Oct. 3, 1967 W. S. BANKSTON, JR 3,344,744

SAFETIED ORDNANCE DEVICE

Original Filed March 12, 1965

FIG. 1

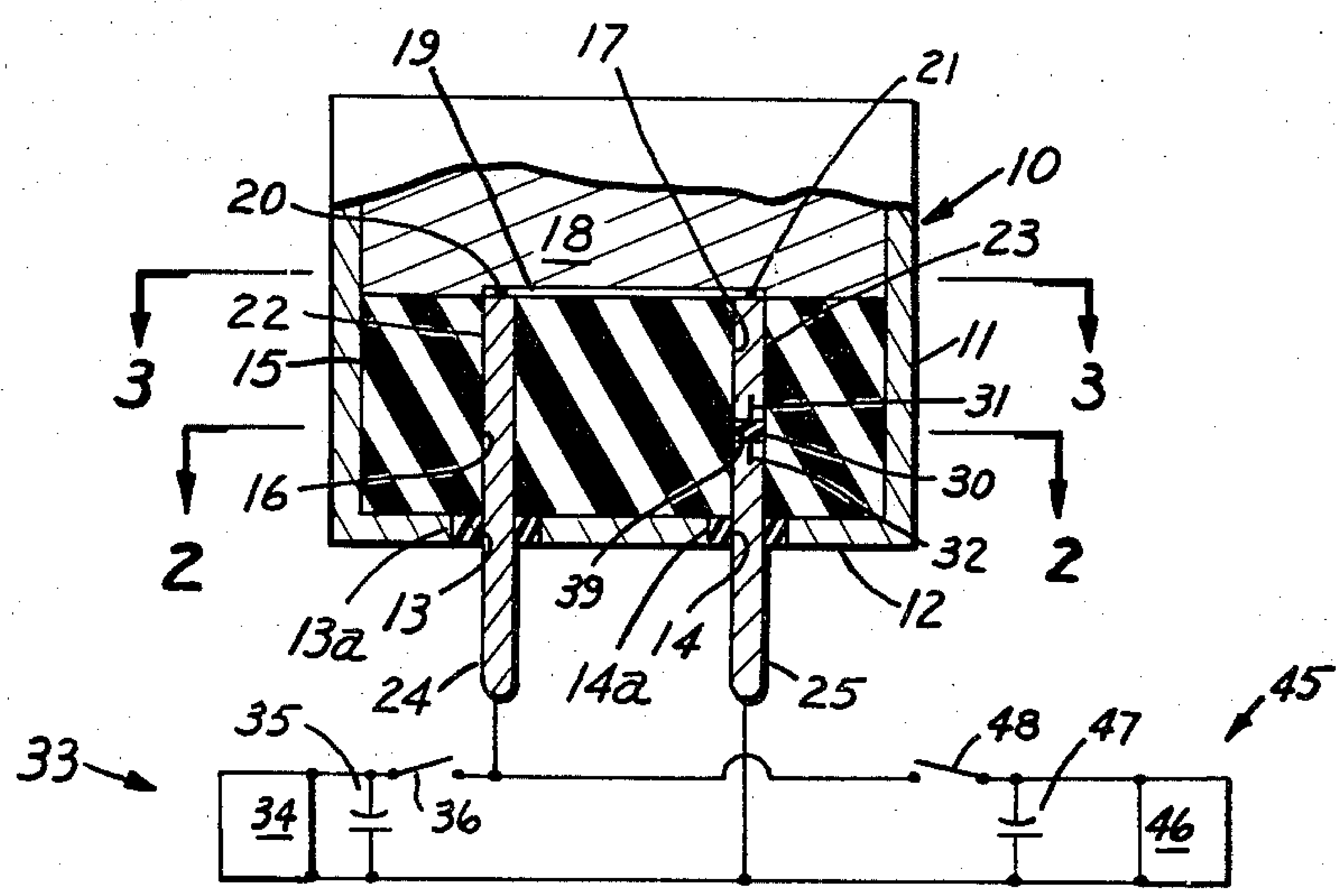


FIG. 2

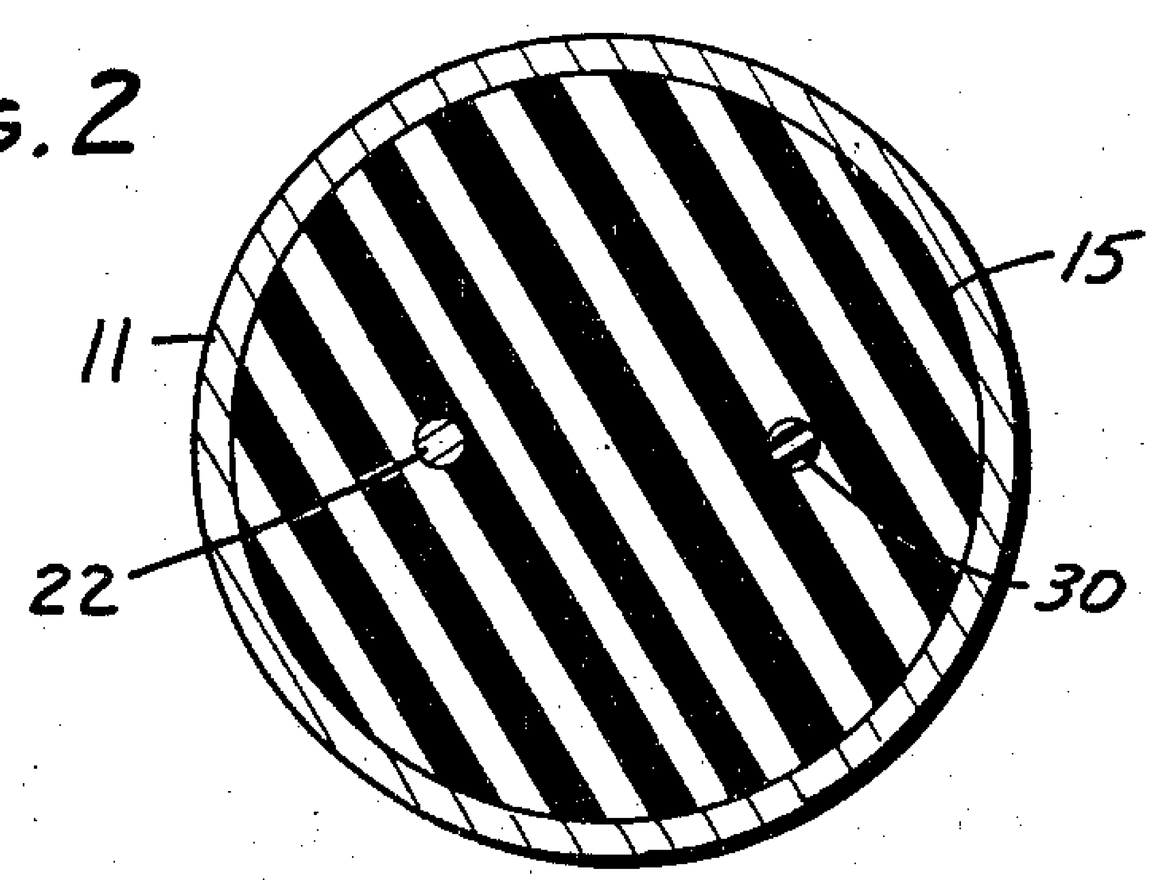


FIG. 4

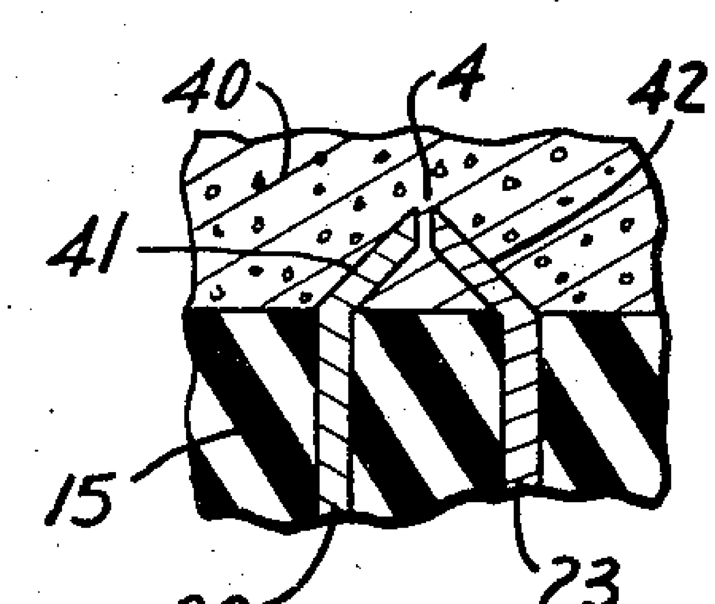
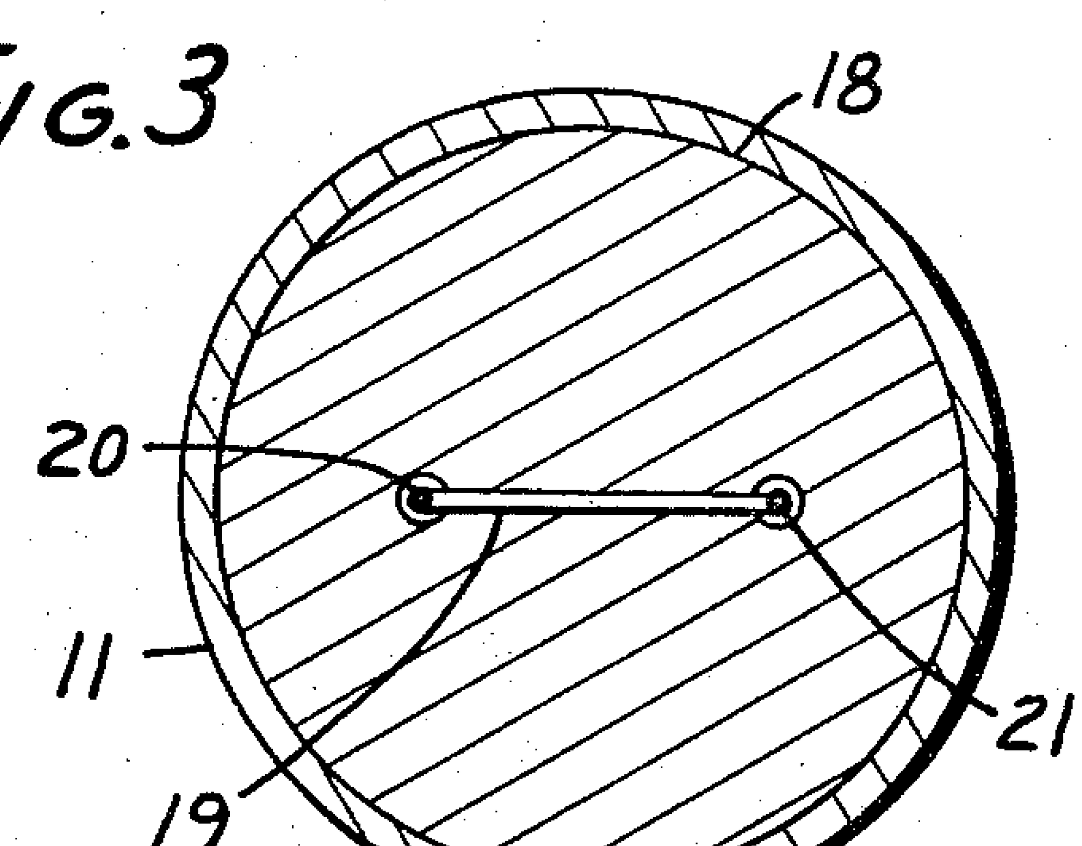


FIG. 3



INVENTOR.
WELDON S. BANKSTON, JR

BY

Angus & Mon

ATTORNEYS.

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SAFETIED ORDNANCE DEVICE

Weldon S. Bankston, Jr., Fountain Valley, Calif., assignor to Hi-Shear Corporation, Torrance, Calif., a corporation of California

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10 Claims. (Cl. 102—28)

ABSTRACT OF THE DISCLOSURE

This invention relates to an ordnance of the exploding bridgewire type which includes safety and check-out provisions. In this invention, the device can be safetied, and armed cyclically and reversibly. In the safetied condition, the device is protected from initiation by stray charges, and can be checked for continuity. In its armed condition it can be fired, but it can be placed in its armed condition without detonation, and can be returned to the safetied condition from the armed condition should this be desirable.

This is a continuation of applicant's co-pending patent application, Ser. No. 439,170, filed Mar. 12, 1965, entitled, "Safetied Ordnance Device," now abandoned.

This invention relates to an automatically safetied ordnance device.

