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Zakheim

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[54] **BIDIRECTIONAL DELAY CONNECTOR**

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[58] **Field of Search** ..... 102/27 R, 28 R

[56] **References Cited**

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2,506,157	5/1950	Loret	102/28 R
2,736,263	2/1956	Lewis et al.	102/27 R
3,078,799	2/1963	Kabik	102/28 R
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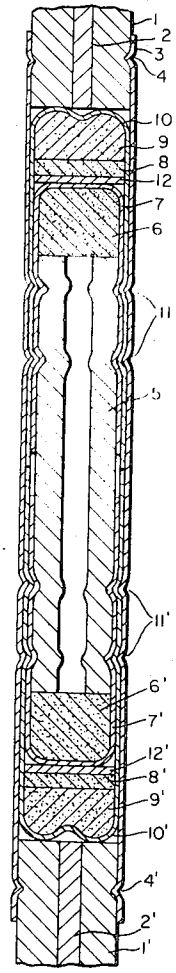
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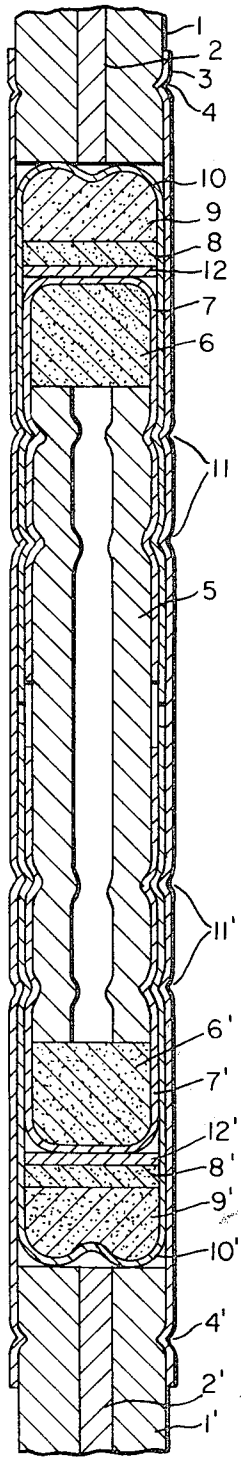
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[57] **ABSTRACT**

Bidirectional delay connectors for detonating fuse having a shell containing two detonating explosive charges, each end of the shell adjacent the detonating charges adapted to receive detonating fuse, heat-sensitive charges adjacent each detonating charge and in close proximity to exothermic charges in opposite ends of a metal relay capsule. A heat conductive metallic delay element is positioned between each heat-sensitive charge and said relay capsule containing exothermic charges.

9 Claims, 1 Drawing Figure





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BIDIRECTIONAL DELAY CONNECTOR

BACKGROUND OF THE INVENTION

This invention is directed to bidirectional delay connectors and, more particularly, to bidirectional delay connectors having consistent, but variable, preselected periods of delay.

Bidirectional, i.e., two-way, delay connectors have won much favor in field use because they do not require consideration of the direction from which the detonation impulse is propagated to the connector, but will function properly when actuated from either end. Bidirectional delay connectors are widely used to introduce time intervals in propagation between explosive charges in blasting, as described, for example, in U.S. Pat. No. 2,736,263.

Basically, delay connectors comprise a tubular shell containing two detonating charges with at least one time-delay element between them, each end of the tubular shell being open and empty and thus adapted to receive the end of a length of explosive cord, e.g., detonating fuse, to abut against a detonating charge. A time delay can be provided by the burning of a continuous column of a delay composition extending between the detonating charges. The delay or time interval is provided primarily by the delay element or portion thereof adjacent to the detonating charge on the output side of the connector, the end of the connector from which the detonation leaves. In general, the delay effect of the delay element or portion thereof adjacent to the input end of the connector is overridden or destroyed by the detonating charge adjacent to the input end. To counteract this effect, either a delay element is positioned adjacent to each detonating charge and a separator, e.g., an empty tube, is interposed between them, or a relatively long column of a burning or delay composition separates the detonating charges.

