

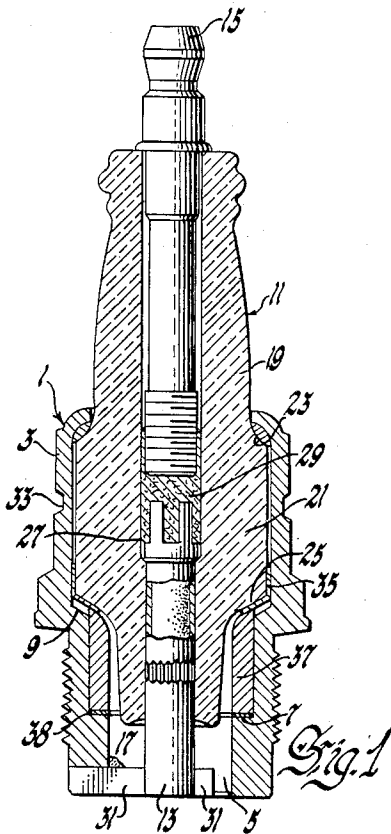
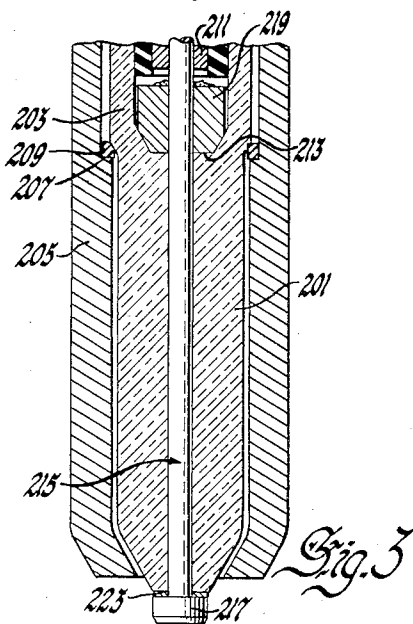
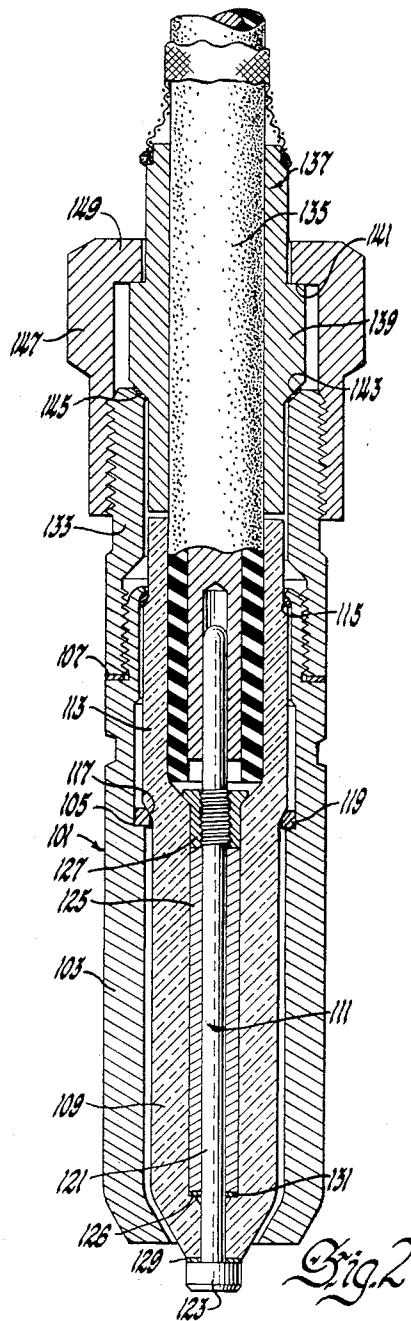
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SPARK PLUG

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SPARK PLUG

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This invention relates to improvements in spark plugs and more particularly to high temperature metal-to-metal and metal-to-ceramic gas-tight seals in spark plugs.