Most common ordnance devices utilize a bridgewire which is exploded or heated up, or a gap in which a spark is discharged, to explode a charge. In the case of the exploding bridgewire, the explosion results from the passage of a relatively high-voltage, high-amperage, current through the bridgewire in a short pulse. For example, several known bridgewires are caused to explode by a current which, when discharging from a 1.0 μf. capacitor charged to about 2500 volts, reaches a peak of about 2000 amperes in about ½ microsecond. It is known that relatively insensitive charges can be caused to explode by the plasma and shock wave created when a bridgewire explodes adjacent to it. In the case of bridgewires which are merely heated, the heat generated is sufficient to discharge only more sensitive charges. The heat of a spark discharge functions similarly to the heated bridgewire.

However, even relatively insensitive charges need certain safety and check-out provisions, and these provisions are often even more important when more sensitive materials are used. For example, stray transient voltages can appear inexplicably in systems, or radio transmission can supply currents which can cause initiation of even relatively insensitive charges. There needs to be a safety feature which protects the device from such stray currents. Furthermore, the fact of continuity or discontinuity in bridgewire circuitry is a critical matter. There needs to be means for passing current to measure conductance at will, which means will function inherently to prevent the passage of currents during testing that are likely to explode the device. Accordingly, it is an object of this invention to provide means for safing a bridgewire-type ordnance device, and for enabling its conductivity to be checked without risk of explosion, still being readily armed, and reversible to the safetied condition.

An ordnance device according to this invention comprises an explosive charge, and means such as a bridgewire or gap that is adapted to explode the charge upon the passage of a current therethrough. A pair of electrodes is provided, one of which is conductively connected to each of the terminals of the bridgewire or gap. A body of conductive plastic material is placed in series connection with one of these electrodes whereby a series electrical circuit can be completed through the body, an electrode, the bridgewire or gap, and the other electrode.

The material which comprises the body has a first and a second state of electrical resistance constituting a relatively higher and a relatively lower resistance. Conversion to the first state of relatively higher resistance when the body is initially in the second state of lower resistance is caused by passage therethrough of a current of sufficient magnitude to accomplish this change. Contrariwise, conversion to the second state of relatively lower resistance from the first state of relatively higher resistance when the body is initially in the said first state of relatively lower resistance is caused by applying across the body a voltage, either AC or DC, of sufficient magnitude to accomplish the change. The magnitude of current passed to the bridgewire in the course of either conversion is limited so as to be insufficient to explode the bridgewire.

According to a preferred but optional feature of the invention, the electrodes are mounted in an insulating base. There is also provided a prong for each electrode which projects beyond the base. One prong is integral with one of the electrodes. The body conductively interconnects the other prong and the other electrodes so as to form a series circuit between them.

According to still another preferred but optional feature of the invention, the bridgewire is of the exploding type.

According to still another preferred but optional feature of the invention, the device is combined with a capacitor discharge-type power supply of the class which provides a sharply defined high-voltage, high-current, pulse to fire the device.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is an axial cross-section of the presently preferred embodiment of the invention;

FIG. 2 is a cross-section taken at line 2—2 of FIG. 1;

FIG. 3 is a cross-section taken at line 3—3 of FIG. 1; and

FIG. 4 is a fragmentary cross-section of another embodiment of the invention.

The presently preferred embodiment of the invention is shown in FIG. 1. It is an automatically safetied exploding bridgewire type ordnance device. It includes a generally cylindrical housing **10** with a generally cylindrical peripheral wall **11** and a flat transverse bottom wall **12** which closes the bottom of the peripheral housing. The top of the housing is closed by conventional means which permit the exit of the products of explosion, this feature being neither shown nor essential to the understanding of the invention. Two holes **13**, **14** are provided in the bottom wall, in which are fitted insulating grommets **13***a*, **14***a*, respectively.

Within the housing there is an insulating base **15** which closely fits the peripheral and bottom walls. This base may be made of any suitable insulating epoxy material or glass. It has a pair of passages **16**, **17** extending therethroughfh and aligned with holes **13**, **14**, respectively. A charge **18** of explodable material is placed adjacent to and generally contiguous with the top surface of the insulating base. An example of a suitable charge material for this device is RDX, which is a relatively insensitive material conveniently exploded by an exploding bridgewire.

