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ELECTRO EXPLOSIVE DEVICE HAVING A SURFACE SPARK GAP

Filed Aug. 14, 1963 2 Sheets-Sheet 1

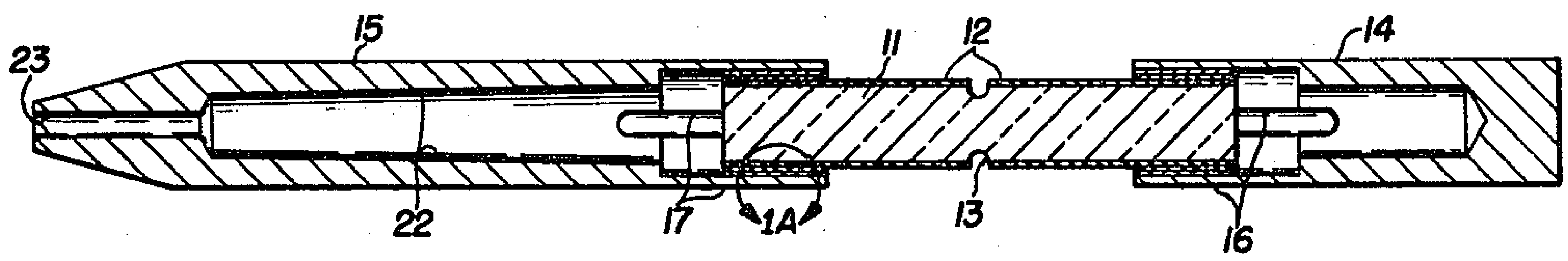

Fig. 1

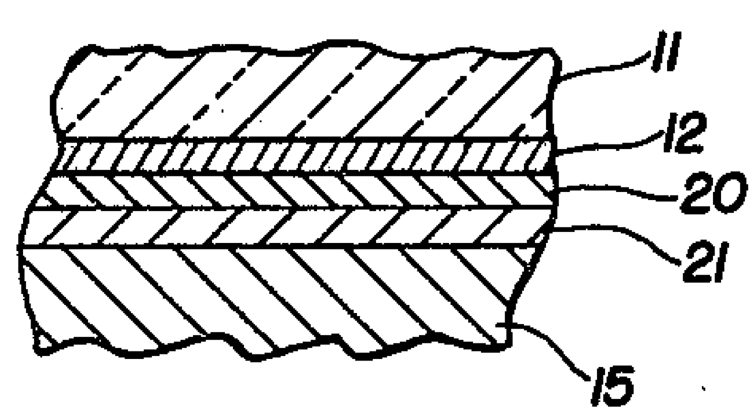

Fig. 1A

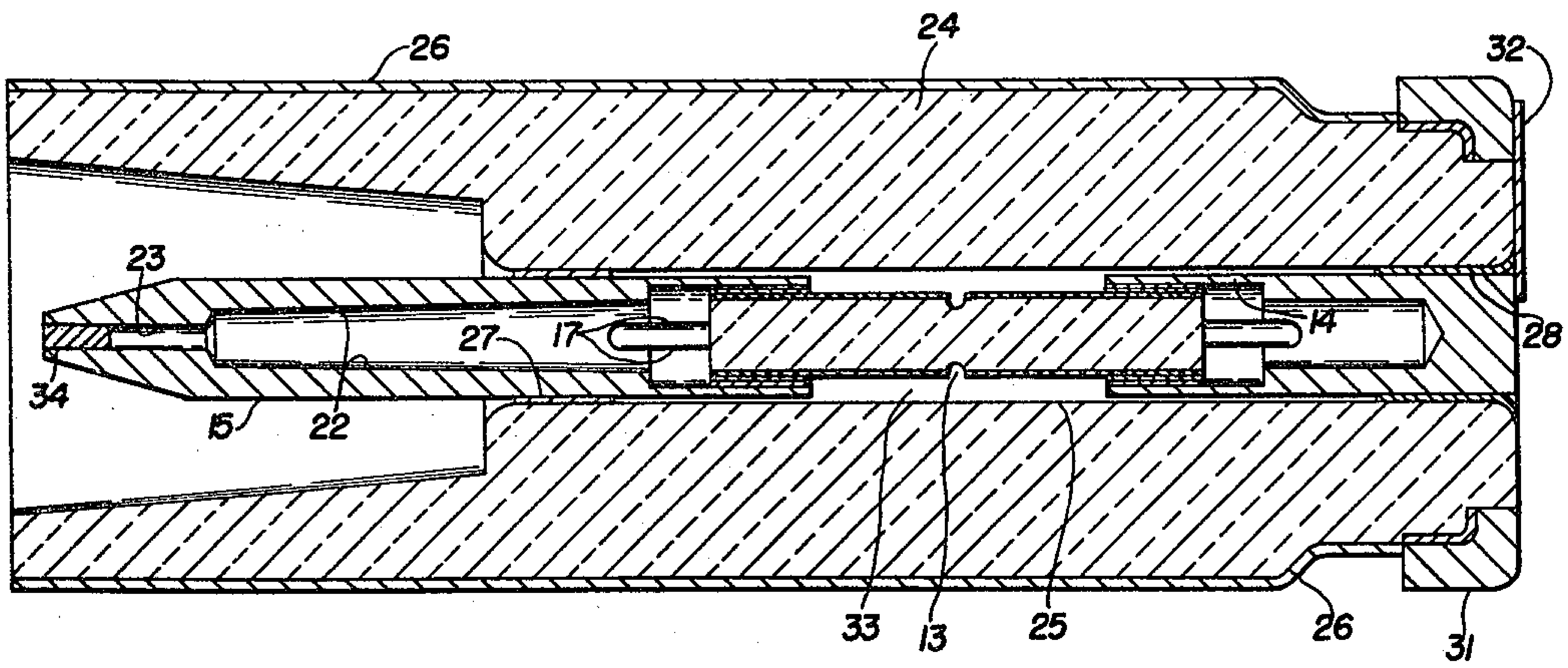

Fig. 2

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ELECTRO EXPLOSIVE DEVICE HAVING A SURFACE SPARK GAP

Filed Aug. 14, 1963 2 Sheets-Sheet 2

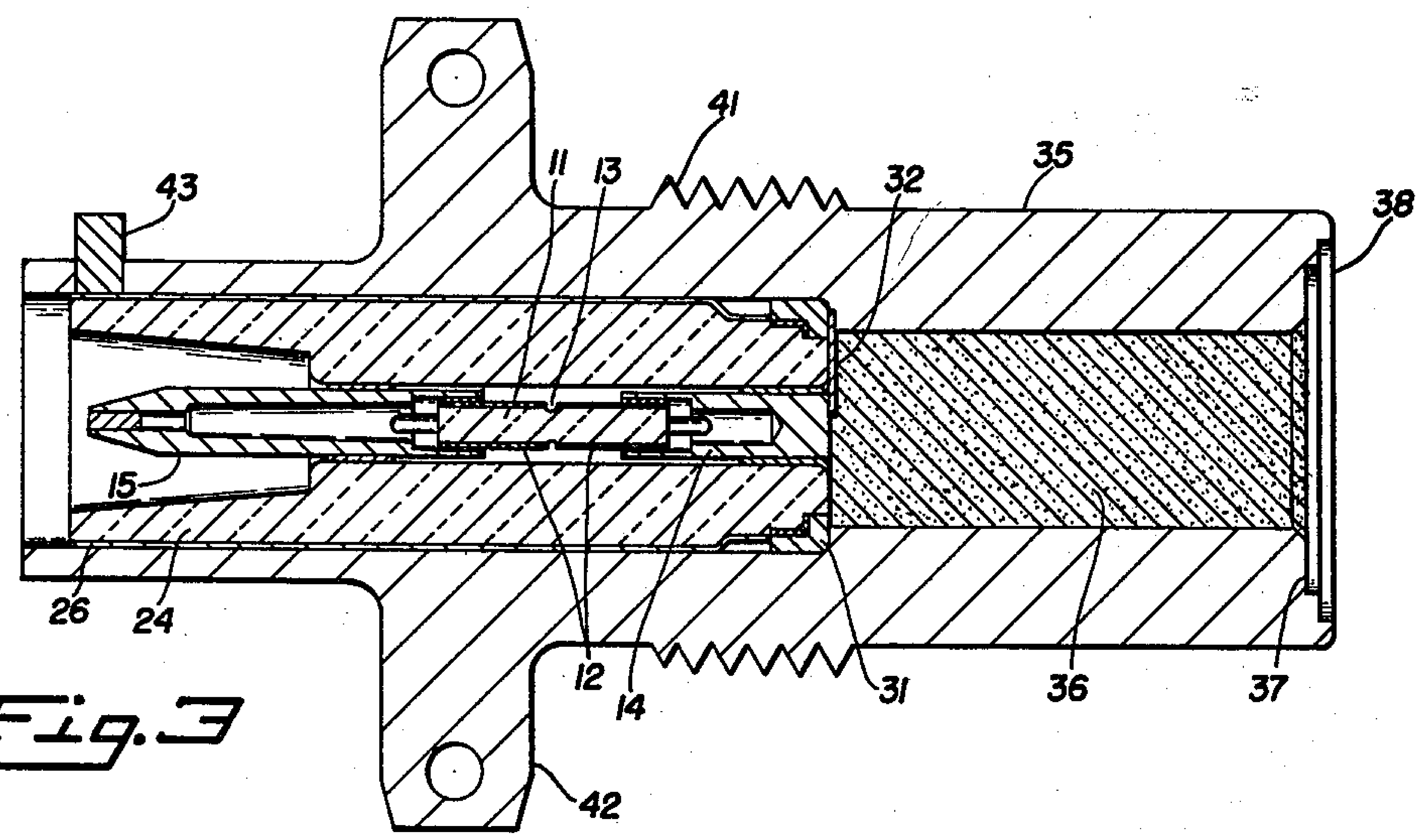

Fig. 3

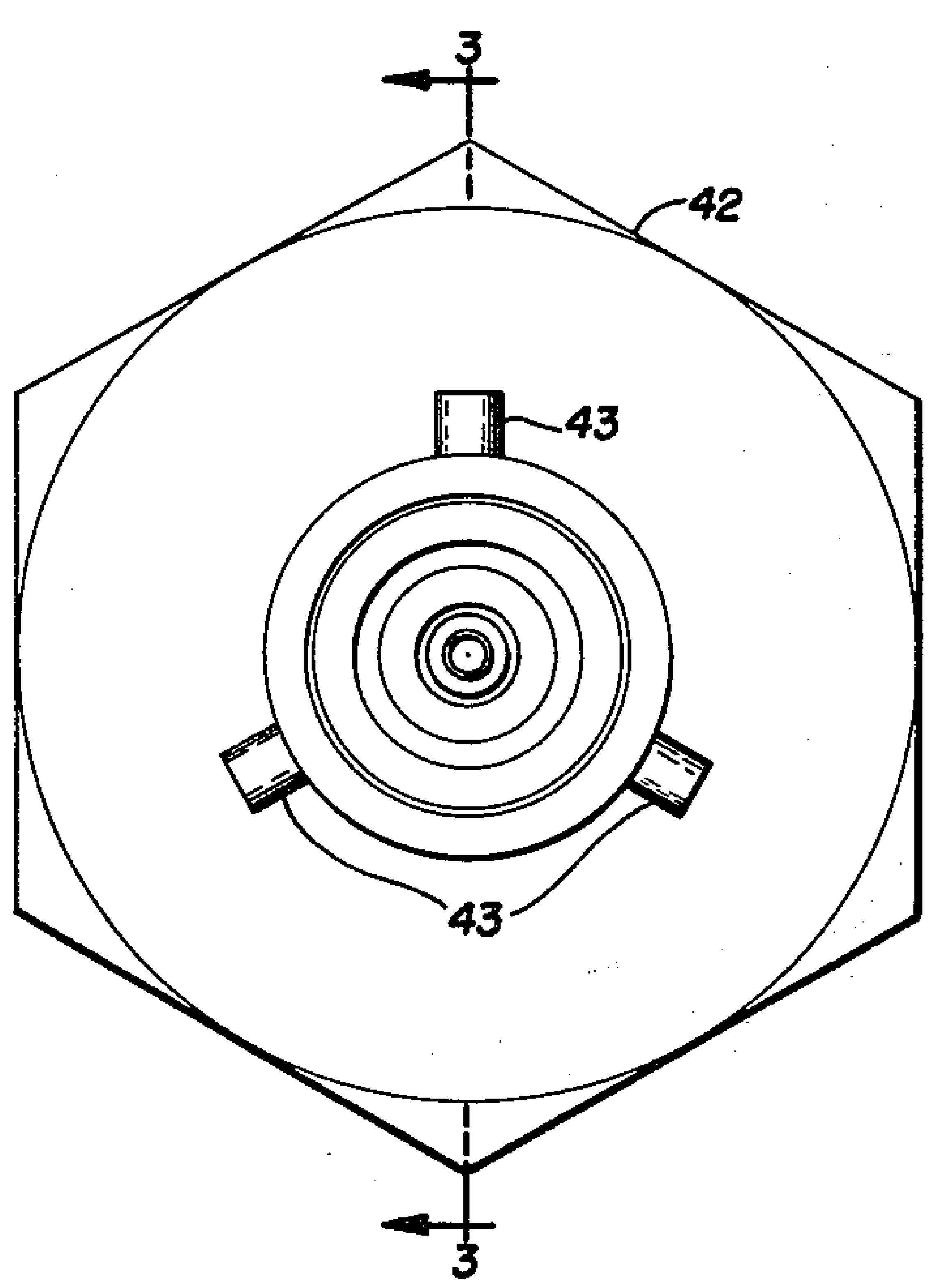

Fig. 3A

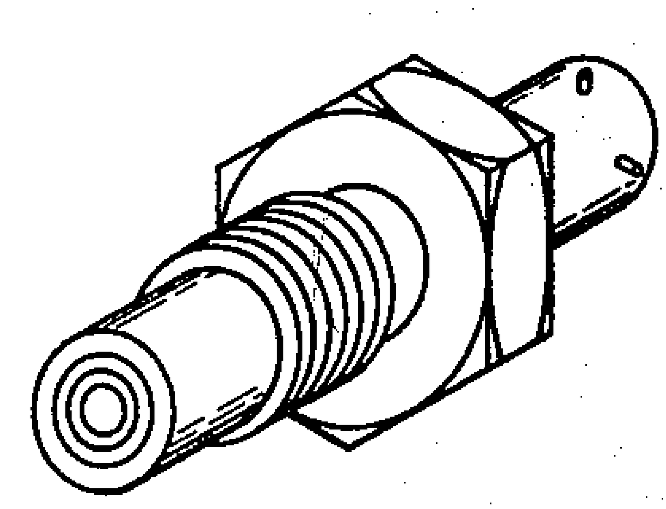

Fig. 4

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ELECTRO EXPLOSIVE DEVICE HAVING A SURFACE SPARK GAP

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This invention relates to electro explosive devices, such as detonators and squibs, and more particularly to a surface spark gap detonator or squib.

Detonators and squibs are devices which are utilized to ignite or detonate explosive charges. One type of detonator utilizes a thin, gold alloy, bridge wire that is positioned adjacent a relatively small quantity of explosive material. By passing a high current through the bridge wire, the bridge wire vaporizes rapidly (explodes) and detonates the small quantity of explosive material. The detonation of this explosive material