It has always been a basic requirement in the design of spark plugs that the plug should be effective to maintain a gas-tight seal in the engine or other combustion chamber in which it is to be used. This is essential for reasons of safety and efficiency and economy in developing the maximum power in the device and presents no great problem where the operating temperatures are relatively low and produce a temperature at the seating gasket not higher than about 400° F.

Experience has shown that for operation within such a seat gasket temperature range, the insulator may be satisfactorily sealed within the plug shell by means of the "Cico" weld or similar process wherein an annular portion of the shell is collapsed under application of heat and axial pressure to clamp the insulator on a soft metal gasket positioned on a seating shoulder formed on the inside wall of the shell. However, it has been found that the "Cico" weld sealing process, operating as it does by stressing the metal of the shell, has its temperature limitations in that the stress begins to be relieved at a temperature of about 400° F. with resultant gradual easing of the sealing pressure on the insulator. Not only does this reduction in sealing pressure result in a breakdown of the seal, but shifting of the insulator in the shell under the effects of engine vibration is also possible with the attendant possibility of actually shorting the center electrode to the side electrodes.

Likewise, it has been found that the center electrode may be sealed in the insulator counterbore very simply by use of an electrically conductive copper-glass sealing powder which fuses on sintering and adheres to both the electrode and the insulator wall on cooling. However, this too has its temperature limitations for the reason that the glass seal has only a limited energy transmitting capacity. It has been found that where the energy level passed by the plug is relatively high, the copper powder oxidizes and causes cracking and even total destruction of the insulator. This problem is especially serious in aviation usage where a relatively high energy level and combustion chamber pressures are used at the same time that the power plant operates at altitudes of from 50,000 to 70,000 feet and at temperatures as high as 1,000° F.

These extreme environmental conditions under which aviation type plugs are called upon to operate present a further sealing problem. As one method of preventing arc-over from the ignition cable at high altitudes, it has been standard practice to pressurize the shielded ignition cable. This has been simply accomplished by use of a resilient grommet at the points of connection of the cable to the plug and the magneto. It has been found, however, that the best available materials such as silicone rubber and Teflon are limited to uses where the temperature is not much over 500° F. since high tem-

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peratures act to crack and deteriorate the rubber with resultant loss of seal and arc-over.

It is therefore an object of my invention to provide a spark plug having a gas-tight connection with an ignition cable effective to maintain the seal at desired high temperatures. It is another object of my invention to provide a spark plug having a gas-tight connection between the center electrode and the insulator effective to maintain the seal at the operating temperature. It is another object of my invention to provide a spark plug having a gas-tight connection between the insulator and the spark plug shell effective to maintain the seal at the operating temperature. It is another object of my invention to provide a spark plug having gas-tight seals adapted to compensate for tendencies to relieve the seal as the operating temperature of the plug increases.

To attain these objects, I provide an element of relatively high thermal expansion properties acting between two separated bearing surfaces, at least one surface being on an adjacent element having a lower coefficient of thermal expansion.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawing wherein a preferred form of the present invention is clearly shown.

In the drawing:

Figure 1 is a vertical sectional view with parts broken away of one form of spark plug embodying the principles of my invention;

Figure 2 is a vertical sectional view with parts broken away of another form of device showing the principles of my invention;

Figure 3 is a vertical sectional view corresponding to the lower portion of the device shown in Figure 2 and showing a further modification embodying the principles of my invention.

