Jan. 7, 1969 R. R. POTTER 3,420,174

PULSE SENSITIVE ELECTRO-EXPLOSIVE DEVICE

Filed Sept. 29, 1967

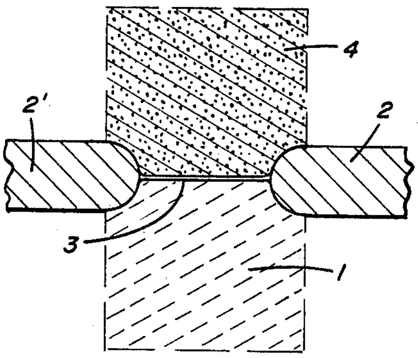

FIG. 1

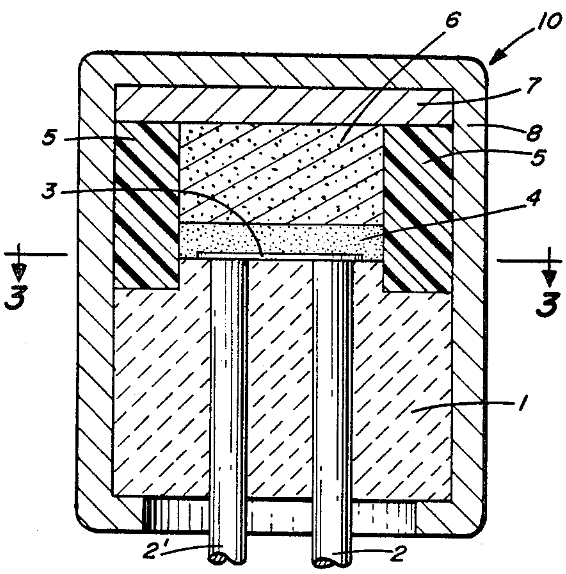

FIG. 2

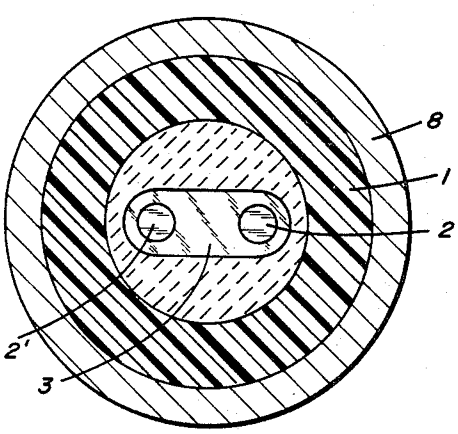

FIG. 3

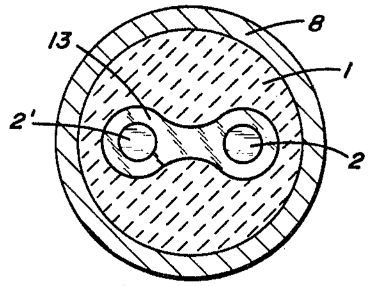

FIG. 4

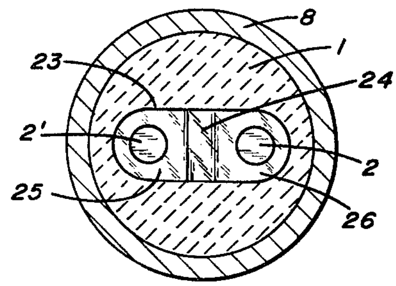

FIG. 5

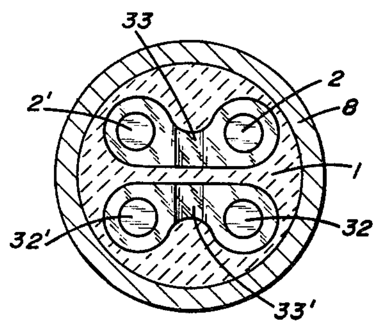

FIG. 6

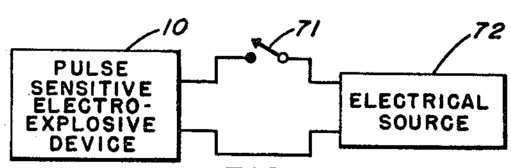

FIG. 7

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PULSE SENSITIVE ELECTRO-EXPLOSIVE DEVICE

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U.S. Cl. 102—28 4 Claims
Int. Cl. F42b *37/00*

