Jan. 30, 1968 G. H. GRUBER, JR 3,366,054

ELECTRIC IGNITION ASSEMBLY

Filed Sept. 9, 1966

FIG. 1

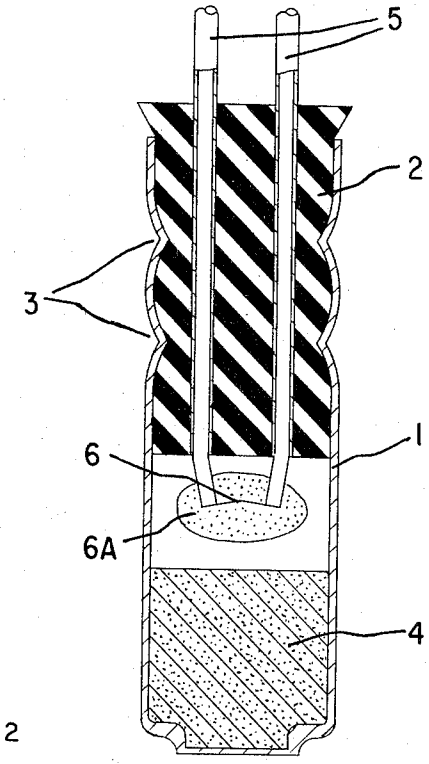


FIG. 2

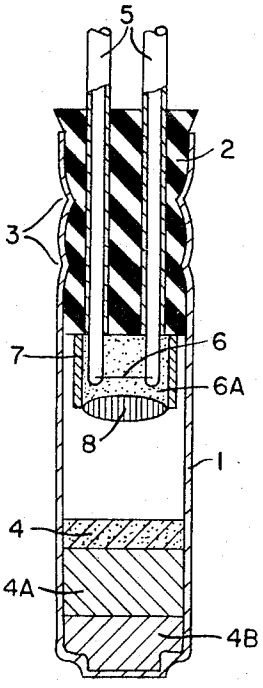
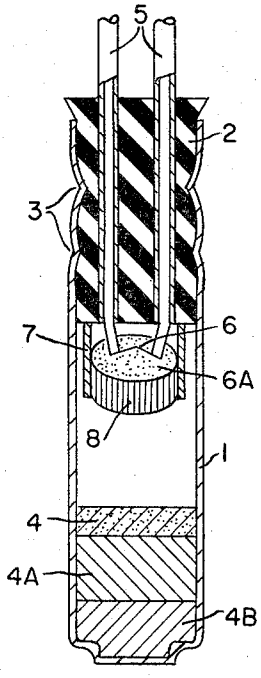


FIG. 3



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ELECTRIC IGNITION ASSEMBLY

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Continuation-in-part of application Ser. No. 475,718, July 29, 1965. This application Sept. 9, 1966, Ser. No. 587,353

11 Claims. (Cl. 102—28)

ABSTRACT OF THE DISCLOSURE

Initiation assembly resistant to spurious electric discharges comprising a bridgewire in contact with a bead comprising a polymeric binder and a mixture of magnesium and tellurium dioxide.

Cross-reference to related application

This application is a continuation-in-part of my application Ser. No. 475,718, filed July 29, 1965, now abandoned.

This invention relates to an electric ignition assembly for explosive initiators, and, more particularly, to an electric ignition assembly resistant to accidental actuation by spurious electric discharges.

In recent years, there has been pronounced effort, particularly by the military, to develop electric initiators, i.e., electroexplosive devices (EED's) which are not subject to accidental actuation by spurious electric currents, e.g., by electromagnetic radiations or static discharges. Such devices are particularly needed and desired when the EED is to be incorporated in an explosive train to be used in aircraft, on shipboard, or in other, similar situations where there is the possibility of accidental actuation induced by exposure to static discharges or electromagnetic radiation (e.g., radiofrequency currents), such as emitted by radio, TV, radar, or beacon transmitters, induction heaters, rotating electrical machinery, and the like. To preclude accidental actuation of EED's by such spurious electric currents, in many cases it is now required that the ignition assembly of the EED not be actuated, i.e., fired by the application of one watt of DC power for five minutes or as the result of the application of one ampere of DC current for five minutes. This requirement must be met without the use of external shunts. Ignition assemblies for EED's which meet these requirements are referred to as having one-watt, one-ampere, five-minute, no-fire characteristics. Additionally the ignition assemblies should be unaffected by exposure to both extremely high and extremely low temperatures, acceleration, shock, and static-electric discharges among others. The ignition assembly should, however, be able to fire the EDD in which it is incorporated, after being exposed to at least one watt of power and one ampere of current, when exposed to at least 5 amperes of current or 5 watts of power for 50 milliseconds.