Referring now to the drawing and more particularly to Figure 1, there is shown a spark plug of the automotive type. The plug body 1 comprises a tubular metal shell 3 having a stepped bore 5, the smallest diameter portion being at the firing end and the largest diameter portion being at the top end of the shell, a portion of intermediate diameter being formed between the upper and lower portions, the interconnecting portions forming two spaced annular ledges 7 and 9, respectively. Positioned within the shell 3 is a ceramic insulator 11 having a substantially axially arranged stepped bore therethrough in which there is positioned the center electrode 13 and terminal screw 15. The insulator 11 is of standard configuration and comprises a tapered lower portion 17, an upper portion 19 and a raised intermediate portion 21 which forms upper and lower shoulders 23 and 25, respectively. The center electrode 13 may be formed of any suitable material such as nickel and is shown as a tubular rod closed at its firing end and having a bifurcated head 27 of larger diameter than the lower portion thus forming a shoulder adapted to seat the electrode on the ledge formed in the insulator bore. The electrode 13 is packed with a metal having a high heat conductivity such as copper or silver, which packing serves to rapidly conduct the heat from the electrode tip to the upper portions of the electrode for rapid heat dissipation through the plug structure. A copper-glass sealing powder 29 is shown packed around the head portion 27 of the electrode and around the lower threaded portion of the terminal screw 15. The glass material 29 serves both as a seal within the insulator counterbore and as a conductor connecting the terminal 15 with the electrode 13. A plurality of equally spaced outer electrodes 31 are shown connected in any

suitable manner, i. e. by welding, to the lower end of shell 3. Electrodes 31 serve as the ground electrodes and project inwardly toward the center electrode 13 and in spaced relationship therewith.

In order that the insulator 11 may be supported within shell 3 in gas-tight relationship therewith, an annular groove 33 is formed on the outer surface of the shell wall between the upper end of the shell and the insulator supporting surface in order that the shell may be collapsed under application of heat and axial pressure to clamp the insulator on a soft metal gasket on the supporting surface. A generally cup-shaped gasket 35 of relatively soft metal such as nickel or copper is positioned on raised portion 21 and shoulder 25 and serves both as the sealing gasket and as a spacer gasket for preventing any shifting of the insulator 11 within the shell 3. Since the gas-tight seal is accomplished by means of a metal stressing procedure, it is subject to being broken by relief of the stress in the shell as will occur during operation of the spark plug at high temperatures. In order to compensate for this tendency to relieve the metal stress and break the seal, I provide a tubular member or sleeve 37 positioned on shoulder 7 in the shell bore and extending upwardly to a position adjacent upper shoulder 9. A gasket 38 may be positioned on shoulder 7 to assure a gas-tight seal at this point. Sleeve 37 is formed of a metal having a relatively high coefficient of thermal expansion, an example of which is stainless steel of the 18% chromium and 8-12% nickel type. A trace of columbium or titanium may be added for toughness. Other materials having a high coefficient of thermal expansion may also be used. The sleeve 37 is positioned in the lower portion of shell 3 in order that it be close to the heat which tends to relieve the stress and break the seal. As is clearly shown in Figure 1, the upper end of sleeve 37 abuts insulator 11 on shoulder 25 and serves to both support and seal the insulator within the shell 3, gasket 35 being positioned therebetween. The upper portion of shell 3 is rolled over onto upper shoulder 23 of the insulator, a soft metal gasket, i. e. copper, being interposed between the rolled-over portion and the shoulder, to clamp the insulator on the sleeve. The relative linear dimensions of the sleeve 37, the insulator raised portion 21 and the shell 3 between shoulder 7 and its rolled-over upper end, are such that the linear expansion of the sleeve and insulator together are equal to or greater than the linear expansion of the shell, thus maintaining a gas-tight seal between the shell and the insulator at the operating temperature.

The operation of my invention as above described may be clearly understood from the following example. Assume that the raised portion 21 of the insulator is approximately one-half inch in length, the sleeve 37 is approximately one-half inch in length and that the length of the shell 3 effective in clamping the insulator is approximately one inch. Assume further that the coefficients of thermal expansion for the insulator, the sleeve and the shell are 4.0×10^{-6} , 9.5×10^{-6} and 6.0×10^{-6} , respectively, and that at operating temperature T_0 the change in temperature from standard atmospheric conditions is 500°F . It follows that at T_0 the increase in length will be

$$\begin{aligned} (500)(4 \times 10^{-6})(\frac{1}{2}) &\text{ or } .001 \text{ for the insulator} \\ (500)(9.5 \times 10^{-6})(\frac{1}{2}) &\text{ or } 0.0024 \text{ for the sleeve} \\ (500)(6 \times 10^{-6})(1) &\text{ or } 0.003 \text{ for the shell} \end{aligned}$$

Accordingly, at T_0 the insulator will be tighter in the shell by

$$0.001 + 0.0024 - 0.003 \text{ or } 0.0004 \text{ inch}$$

an amount sufficient to compensate for the stress relief in the shell at the operating temperature.

