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DETONATOR

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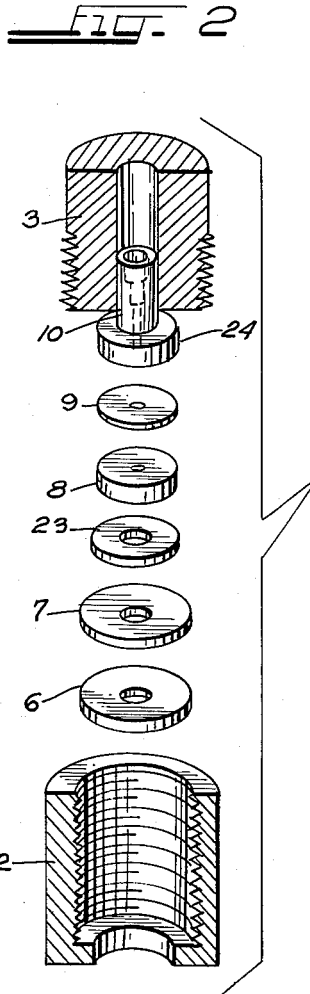
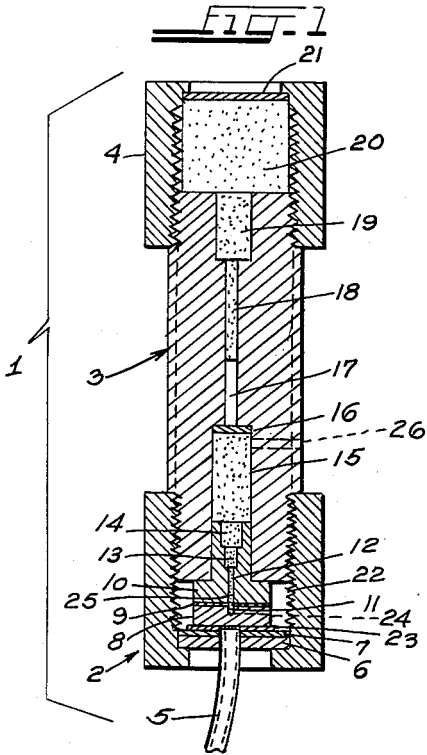
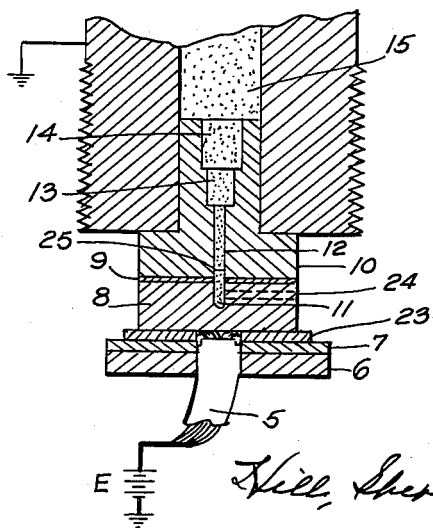


FIG. 3



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**DETONATOR**

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This invention relates to a new and improved detonator and more particularly to its explosive composition and structure whereby the assembled unit is made less sensitive to shock and frictional impact without impairing its functional requirements.

Detonators or blasting caps are employed to effect the explosion of main charges for work where high explosives are utilized. The detonators contain compositions which must have the ability to pick up rapidly to their maximum high velocity detonation when once ignited in order to operate efficiently. Mercury fulminate and lead azide are two materials commonly employed as primary detonating compounds in blasting caps. These compounds, as well as others, exhibit a relatively high order of sensitivity to impact, shock and/or frictional effects than the commonly used main charges, such as dynamite. Primary explosives or charges as termed herein are known as sensitive triggering type explosives as contrasted to the less sensitive main, base or secondary explosives.

In one aspect, the present invention relates to improvements which decrease the impact, shock, and/or frictional sensitivities of an electrically activated detonator device.

In another aspect, the invention relates to a novel firing mechanism.

And still another aspect, the invention relates to a novel detonator structure whereby the length and sensitivity of such devices are substantially reduced.

In a further aspect, the present invention relates to less sensitive delay detonators in which there is included means for controlling the delay time.

