

June 8, 1948.

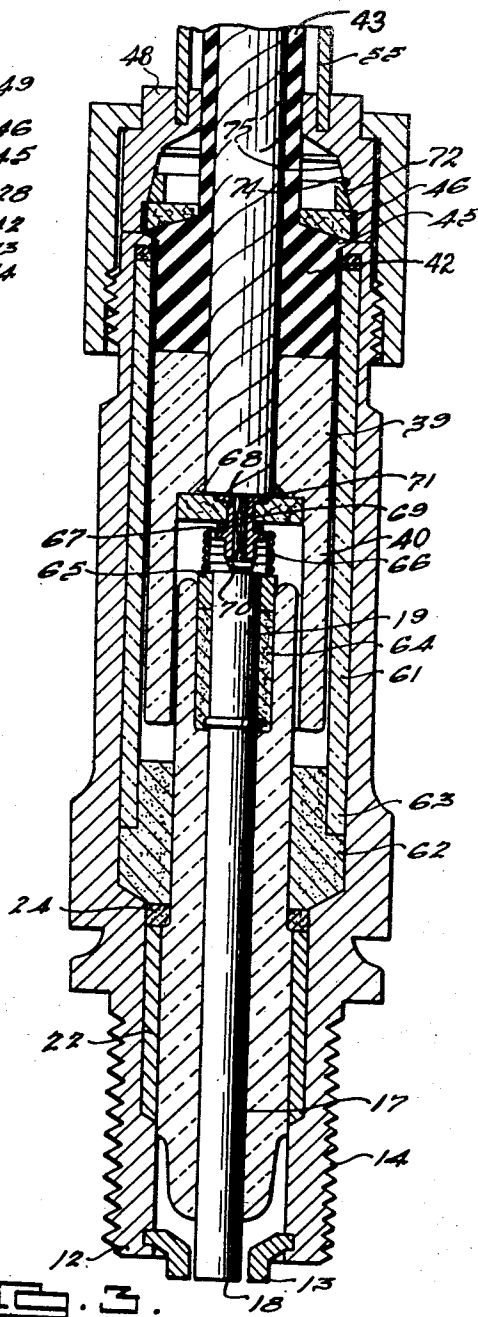
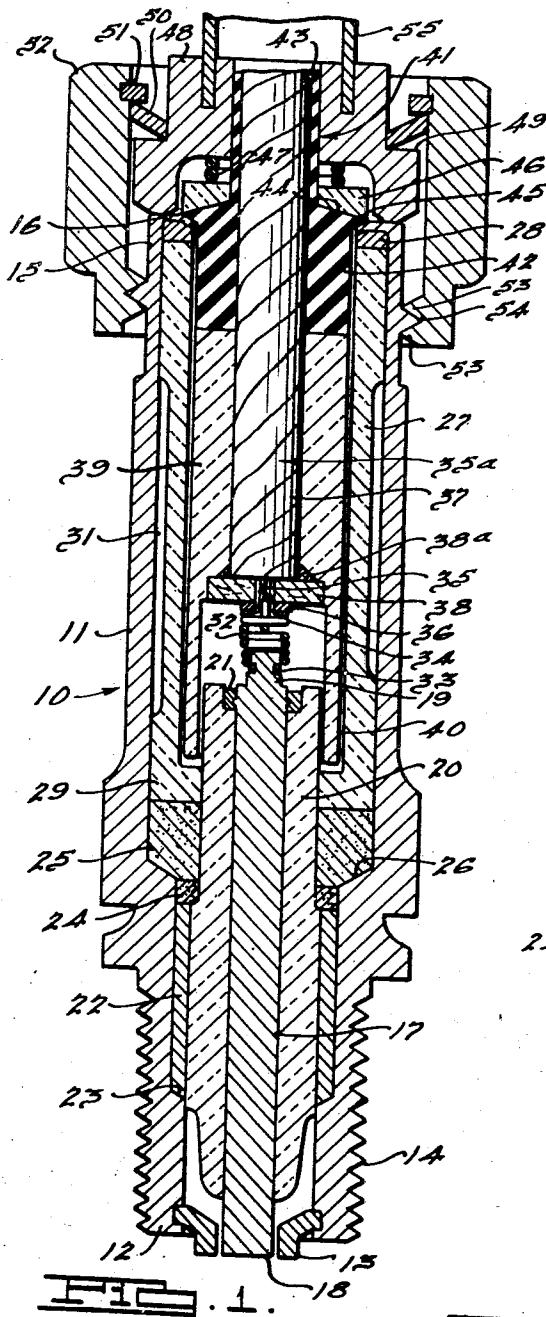
P. T. NIMS ET AL

