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G. A. NODDIN
EXPLOSIVE COMPOSITION AND WATERHAMMER-RESISTANT
DELAY DEVICE CONTAINING SAME
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3,306,201

FIG. 1

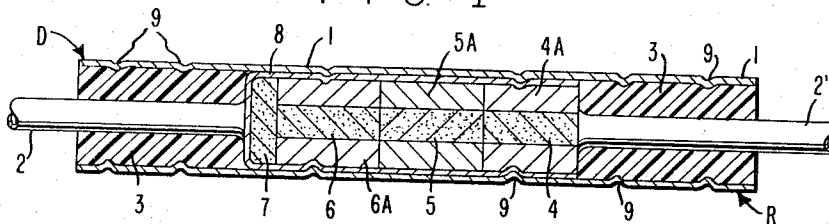


FIG. 2

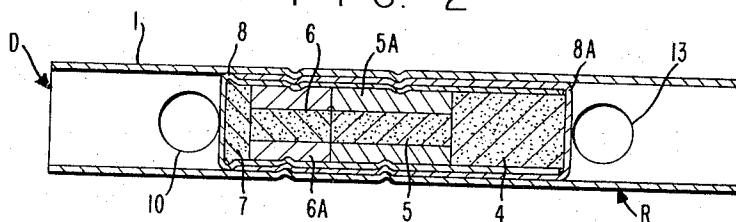


FIG. 3

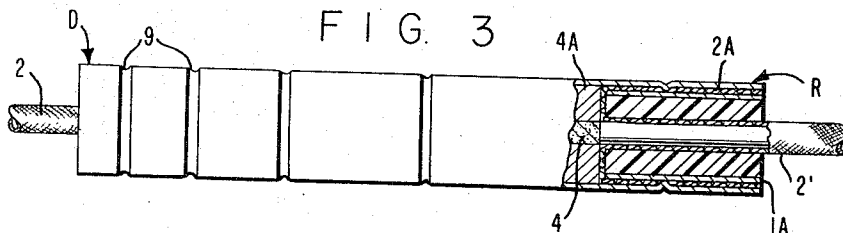
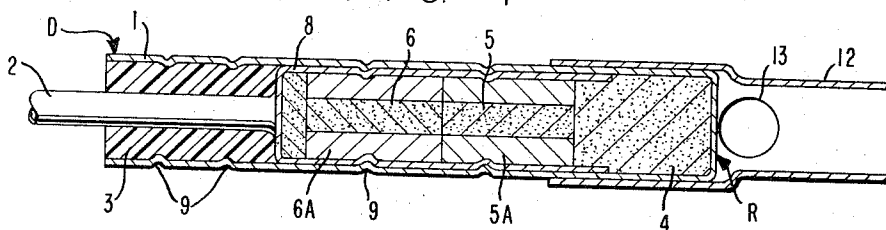


FIG. 4



INVENTOR
GEORGE A. NODDIN

BY *Newton R. Burgess Jr.*

ATTORNEY

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EXPLOSIVE COMPOSITION AND WATERHAMMER-RESISTANT DELAY DEVICE CONTAINING SAME

George A. Noddin, Mantua, N.J., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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The present invention relates to pressure and shock resistant ignition compositions and to waterhammer-resistant delay initiators containing such compositions.

For activities in which the detonation of a series of explosive charges below the surface of water is desired, such as in seismic exploration, well cleaning, underwater signalling, echo-ranging for detection purposes, and the like, there is a need for a reliable and accurate means for actuating the explosive charges in a predetermined sequence, i.e., at precise delay intervals. Commonly available means for actuating the charges in a predetermined sequence, i.e., delay initiators and connectors, such as conventionally used in blasting assemblies are not suitable for use underwater since, particularly at the hydrostatic pressures at great underwater depths and even in shallow water, these initiators and connectors fail to transmit a detonation stimulus reliably, particularly after they have been waterhammered, e.g., shocked by explosion of an explosive charge nearby.