These and other aspects of the invention are accomplished by providing a novel structure, low energy electric detonator containing no primary explosives.

In the illustrative embodiment of the present invention to be described in detail, a detonator structure of general configuration is used, but it is to be understood that the present invention is not limited thereto. That is, various geometries may be employed without departing from the novel concepts embodied herein.

For a better understanding of the invention, the reader's attention is directed to the following more detailed description, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 shows a cross section of a detonator structure in accordance with the present invention;

FIGURE 2 depicts a partially cross sectioned lower portion of the detonator of FIGURE 1 useful in the description thereof; and

FIGURE 3 shows the lower portion of the detonator structure with the steel fitting 2 omitted for use in describing the operation of the electrical firing mechanism.

**STRUCTURE**

With reference now more particularly to the drawings, in FIGURE 1 there is shown a cross section of a detonator, generally identified by the numeral 1. The outer shell comprises three metallic members namely; end fittings 2 and 4 and central portion 3. The central portion 3 may be a cold rolled steel stud adapted to threadably engage fittings 2 and 4. The lower fitting 2 has a circumferentially inwardly extending seat adapted to receive, in abutting relation, the annular steel washer 6.

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A Bakelite washer 7 is placed on top of washer 6 for insulation purposes whose function will be described in more detail in conjunction with the description of FIGURE 3. The washers 6 and 7 have concentric annular passages therethrough adapted to receive electrical ignition lead 5.

The firing lead 5 comprises an insulated bundle of fine strand wire. The lead 5 extends through the openings in washers 6 and 7 such that the insulation extends a fraction above the Bakelite washer 7. The uninsulated wire strands then progress through a concentric opening in a reduced outer diameter copper washer 23. The strands are then radially displaced across the top of washer 23. It is noted, however, that the radial extension of such strands does not exceed the outer radius of copper washer 23.

On top of washer 23, in intimate electrical contact therewith, is a smaller diameter brass piece 8. The brass piece 8 contains a very small diameter passage 11 extending substantially to the mid-thickness thereof on the upper surfaces thereof. Another brass piece 10 is situated atop piece 8 with a suitable insulating washer 9 therebetween. The washer 9 must possess a sufficiently high dielectric constant in order to withstand dielectric breakdown when an electrical firing pulse is applied to the detonator device. The brass pieces 8 and 10 and the insulating washer 9 are bonded together to assure confinement of the explosive and its combustion products and to assure alignment and continuity of sections 11 and 12 in the brass pieces 8 and 10. The holes 11 and 12 and an equal diameter hole through the center of washer 9 are drilled in one operation after the bonding operation has been performed.

The brass member 10 (see FIGS. 1 and 2) is maintained in intimate pressure contact with the lower structural members by the steel stud or sleeve 3. The stud 3 is threadably engaged within the fitting 2. The brass member 10 has annular sections of varying diameters extending therethrough. The lower section 12 has a diameter equal to that of section 11 in member 8. On the other hand, sections 13 and 14 have successively larger diameters. Section 14 graduates into a larger section 15 equal to the smaller outside diameter of member 10. Section 15 is sealed by brass disc 16. The remaining structure essential to the operativeness of one embodiment of our novel detonator are; air gap 17, section 18 and main charge sections 19 and 20. The main charge is contained by an aluminum disc 21.

**OPERATION**

There are several features in the present design which are responsible for the successful initiation of an explosive reaction in the detonator. For the low firing energies to heat secondary explosives to a temperature sufficiently high to cause an adequate reaction, it is necessary that only a small quantity of the explosive be subjected to the available thermal energy. We accomplish this by providing a mixture of RDX, of very small particle size, and "Shawinigan" acetylene black in section 11 and part of 12. Shawinigan acetylene black is a specially processed form of carbon having a chain-like structure well suited for use in conductive mixtures. This carbon is provided by Shawinigan Products Corporation. This material was selected because of its excellent adaptability to our invention, however, we do not intend to be restricted thereto. That is, many conductive materials may be substituted therefor. Likewise, RDX (cyclotrimethylene-trinitramene) may be replaced by any secondary explosives such as tetryl, PETN, HMX and others. PETN and HMX are chemically known as pentaerythrite-tetranitrate and cyclotetramethylene-tetranitramine, respectively.