Attempts to provide an ignition assembly for electric initiators having the desired one-watt, one-ampere, five-minute, no-fire characteristics have, heretofore, involved the use of one or more of the following design features: (1) large diameter bridgewires, (2) special bridge resistors and/or shunts, (3) loose ignition mixtures with high energy ignition requirements or containing heat conductive additives to raise the level of firing current and power needed to bring about actuation of the ignition assembly, or (4) heat sinks to protect the bridgewire when high-energy ignition mixtures are used. Additionally, radio frequency filters or shielding are often provided. Each of these methods of providing the desired one-ampere, one-watt, five-minute, no-fire characteristics used heretofore have one or more of the following disadvantages:

(1) excessively long firing times, typically greater than about 50 milliseconds.

(2) excessively high all fire levels of current and/or power, e.g., greater than about five amperes and/or five watts of power.

(3) dependence on means other than the ignition assembly to dissipate to one ampere of current and one watt of power e.g., heat sinks, conductive metal powders, series resistors, or conductive or semiconductive shunts.

(4) special construction features such as glass-to-metal seals, special plugs, ceramic insulation between ignition powder and outer case, ceramic or metal washers, or other heat sinks adjacent to the bridgewire.

(5) prohibitive expense and poor adaptability to use in low cost, large volume, standard product lines.

(6) lack of interchangeability in devices or explosive trains.

This invention provides electric ignition assemblies having one-ampere, one-watt, five-minute, no-fire characteristics which are free of the disadvantages mentioned above and which can be used with standard, commercially available kinds of EED's, i.e., initiators such as detonators (blasting caps) and squibs, without affecting the output characteristics of the EED's or necessitating changes in their basic design or manufacture. The assemblies of this invention also are relatively inexpensive and suitable for use with a wide range of priming and/or deflagrating powders. In adition, the ignition assemblies of this invention fire to EED in which they are employed reliably within about 50 milliseconds when exposed to currents as low as on the order of 3 to 5 amperes. The one-watt, one-ampere, five-minute, no-fire ignition assemblies of this invention comprise a bridge wire having a resistance of about from 0.2 to 1.0 ohm in contact with, and preferably surrounded by, a bead of ignition composition consisting essentially, based on the total weight of composition, of (a) about from 10 to 30%, and especially about from 10 to 20%, of inert, dielectric polymeric binder having a melting point and decomposition temperature above about 250° F. and preferably above 300° F. and, dispersed in said binder, (b) about from 70 to 90%, and especially about from 80 to 90%, of an intimate mixture of, based on the total weight of said mixture, (1) about from 10 to 50% of magnesium, and (2) about from 90 to 50% of tellurium dioxide.

The bridgewire is an important factor in achieving a satisfactory one-ampere, one-watt, five-minute, no-fire ignition assembly. The resistance of the bridgewire will be within the range of 0.2 to 1 ohm and within close tolerances within this range. A particularly preferred bridgewire is of 0.35 to 0.45 ohm resistance (a range which provides an operating spread of 1.65 amperes between a maximum no-fire current of 1.68 amperes and a minimum all-fire current of 3.33 amperes). Examples of bridgewire metals include alloys of metals of at least one of Groups VI(a) and VIII, optionally together with Group I(b) metals (all according to the "Periodic Table," Webster's New Collegiate Dictionary, page 626 (1953)). Iron and nickel alloys, particularly those containing 50% or more of nickel or noble metal such as the Ni-Cr, and noble metal alloys (e.g., Pd-Au) are preferred. Specific exampes of bridgewire materials are 0.003-inch diameter "Nichrome" (80% nickel, 20% chromium) bridgewire, and the 7294 alloy of 49.5% by weight gold, 40.5% by weight palladium, and 10% by weight iron (commercially available from Baker Division of Englehard Industries) of 0.004 or 0.0045 inch diameter. Of these, the No. 7294

alloy is particularly suitable since it is particularly resistant to change on prolonged exposure to currents approaching the one watt level (ca. 1.5 ampere). The diameter of the bridgewire should be at least about 3 mils (0.003 inch) to preclude fusing during passage of current therethrough. Naturally the bridgewire should be affixed to the lead wires or other elements of the internal EED firing circuit by a thermally-stable, high-strength juncture, such as, for example, by soldering, brazing, sonic bonding, etc.

The relative proportions of magnesium and tellurium dioxide within the bead compositions of this invention which surround the bridgewire will be maintained within the range of 10 to 50% magnesium and 50 to 90% tellurium dioxide to assure the desired one-watt, one-ampere, five-minute, no-fire characteristics of the beaded bridgewire. Within this range, 40% magnesium and 60% tellurium dioxide, and especially 30% magnesium and 70% tellurium dioxide, are particularly preferred. The presence of at least 10% magnesium is needed to absorb heat and to sustain chemical reaction between the magnesium and tellurium dioxide. When magnesium comprises substantially greater than about 50% of the mixture of magnesium and tellurium dioxide, generally insufficient oxidant is present to assure reliable ignition of the composition. The tellurium dioxide will accordingly comprise from about 50% to 90% of the mixture, about 60%, and especially 70%, being preferred. The presence of tellurium in substantial proportions in the tellurium dioxide should be avoided, since tellurium melts with an endothermic reaction which may preclude reliable ignition of the composition under all-fire conditions. Both the magnesium and tellurium dioxide are preferably of a particle size of about 150 to 225 mesh or as small as 500 mesh, U.S. Standard screen, in order to insure thorough mixture with each other and dispersal in the bead binder. This can be assured by screening the magnesium and tellurium dioxide separately immediately prior to mixing then dry blending the components for at least 30 minutes to obtain an intimate mixture. The magnesium-tellurium dioxide must be used in a bead form since loose mixtures of magnesium and tellurium dioxide, regardless of the proportions of constituents, are actuated at levels too low, typically 1.0 to 1.7 amperes and 0.5 to 1.0 watt, using conventional "Nichrome bridgewires" to permit their use in ignition assemblies having the desired one-ampere, one-watt, five-minute, no-fire characteristics.