ABSTRACT OF THE DISCLOSURE

The present invention discloses a pulse sensitive electro-explosive device which is a generic system for the controlled electrical initiation of explosives. The particular device consists of (1) a primary explosive charge which is initiated by application of heat; (2) an electrical bridge formed by using a thin film gold conductor having surface thermal contact with the explosive charge; (3) a beryllium oxide heat sing having high thermal conductivity and capacity; and (4) two electrical leads.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to improvements in electro-explosive cartridges, and more particularly, to improved electro-explosive cartridges of the exploding bridge-wire type that are better protected from accidental firing.

Description of the prior art

In the field of pulse sensitive electro-explosive devices it has been the general practice to employ a high resistance wire, known as a bridge wire, welded to the interior ends of lead-in pins which are directly in contact with the explosive primer. When the firing current passes through the bridge wire, the current heats the bridge wire. The heat from the bridge wire is used to raise the temperature of the explosive primer. When the primer has been heated to its activation temperature, it explodes and fires the cartridge. While such a device has served its purpose, it has not proved entirely satisfactory under all conditions of service for the reason that considerable difficulty has been experienced where the cartridges are used in environments where they are subject to conditions that accidentally send current through the bridge wire. Sometimes the cartridges are exposed to electro-magnetic fields wherein currents are induced in the lead-in pin. Sometimes the cartridges are exposed to electro-magnetic radiation. Cartridges which are ordinarily safe may become dangerous in such environments. Currents sent accidentally through the bridge wire may be sufficient to heat the primer to its critical temperature, causing it and the cartridge to explode.

It has been the objective of the prior art to achieve lower initiation sensitivity to spurious currents over substantial exposure times, while maintaining the same, or preferably, a reduced requirement for input electrical energy for prompt intended initiation of the explosive component. The devices of the prior art were therefore required to deliver a large part of the firing energy as heat to the priming explosive charge while directing almost all of the spurious power to a heat sink. The prior art utilized a heat sink button clamped over a conventional wire bridge to increase the electrical input required to initiate the explosive for both desired and spurious modes. This has proved unsatisfactory since it was not an improvement in the protection ratio, i.e., maximum safe sustained power divided by minimum required firing energy, but merely a general reduction in sensitivity. Further, the heat sink button used in the prior art was limited to use with a

bridge wire. The instant disclosure utilizes a thin film bridge deposited on the surface of an electrically non-conducting heat sink and therefore a heat sink button could not be used successfully with a thin film bridge since it would allow the primary explosive charge to contact the bridge only over the lead wires and would thus prevent exploitation of the advantageous of the thin film bridge.

Another undesirable characteristic of the heat sink button utilized by the prior art was that it conducted heat toward the priming charge rather than away from it. A third disadvantage to the heat sink button utilized in the prior art was that it was more difficult to load the priming explosion charge through the small hole in the button. Further, due to the relatively thick cross-section of the wire bridge, the wire bridge initiators required that the heat flow radially outward through the wire, through the wire explosive interface, and finally into some depth of explosive. Ignition characteristics were constrained by the interdependence between thermal, electrical and geometrical parameters. In addition, the primary charge could not be readily pressed against the wire to insure good thermal contact.

SUMMARY OF THE INVENTION

The pulse sensitive electro-explosive device (PSED), of the present invention, consists of four essential elements: (1) the primary explosive charge which is initiated by application of heat; (2) the electric heating element in the form of a thin film of electrically conducting material having surface thermal contact with the explosive charge; (3) the heat sink made of electrically insulating material having high thermal conductivity and large thermal capacity arranged so as to have good thermal contact with all parts of the heating element; and (4) the electrical leads which conduct electric current to the heating element and which are made of an electrically conductive material of sufficient cross-section so as not to be a significant source of heat to the system from electrical energy dissipation. In thin film bridge initiators electrical energy dissipation takes place either as heating at the interface between the substrate and the explosive or, more probably, as a small explosion of the bridge film itself caused by vaporization of the film along the line across the current path. In practice, the bridge film is shaped with a narrow or thin section where initiation is desired. The total result of the thin film bridge device is electrical energy conversion to heat in a controllable location, efficient transfer of the thermal energy into the priming explosive and substantial independence of thermal, electrical and geometrical parameters. By utilizing a gold thin film bridge deposited on a heat sink of beryllium oxide, the disadvantages of the prior art can be overcome.