When bridgewires not to be exploded are used, such as in the more common blasting applications wherein the wire is merely heated, then the wire will be of the same general appearance, but is usually of larger cross-section, and the explodable material will be more sensitive, such as black powder, lead azide and the like, which can be set off by heat. These latter materials are also suitable for use in the embodiment of FIG. 4, where a gap is the source of the heat. The materials used in the gap-type device of FIG. 4 will ordinarily have some metal compounded into them so as to render them electrically conductive.

Between a portion of the insulating base and the charge, there is disposed an explodable bridgewire **19**. Suitable bridgewires for use with the aforesaid explosive are gold, silver, platinum, copper or alloys containing these elements, having a resistance of about 0.03 ohms, up to about 1 ohm. Resistances of wires intended to be heated only will generally be larger.

The bridgewire has terminals **20, 21** which are respectively conductively connected to electrodes **22, 23** which fit in passages **16, 17**, respectively. Prongs **24, 25**, respectively, pass through holes **13, 14** in the bottom wall and project beyond the housing. Prong **24** is an integral extension of electrode **22**. Prong **25**, however, is connected to electrode **23** through a body **30** of conductive plastic material which will further be described below. Body **30** preferably has a pair of terminals **31, 32** which may readily be imbedded therein, although conductively spaced apart from each other, and which may be conductively attached to electrode **23** and prong **25**, respectively. Alternatively, the body may simply be pressed or poured into conductive contact with the electrode and prong.

It will now be seen that a series circuit can be established through prong **24**, electrode **22**, bridgewire **19**, electrode **23**, body **30** and prong **25**. A capacitor discharge-type power supply **33** may be connected across the prongs so as to supply current and voltage for changing the conductive state of the material comprising the body, or for providing a pulse sufficient to explode or heat the wire, or spark across a gap, as appropriate. A suitable supply includes a power package **34**, such as a battery pack or rectified power source, across whose terminals is connected a capacitor **35**. One terminal of the capacitor is connected through a firing switch **36** to one of the prongs, and the other terminal of the capacitor is connected to the other prong. A suitable capacitor could have a capacity of about 0.25 μf., charged to 2500 volts. The pulse produced from this capacitor as it discharges into the aforesaid ordnance device may be termed a capacitor-type discharge. Its characteristic is a climb to a high voltage in a time on the order of a fraction of a microsecond. Such a pulse will explode a bridgewire of the type described above as an exploding bridgewire. It will also spark across a gap of about 0.002 inch length in FIG. 4, or heat up a wire too large to explode with this discharge to a temperature high enough to initiate the more sensitive materials described above.

The material and the behavior of body **30** and of the material of which it is made will now be described. There is known a family of conductive plastics often called "hypersensors" or "nanosecond fuses" which have the inherent characteristic of being able stably to assume either one of two states of inherent electrical resistance. One is a relatively higher, and one is a relatively lower, resistance. The relatively higher resistance is sometimes referred to herein as the "first state," and the relatively lower resistance is sometimes referred to herein as the "second state." These states are mutually exclusive, and are stable until the material is caused to assume the other state. For example, conversion to the first state (when the body is initially in the second state) is caused by passage therethrough of a current of sufficient magnitude to accomplish this change, in use generally about 10 ma., which is much less than is needed to fire any commercially feasible explosive or heat-generating wire, or to bridge a gap. On the other hand, conversion to the second state (when the body is initially in the first state) is caused by applying a voltage across the terminals of the body of sufficient magnitude to accomplish the change, generally about 1000 volts. Care will be taken that the magnitude of current passed to the bridgewire in the course of either conversion is insufficient to explode the bridgewire.

The chemical constituency of the conductive plastics referred to herein is not generally known at the present time. However, this material may be purchased from Qualtronics Corporation, 1100–1 East Ash Avenue, Fullerton, Calif. It is also available in their line of hypersensors, for example their hypersensor number H–050.

When the material is in its second state of relatively low resistance, the material shows the characteristics of a fixed resistor up to a "trip level" of current applied thereto. This trip level is an inherent function of the material and appears to be a dependent upon its metallic content, surface area, purity, etc. When the current applied to the material reaches the "trip" level, then the material inherently switches to a first condition of relatively higher resistance, which closely approximates the behavior of an open circuit. In the said H–050 device, for example, the trip level is 100 ma. At currents below this level, its resistance is about 10 ohms. After the trip level has been passed, the material acts essentially as an insulator.