Thus it can be seen that by means of my invention not only is any tendency to relieve the sealing stress compensated for but, by proper dimensioning of the parts,

the seal can be made tighter at the operating conditions. The above example assumes that the entire plug is at the same temperature. In actual operation the upper end of the plug would normally be cooler which would result in increased compensation.

Having reference now to Figure 2, there is shown an igniter type plug 101 adapted for use in aircraft, though it should be noted that this type plug is equally as suitable for use in other type mechanisms. The plug body comprises a tubular shell 103 having a stepped bore therein forming an annular ledge 105 on the inner surface. The upper portion of the shell 103 is turned down to form a ledge 107 on its outer surface, the turned-down wall of the shell being threaded. Positioned within the shell bore is an insulator 109 having a stepped bore adapted to receive a center electrode 111. The bore is formed with the smallest diameter portion adjacent the lower end of the insulator and the largest diameter portion in the upper end of the insulator, a portion of intermediate diameter being formed between the two end portions. Insulator 109 is formed with a raised portion 113 which provides the insulator 109 with an upper shoulder 115 and a lower shoulder 117 which function to permit sealing the insulator within the shell in gas-tight relationship. The lower shoulder 117 is positioned on the ledge 105 formed on the internal wall of the shell 103, a metal gasket 119 being positioned between the two shoulders. Insulator 109 is sealed within shell 103 by rolling over the upper end of the shell onto the upper insulator shoulder 115 thereby clamping the lower insulator shoulder 117 on the gasket 119 and shell shoulder 105. While I have shown the insulator 109 sealed within shell 103 by means of an uncompensated "Cico" weld, I wish it to be clearly understood that this is for simplicity and I may use the compensated seal shown in Figure 1 and described above.

Though, as shown in Figure 1, the center electrode is commonly sealed within the insulator bore by means of a glass seal conductor powder, experience has shown that this seal has only a limited energy transmitting capacity. It has been found that where the energy level passed by the plug is relatively high, the copper powder oxidizes and causes cracking and even total destruction of the insulator. By means of my invention I have been able to provide a center electrode seal which operates to maintain the seal as the operating temperature rises and possess substantially unlimited energy transmitting capacity.

As shown in Figure 2, the insulator 109, formed of ceramic material having a low thermal expansion coefficient, has therein a center electrode 111 of the firing button type formed of a normal expansion metal, i. e. nickel. Electrode 111 comprises an elongated rod 121 having a threaded portion on its upper end and a cylindrical firing button 123 on its lower end abutting the lower end of the insulator. A metal sleeve 125 of material having a high thermal expansion coefficient is slidably positioned adjacent rod 123 in the insulator bore of intermediate diameter and seats on the ledge 126 formed at the plane of interconnection of the upper intermediate diameter portion and the smallest diameter portion of the insulator bore. A tensioning nut 127 is threaded, or otherwise secured as by brazing with localized heat, on rod 121 to place its lower surface in abutment with the upper end of sleeve 125. Soft metal gaskets 129 and 131 may be provided between the inner surface of firing button 123 and the firing tip of insulator 109 and between the lower shoulder in the insulator bore and the lower end of sleeve 125. The amount of torque applied to nut 127 may be adjusted with respect to the relative lengths of the sleeve, the insulator between the lower end of sleeve and the inner surface of the firing button, and the length of the rod between the lower surface of the tensioning nut and the inner surface of the

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firing button to obtain the desired sealing action. As in the case of the plug shown in Figure 1, the sum of the changes in length of the sleeve 125 and the insulator portion between the lower end of the sleeve and the inner surface of the firing button 123 is greater than the change in length of the rod 121 coextensive therewith, with a resultant tighter seal as the temperature to which the plug is subjected increases. Viewed in another manner, nut 127 and sleeve 125 together may be described as a tensioning member acting on ledge 126 and electrode 111 to pull button 123 against the insulator to create a seal therewith.