is generally utilized to detonate a larger quantity of explosive material. In order to prevent the detonator from being accidentally set off by stray static charges, transient currents or induced radio frequency currents, a spark gap is serially connected with the bridge wire. The gap is designed so that the magnitude of voltage necessary to produce an arc across the gap is larger than the magnitude of stray and transient voltages present in the environment in which the detonator is to be utilized.

Heretofore in the prior art, the spark gap was obtained by precisely spacing two metallic elements to form an air gap. Since the magnitude of the arc voltage is determined by the dimensions of the air gap, it is necessary to closely control the spacing of the two metallic elements because a variation of as little as .001 inch in the air gap spacing can produce a 20% variation in the arc voltage. Accordingly, due to the precise spacing necessary, prior art spark gap detonators are relatively expensive to fabricate. Also, a large number of rejects occur in fabricating prior art spark gap detonators because the spark gap spacing may change during the processes of fabrication, thereby making the finished detonator unit unfit for its intended use. Further, prior art devices sometimes shattered when fired, showering particles that damaged equipment located nearby.

Accordingly, an object of this invention is to provide an improved spark gap detonator.

Another object of this invention is to provide a surface spark gap detonator.

Still another object of this invention is to provide a spark gap detonator that is reliable and readily fabricated.

A further object of this invention is to provide a mechanically rugged spark gap detonator.

These and other objects and advantages of the present invention are obtained in a detonator device which utilizes an elongated nonconductive rod having a conductive coating thereon. A surface spark gap intermediate the ends of the rod is defined by an annular discontinuity in the conductive coating. An insulating body is disposed around the coated rod and a conductive shell has at least a portion of its length surrounding the insulating body. A bridge wire is electrically coupled between a portion of the conductive coating on the rod and the conductive shell. Means are provided for retaining a quantity of explosive charge adjacent to the bridge wire. The arc voltage of the spark gap is made independent of ambient pressure and temperature by hermetically confining a quantity of inert gas, such as nitrogen, around the spark gap.

This invention as well as other objects, features and advantages thereof will be readily apparent from consideration of the following detailed description relating to the accompanying drawings in which like reference characters designate like or corresponding parts throughout the several views and wherein:

FIGURE 1 illustrates in cross-section a surface spark gap assembly according to the present invention;

FIGURE 1–A illustrates in enlarged schematic form a ceramic to metal seal utilized in the assembly of FIGURE 1;

FIGURE 2 illustrates in cross-section a ceramic body assembly which incorporates the spark gap assembly of FIGURE 1;

FIGURE 3 illustrates in cross-section a complete detonator device in accordance with the present invention;

FIGURE 3–A illustrates an entire end view of the device of FIGURE 3; and

FIGURE 4 is a perspective view of the detonator illustrated in FIGURES 3 and 3–A.

Referring now to FIGURE 1, there is illustrated in cross-section a surface spark gap assembly which includes an elongated cylindrical nonconductive rod **11** having a conductive coating **12** thereon. A spark gap **13** is defined by an annular discontinuity in the conductive coating **12** intermediate the ends of the rod **11**. A metallic support cup **14** is secured to one end of the rod **11** and a metalic support tube **15** is secured to the opposite end of the rod.