Failure of conventional delay initiators when used underwater is believed to be variously due to several factors. In such delay devices, there generally will be an ignition composition between the delay element of the explosive train and the means, e.g., detonating fuse, used to actuate the devices, the ignition composition propagating the initiation stimulus from the actuation means to the delay charge. Conventional ignition compositions for delay initiators tend to be desensitized by hydrostatic pressure as well as waterhammer caused by shock waves from associated explosive devices, and thus fail to propagate the requisite ignition stimulus to the delay charge. Also, with some ignition compositions, waterhammer will itself actuate the ignition composition thereby causing premature firing of the delay initiator. It is seen, therefore, that a satisfactory ignition composition for waterhammer resistant delay initiators must be both resistant to desensitization by pressure and waterhammer, and also to premature actuation by the same causes. Finding an ignition composition which will fulfill these requirements is further complicated by another factor, viz., the composition should also be substantially gasless. Evolution of a substantial quantity of gas during explosive decomposition would, of course, cause rupture of the initiator shell thereby often permitting desensitizing amounts of water to contact the remainder of the delay train. A severe and sudden pressure drop which will cause burning of many ignition and delay compositions to abruptly stop also results from shell rupture.

It has now been discovered that all of the above requirements are met by an explosive ignition composition consisting essentially, by weight, of at least about 88% red lead (lead tetroxide), about from 7 to 11% lead azide, lead styphnate, or a mixture thereof, and 0 to about 2% boron. Such new compositions are not desensitized by pressure, impact, and waterhammer, and are resistant to actuation by these forces, are substantially gasless, and yet are readily initiated by conventional actuation means, e.g., commercial detonating fuses. They are, therefore, particularly well suited for use as the ignition composition in delay initiators designed for underwater use. It is to be understood, however, that they may be used for other applications where one or more of the above properties are

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desirable and that their utility in waterhammer-resistant delay initiators is given only by way of example and not of limitation.

Two further problems associated with underwater use of delay initiators is desensitization of one or more components of their explosive train from water seepage permitted by waterhammer-induced shell collapse or premature rupture of the shell by the actuation means, e.g., detonating cord. I have found that with the above ignition compositions of this invention, these problems are overcome: (a) by separating the ignition composition and other elements of the explosive train from the actuation means with an imperforate partition which will not be ruptured by the detonation stimulus from the actuation means, and (b) by eliminating substantially all air space from between and around such elements.

Accordingly, this invention further provides a waterhammer-resistant delay initiator comprising (a) a shell adapted to receive actuation means at one of its ends, (b) a train of abutting explosive elements within and peripherally engaged by the shell, said elements including a delay composition and the above ignition composition (hereinafter sometimes referred to as the red lead ignition composition) in igniting relationship to said delay composition, and (c) an imperforate, non-rupturable partition adjacent the end of the shell adapted to receive the actuation means, said partition being in contact with the ignition composition and separating it from said end.

The term "initiator" as used herein is intended to include not only detonators and squibs but also connectors for two lengths of detonating cord or fuse.

The term "actuation means" as used herein is meant to include conventional electric or pressure-actuated ignition assemblies, preferably, however, the "actuation means" is an explosive detonation-conveying cord (detonating cord) such as low energy connecting cord (LEDC) as described in U.S. Patent 2,982,210; mild detonating fuse (MDF) consisting of a column of detonating composition in a ductile metal sheath; the cord described in U.S. Patent 3,125,024, which comprises a core of PETN of a specific surface area in a multilayer textile sheath ("Primuline"); conventional detonating fuse ("Primacord") having a core loading up to about 75 grains per foot; and extruded cords of an explosive composition described in U.S. Patents 2,999,793 or 2,992,087 ("Detaflex"), the core of these compositions preferably being at a loading up to about 100 grains per foot and contained in a flexible sheath of ductile metal or polymeric composition such as nylon or braided textile.

When it is stated that the elements of the explosive train are peripherally engaged by the shell, it is intended to include direct peripheral engagement as well as indirect peripheral engagement, e.g., via a shell liner or capsule which itself peripherally engages the explosive elements, the only requirement being that there be substantially no air space between the explosive compositions and the outer shell.

In order to describe the delay initiators of this invention in greater detail, reference now is made to the accompanying drawings wherein:

FIGURE 1 is a cross-sectional view of a delay initiator for connecting two lengths of metal-sheathed detonating cord;

FIGURE 2 is a cross-sectional view of a delay connector designed to be side-actuated by, and to side-initiate, high-energy, high-velocity detonating fuse;

FIGURE 3 is a partial cross-sectional view of means for connecting textile sheathed detonating cords with a connector of this invention, and

FIGURE 4 is a cross sectional view of a delay detonator provided with a removable adapter for converting the detonator to a delay connector.