This form of carbon and the small particle size of the explosive enables rapid heating of the carbon as well as

rapid transfer of heat therefrom to the explosive. The electrical energy E (see FIGS. 1 and 3) is applied between the firing lead 5 and the metal case of the detonator 1. It is noted that the voltage applied to lead 5 is insulated from the metal case by the annular air gap 22 and the Bakelite washer 7. The path of current flow, therefore, is from the metal case of the detonator to the brass member 10, across the highly compressed conductive mixture of Shawinigan acetylene black and RDX in the chambers 11 and 12, the brass member 8, the lead 5 and thus to the source E.

Working models have functioned satisfactorily on the energy of a 1 micro-farad capacitor charged to 200 volts. This corresponds to a level of 200,000 ergs as contrasted to a range of 800,000 to 1,600,000 ergs normally required in present day electric detonators which do not contain primary explosives. The energy used is not intended to and does not represent the minimum energy, limiting voltage, or capacity required for operation of this model. Such limits are controlled by the particular design and application called for.

The high pressure used in loading the conducting mixture enables intimate contact of the carbon with the explosive. Consequently, this pressure loading lowers the electrical resistance which facilitates rapid heating of the carbon as well as rapid heat transfer to the explosive. The line 25 depicts the demarcation between the conductive explosive mixture and the plain RDX which is slightly above insulating washer 9.

In order to allow the reaction of this small quantity of explosive to be sustaining and able to propagate to larger quantities of explosives, we have confined the original reaction against energy losses in the following manner. The plane surfaces of the two brass members 8 and 10 are joined with a thin insulating material therebetween. In this respect, we have successfully employed two pieces of blue Kleenex tissue impregnated with epoxy resin. In this manner, the brass pieces are bonded together with electrical insulation therebetween. The holes 11 and 12 and the equal diameter hole through the center of the insulating layer 9 are drilled in one operation after the bonding operation has been completed. The conductive mixture of acetylene black and RDX is loaded at high pressure into the small diameter chambers, 11 and 12, passing through the insulation layer. Since the conductive mixture is loaded in chambers 11 and 12 the mixture extends across the insulating washer 9. The electrical energy is effectively applied between the two brass members causing current to flow through the conducting explosive mixture bridging the insulating washer 9 around the circumference of the annular passage therethrough. The volume of the annular ring of heated explosive is hence, very small.

A burning or deflagration reaction takes place after thermal decomposition of the explosive across the insulating layer begins. This reaction, in turn, propagates to the plain RDX in chambers 13 and 14. The gradually increasing volumes of explosive subjected to the burning allows the reaction to increase in intensity and finally causes rapid deflagration of the explosive in chamber 15. Upon sufficient back pressure, due to the reaction, the disc 16 ruptures and metal fragments, vapor and hot gases are hurled across the gap 17 and impinge the explosive in section 18. The impinging metal fragments and the shock wave caused by the rupture of the disc 16 causes reaction of the explosive to begin in section 18. The then existing conditions in section 18 are such that the reaction grows in intensity until it is a self-propagating high order detonation and triggering of the main charge is effected thereby.

It has been found experimentally that the air gap 17 plays an important function in the detonator operation. Since no primary explosive is used, it is not possible to obtain a direct detonation at low firing energies. However, burning reaction is initiated and is made to increase

vigorously and effect a transition into a detonation. The air gap 17 and rupture disc 16 make possible the achievement of this transition in the small length and diameter used. It is noted that transitions from burning to detonation can be made to occur in continuous columns of explosives but it has not yet been possible to do this in a space which would be reasonable for most detonator applications. Thus, by the application of our invention the transition is feasible with the continuous columns of explosive unaided by the air gap 17 and rupture disc 16. On the other hand, where a relatively shorter detonator is required the air gap and rupture disc are required.

Satisfactory working models have been constructed. The following table depicts dimensions, materials and pressures in accordance with the principles disclosed herein, of one embodiment in which several successful firings were made.

