Nov. 21, 1967 R. J. MILLER ET AL 3,353,485

BIDIRECTIONAL DELAY CONNECTOR

Filed Dec. 29, 1965

FIG. 1

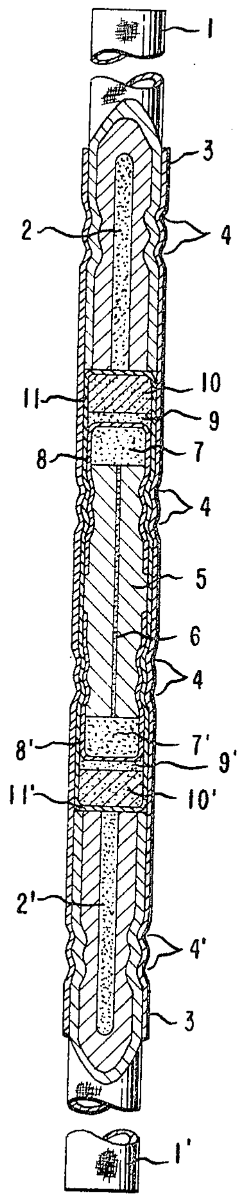
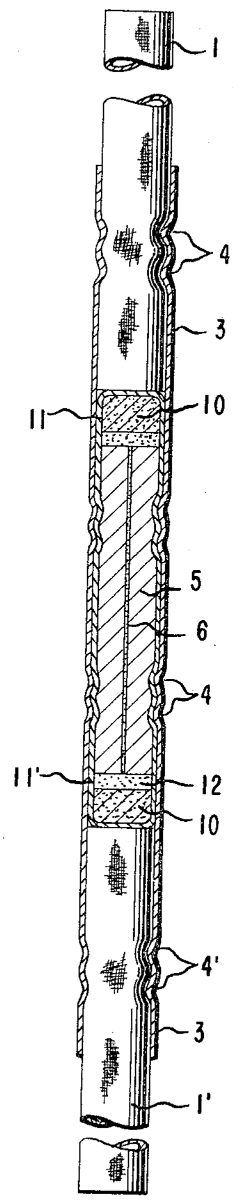


FIG. 2



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United States Patent Office

3,353,485
Patented Nov. 21, 1967

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3,353,485

BIDIRECTIONAL DELAY CONNECTOR

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Filed Dec. 29, 1965, Ser. No. 517,317
9 Claims. (Cl. 102—27)

ABSTRACT OF THE DISCLOSURE

This invention relates to explosive devices, and more particularly to an improvement in bidirectional delay connectors of the type comprising a shell containing two detonating charges, each having a delay element adjacent thereto, the improvement consisting of interposing a positive relay element between the two delay elements.

DISCLOSURE

Bidirectional, i.e., two-way, delay connectors have gained considerable favor in field use because they do not require consideration of the direction in which the detonation impulse is propagated to the connector, but will function properly when actuated from either end. Bidirectional delay connectors are widely used, for example, in introducing delays between explosive charges used in blasting as described in U.S. Patent 2,736,263.

Basically, delay connectors comprise a tubular shell containing two detonating charges with at least one delay element therebetween, the ends of the connector each being unfilled and thus adapted to receive the end of a length of explosive cord, e.g., detonating fuse, in abutting relationship to the detonating charge. A separate delay element can be positioned adjacent each of the detonating charges or, alternately, delay can be effected by a continuous column of delay composition running between the detonating charges.

Delay is governed primarily by the delay element or portion thereof adjacent to the detonating charge on the output side of the connector, that is, the end of the connector from which the detonation leaves. In general, the delay effect of the element or portion thereof adjacent the input end of the connector is overridden or masked by the detonating charge adjacent the input end. To combat this effect, either a delay element is used adjacent each detonating charge and a separator, e.g., lead tube, interposed therebetween, and/or a relatively long column of delay composition is used to separate the detonating charges.

Although, as indicated above, bidirectional delay connectors have found wide use, they still leave room for improvement, particularly with regard to reproducibility (uniformity of delay time) and reduction in the change in delay time with storage and temperature. With some known delay connectors, for example, delay time may vary from two to tenfold at 80° F. as compared with −40° F. This invention provides bidirectional delay connectors having improved reproducibility and reduced change in delay with time and temperature.

