

Aug. 4, 1942.

J. A. DORAN

2,292,216

SPARK PLUG

Filed June 29, 1939

3 Sheets-Sheet 1

*Fig. 1.*

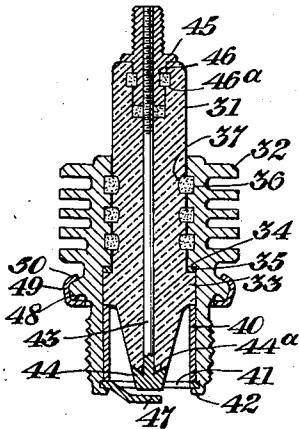


*Fig. 4.*

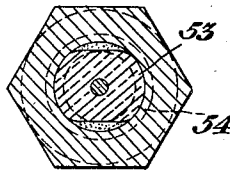


*Fig. 3.*

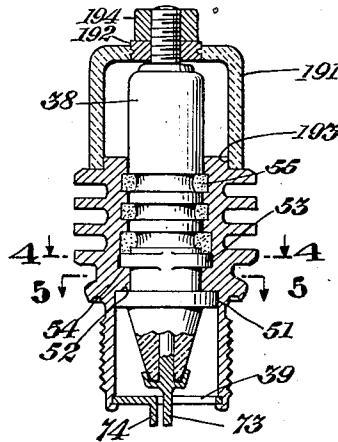


*Fig. 2.*

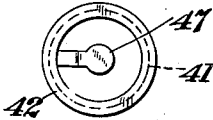


*Fig. 6.*

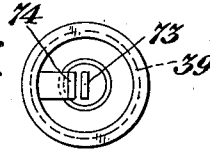


*Fig. 7.*

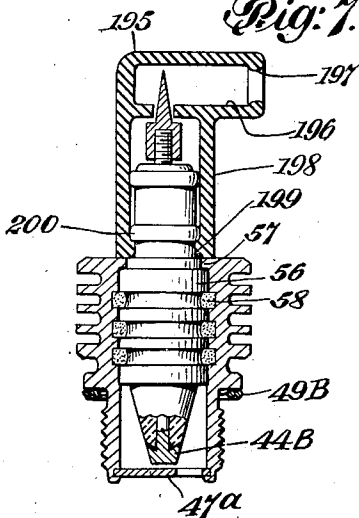


*Fig. 5.*

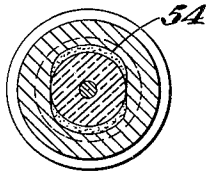
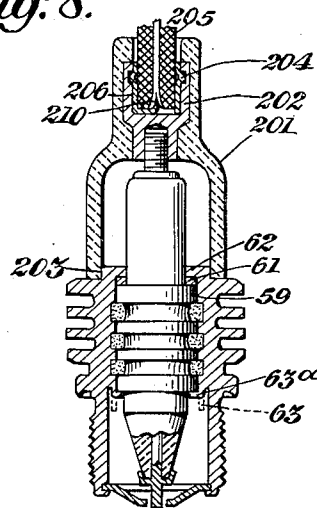


*Fig. 8.*



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*Fig. 9.*

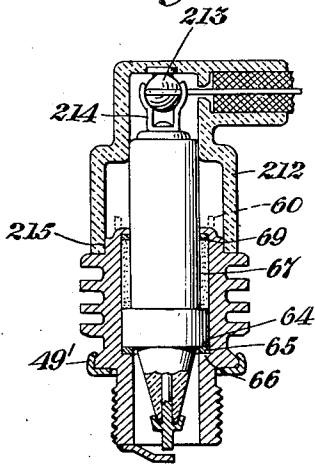


*Fig. 12.*

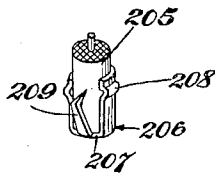


*Fig. 11.*

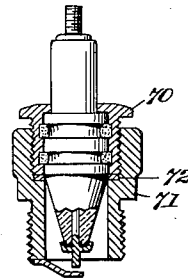


*Fig. 13.*

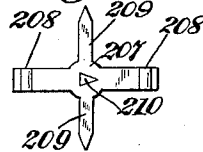


*Fig. 15.*



*Fig. 10.*

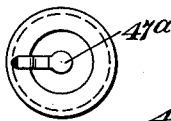


*Fig. 14.*

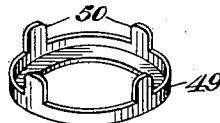


*Fig. 16.*



*Fig. 14a.*



*Fig. 17.*

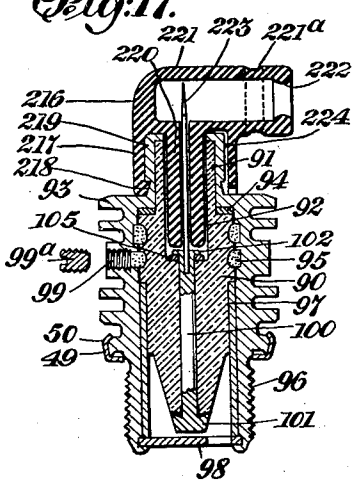


*Fig. 18.*

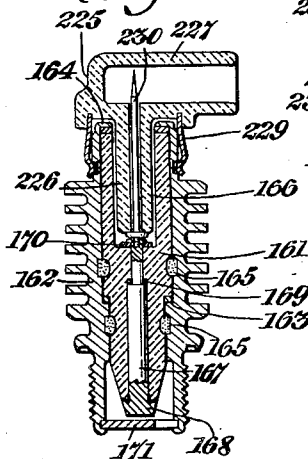
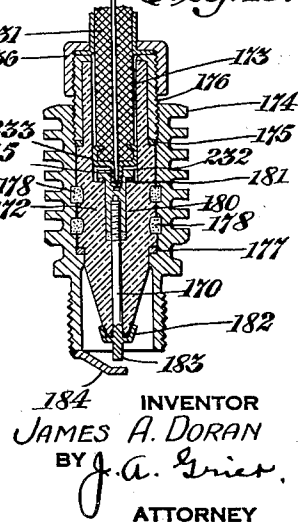


