Jan. 17, 1967 R. M. PURDY 3,298,306

ELECTRO-EXPLOSIVE DEVICE

Filed May 26, 1964

Fig. 1

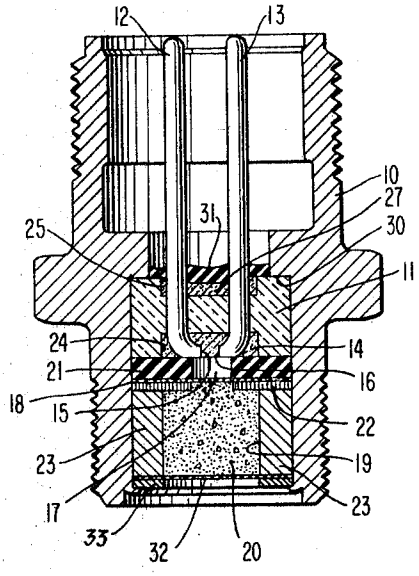


Fig. 2

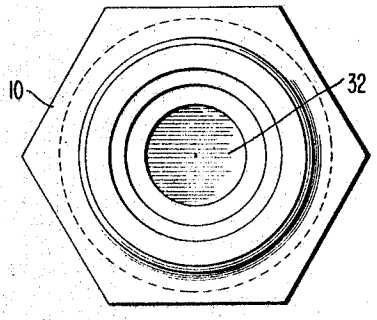


Fig. 3

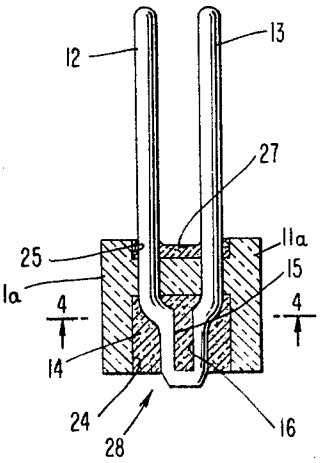
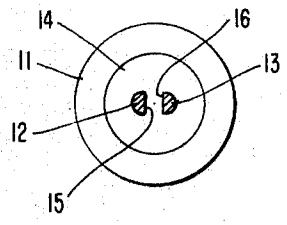


Fig. 4



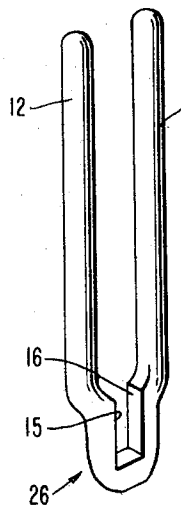


Fig. 5

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United States Patent Office 3,298,306 Patented Jan. 17, 1967

3,298,306

ELECTRO-EXPLOSIVE DEVICE

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Filed May 26, 1964, Ser. No. 370,227
20 Claims. (Cl. 102—28)

This invention relates to electro-explosive devices and more particularly to electrically triggered primers, squibs and like devices adapted to be triggered or fired by an electrical spark.

An object of this invention is to provide a device of aforementioned type which is simple to construct and assemble, and is particularly conducive to being mass produced and sub-miniaturized.

Another object of this invention is to provide a squib device or the like which is highly reliable in operation and is triggered only in response to a signal having at least a predetermined voltage level and energy content.

Still another object of this invention is to provide a squib device which is immune to being fired or damaged by stray energy and particularly by stray radio frequency energy and static charges.

Still another object of this invention is to provide a squib or primer device which is immune to firing or deterioration by electrical signals having a low voltage level regardless of the energy content thereof or by electrical signals having a high voltage level with low energy content.