Bidirectional delay connectors have disadvantages of one sort or another with respect to cost and complexity of manufacture, predictability and reproducibility of delay times, and limit on the maximum delay time obtainable. In bidirectional delay connectors in which the delay element is the combination of an exothermic composition, a blind capsule, and a heat-sensitive composition, the longest delay time that can be provided conveniently is about 25 milliseconds. Longer delay times can be provided but require substantial alteration of some of the elements of the connector. Such variable factors include the kind and amount of exothermic charge, the material and thickness of the capsule end, and the type of heat-sensitive charge. Such variations, changes, and modifications increase the complexity and expense of manufacture of delay connectors and increase the probability of errors in manufacture or assembly of delay connectors that would cause trouble in use, such as wrong delay times, or more seriously, failure of the connector to function at all. For simplicity, economy, and ease of manufacture, it is highly desirable that all but one or two of these variables be held constant so that quality control can be maintained by adjustment of only one or two of the variable factors. More important, however, is the ability to predict and reproduce accurately the desired periods of time delay and to extend them beyond the longest delay period that can be obtained conveniently by connectors of prior art structure.

SUMMARY OF THE INVENTION

This invention is directed to an improved bidirectional delay connector having the above-mentioned desired flexibility and dependability. The bidirectional delay connectors comprise a shell containing two detonating explosive charges, each end of the shell adjacent the detonating charges adapted to receive detonating fuse, heat-sensitive explosive charges adjacent each detonating charge and in close proximity to exothermic charges contained in opposite ends of a metal relay capsule substantially centrally located in the connector, the improvement which comprises positioning a heat-conductive metallic delay element between each heat-sensitive charge and said relay capsule containing said exothermic charges in the shell. Preferably, the metallic delay element is wafer shaped, and the shell is tubular, the wall of which usually extends beyond the detonating explosives at each end, and is adapted to receive detonating fuse.

BRIEF DESCRIPTION OF THE DRAWING

The drawing illustrates a cross-sectional view of a preferred embodiment of a bidirectional delay connector of this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

To illustrate the invention, reference now is made to the accompanying drawing showing the bidirectional delay connector. In the drawing, **1** and **1'** represent separate lines of detonating fuse, each having a core **2** and **2'** of detonating explosive, one end of each line of fuse being held within the open ends of tubular shell **3** by means of crimp or crimps **4** and **4'**. Within the shell, between the two ends of detonating fuse, is a thick-walled empty metal tube **5**. At each end of this tube are like charges **6** and **6'** of an exothermic mixture of pulverulent oxidizing and reducing agents held in position against tube **5** by means of blind metal relay capsules **7** and **7'**, each having a base approximately four times as thick as the side wall of the capsule at its open end. Immediately adjacent to the outside of the ends of these capsules are heat-conductive metallic delay elements **12** and **12'**. Immediately adjacent to the wafer-shaped metallic delay elements **12** and **12'** are like charges **8** and **8'** of the same heat-sensitive composition, and adjacent thereto are like detonating charges **9** and **9'**. These detonating charges are enclosed in blind metal capsules **10** and **10'** which also extend over the heat-conductive metallic delay elements **12** and **12'**, the heat-sensitive charges **8** and **8'**, and the metal relay capsules **7** and **7'** that enclose the exothermic charges **6** and **6'**. Metal capsules **10** and **10'** containing detonating explosive and metal relay capsules **7** and **7'** are crimped about the ends of the empty tube **5**, as indicated by indentations **11** and **11'**.