Of course, due care will be taken to be certain that the spacing apart of prong **25** and electrode **23** is such that there will be no arcing over between their ends so as to frustrate the "open circuit" effect of this material.

On the other hand, when the material is in its first state of relatively higher resistance, it can be "re-set" to the other state by applying a suitably high voltage for the purpose, the current therethrough being limited such that insufficient current can pass with this pulse to explode the bridgewire. There is a line of re-setters available for this purpose from said Qualtronics Corporation, for example their HR–1.

As an example of the constructional features of this invention, it has been found that utilizing one material derived from Qualtronics Corporation under their trade notation HS–100, a ⅛ inch long lozenge of the material having a $\frac{3}{16}$ inch diameter with metallic terminals at each end could be inserted into cavity **39** (this cavity having like dimensions), thereby spacing apart the electrodes as aforesaid. It is desired for the bridgewire with which this body is associated to fire with a voltage of 2500 volts and a peak amperage reached in about ½ microsecond of 2000 amperes.

The device could be converted from its first state of high resistance to a state of relatively low resistance by application of a voltage of approximately 1000 volts (AC or DC) impressing an amperage on the order of tenths of milli-amperes on it, this amperage being below the trip level. At this time, the body acts simply as a fixed resistance and conductance through the bridgewire can readily be measured. Furthermore, this is the preferred rest state for the device. However, assume now that some transient level is considered to be the major risk, such as 220 volts (AC or DC). The material's length, cross-sectional area and composition have been selected to respond for a conversion to the first state of higher resistance by application of such a voltage. This, in a matter of a few nanoseconds (a much shorter time than it would take to fire the bridgewire), switches the device to the first state, and the circuit is esentially open. The length of the body was selected so that arcing over between the prong and the electrode would not defeat its purpose. Should higher voltages be used, then naturally the length of the body will be increased.

A re-setting circuit **45** is also shown in FIG. 1, connected to the prongs. This circuit includes a power package **46**, such as package **34**, connected to the terminals of capacitor **47**. It changes capacitor **47** to 1000 volts, the re-setting voltage, or a voltage somewhat above the re-setting voltage. Capacitor **47** will have a capacity of about 0.002 μf. A re-set switch **48** is connected to one terminal of the capacitor and to one of the prongs, while the other terminal is connected to the other of the prongs.

The transients which are of concern in the safetying of the device ordinarily have little power, and their voltages are not high enough to convert the body to its condition of lower resistance. When the current passes through the device with the material at its lower resistance state, the power is speedily dissipated. However, if the amperage exceeds the trip level, then the body shuts off the flow by reverting to the condition of higher resistance. Now when the device is fired by a current from a capacitor-type discharge, the voltage exceeds the level needed to convert to the lower resistance state, and converts it, holding it there while the current passes through. This is the reason for utilizing the capacitor discharge-type power supply. Its voltage is readily made higher than quite a high voltage level at which the body becomes conductive, and then a substantial current can quickly be applied to the device. Other types of power supplies, such as one which would gradually apply a large current, would simply shut off the device and leave it safetied. In fact, the device described above will resist 250 volts AC applied directly across the prongs.

FIG. 4 shows base **15**, electrodes **22** and **23**, and a charge **40** which will preferably be of one of the aforesaid more sensitive explosives. Instead of a bridgewire, two points **41**, **42** are attached to the electrodes and form a gap **43** between them across which a spark will be passed to explode the material. The points and the charge will be directly substituted for the respective elements in FIG. 1.

It will be observed that the safetying feature shown provides a safe ordnance device for common types of commercial applications, as well as for the more sophisticated exploding bridgewire types which are more often found in very expensive installations such as in missiles.

It will be seen from the aforesaid that this device has several advantages. It permits the ordnance device user to measure the conductance through the bridgewire ciruuit at will when the body is in its second state of lower resistance, which is easily attained by proper voltage pulsing of the device at a voltage too low to cause explosion.

It provides an automatic safing feature to the ordnance device, because the application of current levels which will exceed the design limit in the body will revert the body to a high resistance state which will prevent substantial current from reaching the bridgewire.

The above states are reversibly securable, without deterioration of the device.

It provides a safing gap which can be fabricated as an integral part of the ordnance electrode to overcome the effects of arcing over.