*Fig. 19.*



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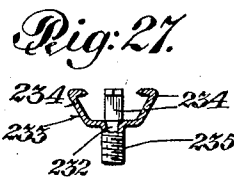
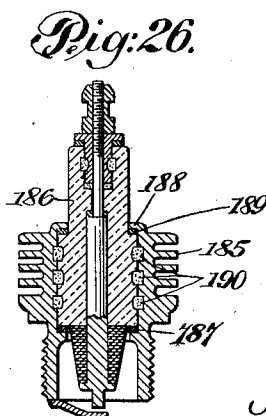
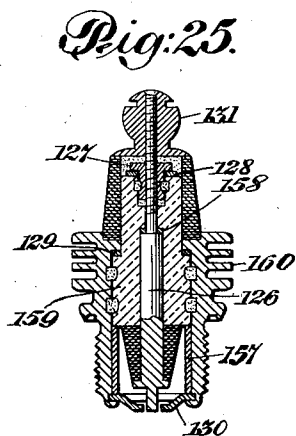
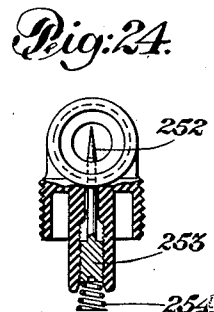
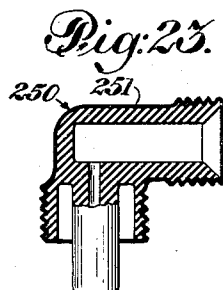
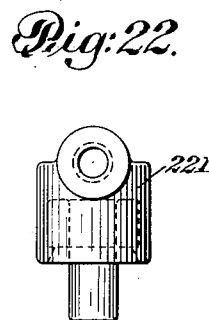
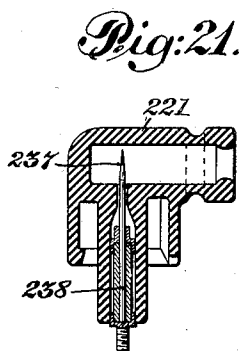
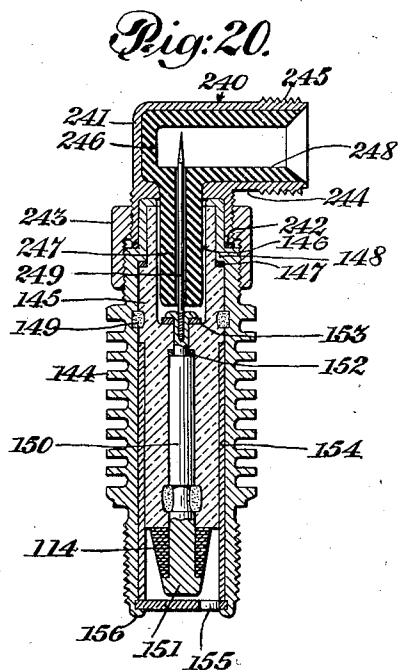
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## UNITED STATES PATENT OFFICE

2,292,216

## SPARK PLUG

James A. Doran, Providence, R. I.

Application June 29, 1939, Serial No. 281,798

10 Claims. (Cl. 123—169)

This invention relates to improvements in spark plugs and has for an object the provision of novel means for assembling the insulators in the shells with which they are associated, and providing a seal between the insulator to produce a plug having substantially zero leakage therethrough, and at the same time establishing a bond between the inner wall of the shell and a corresponding area of the surface of the insulator, thereby establishing a definite maximum conducting path between the shell and the electrode capable of conducting heat to said shell at a sufficient rate to eliminate tendencies for the porcelain of the insulator to crack and to prevent the electrode from overheating.

Another object is the provision of novel methods of securing insulators in the shells to form spark plugs.

A further object is the provision of spark plugs for heavy duty including novel composite insulators.

Another object is the provision of enclosed types of plugs having unitary "well type" insulators and novel means for connecting the electrode to a cable.

Still another object is the provision of novel terminal heads for protecting the insulators against breakage and moisture, in both the open type and the enclosed type insulators.