2,442,858

SPARK PLUG

Filed May 15, 1944

2 Sheets-Sheet 1



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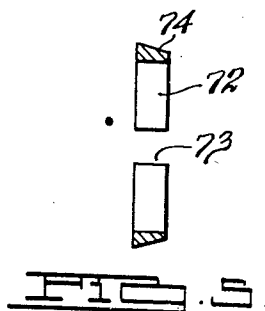
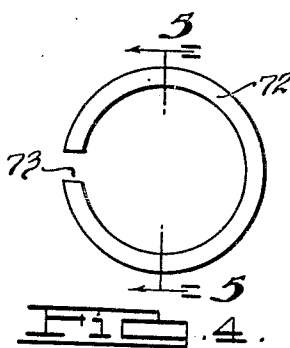
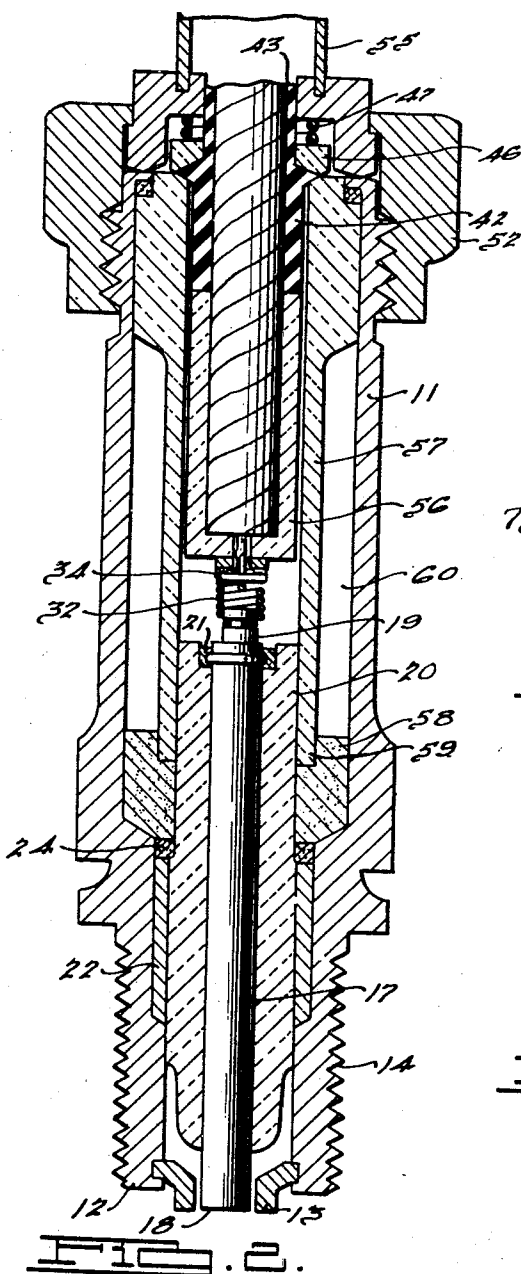
P. T. NIMS ET AL

2,442,858

SPARK PLUG

Filed May 15, 1944

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,442,858

SPARK PLUG

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Application May 15, 1944, Serial No. 535,600

12 Claims. (Cl. 123-169)

1

This invention relates to spark plugs. More specifically, it relates to spark plugs adapted for use in aircraft engines at high altitudes.