It provides a safing gap which can be broken down by the high-voltage, high-current firing pulse which is used in exploding bridgewire technology, and which is also useful in less sophisticated ordnance technologies.

The aforesaid advantages, all of which are extremely important in this field, are readily attained by the simple use of a small body of conductive plastic in series with the exploding bridgewire. It is readily fabricated and highly reliable.

It will, of course, be recognized that more than one of these bodies may be placed in the circuit, such as by providing one between the other electrode and prong. Furthermore, these bodies may be placed outside the prong if preferred, so long as they are in series with the exploding bridgewire. However, in consideration of the fact that the device is of the order of perhaps ¾ inch in diameter, it will be seen that the small space within which the body can be placed is a matter of considerable importance when it is to be used in close quarters.

This invention is not to be limited by the embodiment shown in the drawing and described in the description which is given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. An automatically safetied ordnance device comprising: an explosive charge; an explodable bridgewire adapted to explode the charge and having a pair of terminals; a pair of electrodes, one of which is conductively connected to each of said terminals; and a body of conductive plastic material in series connection with one of said electrodes, whereby a series electrical circuit can be completed through the body, an electrode, the bridgewire, and the other electrode, the material comprising the body having a first and a second stable state of electrical resistance constituting a relatively higher and a relatively lower resistance, conversion to said first stable state when the body is initially in said second stable state being caused by passage therethrough of a current of sufficient magnitude to accomplish the change, and conversion to said second stable state when the body is initially in said first stable state being caused by applying a voltage across the terminals of the body of sufficient magnitude to accomplish the change, said states being attainable from the other without degradation of the ability to return to the former state, the magnitude of current passed to the bridgewire in the course of either conversion being insufficient to explode the bridgewire.

2. An ordnance device according to claim **1** in which the electrodes are mounted in an insulating base, and in which there is a prong for each electrode projecting beyond the base, one prong being integral with one of the electrodes, the body having a pair of terminals, one of which is conductively connected to the other prong and the other of which is conductively connected to the other electrode so as to form a circuit between them.

3. An ordnance device according to claim **2** in which the base includes a cavity, said body fitting in said cavity.

4. An automatically safetied ordnance device comprising: an explosive charge; means adapted to explode the charge and having a pair of terminals; a pair of electrodes, one of which is conductively connected to each of said terminals; and a body of conductive plastic material in series connection with one of said electrodes, whereby a series electrical circuit can be completed through the body, an electrode, the means, and the other electrode, the material comprising the body having a first and a second stable state of electrical resistance constituting a relatively higher and a relatively lower resistance, conversion to said first stable state when the body is initially in said second stable state being caused by passage therethrough of a current of sufficient magnitude to accomplish the change, and conversion to said second stable state when the body is initially in said first stable state being caused by applying a voltage across the terminals of the body of sufficient magnitude to accomplish the change, said states being attainable from the other without degradation of the ability to return to the former state, the magnitude of current passed by the body in the course of either conversion being insufficient to actuate the means.

5. An ordnance device according to claim **4** in which the means is a bridgewire.

6. An ordnance device according to claim **4** in which the means is a spark gap.

7. An automatically safetied ordnance device for use in combination with a capacitor discharge-type power supply, said ordnance device comprising: an explosive charge; means adapted to explode the charge and having a pair of terminals; a pair of electrodes, one of which is conductively connected to each of said terminals; and a body of conductive plastic material in series connection with one of said electrodes, whereby a series electrical circuit can be completed through the body, an electrode, the means, and the other electrode, the material comprising the body having a first and a second stable state of electrical resistance constituting a relatively higher and a relatively lower resistance, conversion to said first stable state when the body is initially in said second stable state being caused by passage therethrough of a current of sufficient magnitude to accomplish the change, and conversion to said second stable state when the body is initially in said first stable state being caused by applying a voltage across the terminals of the body of sufficient magnitude to accomplish the change, said states being attainable from the other without degradation of the ability to return to the former state, the magnitude of current passed by the body in the course of either conversion being insufficient to actuate the means.

8. An ordnance device according to claim **7** in which the means is a bridgewire.

9. An ordnance device according to claim **7** in which the means is a spark gap.

10. An ordnance device according to claim **7** in which said means is an explodable bridgewire.

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BENJAMIN A. BORCHELT, *Primary Examiner.*

V. R. PENDEGRASS, *Assistant Examiner.*