The resinous binder used in forming the bead ignition assembly of this invention is, as stated, of a composition which is thermally stable, i.e., not decomposed or melted by, temperatures of at least about 250° F. and preferably 300° F. The binder should be dielectric, i.e., preferably have a dielectric constant of at least as good as air, i.e., greater than about 1.0. Examples of the types of polymers which can be used are vinyl resins including fluorocarbon polymers such as polytetrafluoroethylene, polychlorotrifluoroethylene and polyvinyl fluoride, polyvinyl acetate, acrylic polymers, and vinyl chloride polymers including homopolymers and copolymers of vinyl chloride; polyesters including polyethylene terephthalate as well as styrene crosslinked maleic acid polyesters; silicone resins and rubbers including alkyl-, aryl-, and alkoxy-substituted polysiloxanes; polyamides such as nylon 6,6; polyimides; and amino- and phenol-formaldehyde resins including phenol-, urea- and melamine-formaldehyde thermosettings resins; epoxy resins; and mixtures thereof. Preferred binders are polyvinyl acetate such as commercially available as "Elvacet" 1, and silicone rubber. Silicone rubber, preferably a room temperature vulcanizing silicone rubber, is particularly preferred for high temperature (>300° F.) applications. The binders are preferably in a viscous paste-like form when combined with the dry blend of magnesium and tellurium dioxide. However, this paste should set-up, either by solvent or dispersant evaporation or in situ polymerization of vulcanization to its final form. For example, polyvinyl acetate ("Elvacet" 1) can be dissolved in a solvent such as butyl acetate (800 g. polyvinyl acetate/3000 cc. butyl acetate) and combined with the dry blend. The silicone rubber is typically employed in the form of a viscous paste comprising a high molecular weight siloxane gum, e.g., polydimethyl siloxane; an inorganic filler, a typically finely divided silicone dioxide; and peroxide or acetic acid curing or vulcanizing agent. A typical silicone rubber is RTV–112 silicone rubber adhesive/sealant commercially available from General Electric, or "Silastic" silicone rubber adhesive commercially available from Dow-Corning.

The percentage of magnesium-tellurium dioxide mixture in the bead composition will, as stated above, generally range from 70 to 90%, and especially 80 to 90%, by weight, whereas the resinous binder comprises from 10 to 30% and especially 10 to 20%. Higher proportions of binder to magnesium-tellurium dioxide are employed in forming the full-sized sleeved bead of FIGURE 2 than are desirable in forming the relatively thick mixture employed in forming the "cruller" type bead shown in FIGURE 3.

In addition to the Mg/TeO_2 blend and binder, the ignition composition optionally can contain small proportions, usually less than 30% and preferably 1 to 20%, based on the total weight of bead composition, of additives to tailor the bead characteristics to particular operating conditions. Such additives can be mixed in the ignition compositions, or, when a coating is provided for the bead added to the coating thereover. One preferred additive is an exothermic burning composition such as a mixture of cupric oxide and aluminum (20/80 weight ratio); potassium chlorate; potassium perchlorate; or barium peroxide. The addition of this exothermic burning composition is particularly advantageous when the EED's are to be incorporated in parallel in a firing circuit since their presence insures complete "burning out" or consumption of the bead when the EED is fired, thereby precluding the formation of a residue, e.g., of carbon. Current carrying residues of this type are detrimental in electric circuits incorporating EED's since they often cause an undesirable drain on the power supply. This is particularly important in military ordnance, e.g., in missiles or on aircraft.