Referring to the drawings:

Figure 1 is a sectional elevation of a novel spark plug having an exposed insulator constructed according to the invention;

Figure 2 shows the ground electrode of the plug shown in Figure 1;

Figure 3 is a sectional elevation of a spark plug in which the porcelain insulator is "bayonet locked" into the shell;

Figure 4 is a sectional view taken along the line 4—4 of Figure 3;

Figure 5 is a sectional view taken along the line 5—5 of Figure 3, and giving with Figure 4, details of the "bayonet lock" effect;

Figure 6 is a fragmentary end view of the plug of Figure 3, showing the electrodes;

Figure 7 is an elevation showing a further modified sealing arrangement and a novel terminal shielding arrangement;

Figure 8 shows another modified spark plug including a novel sealing structure and novel shielding of the terminal end thereof;

Figure 9 shows a plug having a novel terminal and shielding hood;

Figure 10 is a view showing details of the ground electrode of the plug shown in Figure 7;

Figure 11 is an embodiment of the invention in which the sealing and bonding compound is employed, the plug being so constructed that the porcelain insulator may be removed from the shell;

Figure 12 is a perspective view of the cable clip shown in Figure 8;

Figure 13 is a view of a blank stamping from which the cable clip shown in Figures 8 and 12 is formed;

Figure 14 is a perspective view of the gasket shown on the plug in Figure 1, before it is positioned on the plug;

Figure 14a is a modification of the gasket in Figure 14;

Figure 15 is a perspective view of a gasket such as that employed in Figure 7;

Figure 16 is an enlarged cross-sectional view of the gasket shown in Figures 7 and 15;

Figures 17, 18 and 19 illustrate embodiments of spark plugs having enclosed insulators and novel types of terminal heads for connecting cables;

Figure 20 is a view of another modification for heavy duty, the insulator being provided with a mica firing tip, and the terminal end being provided with a novel terminal connection embraced by a metallic shield and particularly adapted for aircraft engines;

Figure 21 is a sectional elevation of a modification of the terminal head shown in Figure 17, with the addition of a resistance element to function as a radio suppressor;

Figure 22 is an end elevation of the terminal head shown in Figure 21;

Figure 23 is a shielded terminal head similar to that shown in Figure 20, except that the shielding metal embracing the head is comprised of a thin coating of metal applied thereto by electro-plating, metal spraying, or any other method of deposition;

Figure 24 is a view of a shielded terminal head similar to that shown in Figure 20, except that its connecting pin is provided with a contact spring for use with aircraft or other "well type" plugs which are not already provided with piercing connection pins mounted in the upper ends of their electrodes;

Figures 25 and 26 depict modified spark plugs which according to the invention are provided with mica insulation adjacent to their firing tips; and

Figure 27 is a view showing details of the cable clip shown in Figure 19.

All of the forms of spark plugs herein shown and described follow a fundamental construction,

in that they primarily have a novel principle of sealing the insulator to the shell and bonding the insulator to the shell. This leads to the following advantages, which are of great importance in modern internal combustion engines:

1. That my method of sealing the insulator to the shell is conducive to zero compression leakage from the engine cylinder through the plug.

2. That sealing compounds may be employed which establish and maintain a bond between the insulator and the shell thereby providing an efficient thermal path for heat transfer from the electrode to the shell and the radiating fins thereon.

3. Having, by my method, established said thermal path, the next step was to eliminate the causes of insulator breakdown which involves two steps:

(a) The formation on the center electrodes, of cupped or dished flanges near the firing tips which protects the lower ends of the insulators, and

(b) The protection of the terminal ends of the insulators from extreme temperature differentials, thereby minimizing any tendency of the insulators, particularly porcelain insulators, to crack.

Another feature which I show is a novel method of effecting a seal between the spark plug flange and the cylinder of an engine. This will be hereinafter described in connection with Figures 14, 15, and 16.

In the embodiment in Figure 1, the shell 32 is provided with radiating fins and has a ceramic insulator 31 mounted therein, through the lower end thereof. The hubbed portion 33 contacts a gasket 35 which in turn contacts a shoulder 34. The shell 32 has annular grooves or recesses 36 formed therein, and corresponding grooves or recesses 37 are formed on the insulator. All contiguous surfaces between the insulator and the interior bore of the shell are spaced apart from each other, making the insulator form a loose or sloppy fit with the shell, whereby such space and said recesses may be filled with a sealing and bonding compound or mixture. This causes a plurality of annuli of compound to form in said grooves, connected by thin cylindrical webs, the whole being bonded to the shell and to the insulator within the area in which the surfaces are adjacent to each other, thereby sealing against leakage through the plug and forming a path through which heat exchange between the ceramic insulator and the shell is effected at a greater rate than it is effected in plugs not so constructed.

The sealing and bonding compound may be applied to the insulator and to the interior of the shell before assembly, or it may be applied through an orifice in the shell after the parts are assembled as will be described in connection with Figure 17.

After the insulator 31 is placed in the shell 32 as described, a sleeve 40 is inserted, then the ground electrode ring 41 is placed as shown and the annular edge 42 is curled or spun over to maintain the parts in proper relation, the sleeve 40 being of a length to cause the proper pressure to be exerted upon the gasket 35 which serves as a cushion for protecting the insulator 31. By then subjecting the plug to heat, the sealing and bonding compound is hardened and set so as to cooperate with the gasket to effect substantially zero leakage therethrough, and the plug is ready

to efficiently transfer heat from the electrode and insulator to the shell.

I employ many types of sealing and bonding compounds, the following of which are given by way of example: Compounds including gypsum, magnesium, barium or the like or combinations thereof; refractory sealing cements capable of high thermal conductivity, the solvents employed being materials having a minimum shrinkage upon evaporation, for example—silicate of soda. I also use semi-plastic compounds including the more highly volatile types of solvents.