Explosive Train Data

Section	Inches		Loading Pressure, p.s.i.	Material
	Dia.	Length		
11 (and part of 12)-----	0.026	$\frac{1}{16}$	60,000	Sub-sieve RDX-10% Shawinigan Acetylene Black.
12 (above line 25, Fig. 1).	0.026	$\frac{1}{8}$	60,000	Sub-sieve RDX.
13-----	0.046	$\frac{1}{16}$	30,000	Do.
14-----	0.081	$\frac{3}{16}$	15,000	Do.
15-----	0.125	$1\frac{3}{16}$	3,000	Coarse RDX.
17-----	0.063	$\frac{1}{4}$	-----	Air gap.
18-----	0.063	$\frac{3}{8}$	12,500	Sub-sieve RDX.
19-----	0.125	$\frac{1}{4}$	12,500	Do.
20-----	$\frac{1}{16}$	$\frac{3}{8}$	15,000	RDX.

As is well known in this particular art sub-sieve denotes particle sizes on the order of -325 mesh or less. In other words, the particle diameters are less than about 44 microns.

Our detonator, containing only a high explosive such as RDX or HMX, but requiring low firing energy will have many applications where out of line detonator safety creates a size, functional or mechanical reliability problem. This is also true where size and weight of the firing energy supply is critical. Furthermore, secondary explosives are more stable at high temperatures, thus, our detonators enable operation under high ambient temperature conditions.

In many cases it is not possible or convenient to employ out of line detonator safety. Therefore, a detonator containing no primary explosive is required. Heretofore such detonators required large amounts of firing energy which necessitated the use of massive cumbersome power supplies. We overcome this problem by providing our unique, low energy, firing train in a detonator of small size.

Also, a detonator can only be as insensitive to impact as its most sensitive component. Consequently, by eliminating explosives of the primary type we have provided a less sensitive detonator containing only explosives of the secondary type.

It will thus be seen that we have provided a low energy electric detonator containing no primary explosives having dimensions acceptable in the art. The special conductive mixture, and the structure of the device to which it is loaded is novel. The heating of an annular ring of explosive rather than a line, plane, or a cylindrical volume is also novel. The disc 16 and air gap 17 and their functional relation are also considered novel.

Further, in applications where the detonator is exposed to heat or fire our invention is relatively insensitive thereto. This is because of the exclusion of highly thermally,

sensitive primary explosives. In many cases our detonator, if thrown into a fire, would (due to thermal expansion of the metal structure thereby decreasing the confinement of the conductive secondary explosive mixture) merely burn at a slow rate insufficient to effect detonation thereof. This expedient may be enhanced or insured by the insertion of radially inwardly extending plugs 24 and/or 26. Plugs 24 and/or 26 are constructed of a metal having a relatively low melting point whereby external heat from a fire would allow the explosive reaction products to expand and consequently the powder train would nonexplosively burn. By relatively low, as used herein and in the appended claims, is meant a low melting point in comparison to the other structural members of the detonator.

Various modifications will occur to those skilled in this art without departing from the spirit and scope of our invention. For example, the firing time may be made variable by varying the length of the powder train or by introducing a pyrotechnic delay. Also the ignition means may be modified whereby a heat source, other than electrical, may be employed to initiate the detonator.

The present invention has been described in detail in the preceding, however, we intend to be limited only by the following claims.

We claim as our invention:

1. An electric detonator and train containing no primary explosive and adapted for mechanical assembly comprising: an elongated hollow metal shell and means therein defining a detonation initiating and conducting train of connected columns of increasing volume comprising, a first cylindrical chamber in and extending along the length of said shell at one end thereof, said first cylindrical chamber being defined by a bore through adjacent and successive first and second metal members with a bored insulating washer therebetween, the second of said metal members providing an enlarged diameter and larger volume portion of said first chamber in a smaller outer diameter end portion thereof in the direction of the propagation of detonation, a second and connected chamber having an internal diameter substantially equal to the smaller outer diameter of said second member's reduced outer diameter portion, a rupturable diaphragm means sealing the far end of said second chamber, an axially extending air gap adjacent to said rupturable diaphragm means and terminating in a base charge of explosive, said base charge of explosive consisting only of an insensitive secondary explosive, only explosive of the insensitive and secondary type in said first and second chambers with the secondary and insensitive explosive in at least said first chamber being mixed with a conductive material to form a conductive ignition composition containing no primary explosives, and means including electrical connections to provide for an electric circuit and for current flow through said conductive mixture for the heating and ignition thereof.