Increase in the altitude with consequent decrease in pressure at which a spark plug operates causes an increase in the tendency of flashover between certain portions of the inner electrode and the outer electrode or casing or barrel where it is not wanted. It is to be understood that the flashover discussed in the present application is not the normal sparking occurring at the desired points between electrodes in a cylinder head.

We have discovered several modes of reducing flashover. One way is to seal the spark plug barrel so that the pressure is maintained at a relatively high level. Another way is to bring about a proper relation of the radii of the inner electrode, the barrel or outer electrode, and the insulating layers between the electrodes, which we have shown experimentally to reduce the tendency of flashover. Still another way is to arrange the path over which the flashover must travel in such a way that the path itself resists the flashover.

It will be understood that the problem is complicated somewhat by the fact that the spark plug in question normally has a long outer electrode or barrel and a shorter inner electrode terminating in an outer end wall within the barrel, into which an electrical conductor is to be inserted and electrically connected with the outer end of the inner electrode in a removable and detachable connection. Because of this connection, the flashover occurs, for, since the connection is removable and detachable, it is extremely difficult if not impossible to provide satisfactory insulation at the connection.

An object of the present invention is to provide an improved spark plug. In a more limited sense the spark plug is to be capable of satisfactorily resisting the tendency of flashover, which may occur at reduced pressures.

Another object is to modify the path over which flashover must travel if at all in a spark plug. This is most advantageously applied to a spark plug of the type in which an electrical conductor is removably and detachably connected to the inner electrode within the outer electrode or barrel.

A further object relates to improvements in the sealing of a spark plug so that the higher pressure due to the sealing reduces the tendency of flashover. The sealing finds special use in a spark plug of the type in which an electrical conductor is removably inserted.

Still another object involves improvements in

2

the proportions of the spark plug by which the tendency toward flashover is decreased. This will involve a proper relation between the sizes of the electrodes and the intervening layers of insulation.

A still further object is to provide means for insuring a good grounding of a shield for a conductor leading to a spark plug. This means may be advantageously applied to an arrangement in which the conductor is removably and detachably connected to the spark plug.

Other objects will appear from the disclosure. In the drawings:

Fig. 1 is a sectional view of one form of spark plug of the present invention;

Fig. 2 is a sectional view of another form of spark plug of the present invention;

Fig. 3 is a sectional view of still another form of spark plug of the present invention;

Fig. 4 is a plan view of an element employed in the spark plug of Fig. 3; and

Fig. 5 is a sectional view taken on the line 5-5 of Fig. 4.

The reference character 10 designates the spark plug of Fig. 1. This spark plug includes an outer electrode or barrel or casing 11, which carries at an inner exposed end segment 13. The outer electrode 11 has adjacent its inner end a threaded portion 14, by which the spark plug is adapted to be attached in a cylinder head. The outer electrode has an outer end 15 provided with an inwardly extending flange 16. Positioned within the outer electrode is an inner electrode 17 having an inner exposed end 18 immediately adjacent the segments 13 and the inner end 12 of the outer electrode. Sparking or flashover will occur in normal operation of the spark plug between the electrodes at the segments 13 and the inner end 18 of inner electrode 17. However, the flashover hereinafter referred to as to be avoided is that occurring between other parts of the electrodes. The inner electrode also has an outer exposed end 19 at a region of the outer electrode intermediate its ends. The inner electrode 17 is surrounded by a hard insulating shell 20 formed preferably of a ceramic and is bonded thereto by cement 21 contained in a groove formed in the shell 20 adjacent the outer end 19 of the inner electrode. The shell 20 fits within a copper seal 22 fitting in turn within the outer electrode 11 and resting against a shoulder 23 formed therein. A small ring of cement 24 and a large ring of cement 25 bond and retain the shell 20 in the outer electrode 11. The ring 25 engages a shoulder 26 formed in the outer electrode. An insulating shell 27 engages the inner side of the

outer electrode 11 and extends from the ring 25 to a ring 28 fitting against the flange 16. The shell 27 may be formed of a ceramic such as porcelain and the ring 28 may be formed of asbestos string so as to act as a shock absorber for the porcelain shell 27. The end of the shell 27 is enlarged, as indicated at 29, to engage both the outer electrode 11 and the shell 20. The end of the shell 20 projects into the shell 27 beyond the inner side of the enlargement 29 thereof so as to be spaced from the shell 27. The shell 27 has a long exterior circumferential groove 31 extending for a substantial portion of the length of the shell so as to provide a space for air at this portion between the shell 27 and the outer electrode 11.