In the preferred types of construction, the insulator is inserted from the bottom of the plug, and has a flanged or hubbed portion which positively members up with a shoulder within the shell, whereby the compression, when the plug is affixed to an engine, does not apply shearing stresses to the sealing and bonding compound; instead, the shoulders, which are provided for the purpose, solidly bear the pressure.

The center electrode 43 has formed therewith a head 44 having a concave seat into which the convex end of the insulator fits, the joint between being filled with cement 44a.

The upper end of the electrode is threaded to be engaged by the terminal 45, the lower portion of which is provided with a groove 46 which matches a groove 46a in the insulator. When the cement is applied to the parts and the terminal 45 is screwed down firmly, the electrode is permanently secured to the insulator in sealed relation. The head 44 protects the insulator tip against breakage, and due to the use of the cement 44a, gas pressures and carbon are prevented from entering the space between the electrode and the insulator, causing the latter to expand and crack.

The ground electrode ring 41, also shown in Figure 2, carries an electrode 47 shaped to form with the head 44, a spark gap between two parallel discs, wherein the positions at which the sparking occurs are constantly changing over the surfaces thereof.

When tested on a Waukesha variable compression engine in comparison with a duplicate plug having the usual concentrated gap, the tests show that the same degree of detonation occurs with the old type concentrated gap at a ratio of 6 to 1, as occurs with my improved disc gaps (the discs being .25" in diameter) at a ratio of 6½ to 1. Furthermore, in testing both types of plugs at a 6 to 1 ratio, the concentrated gap plug showed the same degree of detonation with 78 octane fuel as resulted from my disc type plug with 67 octane fuel.

In Figure 1, the gasket flange is provided with a narrow faced contact annulus 48. The gasket 49, also shown in perspective in Figure 14, is preferably formed of soft copper about .020" thick. It is cup-shaped and provided with ears or tabs 50 to bend over the flange.

The cup-shaped gasket shown in Figure 14a and designated by the numeral 49' is a modification of the gasket shown in Figure 14, the lugs 50 having been omitted. This form of gasket is shown applied to the plug in Figure 9. After it is applied to the plug and is embracing the flange of the plug the rim of the gasket may be bent over the flange at a plurality of points thereby permanently securing the gasket to the plug. Although the bottom surface of the flange of the plug is not undercut, it is obvious that this gasket may also be used on plugs where the undersurface of the flange is

undercut. Examples of such plugs being shown in Figures 1, 3, 8, 17, 18, and 25.

When a plug equipped with this gasket is mounted on a cylinder of an engine the contact annulus 48 digs into the copper about .003" when an 8" wrench has been applied with about 15 pounds of force, thereby establishing about 100,000 lbs. pressure per square inch of contact surface, and producing practically zero leakage between the engine cylinder surface and the flange if the cylinder surface is in reasonably good condition.

In the modification shown in Figure 3, the insulator is secured in the shell by means of a set of quarter turn lugs, resembling a double "bayonet lock." The insulator 38 is provided with a flange 51 bearing against a shoulder 52. Two lugs 53 rest against ledges 54 when the insulator is in the locked position. The bore of the shell on the line 4-4 is milled at 54 to form an oval opening to freely admit the lugs 53 when the insulator is inserted. Before inserting, the proper portions of the insulator and corresponding portions of the interior of the shell are coated with sealing and bonding compound, after which the insulator is inserted from the bottom of the shell. When the lugs have passed through the opening 54, the insulator is rotated about a quarter of a turn, thus bringing the lugs 53 over the shoulders 54 and locking the insulator in the shell and giving full mechanical support to resist not only the compression and explosive forces of the engine but also the vacuum of the intake. The insulator and the inner wall of the shell are provided with grooves 55 similar to those shown and described in Figure 1, so that the sealing and bonding compound may fill such grooves and the clearance spaces between the insulator and the interior of the shell body.

The ground electrode ring 39 carries a ground electrode 74 which presents a parallel rectangular face to the rectangular face 73 of the center electrode. With these parallel faces the sparking positions of the sparks is constantly changing along the surfaces thereof.

The modification in Figure 7 is similar in some respects to Figure 1, except that the spacing tube 40 is omitted and the insulator has a shoulder 56 which rests against a shoulder 57 in the shell. A plurality of matching grooves generally designated by the numeral 58 with the spaces therebetween, as well as the space between the shoulders is adapted to contain sealing and bonding compound. The center electrode firing end 44b is round, and the ground electrode 47a is disc-like and parallel to the bottom end of the electrode 44b. The sealing gasket 49b illustrated also in Figures 15 and 16 is formed of copper of such shape as to contact the spark plug flange along two circular lines of contact and also to contact the cylinder head of the engine in the same manner. The hole in the gasket is tapped or otherwise shaped to conform to the threads on the plug so that after being screwed on it floats in the clearance groove above the mounting threads and will not drop off.

The modification, Figure 8, has an annular rim 63 formed within the skirt of the shell, adapted to be spun against the insulator to retain the same in the shell. The shoulder 59 of the insulator, with a washer 61 therebetween, members up with a shoulder 62 of the shell. 75

The sealing and bonding is effected in the manner previously described.

