode contacts the surfaces of the bore and becomes firmly anchored therein.

The lower end of the upper electrode part **14** is provided with grooves as indicated at **17** in order to better anchor the upper electrode in the glassy material and make it more resistant to any torque produced by tightening a stud screw **18**, in the instance where a separate, threaded stud screw is employed.

An expanded, electrically conducting vitreous sealing material consisting of 82.5 parts by weight of a "Glass A," [1] 12.5 parts by weight of aluminum metal powder, 3 parts by weight of Tennessee ball clay, 3.0 parts by weight of bentonite, and 0.5 part by weight of graphite, and indicated at **19** is disposed generally between the electrode parts **13** and **14** and in contact therewith. The expanded sealing material is confined in its desired position in the insulator bore **11** by the lower electrode part **13**, and the upper electrode part **14**, and pressed, by its expansion, into sealing relationship with the insulator bore **11** thereby acting to prevent a flow of a gas therethrough. The clearance between the upper electrode part **14** and the bore **11** is held to fairly close tolerance since no holding powder or other additional confining means is utilized.

The terms "percent" and "parts" are used herein, and in the appended claims, to refer to percent and parts by weight, unless otherwise indicated.

A modified upper electrode structure is shown in FIG. 2. In this structure, the upper electrode part **20** is provided with threads **21** at the top thereof in order that it may receive a threaded stud washer **22** and stud (not shown). The remainder of the upper electrode part is constructed in substantially the same manner as that shown in FIG. 1, with a vertical knurl **23** being provided beneath the threads **21** and a knurl **24** being provided on the lower end of the upper electrode part **20**.

[1] Glass A has the following composition:

	Percent
PbO	35.19
SiO_2	40.93
Al_2O_3	5.18
B_2O_3	14.63
Na_2O	1.35
K_2O	1.33
Li_2O	0.35
TiO_2, Fe_2O_3, CaO, MgO	0.18

In addition, Glass A has an ignition loss of 0.04%.

The advantages of this upper electrode structure will be subsequently explained in more detail.

Referring now to FIG. 3, the auxiliary gap assembly illustrated therein employing the frictional engagement confining means in accordance with the invention comprises a ceramic insulator **25** having a longitudinal bore **26** extending therethrough. The bore is provided with an internal shoulder **27** adjacent the lower end of the insulator **25** to effect a seat for a nickel, lower sparking electrode part **28**. A center electrode part **29** is positioned in the insulator bore **26** and provided with a raised portion comprising a diagonal knurl **30**. The various projections provided on the surface of the electrode part **29** by the knurl **30** provide a plurality of frictional supports whereby the said electrode part **29** contacts the surfaces of the bore **26** and becomes firmly anchored therein.

An expanded electrically conducting, vitreous sealing material of the same composition as that employed in the assembly illustrated in FIG. 1, and indicated at **31**, is disposed generally between the electrode parts **28** and **29** and in contact therewith. The expanded sealing material **31** is confined in its desired position in the insulator bore **26** by the lower electrode part **28** and the center electrode part **29**, and pressed by its expansion into sealing relationship with the insulator bore **26**, thereby acting to prevent the flow of a gas therethrough. As in the assembly disclosed in FIG. 1, the clearance between the electrode part **29** and the bore **26** is held to fairly close tolerances since no holding powder or other additional confining means is utilized.

An upper or terminal electrode part **32** is positioned in the upper insulator bore and provided with a shoulder **33** to limit the extent of its insertion into the bore, and to provide a predetermined spacing or gap between the upper projection of the center electrode **29** and the lower projection of the electrode part **32**. A suitable knurl **34** is provided on the electrode part **32**, the projections of which contact the surface of the bore **26** and anchor the part **32** therein. The upper or terminal electrode part **32** also includes a cylindrical, pre-formed glass seal **35** having a central cylindrical opening therein, which pre-formed seal is held in position surrounding a portion of the length of the electrode part **32** by any suitable means, such as a nut **36**. The composition of the pre-formed glass seal may suitably consist, for example, of 60 parts of Glass A, 40 parts of alumina and 3 parts of betonite.