Accordingly, one form of the invention features an electrically triggered squib device which comprises, inter alia, an electrical insulating member, a semi-conductive member coupled to the first member and at least two electrodes partially embedded in said members. The two electrodes are terminated in input first terminals and in second terminals in spark gap relation. The second terminals are disposed in a substantially coplanar relationship with a predetermined exterior surface of the semi-conductive member to define thereat a shunted surface spark gap. In addition, the electrodes are spaced within the semi-conductor in a spark gap relationship. The input terminals are remotely disposed from the shunted surface spark gap by the insulating member. A first chamber means is provided which contains a predetermined gas. The gas-filled chamber is closed at one end by means including the shunted surface gap and has a frangible plate-like wall member closing the other end. A second chamber means containing a charge of explosive or ignitable material is also closed at one end by said frangible plate-like member. In operation, the frangible plate-like member or diaphragm is ruptured by thermal expansion of the gas in the chamber **17** which is caused by the heat of a spark discharge across the shunted surface spark gap. By judiciously selecting the parameters of the thermal and electrical circuits of the device, the diaphragm will be rupturable and the device will be fired only in response to an electrical signal having at least predetermined voltage level and energy content appearing across the input terminals of the electrodes. In this manner, access between the ignitable charge and the spark discharge at the shunted surface gap is provided and the squib is fired.

The above and further objects and novel features of the invention will more fully appear from the following detail description when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for the purpose of illustration only, and is not intended as a definition of the limits of the invention.

In the drawing, wherein like reference characters refer to like parts throughout the several views,

FIG. 1 is a side elevation view, illustrated in section for purposes of explanation, of an embodiment of a squib device embodying the present invention;

FIG. 2 is a bottom end view of the squib device of FIG. 1;

FIG. 3 is a detail side elevation view, illustrated partly in cross section for purposes of explanation, of an embodiment of a sub-assembly utilized in constructing the device of FIG. 1;

FIG. 4 is a bottom view of the pre-assembly of FIG. 3, after the lower portion has been removed along the line 4—4 to provide a shunted surface spark gap; and

FIG. 5 is a perspective view of the electrode sub-assembly utilized in the sub-assembly of FIG. 3.

In the exemplary embodiment of the primer or squib device of the present invention illustrated in the drawing, a hollow tubular housing **10**, which is preferably made of a metal such as aluminum, contains an electrical insulating body or member **11**. The insulating body **11** in a preferred embodiment is made of ceramic material and has at least two metallic electrodes **12** and **13** partially embedded therein. The end portions of the electrodes preferably extend or protrude upward from the end surface of the insulating body. These end portions function as input terminals which are adapted to be connected to a suitable triggering source of electrical energy. By way of example only, the upper end portions of the electrodes are illustrated as being in the form of male pin type connectors for detachable connection to the socket part of a connector device. It is to be understood, however, that these portions may be terminated also in other forms and types such as. for example, wire connectors as is apparent to those skilled in the art. It is to be also understood that the end portions may be hollow sockets to provide female connectors. The lower end portions of the electrodes which extend or protrude downwards from the other end surface of the insulating body **11** are substantially embedded in a high impedance semi-conductive mass or member **14**. As shown, member **14** fills a recess in insulator **11** and has an end surface which is flush with the end surface of the insulating member. As will be explained in greater detail hereinafter, the semi-conductive member **14** is fused to the plastic or ceramic body **11** and the lower end portions of the electrodes **12** and **13** and thus provide a seal therebetween. The electrodes are provided with flat opposing surfaces **15** and **16** and these flat surfaces are spaced apart in and at the surface of the semi-conductive member in a spark gap relationship.

At the lower, outer surface of the semi-conductive member **14**, the ends of the electrodes are shown, by way of example, as being disposed in a coplanar relationship therewith to provide a shunted surface spark gap **15**, **16**. The shunted surface spark gap is adjacent to and extends across a small chamber **17** containing a heat expandable gas which, for example, may be air. Extending across the other end of the chamber **17** is a thin frangible or rupturable plate-like member or diaphragm **18**. The latter is adapted to be ruptured by the expansion of the gas confined in the chamber **17** when the gas becomes sufficiently heated by a spark discharge across the shunted surface spark gap **15**, **16** which is produced in response to a triggering signal across electrodes **12** and **13** of at least a predetermined voltage level and energy content.