A coil spring 32 has an end resting in a groove 33 in the outer end 19 of the inner electrode 17. The coil spring 32 engages a tack 34 pressed into a conductor formed of a strand of wire 35 of a cable 35^a. The tack flattens and spreads the end of the strand against a washer 36 surrounding the strand. The strand 35, the tack 34, and the washer 36 may be formed of stainless steel. The strand 35 protrudes from an insulating sheath 37 and extends through a reduced opening formed in a washer 38 bonded in an annular ring of cement as indicated at 38^a in a tubular section 39 embracing the sheath 37. The tubular section 39 may be formed of a ceramic such as porcelain, and has a thin tubular extension 40 extending into the space between the insulating shells 20 and 27. Above the tubular section 39 is a covering 41 formed preferably of neoprene, which has a thick portion 42 and a thin portion 43, there being a shoulder 44 formed between them and an outwardly extending flange 45 formed on the thick portion 42 at the shoulder 44. A ring 46, which may be formed of a plastic, rests against the shoulder 44 and the flange 45. A coil spring 47 engages the ring 46 and a fitting 48, which has a shoulder 49 engaged by an annular spring 50 of frusto-conical form. The spring 50 is retained in place by a snap ring 51 set in an internal groove in a fitting 52, having coarse threads 53 engaging a coarse thread 54 on the outer electrode 11. A tubular shield 55 for the cable 35^a has a lower end secured in a deep annular groove formed in the fitting 48 in a connection that may include soldering or welding. The spring 50 acts, in spite of possible changes in dimensions due to wear and distortion between the fitting 48 and the flange 16, to maintain a low-resistance contact between these parts so that the shield 55 is satisfactorily grounded through the outer electrode 11 and the cylinder, not shown, in which the outer electrode is attached.

The fitting 52 is screwed on the outer electrode 11 by means of the threads 53 and 54 to the point where it acts through the spring 50, the fitting 48, and the spring 47 to cause the ring 46 to press the flange 45 sufficiently against the flange 16 to provide a seal at this point. This seals the interior of the spark plug and particularly the outer end of the inner electrode 17, the coil spring 32, and the strand 35, and thus the pressure is maintained relatively high in spite of low exterior pressure due to great altitude.

When the unit including the cable 35^a, the tubular section 42, and the covering 43 are to be removed from the spark plug, the fitting is disengaged from the outer electrode 11 by unscrewing. It is to be observed that the tubular

section 42 must come out as part of the removable unit. Since the tubular section 42 must be removable, there is a slight space between the tubular section and the insulating shell 27 through which flashover between the outer end 19 of the inner electrode 17 and the flange 16 on the outer end of the outer electrode 11 may pass.

We minimize the tendency of flashover by keeping the pressure of air within the spark plug as high as possible. This is brought about principally by the use of the spring 47 between the ring 46 and the fitting 48. If the flange 45 becomes thinner and the shoulder 44 becomes somewhat displaced as may be the case with usage of the spark plug, the efficacy of the seal formed between the flange 16 and the flange 45 will not be affected, for the spring 47 provides compensation for any shifting or change in dimensions.

We also minimize the tendency of flashover by the provision of the thin tubular extension 40 on the tubular section 39. This extension extends inwardly or downwardly beyond the exposed connection and adjacent portions formed at the outer end 19 of the inner electrode 17, the coil spring 32, the tack 34, the strand 35, and the washer 36. Therefore, the flashover in going from the exposed connection to the flange 16 must first travel away from the flange 16 between the extension 40 and the insulating shell 20, then around the end of the extension, and then toward the flange 16 between the tubular section 39 and the insulating shell 27.