In Figure 9 the insulator is inserted from the top, the annular rim 60 being provided for retaining the insulator in place. The gasket 65 rests on a shoulder 66 in the shell and the shoulder 64 on the insulator rests on the washer 63. Sufficient clearance is provided between the inner wall of the shell for a bushing 67 of sealing and bonding compound, to be inserted, followed by a washer or collar 69. The annular rim 60 is then spun down on the collar 69 to apply pressure on the compound. For convenience the compound is precast in cylindrical form with sufficient clearance to permit easy insertion into the shell after the insulator is in. The cylinders are made longer than the allotted space so that when the pressure of spinning is applied the compound conforms to all clearance spaces available.

In Figure 11, the insulator is mounted in a bushing 70, grooves being formed on the ceramic insulator and in the bushing. The upper shoulder on the insulator seats on a corresponding shoulder in the bushing. The sealing and bonding compound is applied and the parts are forced together and baked or heated to cause the compound to harden or set. The assembly just described is screwed into an internally threaded spark plug shell 71 using a gasket 72 to effect a seal therebetween, thereby providing a spark plug in which the insulator (and bushing) is removable.

In the above described embodiments, the insulators have their terminal ends projecting out of the shells and protected by terminal heads to be presently described. The types now to be described have unitary enclosed insulators having terminal wells formed therein.

In Figure 17, the insulator 90 is made in one piece and has a neck 91, and a well 92 extends downwardly into the body of the insulator. It is mounted in a shell 93 with a gasket 94 between the bearing surfaces. Annular recesses 95 are provided for sealing and bonding compounds as described above. The insulator is inserted from the bottom or skirt end 96 of the shell, the bearing surfaces of both members having been provided with a sealing compound, and a metallic sleeve 97 is placed in the position; after which the ground electrode 98 is placed in position and spun in by means of a rim on the shell for that purpose. As a result, the sleeve 97 via the insulator 90 exerts a gentle but positive pressure on the gasket 94.

The plug may be assembled without the compound and the latter introduced under pressure via a hole 99 formed in the shell 93 for the purpose, the air passing out via the clearance spaces. After the internal spaces are filled with compound the hole 99 may be closed. In closing it with a screw, such as the headless set screw 99a, the pressure on the compound is increased as 99a is screwed. In some instances, it might be desirable to allow the compound itself to seal up the hole.

The center electrode is a stem 100 having a head 101 with a concave sealing surface contacting the lower end of the insulator, cement having been placed therebetween. The upper end of the electrode is spun over at 102 against a gasket 105, sealing compound having previously been applied, thereby effecting a thermal bond with the insulator to accelerate heat dissipation from the electrode head 101 to the shell.

Where the sleeve 87 is made of copper, it will transmit heat at a rapid rate from the insulator and from the ground electrode to the shell; and at the same time it serves as an expansion compensator. The relative linear dimensions of the sleeve, the porcelain, and the shell are such that the linear expansion of the sleeve and the porcelain together are about equal to the linear expansion of the shell, so that at the various operating temperatures, uniform sealing pressure is maintained on the gasket 94.

Thermal compensation may also be effected in the plugs of Figures 1, 20, and 25. The main difference between Figure 20 and Figure 17 is in the proportions of the parts, and the plug in Figure 20 devised for heavy duty work has an insulator provided with a mica nose 114 to obtain better heat insulating of the electrode lower stem and to eliminate all chance of tip breakage. The ceramic body enables me to obtain a positive gas seal, due to my sealing and bonding compound (which is applied as described herein), freedom from short circuits and rapid heat dissipation from the electrode tip to the cooling fins of the shell.

The shell 144 is longer to provide more radiating fins. The ceramic insulator 145 has a well 146 formed therein, and is inserted from the bottom. The shoulder on the insulator bears on a gasket 147 against a shoulder 148 in the shell. Compound grooves 149 are provided to contain sealing and bonding compound which is also applied to all bearing surfaces in the plug. The center electrode 150, is much heavier and as above described, a mica tip 114 is provided, it being positioned on the electrode between the ceramic insulator 145 and the firing end or head 151. A shoulder at the upper end of electrode 150 seats on a gasket 152 and the shank extends into the bottom of the well 146 where it is turned over on a gasket 153, the shank having a tapped hole, to presently be described.

After the insulator is positioned in the shell, a sleeve 154 is inserted, the ground terminal ring 155 is applied, and the rim spun down as indicated at 156.

This provides a heavy duty spark plug particularly adapted for aircraft engines.

The composite insulator described has the important advantage that the mica 114 about the electrode in the firing chamber of the plug is a poor conductor of heat and therefore acts to retard the absorption of heat by the electrode. Heat does, however, enter the electrode via the tip 151. The ceramic portion 145 is a better conductor of heat than the mica, and due to the fact that the ceramic is sealed and bonded to the shell 144, a path is thereby provided through which the heat is delivered to the shell to be radiated and/or dissipated.

Heretofore, aircraft spark plugs have been made with mica insulation throughout, mainly to avoid breakage common to porcelain insulators. However, all-mica insulation is unreliable because of electrical failure where the mica roll or "cigarette" is sealed to the center electrode structure, due to the fact that the mica cracks under the severe constricting pressure necessarily employed, and the current shorts to the ground.

Such mica plugs are troublesome because they invariably develop excessive leakage after comparatively few hours of service. In large heavy duty cylinders overheating and preigniting is

prevalent because the mica retards heat dissipation from the electrode tip.