The illustrated delay connector functions in the following manner. When the core **2** of detonating fuse **1** detonates at metal capsule **10**, detonating charge **9** and heat-sensitive charge **8** explode; the resulting shock destroys heat-conductive metallic delay element **12** and deforms but does not perforate relay capsule **7**. The shock wave creates pressure and heat within the blind relay capsule **7** to ignite the exothermic charge **6** and within the open tube to ignite the other exothermic charge **6'**, and also forces part of charge **6** through the

tube and against charge 6'. In this manner charges 6 and 6' are ignited almost simultaneously. The burning of both exothermic charges 6 and 6' evolves heat that is transferred through the end of capsule 7' and through heat-conductive metallic delay element 12' to ignite heat-sensitive charge 8', after a delay interval, but without burning open the end of relay capsule 7'. After the heat-sensitive charge 8' ignites, it in turn initiates detonating charge 9', which then initiates the core 2' of detonating fuse 1'. It is evident, since the delay connector contains the same sequence of charges at each end, that the connector can be activated equally well by fuse 1' to detonate detonating charge 9', to be followed by a sequence of events parallel to that described above, but in reverse order.

Although the delay connectors of this invention are particularly well adapted for use with relatively brisant detonating fuse, such as "Primacrod" (a product of the Ensign-Bickford Co.) or similar fuse, it is to be understood that these connectors can be used with any type of explosive cord, including other detonating fuse, mild detonating fuse, low energy detonating cord, extruded cords comprising a high-explosive composition in an elastic binder, and other explosive cords comprising a sheath enclosing a core of detonating explosive, such as trinitrotoluene, cyclotrimethylenetrinitramine, pentaerythritol tetranitrate, or lead azide. The explosive cords generally are protected by a covering of lead, textile, or polymeric material, and conveniently are inserted into the ends of the tubular shells of the connectors with the longitudinal axes of the fuse coincident with the longitudinal axis of the connector. If necessary, elastomeric grommets can be used as aids in retaining the ends of the detonating fuse in the ends of the tubular shell.

In the functioning of the delay connector of this invention, the time or duration of delay is about the length of time it takes for the heat evolved by the burning of exothermic charge 6' combined with part of exothermic charge 6 to pass through the end of relay capsule 7' and through heat-conductive metallic delay element 12' to raise the temperature of heat-sensitive charge 8' to its ignition point. This length of time can be controlled by the particular heat-conductive metallic delay element 12'. Accordingly, in the delay connector of this invention, flexibility and dependability of delay time is provided by means of the heat-conductive metallic delay elements, usually wafer shaped, positioned adjacent the heat-sensitive charges. With the other components of the connector being unchanged, the desired delay time can be provided by the proper choice of metal and thickness of the heat-conductive metallic delay element. Moreover, the normal variations in the other components that would affect delay time and that are encountered in commercial manufacture can be easily compensated for by adjustments in the thickness of the metallic delay element. Commercially available connectors usually have a delay time of only about 25 milliseconds. Interposition of the heat-conductive metallic delay element of this invention between the heat-sensitive charge and the relay capsule provides much longer delay times, for example, about 200 milliseconds, and such delays can be reliably and consistently reproduced.

The heat-conductive metallic delay element can be any metal, alloy, or combination of metals or alloys that is suitably heat conductive. Representative metals and alloys include aluminum, aluminum alloys, copper, copper alloys such as brasses and bronzes, iron, steel, stainless steel, lead, lead alloys such as antimonial lead and lead-tin solders, nickel, nickel alloys, tin, tin alloys, silver, silver alloys, zinc, and zinc alloys. Of these, the softer metals and alloys are preferred for their ease of working and good adaptability to the processes of manufacturing the delay connectors. Especially preferred metallic delay elements are made of aluminum, aluminum alloys, lead, lead alloys, tin or tin alloys. The metallic delay element can be formed in a number of ways. It can be a single wafer, or disk, of the desired thickness cut from a sheet or a round bar of the desired metal or alloy, of such diameter that it can be inserted into capsule 10 or 10' with a slight deformation so as to provide a snug fit and intimate contact between the circumference of the wafer-shaped delay element and the inner wall of capsule 10 containing detonating explosive. The metallic delay element can be formed by stacking a plurality of such wafers, or disks, in capsule 10 to the desired height and pressing them into place to bring the faces of the wafers into intimate contact with each other. In this stack form, the wafers can be of the same or different thicknesses, and they can be the same metal or different metals, i.e., the stack can be, for example, a brass wafer between two aluminum wafers. In another embodiment, the wafer-shaped metallic delay element can be formed in place by dropping a measured quantity of a finely-divided metal powder into capsule 10 and 10' and compacting it under pressure by means of, for example, a weighted pin, so as to bring the metal powder grains into intimate contact in a dense powder compact that will be suitably heat-conductive. The powder can be a single metal, for example, powdered aluminum; an alloy, for example, powdered lead-tin solder; or a mixture of two metals, for example, a mixture of powdered aluminum and powdered copper. The desired quantity of powder can be dropped into capsule 10 at one time and pressed, or it can be divided into two or more portions, and the portions can be charged and pressed successively. When the powder is charged and pressed in successive portions, the portions can be equal or different in both quantity and kind; for example, the first portion can be powdered aluminum, the second portion powdered bronze, and the third powdered lead, to form a multilayered wafer having intimate interfacial contact.