The rod **11** may be fabricated from any nonconductive material. However, a suitable ceramic, such as beryllia, or a high alumina (more than 85% alumina) ceramic is preferred. Substantially the entire length of the ceramic rod **11** is initially coated with a conductive metallized surface. Although many types of conductive surfaces may be utilized, a suitable surface is formed by mixing powdered manganese and titanium with a powdered metal selected from the group consisting of molybdenum, and tungsten. In order to reduce the work function of the metallized surface, a quantity of thoria may be added to the mix. The metals can be used in the powdered mixture in various forms. For example, the titanium, manganese and molybdenum or tungsten can each be used in the elemental form or in one of their oxide forms. The titanium can also be used in its hydride form. In preparing a preferred powdered mix 0% to 25% by weight of titanium, 40% to 10% by weight of manganese, about 2% by weight of thoria and a major portion by weight of metal selected from the group consisting of molybdenum and tungsten is intimately mixed, such as by ball milling, in a suitable carrier, such as acetone, methyl amyl acetate or mixtures thereof, preferably with a suitable binding agent, such as nitro cellulose. The resulting metallizing paint composition is brushed, sprayed, printed or otherwise applied to the ceramic rod **11**. The ceramic rod is then fired in an atmosphere furnace. A reducing atmosphere is desirable and commercial hydrogen has been found to be satisfactory for this purpse. The temperature in the furnace should be at least as high as the sintering temperature of the metallizing mixture and below the softening temperature of the ceramic. For example, excellent results have been obtained by firing the coated ceramic at a temperature of about 1425° C. for about 30 minutes.

The spark gap **13** on the ceramic rod **11** is obtained by removing a portion of the metallized surface **12** at an area intermediate the ends of the rod thereby forming an annular discontinuity in the metallized surface. This is accomplished by any suitable means, such as sand blasting or cutting with a wire and diamond paste. Inasmuch as the sintering of the metallized surface **12** on the ceramic rod causes the metallizing materials used to penetrate into the ceramic (a condition generally called "blushing"), the blushed portion of the ceramic in the area of the discontinuity or spark gap is also removed.

This can be accomplished with an ohm meter connected between the two ends of the metallized ceramic rod **11**. As the method used for forming the annular discontinuity removes the blushed ceramic, the resistance of the ceramic rod **11** will continue to increase until the blushed ceramic is totally absent from the area of discontinuity at which time the resistance of the ceramic rod is substantially infinite. The area of blushed ceramic so removed is exaggerated in FIGURES 1, 2, and 3 for purposes of illustration.

The width of the discontinuity defining the spark gap **13** is determined by the magnitude of voltage desired to cause an arc across the gap **13**. In fabricating a detonator device having an arc voltage from 500 to 1000 volts D.C., the width of the spark gap was 5 mils. Since the magnitude of the arc voltage is proportional to the width of the gap **13**, it is necessary to carefully control the width of the spark gap. Once the spark gap **13** is obtained, the arc voltage of the gap may be determined before continuing with the assembly of a complete detonator.

In order to aid in securing the end portions of the metallized ceramic rod **11** to the support cup **14** and the support tube **15**, a layer of metal is applied to the end portions of the metallized ceramic rod **11**. This metal layer may be copper or nickel and is obtained by electro plating or any other suitable means.

The support cup **14** is made from any suitable metal, such as Kovar, and has its open end slotted thereby forming a plurality of circumferentially spaced portions **16** which surround one end of the ceramic rod **11** and are adjacent to the metal layer which covers the end portions of the metallized surface **12**. The support cup **14** is brazed to the coated ceramic rod with any suitable brazing material, such as copper.

The support tube **15**, which is made from any suitable metal, such as Kovar, also has one of its ends slotted to form a plurality of circumferentially spaced portions **17** that engage the other end of the metallized ceramic rod **11** as illustrated in FIGURE 1. The support tube **15** is brazed to the ceramic rod in a manner substantially identical to that of the support cup **14**. An enlarged schematic representation of this brazed joint is illustrated in FIGURE 1–A. Reference to FIGURE 1–A shows that a layer of metal **20** covers the metallized surface **12** which is sintered on the ceramic rod **11**. Interposed between the metal layer **20** and the support tube **15** is a layer of copper brazing material **21**. Brazing is accomplished in a suitable brazing furnace at a temperature of about 1100° C. in this furnace operation, the metal surface layer **20** is also sintered to the metallized surface **12**. The metal surface **20** may be omitted and the support tube **15** and the support cup **14** may be brazed directly to the metallizing layer **12**. However, the presence of the metal layer **20** provides a much superior brazed joint which adheres more tightly to the support tube **15** and the support cup **14**.

The interior of the support tube **15** may have a tapered portion **22** which is connected by a longitudinal opening **23** to the end of the support tube remote from the ceramic rod **11**. The reasons for utilizing this structure will be discussed hereinbelow in detail.