The flashover is due to ionization. The tendency toward flashover decreases with increase in the spacing of the parts between which flashover can occur, or in other words, for a given pressure, flashover occurs at a greater distance only if the voltage is made greater. We have increased the distance over which the flashover must travel by the provision of the tubular extension 40 without increasing the lengthwise dimensions of the spark plug. Moreover, the use of the tubular extension not only increases the length of the path, but it also causes the flashover to travel in a retarding field away from the point eventually reached. Thus the tendency toward flashover is decreased more than by a mere increase in the spacing between points.

We have also discovered experimentally that the tendency toward flashover is reduced by the proper proportioning of the electrodes and the insulating layers between the electrodes. For the construction shown in Fig. 1 this proportioning is expressed by the equation

$$1 = \frac{1}{K_1} \log \frac{r_2}{r_1} + \frac{1}{K_2} \log \frac{r_3}{r_2} + \frac{1}{K_3} \log \frac{r_4}{r_3} + \frac{1}{K_4} \log \frac{r_5}{r_4}$$

where

K_1 = dielectric constant of the air or gas in the space between the inner electrode end 19 and the extension 40

K_2 = dielectric constant of extension 40

K_3 = dielectric constant of insulating shell 27

K_4 = dielectric constant of air or gas in groove 31
 r_1 = radius of inner electrode end 19 or inner radius of layer of gas or air surrounding it

r_2 = inner radius of insulating layer formed of extension 40

r_3 = inner radius of insulating layer formed of shell 27

r_4 = inner radius of insulating layer formed of air or gas in groove 31

r_5 = outer radius of air layer 31 or inner radius of outer electrode 11

5

The air or gas layers between the inner electrode end 19 and the extension 40 and in the groove 31 are important, for they enable the equation to be satisfied most conveniently with appropriate sizes of the electrodes 11 and 17.

The spark plug of Fig. 2 differs from that of Fig. 1 principally in that there is no tubular extension on the tubular section 56 embracing the end of the cable 35^a, an insulating shell 57 surrounding the tubular section 56 has consequently a smaller interior diameter so as to embrace the insulating shell 20, the lower or inner end of the shell 57 does not increase in width and is embedded in a large cement ring 58 as indicated at 59, and there is a relatively thick annular groove 60 formed on the exterior of the shell. Since there is no extension on the tubular section 56, the path for flashover between the inner electrode end 19 and the flange 16 on the outer end of the outer electrode 11 follows generally a straight path. In spite of this, the tendency toward flashover is decreased because the electrodes and the insulating layers between them are chosen in accordance with the following equation:

$$1 = \frac{1}{K_1} \log_e \frac{r_2}{r_1} + \frac{1}{K_2} \log_e \frac{r_3}{r_2} + \frac{1}{K_3} \log_e \frac{r_4}{r_3}$$

where

K_1 =dielectric constant of the air or gas in the space between the inner electrode end 19 and the insulating shell 56

K_2 =dielectric constant of insulating shell 57

K_3 =dielectric constant of air or gas in groove 60

r_1 =radius of inner electrode end 19 or of inner radius of layer of gas or air surrounding inner electrode end 19

r_2 =inner radius of insulating layer formed of shell 57

r_3 =inner radius of insulating layer formed of air in groove 60

r_4 =inner radius of outer electrode 11 or outer radius of insulating layer formed of air in groove 60.

The following general equation may cover the two preceding equations:

$$1 = \frac{1}{K_1} \log_e \frac{r_2}{r_1} + \frac{1}{K_2} \log_e \frac{r_3}{r_2} + \dots + \frac{1}{K_n} \log_e \frac{r_{n+1}}{r_n}$$

where

K_1 =dielectric constant of insulating layer immediately surrounding inner electrode end

$K_2 \dots$ =dielectric constant of next insulating layer

K_n =dielectric constant of outermost insulating layer immediately surrounded by outer electrode

r_1 =radius of inner electrode end or inner radius of insulating layer immediately surrounding inner electrode end

r_2 =inner radius of next insulating layer

$r_3 \dots$ =inner radius of second next insulating layer.

r_n =inner radius of outermost insulating layer immediately surrounded by outer electrode

r_{n+1} =inner radius of outer electrode or outer radius of outermost insulating layer.