As indicated in the attached drawings the assemblies of this invention can be incorporated in a wide variety of EED's including squibs, electric instantaneous and delay blasting caps as well as other detonators. In such applications, the assemblies are connected in the internal EED firing circuit, usually by lead wires. Such lead wires usually pass through a dielectric plug, e.g., of natural or synthetic rubber, or of a synthetic resin potting composition. In any event, the assemblies are juxtaposed to at least one explosive charge ignitible thereby. The ignition assembly, the remainder of the internal firing circuit and the other EED charges are usually all disposed in a metal shell having one open end into which the plug and embedded lead wires fit. Where optimum static resistance and resistance to autoignition is desired, the assembly of this invention is encapsulated in dielectric (i.e., a thermally stable material having a dielectric constant of at least 1.0), for example, a layer of binder without Mg/TeO_2 blend dispersed therein, or a sleeved and binder-capped arrangement such as that shown in FIGURES 2 and 3 and discussed more fully hereinafter. Such encapsulating material usually is up to ⅛ inch and, preferably, 1/16 to 1/32-inch thick. Preferably, any such material between the assembly of this invention and the juxtaposed charge in the EED is combustible and, thus, consumed on ignition of the assembly

In the accompanying drawings which illustrate EED's having ignition assemblies of this inventon:

FIGURE 1 represents one embodiment of the beaded

ignition assembly of this invention used in a squib; and

FIGURES 2 and 3 represent an embodiment of the sleeved, covered, ignition assemblies employed in a detonator.

Referring now to the figures in detail, in the squib of FIGURE 1 , **1** is a tubular shell, e.g., of commercial bronze or aluminum, **2** is a dielectric sealing plug, e.g., of natural or synthetic rubber, **3** are peripheral crimps in the shell wall for maintaining the plug in position. Charge **4** is an exothermic burning squib charge such as black powder; a mixture of barium peroxide, magnesium and selenium; smokeless powder; the complex of lead nitrate and the bis-basic lead salt of 4,6-dinitro-o-cresol (i.e., lead nitrato-bis-basic-lead-4,6-dinitro-o-cresylate, hereinafter "lead salt") or a mixture of, by weight, 50% smokeless powder, 25% lead salt, and 25% potassium chlorate. Extending into the shell **1** through dielectric sealing plug **2** are lead wires **5** whose internal terminals, i.e., extremities, are connected by bridgewire **6** having a resistance within a range of about 0.2 to 1.0 ohm and within a tight tolerance within this range, e.g., 0.35 to 0.45 ohm, the other extremities of the lead wires being connected in an external firing circuit (not shown) comprising a power source. Bridgewire **6** is surrounded by a cohesive bead **6A** comprising 70 to 90% by weight of an intimate blend of 10 to 50% by weight magnesium, 90 to 50% by weight of tellurium dioxide, and 10 to 30% by weight of the total composition of a thermally-stable, dielectric resinous binder.

In FIGURE 2, the charges of the EED are that of a detonator comprising an ignition charge **4**, a priming charge **4A**, and a base charge **4B**. The beaded bridgewire in this embodiment is a "full-size sleeved bead" in which a sleeve **7** extends downward from the base of the plug **2** and the ignition composition **6A** comprising magnesium and tellurium dioxide in a thermally stable resinous binder surrounds the bridgewire and substantially fills sleeve **7**. Layer **8** of a thermally stable dielectric resinous composition seals sleeve **7**.

In FIGURE 3, the bead composition forms a "cruller" **6A** (i.e., disk thinned about its periphery) about the bridgewire and does not fill sleeve **7**, open space being left below the base of the plug **2** and the upper extremity of the "cruller." As in FIGURE 2, a layer **8** of a thermally stable dielectric resinous composition such as a silicone resin seals sleeve **7**.

The functioning of the devices shown in the figures is basically the same. Passage of electric current of one ampere or power of one watt through the bridgewire is insufficient to heat the bridgewire to a degree sufficient to ignite the bead surrounding it. However, the passage of current of at least **5** amperes or power level of at least **5** watts is sufficient to ignite the bead. Ignition of the bead causes charge **4** to be ignited, as is conventional in EED's. Layer **8** in FIGURES 2 and 3 does not preclude ignition of charge **4** by the bead, however this layer and sleeve **7** combine to separate the bead from charge **4** and from shell **1**. The provision of sleeve **7** and layer **8** is particularly advantageous when charge **4** is conductive, e.g., by virtue of the incorporation of particles of metal or carbon therein such as in smokeless powder, or when charge **4** is of a composition, e.g., smokeless powder or the complex of lead nitrate and bis-basic lead salt of 4,6-dinitro-o-cresol, which is easily autoignited by the heat induced in the bead when one watt of power is developed in the bridgewire even though the bead composition is not ignited. The shield provided by sleeve **7** and layer **8** also increases the resistance of the ignition assembly to accidental actuation by electrostatic discharges or other sources of current flow between the lead wires and the shell by increasing the dielectric strength between the bridge circuit and shell.

The sleeve **7** employed as a part of the shield to isolate the ignition assembly from charges in the EED as illustrated in FIGURES 2 and 3, should not be electrically conductive or easily autoignitable. This sleeve preferably should be formed of a material such as Kraft paper having a high (> about 1.0) dielectric constant and capable of withstanding exposure to temperatures of about 250° F. Although such materials as polyethylene, polytetrafluoroethylene, polypropylene, polyvinyl chloride, and acetal resins can be used as the sleeve, a Kraft paper having a wall thickness of 8 to 10 mils is generally preferred owing to its easy availability and low cost. The sleeve **7** is affixed to the base of the plug by an adhesive, typically a silicone rubber, with the longitudinal axis of the sleeve coextensive with that of the plug and the bridgewire-lead wire assembly. The joint between the sleeve and the plug preferably is sealed by a thermally stable resinous composition, e.g., capable of withstanding 250° F., typically a silicone rubber such as that used in forming the bead. The sleeve is sealed below the bead by a layer of a thermally stable resinous composition having a dielectric constant greater than about 1.0, preferably about 3.0, which preferably is of the same composition used as the binder for the bead composition, since such composition is cohesive with the bead forming a tight bond therebetween and sets up to a hardened mass in a reasonably short time.