Below the frangible plate-like member **18**, as viewed in FIG. 1, is a second chamber **19** containing a pyrotechnic or explosive charge **20** which may consist of a powdered mixture of equal parts of titanium and cupric oxide. Thus, when the frangible member **18** ruptures, the charge **20** is exposed to the spark gap discharge ap-

pearing across the shunted surface spark gap **15**, **16** and is ignited thereby.

As is illustrated in the drawing, the gas containing chamber **17** comprises an apertured electrical insulating member **21** which is preferably a laminated plastic washer. Member **21** may, for example, be made of a thermo-setting resin, such as polytetrafluoroethylene, reinforced by layers of glass fiber cloth. The chamber **19** containing the material **20** is illustrated in the drawing as comprising a retaining washer **22** and a bushing or sleeve **23**, which may be of similar metal compositions, such as brass, and a lower frangible sheet-like member **32** which may be of a similar or a different metal, such as preferably aluminum.

Referring now to FIGS. 3 to 5, in constructing the squib of the present invention, the ceramic body **11** is molded, such as, for example, by an injection molding process in an elongated form **11***a*. The ceramic member is provided with recesses **24** and **25** at the end surfaces thereof and two passage-ways adapted to receive the electrode sub-assembly **26** of FIG. 5 now to be described. The sub-assembly **26** may be prepared in a die as an integral member from a length of round wire or bar stock and is provided with the flat opposing faces **15** and **16**. The upper ends of the electrodes **12** and **13** of the sub-assembly are then inserted through the openings or passageways of the ceramic body **11***a*. A high temperature seal **27**, i.e. a seal having a fusing or sealing temperature higher than the fusing temperature of the semi-conductive material **14** is then fused in the recess **25**, thereby forming a gas tight seal between the ceramic body and the stems of the electrodes. Thereafter, the ceramic body is inverted from the position illustrated in FIG. 3 and the semi-conductive material **14** deposited in the recess **24** of the ceramic body **11***a*. The material **14** is then fused to the ceramic body and the parts of the electrode sub-assembly **26**, within recess **24** to complete the pre-assembly **28** illustrated in FIG. 3. The lower portion of the pre-assembly **28** is subsequently removed to a predetermined level, such as the level indicated by the line **4—4**, by grinding or any other suitable operation. In this manner the shunted surface spark gap is exposed and provided as is best illustrated in FIG. 4.

The sub-assembly **28** with this lower portion removed is then inserted in the housing **10**. As illustrated in FIG. 1, an inner configuration of the housing is provided with a shoulder **30** which coacts with the edge of the surface of the ceramic body **11**. A suitable seal, such as an epoxy or low temperature (800° F.) glass seal **31**, is then provided to seal the ceramic body and electrode parts in proximity thereto to the housing and provide a gas-tight seal between insulator **11** and housing **10**. Thereafter, there is inserted into the housing, in the following succession, the plastic disc or washer **21**, the frangible diaphragm **18**, the retaining washer **22**, the sleeve or bushing **23**, the ignitable powder charge **20**, and the closure member **32**. The powder charge **20** should be relatively loose powder so as not to interfere appreciably with the rupturing of diaphragm **18** by a predetermined gaseous pressure build-up in chamber **17**. If desired, an apertured retaining member **33** is provided and inserted adjacent to the exterior surface of the closure sheet **32**. Means are provided to maintain the thus assembled parts in a relatively fixed assembly and preferably comprise, for simplicity, the crimping or staking of the interior edge of the housing **10** over against the exterior surface of the retaining washer for closure member **32**.