The greater thickness of the groove 60 in Fig. 2 as against the smaller thickness of the corresponding groove 31 in Fig. 1 means that the insulating layer of air in the groove 60 exerts a greater effect and reduces the tendency toward flashover.

Fig. 3 shows a spark plug similar to that of Fig. 1 in that there is provided the tubular extension

6

40 on the tubular section 39. Then, as in the case of Fig. 1, the flashover must follow a path that first goes away from the point ultimately reached. An insulating shell 61, surrounding the tubular section 39, has no groove in its exterior. Moreover, its lower or inner end is not widened out and is embedded in a large cement ring 62 as indicated at 63. The outer end 19 of the inner electrode 17 is bonded to the insulating shell 20 by a ring of cement 64 that extends to a considerable depth along the outer end 19, and carries a metallic ring 65, which is abutted by a coil spring 66. The upper end of the coil spring is reduced and engages a flange 67 formed in a sleeve 68 surrounding a bared end of a conductor strand 69, which is upset as indicated at 70 to retain the sleeve 68. A flange 71 on the upper end of the sleeve resting in a recess in the washer 38, also assures retention of the sleeve on the conductor end 69. As in the case of the springs 32 of Figs. 1 and 2, the spring 66 of Fig. 3 provides electrical connection between the removable conductor and the inner electrode. However, the spring 66 is attached to the conductor rather than to the inner electrode. The ring 65, the spring 66, and the conductor 69 may be formed of stainless steel. The plastic ring 46 is pressed against the flange 45 by a ring spring 72 shown in Figs. 4 and 5. As seen in these figures, the ring has a split 73 and a frusto-conical exterior surface 74, which fits in a frusto-conical interior surface 75 within the fitting 48. The inherent resilience of the ring 72 causes it to tend to expand to its form of Figs. 3 and 4, and thus the ring tends to move toward the wide portion of the surface 75 pressing the ring 46 against the flange 45.

The last mentioned formula on relative proportions of electrodes and intervening insulating layers will apply to the spark plug of Fig. 3.

The intention is to limit the invention only within the scope of the appended claims.

We claim:

1. In a spark plug comprising an outer tubular electrode, an inner electrode positioned within the outer electrode in spaced relation thereto and having one end exposed and adjacent one end of the outer electrode exposed at the inside and the other end at a region of the outer electrode intermediate the ends thereof, means mounting the inner electrode within the outer electrode and insulating the electrodes from one another and extending from adjacent the exposed ends of the electrodes to a region intermediate the ends of the outer electrode, means forming on the inner side of the outer electrode an insulating layer extending from the said other end of the outer electrode to the mounting means, and means forming on the inner electrode an insulating layer extending from the said other end of the inner electrode to the mounting means, and a readily detachable unit including a conductor having an end adapted to extend into the said other end of the outer electrode into electrical connection with the said other end of the first electrode and an insulator embracing the end of the conductor, the combination with the insulating layers and the insulator, of an annular space formed between the insulating layers and extending at least a substantial portion of the way from the said other end of the inner electrode to the mounting means, and an extension of the insulator extending beyond the end of the conductor into the annular space.

2. A spark plug comprising a metallic casing serving as an outer electrode, an inner electrode positioned within the casing and spaced there-

from, the inner electrode extending from an exposed inner end adjacent an exposed inner end of the casing to an outer end positioned intermediate the inner end of the casing and the outer end thereof, means mounting the inner electrode within the casing and insulating them from one another, a first insulating means insulating the inner side of the outer electrode and extending from the outer end thereof to a region thereof intermediate the inner end thereof and the outer end of the inner electrode, a second insulating means surrounding and insulating a region of the inner electrode adjacent the outer end thereof, and a removable unit comprising an electrical conductor adapted to be inserted in the outer end of the outer electrode and electrically connected with the outer end of the inner electrode and a third insulating means surrounding and insulating the portion of electrical conductor inserted in the outer electrode and extending beyond the end of the electrical conductor between the first and second insulating means to a region intermediate the ends of the inner electrode.