In the functioning of the delay connector, as hereinbefore described, at the starting or input end the explosive shock from detonating charge 9 and heat-sensitive charge 8 destroys the heat-conductive metallic delay element 12, deforms but does not penetrate relay capsule 7, and creates pressure and heat within relay capsule 7 and tube 5 to ignite exothermic charges 6 and 6'. In this first part of the functioning process of the delay connector, the heat-conductive metallic delay element 12, by its position between the detonating charge 9 and relay capsule 7, absorbs and dissipates some of the explosive shock from the detonating charge and acts as shock barrier or protective shield for relay capsule 7 and the exothermic charges 6 and 6'. When the thickness of the heat-conductive metallic delay ele-

ment is increased, it approaches a critical limit, and delay elements thicker than this limit absorb and dissipate so much of the explosive shock that the remaining energy arriving at relay capsule 7 is not sufficient to ignite the exothermic charges, and the connector fails to propagate. The critical thickness is different for different metals. Generally, the metallic delay elements are no greater than about 0.10 inch thick and at least about 0.002 inch thick. Further, the critical thickness is, of course, also dependent on the kinds and amounts of detonating charges, heat-sensitive charges, and exothermic charges that are used, and will vary for any given set of conditions.

In the foregoing description of the construction and functioning of the delay connector, the connector has been indicated as being completely symmetrical, that is, corresponding elements are identical and their positions relative to each other are the same at each end of the connector. This symmetry gives the connector its bidirectional character and provides that the time of delay is the same regardless of which end of the connector is initiated. However, in certain types of blasting operation, where delay connectors are used, the desired time of delay is not always the same in successive blasts, largely because of changes in the nature of the material to be blasted. Accordingly, the blaster must maintain stocks of connectors having different periods of time delay, from which he can select the period or periods desired. In the delay connectors of this invention, two delay periods can be provided by one connector simply and easily by using different heat-conductive metallic delay elements in each end, i.e., metallic delay elements **12** and **12'** would not be identical in chemical composition and/or thickness. By choice of suitable metallic delay elements, a delay connector can be provided, for example, that would have a period of time delay of, say, 40 milliseconds if initiated at one end, or a period of, say, 80 milliseconds if initiated at the other end. Such a "two-time" connector can be clearly identified as to "fast" and "slow" ends by appropriate markings printed or stamped on the shell, by painting one end one color and the other end a different color, or by other suitable means.