Referring now to the figures in greater detail, in FIGURE 1, 1 designates a tubular shell having a donor end D for receiving the actuation means and a receptor end R. Lengths of metal-sheathed detonating cord 2 (the actuation means) and 2' extend into opposite ends of the tubular shell and are held firmly in place by grommets 3, e.g., of an elastomeric composition which also seal these ends. Within the bore of the tubular shell 1 and in sequence from cord 2' are charge 4 of detonating explosive within heavy-walled tube 4A, priming charge 5 of heat-sensitive priming composition in heavy-walled tube 5A, and column 6 of delay composition in heavy-walled tube 6A. A layer of the red lead ignition composition 7 contacts the column of delay composition. A thin-walled, cup-shaped capsule 8 is inverted over the layer of ignition composition, the base of this capsule holding the layer in place and serving as a non-rupturable partition between it and the end of actuation means 2. The side walls of the capsule extend around the peripheries of the heavy-walled tubes 6A, 5A, and 4A for stability. The end of detonating cord 2 abuts the partition presented by the end of capsule 8. All components within capsule 8 are pressed together firmly to eliminate air chambers within this portion of the device. The ends of the metal sheathed detonating cord within the shell preferably are flanged as shown to prevent their being displaced during handling and shocking. A number of peripheral crimps 9 are provided to hold the grommets and other elements in place in the shell.

In FIGURE 2, the red lead ignition composition 7, elements 6-6A, 5-5A and loose charge 4 of detonating explosive are loaded into capsule 8 which is then inserted into secondary capsule 8A. The thus assembled unit is subsequently pushed through a die about 0.020 to 0.060 inch smaller than the outer diameter of capsule 8A to form a watertight seal between the capsules and lock the explosive element in place. This assembly is then crimped in place in tubular metal shell 1. End D of shell 1 is provided with a pair of aligned apertures 10 (only one seen), which provide a passage through the shell for insertion of an explosive donor cord having sufficient brisance to side-initiate ignition composition 7 through the imperforate partition formed by the base of capsule 8. A suitable cord for this purpose is composed of 77 grains per foot of an explosive composition described in U.S. Patent 2,992,087 encased in a flexible sheath of 420-denier nylon braid. End R of shell 1 contains a pair of apertures 13 which function in the same manner as apertures 10 to permit the cut end of explosive cord to be threaded through the shell. The receptor cord in this embodiment is detonated through its side by detonating explosive 4.

FIGURE 3 shows a delay initiator for connecting the ends of explosive cords composed of an extruded core of flexible explosive countered with a braided textile sheath 2A. Sheathing 2A is unraveled to bare a portion of the core, and the unraveled portions of sheathing folded back and secured between shell 1 and a supplementary tubular shell 1A about grommet 3. Cord 2 is similarly seated in end D or if it is metal sheathed, as shown in FIGURE 1.

FIGURE 4 illustrates a delay detonator of this invention that has been modified for use as a connector by addition of an adaptor sleeve. In this embodiment, tubular metal shell 1 is integrally closed at one end and contains, in sequence from that end, a pressed base charge of a high explosive 4, a heavy-walled ductile metal tube 5A having in its central bore a column of heat-sensitive charge 5, a column of delay composition 6 in heavy-walled tube 6A, and layer 7 of the red lead-lead azide mixture of this invention. A thin-walled, cup-shaped capsule 8 is inverted over layer 7, the base of the capsule serving as a partition between layer 7 and the end of explosive cord 2 which extends into the open end of the shell through an elastomeric grommet 3. Crimps 9 are provided in the shell to hold the grommet and inner

assembly in place. When the initiator is to be used as a delay connector for two lengths of explosive cord, a receptor length of explosive cord is held in propagating relationship to the base charge 4 by removable cylindrical adaptor sleeve 12 which force fits on end R of shell 1. A pair of aligned apertures 13 are provided in the smaller diameter portion of sleeve 12 and are disposed so the receptor cord is firmly held against the closed end of the shell after sleeve 12 is pushed into place. Base charge 4 assures reliable actuation of cord through its sheathing. The assembly of FIGURE 4 without sleeve 12 can be used as a detonator inserted into or butted against an explosive cartridge or a mass of explosive charge, e.g., a sheet or block of a self-supporting explosive composition, in which case the detonation impulse is propagated directly to actuate the explosive cartridge or mass rather than initiating a length of receptor cord.