Thus, this invention provides an improvement in multidirectional delay connectors comprising a shell containing two detonating charges with a delay element adjacent each thereof, the ends of the shell protruding beyond the detonating charges and thus adapting the connector for receiving explosive cord adjacent the detonating charges. The improvement of this invention comprises interposing between the delay elements adjacent the detonating charges, a relay element comprising a column of explosive having a loading of about from 0.5 to 5 and, preferably, 1 to 4 grains per foot and a propagation velocity, i.e., detonation or deflagration velocity, or greater than 300 meters per second. Bidirectional connectors containing a relay element comprising a detonating explosive in a metal, preferably lead, sheath are preferred.

In order to illustrate the invention, reference now is made to FIGURES 1 and 2 which are cross-sectional views of delay connectors of this invention.

In FIGURE 1, which shows a longitudinal cross-section of one preferred embodiment of the delay connector, 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 crimps 4 and 4′. Within the shell, between the ends of the two lines of detonating fuse is a heavy-walled lead tube 5 containing, as the relay element of the connector, thin axial core 6 of relay composition at a distribution of from about 0.5 to 5, and preferably 1 to 4 grains per foot. At each end of the tube 5 are charges 7 and 7′ of a like exothermic mixture of pulverent oxidizing and reducing agents held in position against the ends of lead tube 5 by blind capsules 8 and 8′. Adjoining the outside of these capsules are heat-sensitive charges 9 and 9′, also alike, and adjacent thereto are detonating charges 10 and 10′. The detonating charges 10 and 10′ are enclosed in metal capsules 11 and 11′ which also extend over the heat-sensitive charges 9, 9′ and capsules 8, 8′, which enclose exothermic charges 7, 7′. The capsules 11, 11′, and 8, 8′ are crimped about the ends of the lead tube as shown by indentations 4. As may be seen, the lead tube 5 containing relay composition in its axial bore and the series of enclosed charges at each end fill the space in the shell 3 between the ends of detonating fuse 1, 1′, the end of the fuse abutting capsules 11, 11′ and the core of the fuse in detonation-propagating relationship to detonating charges 10 and 10′.

In FIGURE 2 the elements are as in FIGURE 1 except that capsules 8, 8′, heat-sensitive charges 9, 9′, and exothermic mixtures 7, 7′ are replaced by layers of delay powder 12, 12′.

In the functioning of the connector of FIGURE 1, when the core 2 of detonating fuse 1 detonates at capsule 11, detonating charge 10 and heat-sensitive charge 9 are actuated. The resulting impact passes through capsule 8 to initiate burning in the exothermic mixture 7. The burning of this charge then actuates relay element 6 in heavy-walled tube 5. Actuation of this column causes exothermic mixtures 7′ to be ignited. The burning of exothermic mixture 7′ evolves sufficient heat to ignite heat-sensitive charge 9′ through capsule 8′ after a delay interval, without burning through the capsule 8′. The heat-sensitive charge 9′ actuates detonating charge 10′ whose detonation then initiates detonation in the core of fuse 1′. Since the delay connector contains the same sequence of charges at each end, the connector can be activated equally well by fuse 1′

to initiate detonating charge **10'**. The delay time provided by the connector depends to a large degree upon heat transfer through metal capsules **8** and **8'** and can be controlled by the thickness of the capsule.

The functioning of the connector of FIGURE 2 is similar to that of the FIGURE 1 connector. In this embodiment of the invention, detonation of the core of fuse **1** actuates detonating charge **10** through capsule **11**. Detonation of this charge initiates delay charge **12** and, together with charge **12**, actuates delay element **6**. Actuation of the relay element **6** ignites delay charge **12'** whose burning initiates detonating charge **10'**. In this connector the delay is provided by the slow, regulated burning of delay charge **12'** and can be varied by regulating the type of delay powder charges, the depth of these charges, the pressure at which they are compacted and their confinement. At least a portion of the delay charge can be confined by a heavy-walled tubular delay carrier, e.g., of lead.