The other elements of the connectors can be conventional types. The shell **3**, relay capsules **7**, **7'** and metal capsules **10** and **10'** containing detonating explosive can be aluminum, copper, commercial bronze, brass, or any other easily fabricated metal. The tubular shell is of a diameter such that it will readily receive the end of a length of detonating fuse and yet can be crimped snugly about the detonating fuse, e.g., having an internal diameter of about one-fourth inch. The detonating charges **9** and **9'** can be conventional types and can consist of organic nitrates, nitramines, and nitro compounds and inorganic azides, including RDX, HMX, PETN, TNT, lead azide, and mixtures thereof. The explosive of the detonating charges will preferably be a composition such as, for example, lead azide, mercury fulminate, diazodinitrophenol, or other similar sensitive explosive compound that will be readily initiated by a detonating impulse from the detonating cord or fuse. When a secondary explosive composition such as PETN, RDX, HMX, TNT, or tetryl is used, it is generally preferred to provide layers of a primary detonating explosive, particularly lead azide, between the detonating charges **9** and **9'** and the ends of the capsules **10** and **10'** as part of the detonating charges. The detonating charges usually amount to from about 2 to about 10 grains.

The exothermic composition **6** and **6'** is a burning mixture that is sensitive to initiation by shock and heat and preferably comprises a pulverulent mixture of solid oxidizing and reducing agents that burns with the evolution of little or no gas but with the evolution of large quantities of heat. Examples of such compositions include (1) mixtures of magnesium, selenium, and barium peroxide, (2) mixtures of magnesium, tellurium, and tellurium dioxide, (3) mixtures of magnesium and selenium, (4) mixtures of lead dioxide, ferric oxide, and aluminum, and (5) mixtures of bismuth, selenium, and potassium chlorate. A mixture containing, by weight, 30 parts magnesium, 35 parts selenium, and 35 parts barium peroxide is particularly suitable.

Heat-sensitive charges **8** and **8'** comprise compounds or physical mixtures that are readily ignited by high temperature, for example, mixtures of aluminum, mannitol hexanitrate, and tetracene; mixtures of lead azide and tetracene; mixtures of bismuth, selenium, and potassium chlorate; mercury fulminate; diazodinitrophenol; or other compounds or mixtures having low ignition temperature. A mixture containing, by weight, 85 parts lead azide and 15 parts tetracene is particularly suitable.

The metal tube **5** is usually made of lead or a lead alloy, for example lead alloyed with about 2–4 percent antimony. Other metals may be used, however, such as aluminum, aluminum alloys, copper, brass, and bronze. Lead alloyed with about 3–4 percent antimony is preferred for its convenience in working and handling and for its ability to receive readily the crimps in the shell and capsules, shown at **11** and **11'**, that aid in holding the several components of the connector in place. The length and bore of the metal tube may be varied within wide limits, depending largely on the nature and amount of exothermic composition, **6** and **6'** present. Tubes have been used varying in length from ½ inch to 1½ inches and in bore diameter from 0.046 to 0.135 inch.

The bidirectional connector of this invention can be modified so that it is adapted to receive detonating fuse shown in the assembly described in U.S. Pat. No. 3,349,706. For use as the delay unit in such an assembly, the delay connector of the present invention is modified so that the tubular shell **3** is of such length that it does not extend beyond the ends of the blind metal capsules **10** and **10'** and does not have empty open ends to receive the ends of lengths of detonating fuse. In all other respects the construction of the delay connector of the present invention remains unchanged, and it functions in an unchanged manner, except that when it is the delay unit in the assembly of U.S. Pat. No. 3,349,706, the denotation impulse is received from and transmitted to the detonating fuse through the wall of the fuse and not from or to a cut end of the fuse.

In the following examples which illustrate the invention, parts, percentages, and ratios are by weight unless otherwise indicated.

Example 1

Delay connectors were assembled according to the drawing, as follows:

Shell 3 — commercial bronze, 3¼ in. long, 0.26 in. O.D., 0.24 in. I.D.

Lead Tube 5 — 1⅛ in. long, 0.19 in. O.D., 0.07 in. I.D.

Exothermic composition 6 and 6′ — 1.5 grains of a 30/35/35 mixture of magnesium/selenium/barium peroxide

Relay capsules 7, 7′ — commercial bronze, 0.56 in. long, 0.22 in. O.D., 0.20 in. I.D., 0.025 in. end thickness

Heat-sensitive composition 8, 8′ — 1 grain of an 85/15 mixture of lead azide/tetracene

Detonating charges 9, 9′ — 5 grains of lead azide

Capsules 10, 10′ — commercial bronze, 1 in. long, 0.23 in. O.D., 0.22 in. I.D.