Referring now to FIGURE 2, there is illustrated a cross-sectional view of a ceramic body assembly that includes a centrally apertured **25** nonconductive body **24** that is disposed around the surface spark gap assembly of FIGURE 1. The centrally apertured cylindrical body **24** is formed from a suitable nonconductive dielectric material, such as beryllia, or a high alumina ceramic. It is to be understood, of course, that other insulating materials could be used in place of a ceramic. The outside circumferential surface of the ceramic body is covered with a conductive or metallized surface and a layer of metal, substantially identical to those discussed hereinabove in detail in conjunction with FIGURES 1 and 1–A, which are indicated by the reference character **26**. Each end of the aperture **25** also contains a similar conductive coating and metal layer, indicated by the reference characters **27** and **28**, respectively, which permit hermetically uniting the support cup **14** and the support tube **15** to the inner peripheral surface of the aperture **25** at opposite ends thereof. A copper-silver or copper-tin brazing alloy may be used to obtain the hermetic seal. The brazing is performed after the surface spark gay assembly is inserted into the aperture **25** in the ceramic block **24** such that the support cup **14** lies within and adjacent one end of the ceramic body **24** and the support tube **15** has at least a portion of its length extending into the aperture **25** in a manner as illustrated in FIGURE 2. It is believed that the copper vapor produced by the brazing operation, or the blushing of the ceramic by the metallizing paint, produces a semiconductor layer on the surface of the spark gap **13** which decreases the arc voltage of the spark gap.

A metallic end cap **31** which may be formed from any suitable conductive material, such as nickel, is brazed to the end of the coated ceramic body **24** containing the support cup **14** with a suitable brazing material, such as a copper-silver alloy. Electrically coupled between the support cup **14** and the end cap **31** is a thin bridge wire **32** which is fabricated from any suitable material, such as a gold alloy. The bridge wire may also be formed by metallizing the ceramic **24** or by electroplating or vapor depositing nickel or other materials on the end surface. Photoetching techniques may also be used to deposit a metal bridge wire across the end of the ceramic **24**. In accordance with one embodiment of this invention, the bridge wire selected had a diameter of .0025 inch and had its opposite ends spot welded to the end cap **31** and the support cup **14**, respectively. Although FIGURE 2 illustrates the bridge wire as being directly connected between the end cap **31** and the support cup **14**, it is to be understood that the bridge wire may spiral out, or otherwise emanate, from the support cup **14** and terminate on the end cap **31** so that a predetermined length of bridge wire lies adjacent a quantity of explosive charge.

As illustrated in FIGURE 2, the ceramic body surrounds the spark gap **13** in such a manner as to form a tubular area, indicated by the reference character **33**, which may be filled with a suitable inert gas, such as nitrogen. This is accomplished by baking out the assembly and evacuating the area **33** by way of the passage comprising the opening **23** in the end of the support tube **15** remote from the spark gap **13**, the tapered portion **22** and the slotted space between the circumferentially spaced portions **17**. An inert gas, such as nitrogen or sulfur hexafluoride is then inserted therethrough and is sealed in by pinching off the end of the support tube remote from the spark gap **13**, sealing the opening **23** with a suitable material, such as a solder **34**, or by any other suitable means. The inert gas contained within the area **33** is preferably at atmospheric pressure and makes the arc voltage of the spark gap **13** independent of varying temperature and pressure conditions.

Referring to FIGURE 3, which is a cross-sectional view of a complete detonator unit taken along the line 3—3 of FIGURE 3–A which illustrates a complete end view of a detonator unit, there is illustrated a conductive metal cylindrical shell **35** which surrounds the ceramic body assembly shown in FIGURE 2. The exterior metallized and metal layered surface **26** of the ceramic body **24** is secured to the interior surface of the shell **35** by any suitable means, such as by brazing with a copper-silver or copper-tin brazing alloy.

Disposed adjacent and within one end of the elongated hollow cylindrical shell **35** is a quantity of a suitable explosive material **36**, such as pentaerythryte tetranitrate. The explosive material **36** is contained within the shell **35** by a gasket **37**, which may be formed of mica, and a closure plate 38, which may be formed from stainless steel and which is pressure welded to the shell 35. The ceramic body assembly is positioned within the shell 35 such that its end containing the bridge wire 32 lies adjacent the explosive material 36 and its other end lies adjacent the end of the shell 35 remote from the explosive charge.

Reference to FIGURES 3 and 3–A shows that the shell 35 may have a threaded portion 41 along its length and a flanged portion 42 radially extending from the surface of the shell to provide means for threadedly engaging the detonator device of FIGURE 3 in a threaded aperture contained by a wall, tank or any other threaded apertured structure. A plurality of protrusions 43 extend from the wall of the shell 35 adjacent the end remote from the explosive charge 36 to enable a coaxial connection or coupler to be secured to this end of the detonator. As will be readily apparent to those skilled in the art, a threaded surface may be used in place of the protrusions 43 to provide easy coaxial connection to the detonator device. A perspective view of a complete detonator unit is illustrated in FIGURE 4.