The vitreous sealing material employed in accordance with the invention is, as previously mentioned, one which expands into a vesicular structure upon heating and occupies, after cooling, a volume greater than before such heating. Such glass sealing material may comprise powdered glass in admixture with an infusible substance insoluble in said glass. For example, excellent results have been obtained by using the following compositions as glass seals in addition to the composition previously mentioned and employed in the assemblies of FIGS. 1 and 3:

Material	Parts by Weight		
	1	2	3
Glass A	82.5	77.5	80.0
Aluminum metal powder	12.5	17.5	15.0
Tennessee Ball Clay	3.0	3.0	3.0
Bentonite	2.0	3.0	2.0
Graphite	0-0.5	0-0.5	0-0.5

In addition to Glass A, various other glass compositions may be successfully employed in the vitreous sealing materials. For example, excellent glass seals have been produced when utilizing, in the expansible, sealing composition, a glass consisting of 74.37 percent PbO, 3.77 percent SiO_2, 8.89 percent Al_2O_3 and 9.72 percent B_2O_3, said

glass having an ignition loss of 3.25 percent. A further glass composition that has been successfully employed in producing expansible, electrically conducting seals consists of 66.6 percent of PbO, 23.5 percent of SiO_2, 2.9 percent of Al_2O_3 and 7.0 percent of B_2O_3.

Numerous and various other vitreous compositions exhibit the property of being expanded upon heating and occupying, after cooling, a volume greater than prior to such heating, and the above examples of specific compositions are in no way intended to be limitative thereof. In this respect, reference may be had to the previously mentioned copending application for further examples of suitable, expansible, electrically conducting glass sealing compositions.

The lower or sparking electrode part of spark plug assemblies produced in accordance with the instant invention should be made of a metal or metal alloy, having good high temperature and corrosion resistance. For example, in addition to the use of nickel as the sparking electrode part, excellent results have been obtained with the use of nickel-iron alloys and nickel-manganese alloys.

The raised area or knurl provided on the upper electrode part, and in addition provided on the central electrode part in an auxiliary gap assembly, may be made at any desired position on the electrode part that extends into the insulator bore. However, since the upper portion of the insulator is more apt to be subjected to impact than the lower portion thereof, and since frictional engagement of the upper electrode part, with the upper portion of the insulator is more likely to pre-stress such upper portion of the insulator and thereby increase its resistance to impact, the best results have been obtained when the knurl is constructed at the upper end of the upper electrode part.

To effectively anchor the upper electrode and center electrode parts in the insulator bore in order to prevent them from being forced up by the boiling and expansion of the glass sealing material, the diameter of the raised portion or knurl is preferably constructed approximately 0.002 inch to 0.005 inch larger than that of the insulator bore. Excellent results have been obtained when employing a knurl having a diameter of 0.157 inch with an insulator having a bore diameter of 0.153 inch.

The lower end of the upper electrode part in a conventional assembly, such as shown in FIG. 1, and the lower end of the center electrode part in an auxiliary gap assembly, such as shown in FIG. 3, are preferably, but not necessarily, provided with a roughened surface such as a series of grooves, threads, a knurl or the like, in order to better anchor the electrodes in the glassy material. In addition, in the case of the conventional assembly, the roughened surface also provides an excellent resistance to any torque produced by tightening the stud screw in the instance where a separate stud screw is employed. If desired, the knurl, grooves, or threads may be made to slightly overlap the lower diameters of the said electrode parts and thus also serve to provide an even smaller clearance between the insulator bore and the electrode part at that point. In this respect, it is again noted that the clearance between the upper or central electrode part and the bore of the insulator must be held to fairly close tolerance in the absence of holding powder or other additional confining means. If the clearance is too great, the glass sealing material, upon heating thereof, may boil up into the upper bore causing the glass seal to become honeycombed and thus leak. Preferably, this clearance is held to a maximum of 0.007 inch. Excellent results have been obtained when using an electrode part having a diameter of 0.148 inch to 0.150 inch in an insulator bore of 0.153 inch diameter. The upper or terminal electrode part is preferably made of cold rolled steel or other good heat conducting material.

In producing a spark plug assembly, such as illustrated in FIG. 1, a lower electrode part **13** is first inserted into the insulator bore **11** and seated on the shoulder **12** provided therein. A predetermined quantity of glass sealing material **19** of the desired composition, either in powder form or pellet form, is next inserted into the bore. The upper electrode part **14** is then inserted in the bore and force is applied thereto to advance the raised portion or knurling **16** to enter the bore thereby anchoring the upper electrode part therein. In this respect, it should be noted that the pressure applied to the upper electrode part should be great enough to thoroughly tamp the sealing material into place. Therefore, if greater force is required to accomplish sufficient tamping or upsetting of the sealing material than is necessary to force the knurling into the insulator bore, such greater force must be applied. Generally, a force in the range of approximately 400 pounds to 700 pounds has been found to be sufficient in this respect. After the upper electrode part is securely in place, the assembly is then placed in a suitable furnace and heated to a temperature sufficient to at least soften and mature the sealing material. Generally, the maturing temperature of the expansible, electrically conducting glass sealing compositions employed in accordance with the invention is in the range of 1100° F. to 2200° F.