The following examples illustrate this invention. Parts, where given, are parts by weight.

Example 1

Ninety-nine ignition assemblies for EED's are prepared having bare beads as shown in FIGURE 1, but with varying powder loads as shown in Table 1. In preparing these ignition compositions, powdered magnesium and tellurium dioxide are screened separately through a 200 mesh screen. The powders that pass the screen are then dry blended in proportions of 40 parts magnesium and 60 parts tellurium dioxide in a Fisher-Kendall mixer for at least 30 minutes. The blended dry powders are then mixed, by hand in small quantities, with a solution comprising 800 grams polyvinyl acetate ("Elvacet"–1)/3000 cc. butyl acetate. A 56/44 proportion of the dry blend of magnesium and tellurium dioxide to solution of polyvinyl acetate is used. The viscous blend of bead compositon is placed in a collapsible tube as described in U.S. 2,205,081. A small qauntity of viscous blend is extruded onto the bridgewire of each of preassembled bridge assemblies comprising 0.004 inch diameter No. 7294 alloy of 49.5% gold, 40.5% palladium and 10% iron or an 80/20 Ni/Cr "Nichrome" alloy soldered to the terminal of each of two 22-gage, nylon-insulated copper lead wires. The lead wires extend through and are maintained in dielectric relationship by a molded rubber plug (0.213 inch O.D., ⅜ inch long). The ends of the lead wires to which the bridgewire is affixed extends ⅛ inch below the base of the plug.

As the viscous blend of bead composition is extruded from the tube onto the bridgewire, it is pushed down over one end of, and drawn along, the bridgewire so that it flows down between the lead wires and completely covers the bridgewire but does not protrude more than about 1/64 inch beyond the tips of the lead wires. After the bead composition is applied to the bridgewire, the assembled units are allowed to set at least 24 hours at 120–140° F. to allow the bead to harden into a firm mass. The beads are well supported by the lead wires with the bridgewire completely embedded near the surface. The average weight of each bead is about 0.01 gram.

The resistance of each bridgewire of each test unit is within the range of 0.35 to 0.45Ω as measured on a Wheatstone bridge. The values obtained for each unit are recorded for use in calculating power at the bridgewire with applied current by the relation $P_B=I^2R_B$, wherein P_B is power at the bridgewire, I is the applied current, and R_B is bridgewire resistance as measured. [In making the calculations, the known resistance of the lead wires (0.03Ω/foot per pair of 22-gage copper wires) is subtracted from the value indicated on the Wheatstone bridge to obtain a true value for bridgewire resistance.]

The ignition assemblies are crimped into commercial

bronze EED shells containing powder loads as shown in Table 1; all powder charges are loose loads except as noted.

Subsequently the units are tested by connecting them in the firing circuit of a balance panel comprising a 30 volt DC power source, means for continuously varying the current over a range of 1 to 10 amperes, and means to set a variable resistor equal to the bridge circuit. The units are exposed to one watt firing power for five minutes. As can be seen in Table 1, all units that have pressed loads spaced away from the bead hold, i.e., do not fire. However, some types of loose powders, e.g., smokeless powders and the mixtures of, by weight, 50% smokeless powder, 25% lead salt and 25% potassium chlorate are autoignited when used as loose loads in intimate contact with the beads.

After at least one hour, firing current and timing tests are made using balance panel, an electronic counter-timer, and a photocell and amplifier. Application of firing current from the balance panel to the test unit triggers the counter-timer and fires the test unit. Firing time is recorded by the counter-timer on receipt of the gating signal produced in the photocell-amplifier by the flash from the initiated test unit. Results of the tests are given in Table 1. In the table, lead salt refers to the complex of lead nitrate and the bis-basic lead salt of 4,6-dinitro-o-cresol.