It is therefore an object of the present invention to provide a pulse sensitive electro-explosive device which has greater resistance to accidental actuation.

Another object of the present invention is to provide an improved pulse sensitive electro-explosive device which combines greater resistance to accidental actuation with unchanged or shorter delay of time of intentional firing.

A further object of the present invention is the provision of a pulse sensitive electro-explosive device that requires about one-fourth the firing energy of conventional electro-explosive devices but tolerates five to six times as much spurious input current.

Still another object of the present invention is to provide a pulse sensitive electro-explosive device giving a hundredfold or more improvement in the protection ratio compared to a conventional wire bridge electro-explosive device.

Yet another object of the present invention is the provision of a thin film bridge pulse sensitive electro-explosive device that has the advantages of ruggedness, ease of fabrication and safety from accidental initiation.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a conceptual view of the essential elements of a pulse sensitive electro-explosive device;

FIG. 2 is a view in elevation and in section of an electro-explosive device embodying the principle of the present invention;

FIG. 3 is the top view of a section taken along line 3—3 of FIG. 2;

FIGS. 4, 5 and 6 are alternative configurations taken along the line 3—3 in FIG. 2; and

FIG. 7 is a schematic diagram of an external firing circuit for the pulse sensitive electro-explosive device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, FIG. 1 shows the conceptual arrangement of the four essential elements: the priming explosive charge **4**, which is initiated by the application of heat; the electric heating element **3**, in the form of a gold thin film bridge deposited on the surface of heat sink and having surface thermal contact with the explosive charge; the heat sink **1**, made of electrically insulating material, such as sintered beryllium oxide, having high thermal conductivity and large thermal capacity; and arranged so as to have good thermal contact with all parts of the heating element **3**; electrical leads **2** and **2'**, which conduct electric current to the thin film bridge and which are made of an electrically conductive material of sufficient cross-section so as not to be a significant source of heat to the system from electrical energy dissipation. By utilizing a gold thin film for the bridge, the bridge is compatible with the explosive and is ductile enough and thick enough to ensure reliable continuity. Further, it allows the film to be a sufficient thickness to offer an adequate electrical load to the source of electrical initiating energy without destroying the initial protective ratio of electrical to thermal conductivity.

FIG. 2 shows a conventional electro-explosive configuration modified to incorporate the PSED features of FIG. 1. The leads **2–2'** are molded or cemented into the heat sink **1**. The heat sink is made of a strong stable material such as beryllium oxide ceramic so as to have a surface on which to support the bridge film. A bridge film **3**, composed of gold is deposited on the polished surface of the heat sink. A metal or plastic charge holder **5** is attached to heat sink **1** and a priming charge **4** is pressed against the surface of bridge **3** to ensure good thermal contact and proper density of charge. A working explosive **6** is pressed into place above the priming charge **4** to give the device the desired ignition or detonation characteristics. Any conventional explosive could be used so long as the primer chosen is sufficient for ignition. A cover disc **7** is installed over the charge holder **5** and the working explosive **6**. Finally, the assembly is permanently sealed by crimping a metal cup **8** over the base of heat sink **1**.

FIG. 3 is a view taken along 3—3 of FIG. 2 showing the leads **2** and **2'**, thin film bridge **3**, heat sink **1** and metal cup **8**. The ends of the two leads **2** and **2'** are made flush with the surface of heat sink **1** so that the thin film bridge **3** may be deposited on the heat sink surface and may also make good electrical contact with the leads **2–2'**.

For better firing efficiency it is advantageous to concentrate the firing energy in a limited central area. FIG. 4 shows an alternative configuration for the bridge shown in FIG. 3. Thin film bridge **13** is identical to thin film bridge **3** except that the shape has been contoured to be narrow at the center. In so doing, there is a greater concentration of electrical energy at this point which aids in igniting priming charge **4**.

The same effect can be accomplished by depositing extra film over the leads. This is depicted in FIG. 5. Bridge **23** consists of three regions. A thin film **24** is deposited on the heat sink. An additional layer of film **25** and **26** is then placed over leads **2** and **2'**. This provides a better and more reliable contact between the bridge and leads as well as having more efficient power dissipation at the center.