2. An electric detonator containing no primary explosive adapted for mechanical assembly comprising: an elongated metal shell having means therein defining a detonation initiating and conducting train of columns of increasing volume comprising, a first cylindrical chamber at a detonation initiating end of said shell, said first chamber being defined by successive first and second metal members and an insulating washer therebetween with a bore through all three, said second member having a reduced and smaller outer diameter at its far end enclosing an enlarged diameter and larger volume portion of said first chamber, means forming a second chamber axially connected with said first chamber and having a diameter substantially equal to the smaller outer diameter of said second member, a rupturable means sealing the far end of said second chamber, an air gap adjacent to said rupturable means and terminating in a base charge of only secondary explosive, a conductive ignition composition containing no primary explosives in at least said

first chamber and secondary explosives only in said second chamber and forming said base charge, connection means to form an electric circuit for the conduction of current through said conductive ignition composition to heat and ignite the same whereby said connected chambers increase the intensity of the ignition and burning to a level causing the rupture of said rupturable means to act across said air gap to impinge on said secondary explosive base charge with sufficient energy to cause the detonation thereof.

3. An electric detonator containing no primary explosive and adapted for mechanical assembly, said detonator comprising, an elongated hollow metal shell with a first cylindrical chamber at the ignition initiating end thereof, said first chamber being defined by first and second successive metal members having an insulating washer therebetween and in contact with said metal members on respective opposite sides of said washer and with a bore through said first and second metal members and said washer, said second member being positioned within the shell and having a reduced and smaller outer diameter at its end not in contact with said washer with successive enlarged diameter and larger volume chamber portions with the largest volume portion terminating at said end not in contact with said washer, means in said shell forming a second chamber axially connected to said first chamber having an internal diameter substantially equal to the reduced outer diameter of said second member, metal plug means extending radially inward to said first chamber and to said second chamber through said metal shell and at least through said first member which plug means have melting points lower than said metal members, said shell and said means forming said second chamber to provide for a safety release of pressure upon the accidental heating of said detonator, rupturable means sealing the end of said second chamber not in contact with said first chamber, an air gap next to said rupturable means in coaxial relation therewith and extending axially therefrom and terminating in an axially spaced base charge, an ignition composition of a current carrying mixture of a conductive material and a secondary type explosive only in at least said first chamber, explosive only of the secondary type in said second chamber and in said base charge, means to provide an electric circuit connected across said ignition composition to provide for the flow of an electric current therethrough, whereby the increasing cross-section and volume of said chambers provides for increasing intensity of the burning action to a level causing the abrupt rupture of said rupturable means to hurl the resulting products across said air gap to impinge on said base charge with sufficient energy to cause the detonation thereof.

4. In a low energy electric detonator containing no primary explosive comprising in combination: an elongated hollow metal shell with a first cylindrical chamber containing a confined, current carrying ignition composition comprising a mixture of conductive material and an explosive of only the secondary type; succeeding, successively larger volume chambers within said shell containing secondary explosive trains of only secondary explosive connected to said ignition composition at one end thereof with the other end of said train terminating in abutment with a rupturable disc; a cavity within said shell defined by said disc said metal shell and second succeeding, successively larger volume chambers within said shell containing secondary explosive trains of only secondary explosive; and a last chamber beginning at the end of said second succeeding successively larger volume chambers containing a base charge of only explosive of the secondary type.

5. A low sensitivity, stable, and safe electric detonator device comprising a compressed and intimate mixture of a conductive material and an explosive of only the secondary explosive type to form a conductive current carrying path to be heated and ignited by said current, means

forming electrical connections to said mixture to provide for the flow of electric current through said mixture to heat and ignite the same, explosive train means connected to said mixture to increase the energy intensity of said ignited mixture including a plurality of coaxial connected transition columns of increasing volumes, said columns comprising only explosive of the secondary explosive type, and means to reduce the effective over-all length required in said detonator device comprising a rupturable diaphragm means in abutment with a last of said transition columns followed by an empty chamber within said detonator, and second explosive train means immediately following said empty chamber comprising transition columns of increasing volumes with said columns containing only explosive of the secondary explosive type wherein said diaphragm and said empty chamber are in coaxial relation and mutually coextensive.

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