In producing the assembly illustrated in FIG. 1, it will be appreciated that care must be taken in correlating the size of the glass sealing pellet or amount of glass sealing powdered material employed, the length of the upper electrode part below the shoulder thereof, and of the diameter of the bore, with the force required to urge said upper electrode into place and tamp and upset said sealing material. For example, if a pellet is not of sufficient mass, or if too little powder is provided, or if the bore is larger than usual, said pellet may not receive the full tamping pressure and the resulting seal may leak. On the other hand, if the pellet consists of too great a mass or if too much powder is provided, or if the bore is smaller than average, the shoulder on the upper electrode part will not be flush with the top of the insulator causing the spark plug stud to have a weak appearance.

In order to overcome this difficulty, use can be made of the modified upper electrode structure illustrated in FIG. 2. When employing this structure, the full force on the electrode would be transmitted to the glass sealing material in all cases, even when the amount of glass sealing material varied, since the stud washer is screwed in place after the pressure has been applied. Further, closure contact of the stud washer and stud to the insulator would also be assured, and hence the upper portion of the insulator would be more apt to be pre-stressed and therefore more resistant to impact.

In producing the auxiliary gap spark plug assembly illustrated in FIG. 3, the lower electrode part **28** is first inserted into the insulator bore **26** and seated on the shoulder provided therein. A predetermined amount of glass sealing material **31** in powder or pellet form is then inserted into the bore. The center electrode part **29** is then inserted into the bore and force applied thereto to advance the knurling **30** provided thereon into the bore and additionally to cause the center electrode part to upset or tamp the pellet or powder in place. A preformed glass seal **35** is placed on the upper electrode part and held in place thereon by the nut **36** secured to the lower end of the upper electrode part **32**. The electrode part **32**, together with the preformed seal is then inserted into the insulator bore and force is applied thereto to advance the knurling provided thereon into the bore and to seal the shoulder **33** of the electrode part **32** on the top of the insulator. After the upper electrode part **32** is securely in place, the resulting assembly is placed in a suitable furnace and heated to a temperature sufficient to soften and mature the sealing material. The assembly is then removed from the oven and allowed to cool.

The following example constitutes the best presently known mode for practicing the instant invention and describes the formulation of a suitable, expansible, electri-

cally conducting, vitreous sealing means, and the construction and method of assembly of the various parts employed in producing a spark plug in accordance with the invention.

Example

An insulator, such as shown in FIG. 1, having an upper bore diameter of 0.153 inch was provided and a lower, nickel electrode inserted therein and seated upon the shoulder formed by the transition of the said upper bore diameter into the smaller diameter, lower bore. A cylindrical glass sealing pellet 0.320 inch in length and having a diameter of 0.149 inch and a central cylindrical opening therein of about 0.054 inch diameter was then inserted into the upper bore. The glass sealing pellet weighed about 0.21 gram and had the following composition:

	Parts
Glass "A"	77.5
Aluminum metal powder	17.5
Tenn. ball clay	3.0
Bentonite	2.0
Graphite	0.5

An upper electrode part such as shown in FIG. 2, having a major diameter of 0.150 inch and a rectangular, cross sectional shaped projection at the lower end thereof approximately 0.0875 inch by 0.061 inch and 0.125 inch in length was then inserted in the insulator bore. The electrode part was knurled at its upper end just beneath the threads, the projections of the knurl extending outwardly from the electrode part approximately 0.007 inch. A force of 500 pounds was applied to the upper electrode part, a later section of the completed assembly showing such pressure produced a gap of approximately 0.1875 inch between the upper lob of the lower electrode and the bottom of the projection on the upper electrode.

A stud washer was then applied to the threaded end of the upper electrode and screwed down until it was flush with the insulator. A stud screw was then threaded on the upper electrode to complete the assembly.

The resulting assembly was then placed in a furnace previously heated to 1450° F.; the furnace was allowed to come back to temperature; and the assembly was held at such temperature for 15 minutes and was then removed from the furnace and allowed to cool.