In operation, when a spark of sufficient intensity is generated between the lower exposed ends **15** and **16** of electrodes **12** and **13** by a signal having a voltage and energy content of a predetermined level within a relatively narrow range, the gas confined in the chamber **17** will expand and rupture the frangible member **18** as aforementioned. Upon rupture, the powder **20** in chamber **19** is ignited by the spark discharge at the shunted surface gap **15**, **16** causing the powder to burn or explode and rupture the closure member **32**, which may be in proximity to a device, not shown, that is to be actuated or energized by the detonation or burning of the charge **20**. By judiciously selecting the parameters of the thermal and electrical circuits of the assembled squib, accidental or deliberate signals, which may be either static, radio frequency, or combinations thereof, and not having the predetermined voltage level and energy content, will be incapable of triggering or firing the squib. Thus, for example, if the signal applied across terminals **12** and **13** is of a voltage level lower than the approximate triggering level predetermined for the device, such signal, regardless of its energy content, will be dissipated primarily through the semi-conductive material **14** bridging the opposing surfaces **15**, **16** of the electrodes without providing sufficient heat to sufficiently expand the gas in the chamber **17** to cause member **18** to rupture. Likewise, any signals, which have a voltage level higher than the approximate triggering level predetermined for the device but an energy content which is lower than the energy predetermined for triggering the device, will also be dissipated primarily through and across the surface of semiconductive material **14** between the opposing surfaces **15** and **16** of the electrodes embedded therein. In the last-mentioned case, the signals will also provide insufficient heat to expand the gas in the chamber **17** sufficiently to cause the member **18** to rupture. Thus, it will be seen that the squib device of the present invention is immune to being triggered by most stray and accidental signals and is particularly adaptable to those applications or systems, such as missile systems and the like, wherein the squib device is in proximity to stray electrical energy and especially radio frequency energy which may be generated, for example, by radar beams or the like.

Furthermore, by judiciously selecting the parameters of the thermal circuit of the present invention any heat generated by spark discharges created by signals not of the predetermined voltage level and energy content required to trigger the device will be dissipated without "dudding" or otherwise detrimentally affecting the powder charge. In a device embodying the invention, and particularly where the insulating body **11** is a ceramic, it is preferred that the electrodes **12** and **13** be made of a material known under the trademark Kovar to insure a good seal and hence gas tightness which will prevent loss of pressure or blow back from chamber **17** upon thermal expansion of the gas therein. A satisfactory melt type composition for the semi-conductive mass **14** may consist of a fused or baked mixture of copper oxide (33.6%), iron oxide (6.4%) and magnesium oxide (60%) powders suspended in distilled water for application before baking at 2000° F. The stated percentages are by weight. This novel semi-conductive composition forms an effective seal around the electrodes, and has good stability, desirable electrical resistance and suitable heat conductivity to effect rapid dissipation of heat build-up from stray electrical pulses below the voltage and energy required for firing the device. The seal **27**, which also prevents leakage of the fused mass **14** along the electrodes during assembly, may be a high temperature glass seal having affinity for the insulator **11** as well as for the metal electrodes **12** and **13**. A high temperature (2550° F.) glaze has been found satisfactory for this purpose.

Operable devices may be and are generally much smaller than the device illustrated in the drawing. For example, some successful embodiments wherein the casing **10** had a diameter of less than one half inch, the volume of spark chamber **17** was .0014 cu. in. In such a device, the thickness of the diaphragm **18** when made of aluminum foil depends upon the desired firing characteristics but a thickness of .002 inch was satisfactory to give a firing point at about 2.2 joules stored energy discharged

from a capacitor at about 2300 volts across the gap **15**, **16**. Different parameters may be chosen to obtain different desired and controllable firing points. It is preferred that the various parts or elements of the squib of the present invention, as illustrated in the drawing, have cylindrical or circular configurations and be symmetrically assembled and disposed about the longitudinal axis of the squib. In this manner, the squib and the parts thereof are easily fabricated and assembled and are especially conducive to being sub-miniaturized and mass produced.

Although only one embodiment of the invention has been illustrated in the accompanying drawing and described in detail in the foregoing specification, it is to be expressly understood that changes may be made therein. For example, one of the spark gap electrodes may be annular and one or both of the electrodes may extend beyond the outer face or surface of semi-conductive mass **14**. Various other changes, such as in the relative dimensions and configurations of the parts, materials used, and the like, may also be made without departing from the spirit and scope of the invention as will now be apparent to those skilled in the art.