In Figure 25, the insulator is composite, being formed of a ceramic body 159 with a mica firing tip. The mica washers forming this tip as well as those forming the nose or tip 114 in Figure 20 are coated with a compound for bonding the mica together and to the stem of the center electrode. The electrode 125 is seated on the gasket 158 by means of nut 127 bearing against a second gasket 128. The insulator is applied through the bottom of the shell 160, and is seated on the gasket 129 under pressure via the sleeve 157 and the ground electrode 130; all bearing surfaces having had sealing and bonding compound applied thereto. After the rim is spun against the ground electrode ring, a stack of mica washers (coated with compound) is applied to cover and protect the terminal end of the ceramic and a terminal nut 131 is screwed down firmly to squeeze out surplus compound and to maintain the electrode in sealed relation with the insulator. This provides another plug having a mica firing tip which cannot be broken and yet the ceramic body dissipates the heat rapidly, making a superior unshielded aircraft plug.

In the plug in Figure 18, the ceramic insulator 161 is inserted into the shell 162 through the top and seats on a gasket 163 and the rim 164 is spun down on the top of the insulator preferably with a gasket therebetween. Compound grooves 165, 165 are provided. The insulator has a well 166. A shoulder on the electrode bears against a washer 169 to seal it to the ceramic, and a portion of the electrode 167 extends into the well 166 and is secured in sealed relation at 170 in the same manner as described in Figure 17. A ground electrode ring 171 is secured to the bottom of the shell with its electrode surface parallel to the bottom of the head 168.

In Figure 19, the insulator 172 is provided with a well 173, and is inserted into the shell 174 from the top, after which a gasket 175 is inserted and a threaded sleeve 176 is screwed into the shell to firmly press the insulator down on the gasket 177, all bearing surfaces and the grooves 178 having previously been coated with sealing and bonding compound.

The electrode 179 has its upper end threaded and an internally threaded sleeve 180 is screwed thereon to have its head bear against the gasket 181 to seal the electrode in, cement having been applied to the thread on the electrode and under the head 182 near the firing tip 183. A ground electrode 184 is welded to the shell.

In Figure 26 the shell 185 has the insulator 186 inserted from the top to rest on gasket 187, and the rim 188 is spun down on washer 189, sealing and bonding compound having been previously applied to the bearing surfaces and to the surfaces of the annular rings 190.

In the embodiments with exposed insulators, Figures 3, 7, 8 and 9, various forms of terminal heads are shown for protecting the insulator against moisture and breakage.

In Figure 3 a moulded terminal cap 191 has an internally threaded insert 192 whereby the cap may be screwed down on the electrode stem until the skirt of the cap embraces the shoulder 193 on the shell, giving side support to the cap. A terminal nut 194 secures the cable to the plug in the usual manner.

The terminal head 195 in Figure 7 is made of rubber, with a horizontal socket 196 for the cable with an internally disposed bead 197 to grip the

cable tightly and prevent moisture from entering the socket. The vertical leg 198 fits over the insulator, and an inwardly disposed bead 199 tightly grips the insulator under a boss 200 formed thereon.

In Figure 8, a terminal head 201 is a plastic moulding having a metallic socket 202 moulded therein having a tapped hole whereby the head may be screwed on to the plug. The skirt of the terminal head engages the annular shoulder 203 on the plug. The socket has an annular groove 204 formed therein to be engaged by a terminal clip.

In Figure 12 is shown a piece of cable 205 with my new clip, generally designated by the numeral 206, applied thereto. The blank from which the clip is formed is shown in Figure 13 and consists of a disc 207 having oppositely disposed arms 208 formed integral therewith, and oppositely disposed piercing members 209 on an axis at 90° with the axis of said arms. In the center of the disc 207 is a struck up member 210 which pierces the end of the cable and establishes contact with the wire therein. The pointed tips of the piercing members 209 are bent upwardly after which the piercing members are bent upwardly, so that the tips pierce the insulation of the cable in the manner shown in Figure 12. The arms 208 form spring jaws which tend to spring outwardly from the cable so that when the cable is inserted in the socket, curved portions of the jaws engage the groove 204 and retain the cable in the socket. This clip has the advantage over those of the prior art, in that the piercing members serve only to retain the clip on the cable and the arms 208 serve only to retain the cable in the socket, whereas the clips of the prior art expect their arms or the like to do both jobs which is impossible.

I may make the piercing members 209 longer than shown, so as to pierce the insulation and contact the conductor therein.

In Figure 9 a terminal head 212 is moulded of plastic material and has ball insert 213 therein. The ball is gripped by spring jaws 214 secured to the top end of the electrode. A groove may be formed in the ball so that a loop of the conductor may lie therein to be engaged by the spring jaws when the terminal head is applied to the plug. The skirt of the head engages a bossed portion 215 of the plug.

The following terminal heads are described in connection with enclosing insulator plugs.

In Figure 17 the head 216 is made of rubber or the like. It has a skirt portion 217 extending downwardly with an inwardly disposed bead 218 which engages and locks in a groove formed on the plug neck 219. A tubular portion 220 formed integral with the head extends into the well 92 of the plug. A socket portion 221 of the head is angular with respect to the axis of the tubular portion 220 and has at its end an inwardly disposed bead 222 for firmly engaging the cable. Although the socket portion 221 is shown at right angles to the axis of the plug, it must be understood that I may form this socket at angles greater than or less than 90° with the plug axis.