I have also shown on Figure 2 means for obtaining a gas-tight seal between the ignition cable and the plug. As shown on the drawing, a shield sleeve 133 is threaded onto the upper portion of shell 103 in order to shield the upper portion of the insulator 109 and the attached ignition cable 135. As shown, the cable 135 is attached to the center electrode by means of a friction fit between the end of the electrode and the conducting wire which is provided with an end passage for connection therewith. In order to make the connection between the cable and the plug, a ferrule 137 made of a high thermal expansion material such as the stainless steels above described is positioned about the insulated cable 135 and is formed with raised portion 139 which thereby provides an upper shoulder 141 and a lower shoulder 143 for purposes fully described hereinafter. The lower shoulder 143 is positioned on a correspondingly formed ledge on the upper end of shield sleeve 133 which functions to support the ferrule and seal the cable connection to the plug. A soft metal gasket 145 may be positioned between the sealing surface. In order to clamp the ferrule 137 on the upper end of the shield sleeve 133 with pressure sufficient to maintain the seal under the conditions of operation, a clamping nut 147 having a low coefficient of thermal expansion is positioned about ferrule 137, the upper end of the nut being turned inwardly to form an annular flange 149 adapted to abut the upper shoulder 141 of the ferrule. The upper end of sleeve 133 and the lower end of nut 147 are provided with threads for their secure attachment. Upon assembling the ignition cable 135 on the center electrode rod 123 with ferrule 137 in abutment with the upper end of sleeve 133, the torque applied to nut 147 may be adjusted to give the desired tightness of seal under the operating temperature and pressure conditions. As in the above embodiments, the expansion of the raised portion of the ferrule 139 between the clamping flange 149 and the upper end of sleeve 133 is greater than the expansion of the nut between those two points with a corresponding increase in tightness of seal. Though I disclose the nut 147 as having threaded attachment with the end of sleeve 133, it should be understood that the threaded connection may be provided on a lower portion of sleeve 133.

Figure 3 discloses a modification of the center electrode seal shown in Figure 2. The ceramic insulator 201, having a low coefficient of thermal expansion, is formed with a raised upper section 203 providing upper and lower shoulders for sealing the insulator within the shell 205 in the same manner as described with reference to Figure 1 or 2. As in Figure 2, insulator 203 is clamped on a ledge 207 formed on the inner surface of shell 205, a soft metal gasket 209 being positioned thereon. Insulator 203 is provided with a stepped bore having a large diameter portion in its upper end for receiving the ignition cable 211 and a small diameter portion in its lower end for receiving the center electrode 215, thus forming a ledge 213 therein. Electrode 215 is of the button type having a cylindrical firing button 217 positioned on the firing tip of the insulator 203, the upper portion of the electrode extending axially through the insulator to the large diameter portion of the bore. Electrode 215 is formed of a relatively high thermal expansion material such as nickel, copper, etc. In order

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to assure the seal of the center electrode within the insulator bore at the operating temperature range, a tensioning nut 219 is secured to the upper portion of electrode 215 in any suitable manner, i. e. by a threaded connection, brazing, etc., at a temperature appreciably higher than the operating temperature of the assembled plug. In establishing the seal using brazing as shown, insulator 201 with the center electrode 215 positioned therein is supported on the firing button 217, the tensioning nut 219 is positioned about the upper end of the electrode 215 in the large diameter portion of the center bore, and the temperature of the assembly is raised to about 1900° F. to enable copper brazing of the nut to the electrode. A load is imposed on the upper surface of the nut during the copper brazing to force it into abutment with ledge 213. On cooling, the nut is firmly secured to the electrode and upon further cooling and shrinkage of the electrode, the electrode button 217 is pulled tightly against the insulator thus maintaining a gas-tight seal. Since the brazing material is chosen to have a solidifying temperature well above the operating temperature of the assembled plug, about 1000° F., a tight seal is assured at such operating temperature. As shown on the drawing, a soft metal gasket 223, i. e. nickel, may be provided between the firing end surface of the insulator and the inner surface of the electrode button 217.