3. A spark plug comprising an outer electrode, an inner electrode positioned within the outer electrode and having an inner exposed end adjacent an inner exposed end of the outer electrode and an outer end intermediate the inner end and outer end of the outer electrode, means mounting the inner electrode in the outer electrode and insulating the electrodes from one another, the outer end of the outer electrode being adapted to receive an end of a removable unit comprising a conductor adapted to be electrically connected to the outer end of the inner electrode and means insulating the conductor from the outer electrode, there being insulating layers surrounding the inner electrode adjacent the outer end thereof, these layers being so proportioned with respect to the electrodes that the following equation is satisfied:

$$1 = \frac{1}{K_1} \log_e \frac{r_2}{r_1} + \frac{1}{K_2} \log_e \frac{r_3}{r_2} + \dots + \frac{1}{K_n} \log_e \frac{r_{n+1}}{r_n}$$

where $K_1, K_2 \dots K_n$ are the dielectric constants of respectively the layer immediately surrounding the inner electrode, the next layer ... the layer lining the outer electrode, and $r_1, r_2, r_3 \dots r_n, r_{n+1}$ are the inner radii of, respectively, the layer immediately surrounding the inner electrode, the next layer, the second next layer ... the layer lining the outer electrode, the outer electrode.

4. A spark plug comprising a metallic casing serving as an outer electrode, an inner electrode positioned within the casing and spaced therefrom, the inner electrode extending from an exposed inner end adjacent an exposed inner end of the casing to an outer end positioned intermediate the inner end of the casing and the outer end thereof, means mounting the inner electrode within the casing and insulating them from one another, a first insulating means insulating the inner side of the outer electrode and extending from the outer end thereof to a region thereof intermediate the inner end thereof and the outer end of the inner electrode, a second insulating means surrounding and insulating a region of the inner electrode adjacent the outer end thereof, and a removable unit comprising an electrical conductor adapted to be inserted in the outer end of the outer electrode and electrically connected with the outer end of the inner electrode and a third insulating means surrounding and insulating the portion of electrical conductor inserted in

the outer electrode and extending beyond the end of the electrical conductor between the first and second shielding means to a region intermediate the ends of the inner electrode, the insulating means comprising insulating layers so proportioned with respect to the electrodes that the following equation is satisfied:

$$1 = \frac{1}{K_1} \log_e \frac{r_2}{r_1} + \frac{1}{K_2} \log_e \frac{r_3}{r_2} + \dots + \frac{1}{K_n} \log_e \frac{r_{n+1}}{r_n}$$

where $K_1, K_2 \dots K_n$ are the dielectric constants of, respectively, the layer immediately surrounding the inner electrode, the next layer ... the layer lining the outer electrode, and $r_1, r_2, r_3 \dots r_n, r_{n+1}$ are the inner radii of, respectively, the layer immediately surrounding the inner electrode, the next layer, the second next layer ... the layer lining the outer electrode, the outer electrode.

5. A spark plug comprising an outer electrode, an inner electrode positioned within the outer electrode and having an inner exposed end adjacent an inner exposed end of the outer electrode and an outer end intermediate the inner end and outer end of the outer electrode, means mounting the inner electrode in the outer electrode and insulating the electrodes from one another, insulating layers surrounding the inner electrode adjacent the outer end thereof, a removable unit comprising a conductor extending into the outer end of the outer electrode to electrical connection with the outer end of the inner electrode and an insulating covering for the conductor being of enlarged thickness at the portion within the outer electrode so as to present adjacent the outer end of the electrode a shoulder having a flange seated on the end of the outer electrode, retaining means surrounding and detachably engaged with the outer end of the electrode, and means including a spring for resiliently pressing the flange into sealing engagement with the outer end of the outer electrode.

6. In the spark plug of claim 5, the last mentioned means comprising a ring engaging the flange and a coil spring acting between the ring and the retaining means.