TABLE 1

Number Tested	Bridgewires		Powder Charge	Results of No-Fire Tests at 1 watt	Subsequent Firing Current, amperes	Results and Firing Times
	Diam., inches	Type				
2	0.003	80/20 "Nichrome"	Lead azide (pressed)	All held	3	Fired, 51–59 ms.
2	0.003	do	do	do	5	Fired, 8–11 ms.
1	0.003	do	do	do	10	Fired, in 4 ms.
2	0.003	do	do	do	15	Fired in 3–9 ms.
22	0.003	do	Pressed lead salt	do	3	Fired in 19–36 ms.
10	0.003	do	Black powder	do	3	9 fired, 1 failed.[1]
19	0.003	do	do	do	5	All fired, <50 ms.
3	0.003	do	Pressed mixture of 50% smokeless powder, 25% $KClO_4$, and 25% lead salt [3].	do	3	Do.
5	0.003	do	Mixture of 50% smokeless powder, 25% $KClO_4$ and 25% lead salt.	4 held, 1 fired [2]	3	Remaining 4 fired, <50 ms.
6	0.003	do	30%/35%/35% mixture of $Mg/BaO_2/Se$	All held	3	All fired, <50 ms.
7	0.003	do	Smokeless powder	4 held, 3 fired [2]	3	Do.
4	0.0045	No. 7294 Pd/Au/Fe alloy	Black powder	All held	3.5	All fired, 31–93 ms.
6	0.0045	do	do	do	5	All fired, 12–23 ms.
6	0.0045	do	do	do	10	All fired, 6–12 ms.
4	0.0045	do	do	do	15	All fired, 5–7 ms.

[1] Bridgewire fused.
[2] Powder autoignited.
[3] Open space between pressed charge and bead. Alternatively, an empty lead carrier pressed over charge can be used to separate bead from load.

Example 2

Two hundred and sixty-five sleeved ignition assemblies are prepared resembling that of FIGURES 2 and 3. In preparing these assemblies, the bead composition is screened, dry blended and mixed with binder and placed on the bridgewires generally as described in Example 1, 50 parts of the 40/60 Mg/TeO_2 blend being incorporated with 50 parts of the solution of polyvinyl acetate binder for the "full-size" beads and 56 parts of Mg/TeO_2 blend and 44 parts of binder solution being combined for the "cruller" type bead. All bridgewires are the No. 7294 alloy of palladium, gold, and iron and have a resistance of 0.35–0.45Ω as measured by the Wheatstone bridge. 0.004 inch diameter bridgewires are used with No. 5 plugs 0.213 in. O.D. and ⅜ in. long and 0.0045 inch diameter bridgewires are used with No. 1B plugs 0.250 in. in diameter and 7/16 inch long. The beaded ignition assemblies are inserted in a Kraft paper sleeve 7/32 inch long, 0.175 inch O.D. and having a wall thickness of 0.008–0.010 inch which is affixed to the base of the plug. The lower extremity of the paper sleeve (below the bead composition) is sealed by RTV–112 silicone rubber. The layer of silicone rubber sealing the sleeve is 1/32 to 1/16 inch thick. The ignition assemblies are inserted into commercial bronze EED shells containing powder charges as shown in Table 2 and crimped into place. All powder charges are loose loads except as noted. No-fire testing was carried out as described in Example 1 and after a lapse of one hour all-fire test currents were applied to the test units. Results of the tests are shown in Table 2.

Note in Table 2 that the sleeve and layer of silicone rubber below the bead allow the use of the ignition assembly with powder charges, viz, smokeless powder as well as the mixture of 50% smokeless powder, 25% of the complex of lead nitrate and bis-basic lead salt of 4,6-dinitro-o-cresol, and 25% $KClO_4$, with which the bare bead is incompatible in some cases. In the table, "lead salt" refers to the complex salt of lead nitrate and the bis-basic lead salt of 4,6-dinitro-o-cresol.

TABLE 2

No. Tested	Plug Size	Type Sleeved Bead	Powder Load	No-Fire Test Results	Subsequent Firing Current, amps	Results
7	#1B	Full-size	$Mg/BaO_2/Se$ (30/35/35)	All held	5	All fired.
6	#1B	do	$Mg/BaO_2/Se$ (30/35/35)	do	10	Do.
6	#1B	do	$Mg/BaO_2/Se$ (30/35/35)	do	15	Do.
6	#1B	do	Pressed lead azide	do	5	Do.
6	#1B	do	do	do	10	Do.
6	#1B	do	do	do	15	Do.
6	#1B	do	Lead Salt (loose)	do	5	Do.
6	#1B	do	do	do	10	Do.
6	#1B	do	do	do	15	Do.
8	#1B	do	Pressed lead salt	do	5	Do.
6	#1B	do	do	do	10	Do.
6	#1B	do	do	do	15	Do.
6	#1B	do	Black powder	do	5	Do.
6	#1B	do	do	do	10	Do.
6	#1B	do	do	do	15	Do.
7	#1B	do	Smokeless powder $KClO_4$ and lead salt (50/25/25).	do	5	All fired between 11 and 26 milliseconds.
7	#1B	do	do	do	10	All fired between 3 and 6 milliseconds.
6	#1B	do	do	do	15	All fired between 2 and 4 milliseconds.
4	#5	do	$Mg/BaO_2/Se$ (30/35/35)	do	3.5	All fired.
4	#5	do	$Mg/BaO_2/Se$ (30/35/35)	do	5	Do.
3	#5	do	$Mg/BaO_2/Se$ (30/35/35)	do	10	Do.
2	#5	do	$Mg/BaO_2/Se$ (30/35/35)	do	15	Do.
4	#5	do	Pressed lead azide	do	3.5	Do.
4	#5	do	do	do	5	Do.
4	#5	do	do	do	10	Do.
2	#5	do	do	do	15	Do.
4	#5	do	Lead salt	do	3.5	Do.
4	#5	do	do	do	5	Do.
4	#5	do	do	do	10	Do.
4	#5	do	do	do	15	Do.
4	#5	do	Pressed lead salt	do	3.5	Do.
4	#5	do	do	do	5	Do.
3	#5	do	do	do	10	Do.
3	#5	do	do	do	15	Do.
4	#5	do	Black powder	do	3.5	Do.
4	#5	do	do	do	5	Do.
4	#5	do	do	do	10	Do.
3	#5	do	do	do	15	Do.
4	#5	do	Smokeless powder $KClO_4$ and lead salt (50/25/25).	do	3.5	Do.
4	#5	do	do	do	5	Do.
4	#5	do	do	do	10	Do.
4	#5	do	do	do	15	Do.
9	#5	do	do	No test	3.5	All fired between 19 and 30 milliseconds.
22	#5	Cruller	PETN (base) and lead azide (primer); both pressed.	All held	3.5	All fired.
25	#5	do	do	do	3.5	All fired between 11 and 33 milliseconds.
4	#5	do	do	do	5	All fired between 7 and 10 milliseconds.
4	#5	do	do	do	10	All fired between 3 and 8 milliseconds.
[1] 265						