In operation of the above initiators, percussion of the detonation stimulus from the actuation means against the imperforate partition actuates layer 7 of the red lead ignition composition. Actuation of layer 7 initiates burning of the column of delay composition 6. The slow, regulated burning of this column provides the precise delay of the initiator. When the hot front produced by the burning of column 6 contacts column 5 of heat-sensitive composition, the latter ignites, thereby detonating explosive charge 4, which in turn actuates the acceptor length of cord or a mass of explosive charge as the case may be. The initiator can be designed to provide any desired delay, the length of the delay period provided depending upon the length of delay composition and the confinement provided for this composition.

The resistance of the initiator of this invention to desensitization or inadvertent actuation by impact and waterhammer is primarily due to the protected layer of impact-insensitive red lead ignition composition which picks up the detonation stimulus from the actuation means and propagates it to the other elements of the explosive train. Also, as stated above, open space within and around the explosive train is minimal and no inner air chamber is present as in conventional delay initiators; accordingly, there is little chance of shell collapse under hydrostatic pressure and waterhammer. Furthermore, should the actuation means rupture the donor end D of the shell, the imperforate and non-rupturable partition prevents desensitizing amounts of water from entering the explosive train. For added waterhammer-resistance it is desirable that at least the delay and primer charges be contained in heavy-walled tubes, e.g., of lead, which act as shock wave absorbers.

The shell 1 must be of a material rigid enough to withstand both hydrostatic pressures and abrasive actions present in underwater operations. Premature rupture of any section of the shell below capsule 8 could allow desensitizing amounts of water to contact the charges. Commercial bronze is a particularly preferred material for shell 1 and capsules 8 and 8A. Metals such as aluminum, copper and copper alloys such as brass, steels, nickel, or polymeric materials possessing similar physical characteristics, also may be used for shell 1 and capsule 8. Lead is preferred for the heavy-walled tubes around the delay and primer charges since it is a good shock absorber and also gives the confinement needed for reliable functioning of many delay charges. Moreover, lead's malleability and ductility facilitate the desirable swaging and crimping of the tubular shell to eliminate voids, provide watertight seals, and hold the elements of the explosive train in place.

The ignition composition of this invention is a mixture consisting essentially, by weight, of at least about 88 percent lead tetroxide (red lead), about from 7 to 11% primary detonating explosive of the group consisting of lead azide, lead styphnate and mixtures thereof, and up to about 2% boron. The above percentages are based on

pure materials; thus dextrinated lead azide, for example, which has a lead azide content of 93%, could be about from 8 to 12% of the ignition composition. The ignition composition of this invention is able to be actuated through the imperforate partition 8 and to pass on the actuation impulse to the delay charge abutting it without venting or rupturing the shell. Yet the mixture is not desensitized by pressure and waterhammer, and is insensitive to actuation by these forces. In particular, the ignition composition is not actuated by the impact of a 1/2-inch-diameter steel ball dropped from a height of 45 inches. The ignition composition should be kept substantially anhydrous (preferably < about 0.08% moisture, by weight), since the wet mixtures, e.g., ones exposed 16 hours to 85% relative humidity at room temperature (68° F.), become too lumpy to load into small I.D. shells, and will not propagate an initiation stimulus imparted thereto through the imperforate barrier. For other applications, however, moderate amounts of moisture may not be objectionable.

Ignition compositions of this invention containing less than 7% of primary detonating explosive cannot be reliably ignited by the stimulus imparted thereto by detonation of an explosive cord having a core loading of 10 grains/foot or less through a commercial bronze partition (the capsule bottom) 0.022 inch thick, whereas mixtures containing more than about 11% of such explosive tend to vent capsule 8. The primary detonating explosive in the mixture preferably is dextrinated lead azide since mixtures containing other types of lead azide, e.g., RD 1333 or RD 1343 lead azide, polyvinyl alcohol-precipitated lead azide, colloidal lead azide, service lead or lead styphnate are more sensitive to accidental actuation by impact. However, the use of lead styphnate or any of the conventional forms of lead azide is not outside the scope of this invention. The presence of up to about 2% boron aids in igniting the delay charge and also improves the flowability of the ignition composition; and therefore, the boron containing compositions are preferred. However, as the amount of boron increases so does the heat of the reaction of the composition. Accordingly, amounts in excess of about 2% should be avoided to prevent the mixture from softening the surrounding metal and cause venting. The amount of red lead ignition composition employed in the initiators of this invention or other explosive devices will, of course, depend on the size of such initiator or device, the thickness of the confining metal, and the ease of initiation of the delay composition it is intended to actuate.