7. In the spark plug specified in claim 5, the spring being in the form of a ring having a frusto-conical exterior surface and being split so as to have spaced opposed ends.

8. In an assembly comprising a spark plug having an outer electrode and an inner electrode having an inner end adjacent the inner end of the outer electrode and an outer end intermediate the inner end and the outer end of the outer electrode, a removable conductor insertable within the outer electrode for electrical connection with the outer end of the inner electrode, a shield for the conductor, a first fitting receiving an end of the shield and engageable with the outer end of the outer electrode, the combination with the shield, the first fitting, and the outer end of the inner electrode, of means for firmly pressing the first fitting against the outer end of the outer electrode to obtain low-resistance contact between the outer electrode and the first fitting and therewith a good grounding of the shield through the outer electrode, said means comprising a second fitting detachably connected to the outer electrode and resilient means acting between the first and second fittings.

9. In the assembly of claim 8 the resilient means comprising a frusto-conical spring ring.

10. In an assembly comprising a spark plug

having an outer electrode and an inner electrode having an inner end adjacent the inner end of the outer electrode and an outer end intermediate the inner end and the outer end of the outer electrode, a removable conductor insertable within the outer electrode for electrical connection with the outer end of the inner electrode, a shield for the conductor, a first fitting receiving an end of the shield and engageable with the outer end of the outer electrode, the combination with the shield, the first fitting, and the outer end of the inner electrode, of means for firmly pressing the first fitting against the outer end of the outer electrode to obtain low-resistance contact between the outer electrode and the first fitting and therewith a good grounding of the shield through the outer electrode, said means comprising a second fitting surrounding the first fitting and the outer end of the outer electrode and detachably connected therewith and resilient means acting between the first and second fittings.

11. In an assembly comprising a spark plug having an outer electrode having an inner end and an outer end provided with an inwardly extending flange and an inner electrode having an inner end adjacent the inner end of the outer electrode and an outer end intermediate the inner end and the outer end of the outer electrode, a removable conductor insertable within the outer electrode for electrical connection with the outer end of the inner electrode, a shield for the conductor, a first fitting receiving an end of the shield and engageable with the flange on the outer end of the outer electrode, the combination with the shield, the first fitting, and the flange on the outer end of the inner electrode, of means for firmly pressing the first fitting against the flange on the outer end of the outer electrode to obtain low-resistance contact between the outer electrode and the first fitting and therewith a good grounding of the shield through the outer electrode, said means comprising a second fitting surrounding the first fitting and the outer end of the outer electrode and detachably connected therewith, a snap ring mounted within the second fitting, and a frusto-conical annular spring acting between the snap ring and the first fitting.

12. In combination, an outer electrode having an inner end and an outer end provided with an inwardly extending flange, an inner electrode positioned within the outer electrode and having an inner end adjacent the inner end of the outer electrode and an outer end intermediate the ends of the outer electrode, insulating means mounting the inner electrode in the outer electrode, a removable conductor having an end inserted within the outer end of the outer electrode into electrical connection with the outer end of the inner electrode, an insulating covering surrounding the conductor and having a flange engageable with the flange on the outer end of the outer electrode, a shield surrounding the conductor, a first fitting receiving an end of the shield and engaging the flange on the outer end of the outer electrode, resilient means acting between the first fitting and the flange on the insulating covering to press this flange firmly against the flange on the outer end of the outer electrode for sealing the connection of the conductor with the outer end of the inner electrode within the outer electrode, a second fitting detachably connected to the outer electrode, and resilient means acting between the fittings to press the first fitting firmly against the flange on the outer end of the outer electrode for obtaining low-resistance contact between the outer electrode and the first fitting and therewith a good grounding of the shield through the outer electrode.

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Certificate of Correction

Patent No. 2,442,858.

June 8, 1948.

PAUL T. NIMS ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 27, for the word "segment" read *segments*; column 8, claim 4, in the equation thereof, for the fraction

$$\frac{r_2}{r_3} \quad \text{read} \quad \frac{r_3}{r_2}$$

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 31st day of May, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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[SEAL]

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