[1] Total.

Example 3

Two hundred and thirty EED's are prepared as in Examples 1 and 2, 70 having bare beads as prepared in Example 1 and FIGURE 1 and 160 having sleeved beads as prepared in Example 2 and shown in FIGURE 2. The powder charges are as shown in Table 3. Static tests are performed using electrostatic testing apparatus comprising a DC high voltage supply having a voltage output continuously variable from 0 to 25,000 volts, DC, and condenser discharge units consisting of several banks of capacitors which may be selected to give capacity values of 100 to 12,000 picofarads. The capacitors are charged from the DC power supply and discharged through the EED (lead wire to shell) by a solenoid-actuated high-voltage vacuum switch. Results of the tests are shown in Table 3. In the table 0.015 joule is the minimum static sensitivity acceptable by some manufacturers in the design of commercial EED's. 0.156 joule is adapted as a desirable "factor of 10" static sensitivity improvement criterion for the one-ampere, one-watt, five-minute, no-fire ignition assembly. Note that the provision of the sleeve and layer of silicone rubber surrounding the bead significantly increases its resistance to actuation by static discharges (this is also true for other sources of electric potential applied between the lead wires and shell). Static sensitivity of a given test unit is affected by the powder charge as well as by the ignition assembly; accordingly it is necessary to test a series of loads within the ignition assembly. In Table 3, 50/25/25 refers to the mixture of 50% smokeless powder, 25% lead salt, and 25% $KClO_4$.

TABLE 3

Ignition Bead	Plug Size	Powder Load in EED (Loose Loads Except as Noted)	No. Tested	No. Dets. with 0.015 joule Applied	No. Dets. with 0.156 joule Applied
2/3 Mg/TeO_2 (Bare Beads)	No. 5	Smokeless powder	10	0	0
Do	No. 5	Lead salt	10	0	5
Do	No. 5	Lead salt, pressed	10	0	3
Do	No. 5	$Mg/BaO_2/Se$ (30/35/35)	10	0	4
Do	No. 5	Lead azide, pressed	10	0	6
Do	No. 1B	do	10	0	7
Do	No. 1B	Black powder	10	0	3
2/3 Mg/TeO_2 (Sleeved Beads)	No. 1B	do	10	0	0
Do	No. 1B	$Mg/BaO_2/Se$ (30/35/35)	10	0	0
Do	No. 1B	Lead salt	10	0	0
Do	No. 1B	Lead salt, pressed	10	0	0
Do	No. 1B	Lead azide, pressed	10	0	0
Do	No. 1B	50/25/25	8	0	0
Do	No. 5	50/25/25	16	0	0
Do	No. 5	Black powder	16	0	1
Do	No. 5	$Mg/BaO_2/Se$ (30/35/35)	16	0	2
Do	No. 5	Lead salt	16	0	0
Do	No. 5	Lead salt, pressed	16	0	1
Do	No. 5	Lead azide, pressed	16	0	0
Do	No. 5	PETN (base) and lead azide (primer), both pressed.	36	0	No tests

Example 4

A number of EED's are prepared as in Example 1, having loads of loose black powder and tested as shown below:

No-fire test.—The EED's are conditioned at 225° F. in environmental chamber for 12 hours and then subjected to one watt of power for five minutes at the bridge while at 225° F. EED's are then removed from chamber, cooled to room ambient temperature, and fired.