The opertaion of the device illustrated in FIGURES 3 and 3–A is such that a voltage is applied to the detonator by way of a coaxial line (not shown) which is engaged with the end of the detonator remote from the explosive charge so that the outer conductor of the coaxial line is electrically connected to the shell 35 and the center conductor of the coaxial line is electrically connected to the support tube 15. Whenever the voltage between the support tube 15 (which acts as a center conductor) and the shell 35 (which acts as an outer conductor) exceeds a predetermined amount, a current flows from the support tube 15, through the metallized coating 12, produces an arc across the spark gap 13 causing current to flow through the metallized surface 12 on the other side of the spark gap 13, through the support cup 14, through the bridge wire 32, through the end cap 31, through the shell 35 and back to the coaxial input. The current flow through the bridge wire 32 causes it to rapidly vaporize (explode) which detonates the explosive charge 36. The detonation of the explosive charge 36 is generally utilized to detonate a larger quantity of explosive charge (not shown). The operation of the device is such that the metallized surface 12 of the ceramic rod 11, the support tube 15 and the support cup 14 function as a center conductor and the conductive coating 26 on the exterior of the ceramic body 24 and the shell 35 function as an outer conductor.

The detonation of the explosive charge 36 creates a very high pressure in the neighborhood of 4 million pounds per square inch. The ceramic metal detonator structure illustrated in FIGURE 3 is such that it remains essentially intact under such high pressures even though it was discovered that the force of the exposion drove the metallized ceramic rod 11 into the support tube 15. However, the support tube 15 retained its position and prevented the metallized ceramic rod 11 from escaping the detonator device. If desired, the retaining action of the support tube 15 on the metallized ceramic rod 11 can be increased by tapering the interior surface 22 of the support tube 15 in a manner as illustrated in FIGURES 1, 2 and 3.

Due to the coaxial structure of the detonator device, the outer conductor portion (the shell 35) of the device may be at ground potential thereby shielding the spark gap assembly from radio frequency fields that tend to induce current in the detonator circuit and accidentally set off the detonator. Also the ceramic insulating body 24 interposed between the shell 35 and the spark gap assembly permits the application of a large magnitude of voltage to the device without danger of a voltage breakdown occurring between the shell 35 and the spark gap assembly.

As will be apparent to those skilled in the art, the fabrication of the device of FIGURE 3 is such that the arc voltage of the spark gap 13 can be checked at various steps in the detonator assembly, and if found defective, easily replaced before completing an entire assembly. Also, once the spark gap 13 is formed on a single piece of ceramic, as discussed hereinabove in detail, and found adequate, there is no reason why the arc voltage of the gap will change during assembly processes because the gap space remains constant throughout the assembly of the detonator.

It is to be understood that the present invention is not limited to the shell 35 functioning as an electrical conductor; for a conducting rod or conductor (not shown) may also pass through the insulating body 24 such that the second rod is insulated from the shell 35 and the spark gap assembly. For this type of construction, the bridge wire 32 would be coupled between the support cup 14 and the second conducting rod. Also, the voltage used to operate this type of detonator structure would be applied by any well known means between the support tube 15 and the end of the second conducting rod remote from the bridge wire 32.

What has been described is a reliable and easily fabricated detonator device which comprises a metallized ceramic rod having a surface spark gap thereon, a conductive shell disposed around said metallized ceramic rod, a ceramic body insulating interposed between the metallized ceramic rod and the conductive shell, and a bridge wire electrically coupled between the metallized ceramic rod and the shell and being positioned adjacent a quantity of explosive material.

It should be understood, of course, that the foregoing disclosure relates only to preferred embodiments of the present invention and that it is intended to cover all changes and modifications of the examples of the invention herein chosen for the purposes of disclosure, which do not constitute departures from the spirit and scope of the invention set forth in the appended claims.

What is claimed is:

1. A detonator device comprising: a metallized ceramic rod having a surface spark gap intermediate the ends thereof, a conductive shell coaxially disposed around said spark gap on said metallized ceramic rod, a ceramic body coaxially interposed between said metallized ceramic rod and said conductive shell, and a bridge wire electrically coupled between an end portion of said metallized ceramic rod and said conductive shell.

2. The combination according to claim 1 wherein said shell is adapted to contain a quantity of an explosive charge adjacent said bridge wire.

3. A detonator device comprising: at least one elongated nonconductive rod having a conductive coating thereon, a spark gap associated with said coated rod including a discontinuity in the conductive coating intermediate the ends of said rod, an insulating body coaxially disposed around said coated rod, electrical conducting means, and a bridge wire electrically coupled between said electrical conductive means and a portion of said conductive coating on said rod.

4. The combination defined in claim 3 wherein said metallized coating on said ceramic rod comprises a mixture of metal powders including 0% to 25% by weight of titanium, 40% to 10% by weight of manganese and a major proportion by weight of a metal selected from the group consisting of molybdenum and tungsten.