What is claimed is:

1. A squib comprising means forming a substantially sealed gas-filled chamber, said means including a thin frangible sheet closing one end of the chamber, and means confronting the gas in the chamber and forming a spark gap at the other end of said chamber, said sheet being rupturable by the thermal expansion of the gas in said chamber only upon a spark discharge of at least predetermined minimum intensity across the gap through said gas.

2. A squib as defined in claim **1** wherein the spark gap is a shunted surface gap comprising electrodes terminating in spark gap relation and bridged by a non-inflammable semi-conductive wall surface of said chamber.

3. A squib as defined in claim **1** wherein the chamber forming means includes an insulator having a recess in one end thereof and wherein the spark gap comprises electrodes extending through said recess and terminating in spark gap relation and a semi-conductive non-inflammable mass in said recess having a surface forming a part of the wall of said chamber and bridging said electrodes.

4. A squib as defined in claim **3** wherein said insulator has a second recess in the other end thereof through which said electrodes extend and comprising electrically insulating means set from a flowable state in said second recess and forming a seal between said insulator and said electrodes.

5. In a squib, means forming a shunted surface spark gap including spaced electrodes and semi-conductive means bridging the gap between said electrodes, and means for forming a substantially sealed gas-filled chamber with said gap therein at one side thereof, at least a portion of the wall of the chamber opposite said spark gap being constituted by a thin frangible sheet which is rupturable by gaseous pressure generated in said chamber by the heat of a spark discharge of at least predetermined intensity at the spark gap through the gas in said chamber.

6. A squib as defined in claim **5** comprising electrical insulating means supporting said electrodes and having a recess therein, the terminal end portions of said electrodes being embedded in said semi-conductive means within said recess, the end surfaces of the electrodes being flush with the surface of said semi-conductive means exposed in said chamber.

7. A squib as defined in claim **6** wherein said chamber is formed within the recess is in said insulating means.

8. A squib as defined in claim **7** wherein said insulating means comprises two insulators in end-to-end relation and said chamber is formed in a passage through one of said insulators.

9. A squib comprising in combination a tubular housing, a shunted surface spark gap assembly in the housing comprising an insulator having passages therethrough, a pair of electrodes extending through said passages and terminating at their inner ends in spark gap relation and semi-conductive means bridging said inner ends to form a shunted surface spark gap, and means forming a closed chamber containing said spark gap, said chamber having a thin frangible wall opposite said spark gap and rupturable by gaseous pressure within the chamber upon a spark discharge of predetermined intensity at the spark gap through the gases in the chamber.

10. A squib as defined in claim **9** wherein said spark gap assembly further comprises insulating means forming a seal between said insulator and said electrodes.

11. A squib as defined in claim **9** comprising means forming a seal between said housing and said insulator.

12. A squib as defined in claim **9** wherein said chamber forming means comprises an insulating member abutting said insulator and having a passage therethrough in registry with said spark gap.

13. A shunted surface spark gap assembly comprising an insulator having spaced passages therethrough and a recess in one end thereof, two elongated electrodes extending through said passages and terminating in said recess, the terminal end portions of said electrodes being turned inwardly toward each other and having plane flat surfaces in face-to-face spark gap relation, and an electrically semi-conductive mass in said recess between said surfaces.

14. A spark gap assembly as defined in claim **13** wherein said terminal ends of the electrodes are embedded in said semi-conductive mass with only the end surfaces thereof exposed in a common transverse plane.

15. A spark gap assembly as defined in claim **13** wherein said semi-conductive mass comprises a fused mixture of copper oxide, iron oxide and magnesium oxide.

16. A squib comprising an electrical insulating first member, a semi-conductive second member adjacently coupled to said first member, at least two conductors partially embedded in said first and second members and terminating in input terminals at one end and in electrodes at the other end, the ends of said electrodes being in a substantially coplanar relationship with a predetermined exterior surface of said second member to define thereat a shunted surface spark gap, first chamber means adjacent said shunted surface gap containing a gas and having an aperture and a frangible plate-like wall member across the aperture to confine said gas in the chamber means, and second chamber means containing a charge of ignitable material and having an aperture covered by said frangible plate-like member, the latter being rupturable by the thermal expansion of said gas caused by a spark discharge across said shunted surface spark gap within said first chamber means in response to an electrical signal having a predetermined voltage level and energy content appearing at the input terminals of said conductors to provide access between said charge and the spark discharge at said shunted surface gap for firing said charge.