TABLE 4

No. Tested	Bridge Wire Diameter and Type	Plug Size	No-Fire Test Results	Subsequent Firing Current Applied, amperes	Firing Test Results
2	0.003" 80/20 "Nichrome"	No. 5	All held	3	All fired.
3	do	No. 5	do	5	Do.
3	do	No. 5	do	10	Do.
2	do	No. 5	do	15	Do.
5	0.0045" No. 7294 Alloy	No. 1	do	5	Do.
3	do	No. 1	do	10	Do.
2	do	No. 1	do	15	Do.

All-fire test.—EED's are conditioned at −80° F. in environmental chamber for 12 hours and then fired at −80° F. with 5 amperes applied to the bridgewire. Length of application of firing current is recorded by an oscilloscope.

No. Tested	Bridge Wire Diameter and Type	Plug Size	All-Fire Test Results	Firing Times, milliseconds
10	0.003" 80/20 "Nichrome,"	No. 5	All fired	7 to 9.
10	0.0045" No. 7294 Alloy	No. 1	do	21 to 25.

Example 5

EED's as prepared in Example 1 having a bare cruller bead and a pressed load of a mixture of 50% smokeless powder, 25% $KClO_4$, and 25% of the complex of lead nitrate and the bis-basic lead salt of 4,6-dinitro-o-cresol are tested in lots, as indicated in Table 4. Each lot is subjected to one hour in a jumble tester into which the tests units are placed and rotated about a nonsymmetric axis. After the units are removed from the container, some are cut open and visually examined for damaged beads and loose or cracked powder charges. The remaining units are tested by checking the resistance of the bridge circuit and performing all-fire tests. Results of the tests are shown in Table 5.

TABLE 5

Test No.	No. in Lot	Condition of Pressed Load	Results of Visual Inspection of Dismantled EED's Following Jumble Test			No. Tested	Results of Circuit and Firing Tests Following Jumble Tests	
			No. Insp.	Beaded Bridge	Powder Load		Bridge Circuit	Firing Test
1	6	Empty lead carrier pressed over load at 300 lbs	2	Intact	Intact	4	All intact	All fired.
2	6	Load pressed at 300 lbs	2	do	do	4	do	Do.
3	4	Load pressed at 200 lbs	1	do	do	3	do	Do.
4	4	Load pressed at 100 lbs	1	do	do	3	do	Do.

Example 6

Twenty-three EED's are prepared basically as described in Example 1, 75 parts of a 30/70 Mg/TeO_2 blend being incorporated with 25 parts of a silicone rubber applied as a viscous paste commercially available as RTV-112 silicone rubber adhesive/sealant commercially available from General Electric. A small quantity of the viscous blend is extruded onto the bridgewire of each of preassembled bridge assemblies comprising 0.004 inch diameter No. 7294 alloy (as described above), soldered to the terminals of two 22-gage, nylon-insulated copper lead wires held in place by a molded rubber plug. The resistance of each bridgewire is within the range of 0.35 to 0.45Ω as measured on a Wheatstone bridge.

When the units are subjected to no-firing testing as described in Example 1, none of the units fired. When firing current tests are carried out after at least one hour, all units first within about 20 milliseconds when 5 watts of power is applied.

I claim:

1. An ignition assembly which comprises a bridgewire having a resistance of about from 0.2 to 1.0 ohm in contact with a bead of an ignition composition consisting essentially of. based on the total weight of said composition, (a) about from 10 to 30% of inert, dielectric, polymeric binder having a melting point and decomposition temperature above about 250° F., and (b) about from 70 to 90% of an intimate mixture of, based on the total weight of said mixture, (1) about from 10 to 50% of magnesium and (2) about from 90 to 50% of tellurium dioxide.

2. An assembly of claim 1 wherein said binder consists essentially of polyvinyl acetate.

3. An assembly of claim 1 wherein said binder consists essentially of silicone rubber.

4. An assembly of claim 1 wherein said bridgewire is a nickel alloy.

5. An assembly of claim 1 wherein said bridgewire is a nobel metal alloy.

6. An ignition assembly which comprises a bridgewire of Group VIII metal alloy having a resistance of 0.35–0.45 ohm and a diameter of at least about 3 mils in contact and surrounded by a bead of ignition composition consisting essentially of. based on the total weight of said composition, (a) about from 10 to 30% of inert dielectric polymeric binder having a melting point and decomposition temperature above about 300° F., and (b) about from 70 to 90% of an intimate mixture of, based on the total weight of mixture, (1) about from 10 to 50% of magnesium and (2) about from 90 to 50% of tellurium dioxide, said mixture having a particle size of about from 150 to 500 mesh.

7. An assembly of claim 6 wherein said bridgewire is a nickel-chromium alloy.

8. An assembly of claim 6 wherein said bridgewire is a gold-palladium-iron alloy.

9. An assembly of claim 6 wherein said binder is polydimethylsiloxane.

10. An assembly of claim 6 wherein said bead or a covering for said bead additionally contains up to 30% of at least one of the group consisting of potassium chlorate, mixtures of CuO and Al, potassium perchlorate and barium peroxide.

11. A composition of claim 6 wherein said mixture contains about 30% of magnesium and about 70% of tellurium dioxide.

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