A connecting pin 223 may be screwed into the end 102 of the electrode 100 or otherwise attached thereto, and the cable end (cut off square) is inserted into the socket 221 before the head is applied to the plug. In applying it to the plug, the tubular portion 220 enters the well with the connecting pin 223 entering the hole in

said tubular portion. By the time the head is pushed down to a position where the bead snaps into the groove on the spark plug neck, the connecting pin has pierced the cable and is making good contact with the wire therein. A slot 224 is formed throughout the length of the skirt portion, and forms a vent providing pressure relief for expanding air in said well while the plug is heating up to its maximum operating temperature.

In Figure 18 the terminal head 225 is similar to the head 216, having a tubular portion 226 extending into the well of the plug, and having a tubular socket 227. However, instead of a skirt engaging the neck of the plug, the head 225 has a plurality of spring clips 229 moulded in, and the head is made of plastic instead of rubber. It is applied to the plug in the same manner as described for Figure 17, and the spring clips 229 engage the groove in the neck of the plug. The piercing pin 230 has a head contacting the electrode 167.

In Figure 19, a metal shielded cable 231 has the insulation skinned back to expose a short length of conductor to fit in the socket 232 formed in the clip 233, after which the spear pointed arms 234 are pressed toward the insulation of the cable. The spear points enter the insulation and retain the clip on the cable. The pressing of the arms as described makes the socket 232 firmly contact the conductor.

The threaded portion 235 is screwed into the hole in the bushing 181 to attach the cable to the plug, and a bushing nut 236 on the shielding is then screwed on to the threads on the outside of the bushing 176 of the plug.

In the arrangement shown in Figure 19 the threads on the threaded portion 235 may be left hand threads and the hole in the bushing 181 may be tapped for left hand threads so that when the cable is to be connected to the plug, the act of screwing the plug into the cylinder head in a right hand direction will cause the threaded portion 235 to be screwed into the hole in the bushing 181, thereby electrically connecting the cable to the plug, after which the bushing nut 236 on the shielding is then screwed onto the bushing 176 of the plug.

The terminal head shown in Figures 21 and 22 are similar to that shown in Figure 17, except that instead of the piercing pin 223, it may accommodate a piercing pin 237, which includes a resistance element 238 for radio suppression.

In Figure 20 the terminal head 240 is comprised of an elbow-like metal shell 241 containing the insulator assembly. One leg of the shell beds down on a gasket 242, and is secured to the plug by a right and left threaded hexagonal coupling nut 243. The other leg 244 has a thread 245 to receive the standard union nut on a shielding conduit.

The body 246 is comprised of a tubular portion 247 to enter the well and a socket portion 248 for the cable. It may be moulded of rubber or any suitable plastic capable of withstanding the temperatures encountered. The tubular portion has a longitudinal hole therein for the conducting pin 249 mounted in the electrode 150.

The terminal cap 250 in Figure 23 is moulded of rubber or plastic of substantially the same size as the cap 240 and is afterwards coated with a thin coating of metal 251 by any suitable known means, such as electroplating, and other modes of deposition.

The terminal cap in Figure 24 is similar to

those in Figures 20 and 23 except that the hole in the tubular portion is provided with a contact pin 252, a shank 253 and a spring contact member 254 secured thereto.

In the plug shown in Figure 20, the gaskets 147 and 153 are preferably made of aluminum to more readily conform to the surface irregularities of the ceramic, and the distance between them is kept at a minimum, so that the linear expansion of the electrode stem will be negligible and the zero leakage qualities will not be affected.

In spark plugs for modern internal combustion engines, one of the most important requisites is the provision of means for conducting heat away from the electrodes. In all of the forms herein described, I utilize a sealing and bonding compound in clearance spaces between the shell and the insulator which provides a heat conductive path between the insulator and the shell of the spark plug. In some instances the insulator and the shell have one or more sets of grooves into which the compound is placed, thereby forming therebetween one or more annuli or rings of compound joined by webs of compound.

In other instances, I employ a copper or other highly conductive sleeve to aid in positively retaining the insulator in the shell, also as a heat conductor to aid in keeping the electrodes cool, and further to provide temperature compensation by proportioning the lengths of the insulator hub and the length of the tube to get a combined expansion and contraction practically equal to the expansion and contraction of the shell paralleling these members, thereby maintaining the pressure on the sealing gasket in the plug nearly constant for all temperatures of the plug.

In heavy duty plugs such as shown in Figures 20, 25 and 26, I have found that a distinct advantage is obtained by preventing, within certain limits, the acquisition of heat by the center electrode. Of course the firing tip of the electrode must be exposed so that sparks can jump across the spark gap. By leaving only the firing end exposed to the flame in the cylinder, and embracing the remainder of the electrode lying within the firing chamber of the plug with a material which is a poor conductor of heat (such as mica, or certain compounds having similar characteristics), the amount of heat absorbed by the electrode is substantially reduced. The portion of the composite insulator from the firing chamber up is made of a material which is a better conductor of heat (such as porcelain) which facilitates the conduction of heat from the stem of the electrode to the shell. This is further aided where my compound bonds the porcelain to the shell and/or by the employment of a metallic sleeve in the manner shown and described.

Many changes may be made in the arrangement of the elements of the devices herein shown and described and equivalents may be substituted for many of the elements without departing from the spirit of the invention as set forth in the following claims.

I claim:

1. In a spark plug, the combination of a shell member and an insulator member having shoulders sealed together with a gasket, and a sleeve confined within said shell member and having one end thereof positively engaging the face of said insulator shoulder opposite its sealed shoulder, the other end of said sleeve being engaged by a portion of said shell under pressure for maintaining said members in sealed relation.