As can be seen from the above description, I am able to assure the gas-tight seal of a spark plug at its several critical sealing locations in a very simple and inexpensive manner by providing an element of relatively high thermal expansion properties which is so positioned as to create a seal on an adjacent element having a lower coefficient of thermal expansion.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, as may come within the scope of the claims which follow.

What is claimed is:

1. The method of forming a gas-tight seal between a spark plug insulator and a center electrode positioned therein comprising the steps of forming a monolithic non-compressible insulator with a stepped bore therethrough to provide a ledge therein, positioning a center electrode in said bore with its firing button in abutment with a relatively soft heat resistant metal gasket positioned on the lower end of said insulator, heating said insulator and electrode to a temperature above the operating temperature of the plug, brazing a tensioning nut on said electrode with its lower end in abutment with said ledge, cooling said insulator, said electrode, and said nut, and applying a load to the upper surface of said nut while brazing, the temperature at which the brazing metal solidifies being higher than the plug operating temperature.
2. In combination in a shielded spark plug adapted for use at high temperature and low pressure, a tubular shell having a bore therethrough, an insulator having a low coefficient of thermal expansion mounted in said bore and having a stepped bore therethrough providing a ledge therein, a center electrode positioned within said insulator bore having a threaded portion on its upper end and a cylindrical firing button on its lower end abutting the lower end of said insulator, a gasket positioned between the lower end of said insulator and said button, a sleeve having a relatively high coefficient of thermal expansion positioned in the upper portion of said bore on said ledge adjacent said electrode, a gasket positioned between the lower end of said sleeve and said ledge, a tensioning nut threaded to said center electrode and having its lower end in abutment with the upper end of said sleeve, a shield sleeve having an externally threaded upper portion secured to the upper end of said shell and extending above the top of said insulator, an ignition cable extending into the upper portion of said insulator bore and having secure electrical connection with said

electrode, a ferrule having a relatively high coefficient of thermal expansion positioned on said cable and having a raised portion thereon forming an upper and lower shoulder, said lower shoulder being seated on the top of said shield sleeve, a gasket positioned between said shoulder and said sleeve, and a clamping nut having a relatively low coefficient of thermal expansion removably secured to the upper portion of said sleeve and having an inwardly extending annular flange in abutment with said upper shoulder.

3. In a spark plug adapted for use at high temperature and low pressure, a tubular shell, a non-compressible ceramic insulator having a low coefficient of thermal expansion mounted in said shell and having a stepped bore therethrough providing a ledge therein, a center electrode positioned within said bore having a firing button on its lower end abutting the lower end of said insulator, a metal sleeve having a relatively high coefficient of thermal expansion positioned about said electrode in the upper portion of said bore, the lower end of said sleeve being positioned upon said ledge, and a tensioning member secured to said electrode and having its lower end in abutment with the upper end of said sleeve, the operation of said plug at elevated temperatures being effective to expand said sleeve between said ledge and the lower end of said tensioning member to produce a gas-tight seal between said firing button and the lower end of said insulator.

4. The method of forming a gas tight seal between an insulator and a center electrode positioned therein comprising the steps of forming a non-compressible ceramic insulator with a stepped bore therethrough to provide a ledge therein, positioning a center electrode in said bore with its firing button in abutment with a relatively soft heat resistant metal gasket positioned on the lower end of said insulator, heating the complete insulator and center electrode to increase the length of said electrode, forcing a tensioning member in abutment with said ledge, securing said tensioning member at said elevated temperature to said electrode and cooling said insulator, said electrode and said member while applying a load to the upper surface of said member, the temperature at which heating is accomplished being higher than the plug operating temperature.

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