Upon testing the assembly, it was found that the seal was completely gas tight under operating conditions, there being no leak when the assembly was subjected to a 1000 p.s.i. leakage test. By visual examination of the sectioned seal, it was found that the seal exhibited the requisite expansion, and was vesicular in structure.

It will be appreciated that the present invention provides a spark plug assembly in which the sealing material is prevented from foaming or boiling out while the seal is being fired, and in which the confinement of the sealing material by the firmly anchored upper electrode part causes an internal pressure which promotes wetting of the metal electrode parts and of the ceramic insulator by the glassy material. Further, the assembly employed in accordance with the invention makes possible the mass scale production of spark plugs in which an expanded vesicular, flexible seal is formed by melting of the glassy material during the passage of an assembled unit through a furnace.

While the foregoing description is considered to be of the more advantageous embodiments of the invention, it is obvious that many modifications and variations can be made in the compositions and specific procedures discussed without departing from the spirit and scope of the present invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention as defined by the appended claims.

This application is a continuation-in-part of co-pending application Serial No. 447,792, filed August 4, 1954, now Patent No. 2,898,395.

I claim:

1. In a spark plug assembly, an insulator having a firing end and a terminal end, and having a central bore extending therethrough, a first electrode part seated in the bore of said insulator, a second electrode part spaced axially in said bore from said first electrode part, anchoring means on second electrode part comprising a plurality of spaced, discontinuous, outwardly extending circumferential projections, the radii of which are greater than the radius of the insulator bore whereby said projections frictionally engage said insulator bore and anchor the second electrode part relative thereto, and an expanded, substantially gas-impervious, electrically conducting, vitreous sealing means disposed in at least a part of the insulator bore substantially filling the portion of the bore between, and in contact with each of, said electrode parts, said vitreous sealing means being vesicular in structure, and pressed by its expansion into sealing relationship with the insulator bore, and effective to prevent the flow of a gas therethrough.

2. In a spark plug assembly, an insulator having a central bore, an electrode element extending axially through the bore and comprising a terminal end part and a separate, axially spaced sparking end part, each of said parts having an outer end externally of the bore, anchoring means on at least a portion of the terminal end part extending into the insulator bore comprising a plurality of spaced, discontinuous, outwardly extending circumferential projections, the radii of which are greater than the radius of the insulator bore whereby said projections frictionally engage said insulator bore and anchor the terminal end part relative thereto, and an expanded, substantially gas-impervious, electrically conducting, vitreous sealing means disposed in at least a part of the insulator bore substantially filling the portion of the bore between, and in contact with both, said electrode parts, said vitreous sealing means being vesicular in structure and pressed by its expansion into sealing relationship with the insulator bore, and effective to prevent the flow of a gas therethrough.

3. A method of sealing the bore of a spark plug insulator and assembling an electrode therein, which comprises, seating a first electrode part in a central bore of an insulator, inserting a quantity of a vitreous sealing material into the insulator bore, said sealing material being one which, when heated, expands into a vesicular, electrically conducting structure and occupies, upon cooling, a volume greater than before such heating, urging a second electrode part into the insulator bore and into a position where it is frictionally anchored to the insulator, with at least a portion of said vitreous sealing material confined between and in contact with each of said electrode parts, and then heating at least the vitreous sealing material to a temperature sufficient to cause the expansion thereof into a vesicular, electrically conducting structure, whereby said vitreous sealing material is pressed, by its expansion, into sealing relationship with the insulator bore and is effective to prevent the flow of a gas therethrough while said second electrical part remains in its said position.

4. A method of sealing the bore of a spark plug insulator and assembling an electrode therein, which comprises, seating a first electrode part in a central bore of an insulator, inserting a quantity of a vitreous sealing material into the insulator bore, said sealing material being one which, when heated, expands into a vesicular, electrically conducting structure and occupies, upon cooling, a volume greater than before such heating, urging a second electrode part into the insulator bore and into a position where it is frictionally anchored to the insulator, with at least a portion of said vitreous sealing material confined between and in contact with each of said electrode parts, urging a third electrode part into the insulator bore and into a position where it is frictionally anchored to the insulator but is spaced longitudinally a predetermined dis-

tance from the second electrode part and then heating at least the vitreous sealing material to a temperature sufficient to cause the expansion thereof into a vesicular, electrically conducting structure, whereby said vitreous sealing material is pressed, by its expansion, into sealing relationship with the insulator bore and is effective to prevent the flow of a gas therethrough while said second electrode part remains in its said position.

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