2. In a spark plug in combination, a shell

member having externally disposed cooling fins, an insulator member seating in said shell member with a sealing gasket therebetween, an electrode carried by said insulator member, and a straight cylindrical sleeve member made of material highly heat conductive having at least a portion of its length interposed between and thermally bonded to the shell member and to the insulator member and adapted to accelerate the transmission of heat from the electrode to the shell, one end of said sleeve engaging said insulator and the other end being engaged under pressure by means on said shell member.

3. In a spark plug, a shell member having a bore extending therethrough and having a shoulder formed in said bore, a gasket contacting said shoulder, an insulator positioned in said bore and having a hub portion one edge of which members up with said gasket, a tubular member positioned in said bore with one end against the other edge of said hub portion, and means on said shell member solidly engaging the other end of said tubular member and thereby maintaining said shoulder, said gasket, and the first mentioned edge of said hub portion in sealed relation.

4. In a spark plug, a shell member having a bore extending therethrough and having a shoulder formed in said bore, a gasket member up with said shoulder, an insulator mounted in said bore and having a hub portion one edge of which members up with said gasket, a metallic tubular member in said shell having one end in contact with the other edge of said hub portion and having its other end firmly engaged by a spun over portion of said shell member, and a sealing and bonding compound within the space between the shell and said insulator at least along a portion of the length of the latter.

5. In a spark plug, a shell member having a bore extending therethrough and having a shoulder facing toward the firing end thereof, a second shoulder formed in said bore at the firing end, a thin annulus of metal extending from said firing end of the shell member, an insulator having a hub portion mounted in said shell and having one edge of said hub portion engaging a gasket which in turn engages said first shoulder, a metallic sleeve-like member in contact with and extending from the other edge of said hub portion to a point adjacent to and beyond said second shoulder, a ground electrode ring adapted to engage said second shoulder when said annulus is spun down on said ring, whereby a sealing pressure acting positively against said other edge of said hub portion via said sleeve maintains the insulator, the gasket and said first shoulder in sealed relation, and a center electrode carried by said insulator.

6. In a spark plug, a shell having a bore therethrough, said bore having a shoulder formed therein, an insulator mounted in said bore and having a hub portion one end face of which is adapted to member up with said shoulder with a sealing means therebetween, a sleeve in said bore having one end contacting the other end face of said hub, and retaining means on said shell imparting pressure to the other end of said sleeve for positively maintaining said shoulder, said sealing means and said first end face in gas-tight relation, the length of said hub portion and said sleeve being so proportioned that their expansion and contraction due to temperature changes is practically equal that of the portion of the shell between said shoulder and said retaining means.

7. In a spark plug, a shell member having a stepped bore therein forming a shoulder, an insulator member having a hubbed portion the annular faces of which form shoulders, one of which is sealed to said first shoulder with a gasket, a metallic sleeve member in said bore with one end acting against the other shoulder on said insulator, and means on said shell engaging the other end of said sleeve member under stress and positively maintaining said insulator in sealed relation with said shell.

8. In a spark plug, the combination of a shell member and an insulator member having shoulders sealed together with a gasket, a straight cylindrical sleeve confined within said shell member and positively exerting pressure against said insulator member for maintaining the seal between said shoulders, matching grooves formed in said shell member and said insulator member, and a sealing and bonding compound in said grooves forming a thermal bond between said insulator member and said shell member.

9. In a spark plug, in combination, a finned shell member having a threaded portion at one end thereof for mounting in an engine cylinder and means formed on its other end for engaging a terminal head, an interior bore in said member having a shoulder and sealing grooves formed therein, an insulator member having a power electrode therein the lower end of which partially embraces the firing tip thereof and carries a plane firing surface, a terminal well formed in the other end of said insulator member, a terminal block at the bottom of said well and connected to said electrode, a sealing shoulder on said electrode in sealed relation with the interior of said insulator member, a sealing shoulder on said insulator member and sealing grooves matching the grooves formed in the bore of said shell member,

sealing compound between said shoulders and in said grooves bonding and sealing said insulator member to said shell member, a ground electrode having an annular portion and a plane firing surface parallel to said first plane surface and forming a parallel plane spark gap, sleeve means having one end engaging said insulator member and its other end engaged by the annular portion of said ground electrode; means on said shell member for retaining the insulator member, said sleeve means, and said ground electrode in said shell member in stressed contact; a terminal elbow having an insulated socket for an ignition cable and secured to said means on said shell member, and a conducting pin connected to said terminal block and adapted to pierce said cable laterally.

10. In a spark plug, in combination, a unitary shell with a sealing shoulder formed therein, a unitary insulator member having a sealing shoulder formed thereon and held in sealed relation with the sealing shoulder in said shell, a power electrode sealed into said insulator member and having a plane firing surface, a terminal well formed in said insulator, a terminal block in said well and connected to said electrode, a ground electrode including a plane sparking area parallel to said plane firing surface, a sleeve member between said ground electrode and the sealing shoulder on said insulator member; means on said shell for confining said ground electrode, the sleeve member, and the shoulder of said insulator member in said shell, a terminal head member secured to the upper portion of said shell and having a cable receiving socket formed therein, and a needle like member to conduct current from a cable in said socket to said terminal block.

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