5. A detonator device comprising: at least one rod having a metallized surface thereon, a spark gap on the surface of said metallized rod including an annular discontinuity in the metallized surface intermediate the ends of said rod, an insulating body coaxially disposed around said metallized rod, means for confining an inert gas in the vicinity of said spark gap, electrical conducting means associated with said insulating body, and a bridge wire electrically coupled between said conductive means and the portion of said metallized coating located adjacent one side of said spark gap.

6. The combination according to claim 5 further including means to contain a quantity of an explosive material adjacent said bridge wire.

7. A detonator device comprising: a cylindrical ceramic body having a metallized surface thereon, a spark gap on said metallized ceramic body including an annular discontinuity in the metallized surface at an area intermediate the ends of said metallized ceramic body, a first conductive section electrically connected to said metallized surface adjacent one end of said metallized ceramic body, a second conductive section electrically connected to said metallized surface adjacent the other end of said metallized ceramic body, an insulating body disposed around said metallized ceramic body and having opposite end portions hermetically united to said first and second conductive sections respectively, a quantity of inert gas confined around said spark gap by said first and second conductive sections and said insulating ceramic body, a conductive shell surrounding said insulating ceramic body, and a bridge wire electrically coupled between one of said first and second conductive sections and said conductive shell.

8. The combination according to claim 7 wherein said metallized ceramic body has an annular groove in the surface thereof at the area of discontinuity in the metallized surface defining said spark gap.

9. In a device which utilizes a protective spark gap electrically in series with a bridge wire that sets off an explosive charge when sufficient current is passed through the bridge wire, an improved spark gap structure comprising a nonconductive rod having a conductive coating thereon, and a surface spark gap on said coated rod including a discontinuity in the conductive coating intermediate the ends of said rod.

10. The combination defined in claim 9 wherein said rod has an annular groove in the surface thereof at the area of discontinuity in the conductive coating defining said spark gap.

11. The combination defined in claim 9 wherein said conductive coating comprises a mixture of metal powders including 0% to 25% by weight of titanium, 40% to 10% by weight of manganese and a major proportion by weight of a metal selected from the group consisting of molybdenum and tungsten.

12. A detonator device comprising: a hollow metal body, said metal body functioning as the outer conductor of a coaxial circuit and adapted to receive an explosive charge within and adjacent one end of the metal body, a centrally apertured first ceramic body located within said metal body with one of its ends adjacent the area adapted to receive an explosive charge and its other end adjacent the other end of said metal body, said first ceramic body having a conductive coating on its exterior surface which is coupled to the interior surface of said metal body, a first center conductor section having at least a portion of its length extending into said aperture in said first ceramic body at the end adjacent said other end of said metal body, a second center conductor section contained within said aperture in said first ceramic body at the end adjacent said area adapted to receive an explosive charge, a second ceramic body located within the aperture of said first

ceramic body and between said first and second center conductor sections, said second ceramic body having a conductive coating thereon and its opposite ends secured to said first and second center conductor sections, a spark gap including a discontinuity in the conductive coating on said second ceramic body at an area intermediate the ends of second ceramic body, said first and second center conductor sections and said first ceramic body confining a quantity of inert gas around said second ceramic body and said spark gap, and a bridge wire connected between said metal body and said second center conductor section and having at least a portion of its length adjacent said explosive charge.

13. A detonator device comprising: a hollow metal cylindrical body, said cylindrical body functioning as the outer conductor of a coaxial circuit, an explosive charge located within and adjacent one end of the cylindrical body, a centrally apertured first cylindrical ceramic body located wtihin said metal cylindrical body with one of its ends adjacent said explosive charge and its other end adjacent the other end of said metal cylindrical body, said first ceramic body having its exterior surface metallized and brazed to the interior surface of said metal cylinder, a first metal center conductor section having a portion of its length extending into said aperture in said first ceramic body at the end adjacent said other end of said metal body, a second metal center conductor section contained within said aperture in said first ceramic body at the end adjacent said explosive charge, said aperture in said first ceramic body having metallized surface portions brazed to said first and second center conductor portions, a second ceramic body located within the aperture of said first ceramic body and between said first and second center conductor sections, said second ceramic body having a metallized surface thereon and its opposite ends brazed to said first and second center conductor sections respectively, a spark gap including an annular discontinuity in the metallized surface on said second ceramic body at an area intermediate the ends of second ceramic body, said first and second center conductor sections and said first ceramic body confining a quantity of inert gas around said second ceramic body and said spark gap, and a bridge wire electrically connected between said metal body and said second center conductor section and having at least a portion of its length adjacent said explosive charge.

14. The combination according to claim 13 wherein said inert gas is nitrogen.

15. The combination according to claim 13 wherein said inert gas is sulfur hexafluoride.

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