The imperforate partition insures the water-resistance of the initiator such that inadvertent seepage of water into the shell or rupture of donor end D by the actuation means will not retard actuation of the novel ignition composition and thus the delay and other charges. The partition should be capable of appreciable deformation without rupture upon actuation of the actuation means. Premature rupture or fracture of the partition would allow desensitizing amounts of water to contact the delay charges. The partition, which preferably is provided by the base of a capsule inverted over the explosive train, may be formed of any material which is ductile, malleable, and imperforate at the external pressures developed by actuation of the actuation means, i.e., by detonation of the explosive cord. Exemplary materials include copper and such copper alloys as commercial bronze and brass, aluminum, steels, lead, nickel and the like or polymeric materials of similar characteristics. The partition thickness, naturally, will be determined from the physical characteristics of the material used and the core loading of explosive used as the actuation means, smaller loadings requiring thinner partitions. With an explosive cord having a core of the composition of U.S. 2,992,087, at a core loading of 10 grains/foot, the thickness of a commercial bronze partition will be about from 0.018 inch to about 0.032 inch. For explosive cord hav-

ing a core loading of 75 grains/foot, the thickness must be greater than 0.022 inch, about 0.40 usually being satisfactory.

The composition of the elements of the explosive train other than the ignition composition are neither critical to, nor form part of, the initiators of this invention.

For the delay composition a mixture of solid oxidizing and reducing agents of the type conventionally used in ventless delay initiators is preferred, e.g. boron-red lead, boron-red lead-dibasic lead phosphite, aluminum-cupric oxide, magnesium-barium peroxide-selenium, or silicon-red lead. The delay composition may be present in the bore of a metal carrier 6A, e.g., of lead, or may be a simple layer. The delay period is dependent upon the length or depth of the delay charge as well as its degree of compaction and confinement; and therefore, this charge will usually be compacted in a heavy-walled carrier. If desired, the delay composition may be grained prior to use for example, with neoprene, gum, shellac, polyethylene glycol, "Thiokol," and carbowaxes, to facilitate loading.

The composition used for base charge 4 may be any of the conventional base charges, e.g., pentaerythritol tetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), lead azide, picryl sulfone, nitromannite, cyclotetramethylenetetranitramine (HMX), and the like. This charge can be loose or compacted e.g., into the heavy-walled tube 8A.

The priming charge 5 can be any heat-sensitive detonating composition which is readily initiated by burning of the delay composition, e.g., lead azide, mercury fulminate, diazodinitrophenol, or a similar composition. Lead azide in a heavy-walled lead tube is preferred to withstand severe shock and waterhammer.

In order to illustrate the invention, reference now is made to the following examples.

Example 1

A number of delay connectors are prepared resembling that shown in FIGURE 1. The connectors are designed for use with explosive cord comprising a core of the flexible explosive composition described in U.S. 2,992,087, at a nominal loading of 10 grains/ft., in a lead sheath, the outer diameter of the cord being 0.105 inch. In each case, the outer shell 1 is a commercial bronze tube 2.562 inch long and having an inner diameter of 0.259 inch and a wall thickness of 0.014 inch. In preparation for loading the shells, a layer comprising one grain of an 88/10/2 mixture of red lead/dextrinated lead azide/boron is positioned in the base of a commercial bronze cup-shaped capsule 8 which is 1.625 inches long, 0.258 inch in outer diameter and has a wall thickness of 0.0065 inch and a bottom thickness of 0.022 inch. Above this layer are loaded in sequence from the bottom of the capsule (1) an 0.245 inch O.D. tubular lead delay carrier 0.31 inch long, having a central bore 0.130 inch in diameter, containing a column of a delay composition composed of a mixture of boron, red lead, and dibasic lead phosphite, ("Dyphos"), (2) a tubular lead carrier 0.245 inch in outer diameter, 0.130 inch in inner diameter, 0.25 inch long and containing a continuous column of 0.7 grain of dextrinated lead azide in its bore, and (3) a tubular lead carrier, 0.250 inch long, 0.245 inch in outer diameter and containing a central core of 1.0 grain of PETN. Each of these tubular carriers is pressed firmly into capsule 8 and the side walls of the capsule crimped about the assembly of tubes. The capsule containing the assembly of tubes is then inserted into the tubular shell, a space of 0.812 inch being left at each end of the shell for the insertion of neoprene grommets, 0.255 inch in outer diameter, 0.875 inch long, and having a central bore 0.105 inch in diameter. The explosive cord is threaded through the bore of the grommets to a position such that the end of the cord extends about 0.0625 inch beyond the face of the grommet and this extending portion of cord flanged outward to aid in retention of the cord in the grommet. Sub-

sequently, the grommets are inserted into the shell and the flared ends of the cord held by the grommets brought into contact with the end of the capsule at the donor end of the connector and with the exposed end of the carrier containing PETN of the acceptor end. The shell is crimped about the grommets and the capsule at a plurality of areas to secure these elements in place in the shell.