17. A squib according to claim **16** wherein said second member is fused to said first member and said electrodes.

18. A squib according to claim **16** wherein parts of said electrodes embedded in said second member have opposing flat parallel surfaces.

19. A squib comprising an electrical insulating ceramic first cylindrical member, a semi-conductive second cylindrical member having a predetermined end surface fused to an end surface of said first cylindrical member, at least two elongated metallic electrodes embedded in said first and second cylindrical members and terminating in input first terminals and in second terminals, the ends of said second terminals being in substanially coplanar relationship with the exterior surface of the other end of said second cylindrical member to define thereat a shunted surface spark gap, parts of said electrodes em-

bedded in said second cylindrical member having adjacent flat opposing parallel surfaces spaced in a spark gap relationship, at least part of said insulating first cylindrical member being disposed between said shunted surface spark gap and said input terminals, a first chamber containing a gas therein and comprising a cylindrical first tubular member and having one end thereof adjacent to said shunted surface gap and covered by a predetermined part of said exterior surface, a second chamber containing a charge of explosive material therein and comprising a cylindrical second tubular member, a first frangible plate-like member having a first surface adjacent the other end of said first tubular member and having a second surface adjacent a predetermined end of said second tubular member, and a second frangible plate-like member adjacent to the other end of said second tubular member, said first plate-like member being rupturable by the thermal expansion of said gas caused by a spark discharge across said shunted surface spark gap in response to an electrical signal having a predetermined voltage level and energy content appearing at the input terminals of said electrodes and said second frangible plate-like member being rupturable by the burning of said charge.

20. An electrically triggered squib device comprising an electrical insulating ceramic first cylindrical member, a semi-conductive second cylindrical member having a predetermined end surface fused to an end surface of said first member, at least two elongated Kovar electrodes embedded in said first and second cylindrical members and terminating in input first terminals and in second terminals, said second terminals being in substantially coplanar relationship with the exterior surface of the other end of said second cylindrical member to define thereat a shunted surface spark gap, the parts of said electrodes embedded in said second cylindrical member having respective flat opposing surfaces and being spaced in a spark gap relationship, at least part of said insulating member being disposed between said shunted surface spark gap and said input terminals, a first chamber containing a gas and comprising a cylindrical first tubular electrical insulating member having one end thereof adjacent said shunted surface gap and covered by a predetermined part of said exterior surface, a second chamber containing a charge of explosive material therein and comprising a cylindrical second tubular member, a first frangible plate-like cylindrical member having a first surface at the other end of said first tubular member and having a second surface adjacent to an end of said second tubular member, a second frangible plate-like cylindrical member adjacent to the other end of said second tubular member, and a cylindrical exterior metal tubular shield for housing said first and second cylindrical members, said electrodes, said first and second chambers, and said first and second frangible plate-like members, said first plate-like member being rupturable by the thermal expansion of said gas caused by a spark discharge across said shunted surface spark gap in response to an electrical signal having a voltage level and energy content to produce a spark discharge of predetermined intensity and said second frangible plate-like member being rupturable by the explosion of said charge.

References Cited by the Examiner

UNITED STATES PATENTS

2,821,138	1/1958	Apstein et al.	102—28 X
2,821,139	1/1958	Apstein et al.	102—28 X
2,996,944	8/1961	Chessin et al.	102—28 X
3,019,732	2/1962	Kaspaul	102—28
3,100,447	8/1963	Betts	102—28
3,110,846	11/1963	Wedwick	102—28 X
3,117,519	1/1964	Hamilton et al.	102—28
3,118,375	1/1964	Jasse	102—28
3,135,200	6/1964	Jackson	102—28
3,196,041	6/1965	McNulty et al.	102—28 X

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