Metallic heat-conductive delay elements 12, 12′ — 97/3 alloy of lead/antimony as wafers 0.006 in. thick, stacked and pressed to desired thickness at a pressure of about 5,000 lb/sq. in.

In the following table are listed the lengths of delay period obtained when connectors having different wafer thickness were tested.

Wafer Thickness inches	Number Tested	Av. Delay Time milliseconds
none	5	7.4
0.006	4	8.9
0.012	5	15.7
0.018	5	24.8
0.024	5	35.6
0.030	5	48.0
0.060	5	99.0
0.090	5	235.0

Example 2

Five connectors were assembled as in Example 1, except that the metallic delay element was one 0.027-inch thick wafer of aluminum. When tested, these had an average delay time of 54 milliseconds. Five more such connectors were assembled except that the metallic delay element comprised two 0.027-inch aluminum wafers to make a total thickness of 0.054 inch; the average delay time was 208 milliseconds.

Example 3

Bidirectional delay connectors were assembled as in Example 1, except that the heat-conductive metallic delay element was formed in wafer shape, in place, by dropping a weighed amount of powdered lead into the capsule and compacting it under a pressure of about 10,000 lb/sq. in. The delay times are listed in the following table.

Lead Powder grains	Number Tested	Av. Delay Time milliseconds
none	4	5.5
1.2	4	10.1
2.0	5	20.6
2.4	5	25.4
3.6	5	55.4
6.0	5	103.0

Example 4

Connectors were assembled as in Example 3, except that powdered aluminum was used in place of powdered lead.

Aluminum Powder grains	Number Tested	Av. Delay Time milliseconds
none	5	6.1
0.3	5	16.6
0.6	5	42.1
0.9	5	69.6

Example 5

Connectors were assembled as in Example 3, except that powdered brass was used in place of powdered lead. The brass was an alloy of about 90 parts copper and 10 parts zinc.

Brass Powder grains	Number Tested	Av. Delay Time milliseconds
none	5	6.7
0.3	5	9.8
0.6	5	19.3
0.9	4	32.0
1.2	5	47.4

Example 6

Connectors were assembled as in Example 1, except that the metallic delay elements were stacks of 0.005-inch thick disks cut from a sheet of an alloy of about 60 parts tin and 40 parts lead.

Wafer Thickness inches	Number Tested	Av. Delay Time milliseconds
none	4	5.1
0.010	5	30.1
0.020	5	61.4
0.030	4	137.0

I claim:

1. In a bidirectional delay connector comprising a shell containing two detonating explosive charges, each end of the shell adjacent the detonating charges adapted to receive detonating fuse, heat-sensitive explosive charges adjacent each detonating charge and in close proximity to exothermic charges contained in opposite ends of a metal relay capsule substantially centrally located in the connector, the improvement which comprises positioning a heat-conductive wafer-shaped metallic delay element having a thickness in the range 0.002 to about 0.10 inch between each heat-sensitive charge and said relay capsule containing said exothermic charges in the shell.

2. The product of claim 1 wherein the metallic delay elements contain aluminum.

3. The product of claim 1 wherein the metallic delay elements contain lead.

4. The product of claim 1 wherein the metallic delay elements contain tin.

5. The product of claim 1 wherein the metallic delay elements are finely-divided metal powder.

6. The product of claim 1 wherein the shell is tubular and the wall of which extends beyond the detonating explosive and is adapted to receive detonating fuse.

7. The product of claim 1 containing a plurality of wafer-shaped metallic delay elements between the relay capsule and each heat-sensitive charge.

8. The product of claim 1 wherein the metallic delay elements in each end of the connector are of different thicknesses.

9. The product of claim 1 wherein the metallic delay elements in each end of the connector are of different chemical composition.

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