These connectors are tested by firing two lots of five connectors in series in water, one lot after being exposed to the waterhammer conditions developed by a 72-gram charge of sheet explosive containing 63% by weight of PETN (commercially available as "Detasheet"-C), spaced six inches from the connectors.

The average functioning time of the five fired in series is 0.51 second, the total time being 3.06 seconds. The average functioning time of the connectors which have been exposed to waterhammer conditions is 0.522 second.

Example 2

A number of delay detonators were prepared resembling that of FIGURE 4. The shell was of commercial bronze, 2 inches long, 0.259 inch in inner diameter, 0.289 inch in outer diameter and was integrally closed at one end. 3 grains of cap grade PETN was loaded into the base of the shell and pressed into place at 150 lb. applied by a flat ended press pin. Into a commercial bronze capsule 0.75 inch long, 0.258 inch outer diameter, 0.022 inch bottom thickness were loaded, in sequence, from the base of the shell, (1) 1 grain of a 90/10 red lead/dextrinated lead azide mixture, (2) a tubular delay carrier, 0.31 inch long, 0.245 inch outer diameter, and having a longitudinal bore 0.130 inch in diameter filled with the delay composition used in Example 1, and (3) 3 grains of a priming charge comprising a 50/50 mixture of superfine PETN/dextrinated lead azide. The loaded capsule was inserted into the shell above the charge of PETN and pressed down by 150 lb. exerted on a press pin. A tubular rubber grommet, 0.25 outer diameter, 0.875 inch long having the end segment of a length of the explosive cord used in Example 1 inserted therethrough, was sealed in the open end of the shell with the end of the cord abutting the bottom of the inverted capsule; the bottom of the capsule separating the layer of 90/10 lead tetroxide/lead azide from the flared end of the cord. The average functioning time of initiators of this type fired in air is 0.50 second. When initiators of this type are fired after being exposed to waterhammer conditions as in Example 1, the average functioning time is 0.48 second.

I claim:

1. An explosive ignition composition consisting essen-

tially, by weight, of at least about 88% red lead and about from 7 to 11% lead azide, lead styphnate, or a mixture thereof.

2. An explosive ignition composition of claim 1 which consists essentially of boron, red lead, and lead azide, lead styphnate or a mixture thereof, the boron constituting up to about 2%, by weight, of the total composition.

3. An explosive ignition composition consisting essentially, by weight, of at least about 88% red lead, about from 8 to 12% dextrinated lead azide, and boron, the boron constituting up to about 2% of the total composition.

4. A waterhammer-resistant delay initiator comprising (a) a shell adapted to receive detonation-conveying actuation means at one of its ends (b) a train of abutting explosive elements within and peripherally engaged by the shell, said elements including a delay composition and an ignition composition consisting essentially, by weight, of at least about 88% red lead and about from 7 to 11% lead azide, lead styphnate or a mixture thereof, in contact with said delay composition, and (c) an imperforate partition in contact with the ignition composition and separating it from said end of the shell, said partition being of sufficient strength that it will not be ruptured by the detonation stimulus from the actuation means.

5. An initiator of claim 4 wherein the partition is the base of a capsule inverted over the elements of the explosive train.

6. An initiator of claim 5 wherein the actuation means is an explosive cord, and this cord is in contact with said partition.

7. An initiator of claim 6 provided with means for sealing the end of the shell opposite said one end, said sealing means abutting the terminal element of the explosive train.

8. An initiator of claim 7 wherein said sealing means is the integral end wall of the shell.

9. An initiator of claim 7 wherein said sealing means includes a second explosive detonation-conveying cord extending axially into the shell, the core of said cord being in detonation-receiving relationship to said terminal element.

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BENJAMIN A. BORCHELT, *Primary Examiner.*

50 V. R. PENDEGRASS, *Assistant Examiner.*