FIG. 6 shows an alternative embodiment where two independent firing circuits are incorporated in a single PSED by having two identical bridges **33** and **33'** and four leads **2** and **2'** and **32** and **32'**. Bridges **33** and **33'** combine the features shown in FIGS. 4 and 5 wherein the bridge is narrow at the center as well as being thin at the center due to an additional deposit of gold film being placed on the lead wire surface. This configuration yields a higher reliability since the charge can then be detonated from two sources.

In use the PSED must be connected to an external firing circuit as shown schematically in FIG. 7. When firing switch **71** is closed current from source **72** flows through the leads **2** and **2'** and therefore through the film bridge of FIG. 2. Electrical power dissipation in the film bridge causes heat to flow into the heat sink from the bridge. The temperature of the bridge depends on the rate of heat flow, being less than the ignition temperature for moderate values of input power. If source **72** and the firing circuit supply electrical power to the bridge at a high enough rate, the bridge temperature will rise above the ignition temperature of the primary explosive, and an explosion will eventually result. The most desirable effect would be for the bridge film to fail along a line across the current flow because of a regenerative local rise in temperature, resistivity and dissipation. The resulting spark explosion would suddenly deliver more energy to the explosive and the priming charge would be immediately initiated.

Several factors affect the efficiency of operation. For intentional firing of the device, heat flow into the heat sink is a loss. This loss increases with time and is dependent on thermal contact between film bridge and its heat sink substrate. If the external firing circuit delivers electrical energy to the film bridge as a very short pulse of high power, the resultant burnout and spark explosion of the film bridge will produce three beneficial effects: (1) heat will be concentrated in a small region, (2) the film explosion will carry a significant part of the heat energy away from the surface of the heat sink, and (3) the film explosion will carry heat energy into the explosive effecting an improvement over the quiescent thermal contact between film bridge and explosive. By constructing the film bridge with a narrow and/or thin region, the efficiency of ignition can be further optimized as a trade-off with reliability.

Among the advantages of the pulse sensitive electro-explosive device fabricated in accordance with the disclosed process are the following (1) the pulse sensitive electro-explosive device with a film bridge on a beryllium oxide heat sink required only one-ninth as much firing energy as a conventional wire-bridge electro-explosive device but tolerated from one and one-quarter to two times as much spurious current without firing as the wire-bridge device. Therefore, use of the film bridge on a beryllium oxide heat sink improved the protection ratio more than tenfold compared to a conventional bridge wire electro-explosive device; and the pulse-sensitive electro-explosive device with a gold film bridge on a beryllium oxide heat sink required about one-fourth the firing energy of a conventional electro-explosive device but tolerated five to six times as much spurious input current, i.e., 25 to 36 times as much input power. Thus, the pulse sensitive electro-explosive device gave a hundredfold or more improvement in the protection ratio compared to a wire bridge electro-explosive device.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A pulse sensitive electro-explosive device comprising
a cup-shaped housing;
an explosive capsule disposed within said cup-shaped housing consisting of
a beryllium oxide heat sink;
two lead wires passing through said heat sink;
a first gold thin film bridge deposited on one surface of said heat sink and connecting said lead wires wherein
said deposited thin film bridge is of non-uniform thickness being thicker at the junctions with said lead wires;
a heat sensitive explosive prime charge adjacent to said bridge and heat sink surface;
a working explosive adjacent to said prime charge;
a charge holder circularly enclosing said prime charge, said working charge and said bridge being adjacent to said heat sink; and
a cover disc placed atop said charge holder and said working explosive.

2. A pulse sensitive electro-explosive device as in claim **1** wherein said deposited thin film bridge is narrower at its center than at said lead wire junctions and is of non-uniform thickness being thicker at the junctions with said lead wire.

3. A pulse sensitive electro-explosive device as in claim **1** wherein an additional deposited thin film bridge is connected to two additional wires and placed adjacent to said first thin film bridge to form two alternative detonating circuits.

4. A pulse sensitive electro-explosive device as in claim **3** wherein said first and said additional deposited thin film bridges are narrower at their center than at said lead wire junctions and are of non-uniform thickness being thicker at the junctions with said lead wires.

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