Although the connectors of this invention are particularly well adapted for use with relatively brisant detonating fuse such as "Primacord" (available from Ensign-Bickford) or similar fuse available from Austin Co., it is to be understood that these connectors can be used with any type of explosive cord including other detonating fuse, for example, Cordeau, which is a lead wrapped column of TNT, mild detonating fuse or low energy connecting cord, "Primaline," and extruded cords of the explosive compositions, for example, of the types described in U.S. 2,992,087 and 2,999,743, which comprise a high explosive composition in an elastomeric binder, as well as delay ignition fuse such as that described in U.S. Patent 3,207,-073. The explosive cords preferably are protected by a sheathing of lead, nylon, or braided textile. The cords generally 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 an aid in retaining the ends of the detonating fuse in the ends of the tubular shell.

The explosive used in the relay element can be any explosive which will propagate an initiation stimulus at a loading within the range of 0.25 to 5 grains/foot at a detonation or burning rate of at least about 300 meters per second. Accordingly, its actuation does not materially contribute to the delay timing of the connector. The presence of this column does assure transfer of a deflagration or detonation stimulus from one end of the connector to the other end. Examples of relay compositions are lead azide, mixtures of lead azide with metal powders, tetracene, mercury fulminate, nitromannite, or lead styphnate, compositions usually known as initial or primary detonating agents, the double salt of lead nitrate and the lead salt of dinitro-o-cresol, and mixtures of the foregoing. Alternatively, as indicated hereinafter, any of the compositions disclosed in U.S. Patents 2,982,210 and 3,207,073 which are incorporated herein by reference, can be used. If the relay composition is a secondary explosive, e.g., PETN, RDX, HMX, or tetryl, it is usually necessary to provide a layer of a primary explosive such as lead azide at each end thereof. Usually the column of explosive has a diameter of about from 0.003 to 0.025 inch, and preferably has a detonation velocity of about from 2000 to 5000 meters per second. In the case where explosive/nonexplosive mixtures, e.g., explosive/metal powders (aluminum), are used the loading of explosive therein should be at least about 0.25 grain per foot. The relay element need only be long enough to insure that the input detonating charge does effect the delay element at the output. Usually the length of the relay element is at least about ½ inch and preferably about 1.0 inch to 1½ inch.

The column of explosive comprising the relay element can be confined by a variety of materials including plastics such as nylon, polytetrafluoroethylene, and polyoxymethylenes; impregnated fabrics such as fiber glass, as well as metals such as lead, brass, bronze, aluminum, copper, and zinc; or a combination thereof, e.g., as in countered low-energy detonating cord. "Confined," as used herein refers to the fact that sheath around the column of explosive is not destroyed or ruptured by detonation thereof although minor venting may be permissible. The thickness of the sheath, in general increases with the explosive load and the pressure developed by explosive and decreases as the tensile strength of the sheath increases. Sheaths having a longitudinal tensile strength of at least 25 p.s.i. and a thickness of at least 0.025 inch are preferred. Usually, the relay element will be in snug peripheral engagement with the inner walls of the tubular shell **3**. Short countered or uncountered sections of explosive cords disclosed in U.S. Patent 2,982,210 as well as sections of those disclosed in U.S. Patent 3,207,073, having a velocity of at least about 300 meters per second are particularly convenient for use as relay elements in the connectors of this invention.

The remaining elements of the connectors of this invention can be of the conventional type. Thus, the shell **2** and any capsules in the connector can be of aluminum, commercial bronze, brass or any other easily fabricated metal. The detonating charges (base charges **10** and **10'**) can be of the conventional type and can comprise organic nitrates, nitramines and nitro-compounds and inorganic azides including RDX, HMX, PETN, TNT, tetranitrodibenzotetrazapentylenes, lead azide and mixtures thereof as well as other explosive of the type used in the relay element. The explosive of the detonating charges will preferably be a composition such as, for example, lead azide, mercury fulminate, diazodinitrophenol and other similar sensitive explosive compounds which are capable of being readily initiated by a detonating impulse from the detonating fuse or cord. When a secondary explosive composition such as the above mentioned PETN, RDX, HMX, tetryl, TNT, or tetranitrodibenzotetrazapentylenes are employed it is usually preferred to provide a layer of a primary detonating explosive, particularly lead azide, between the detonating charges **10** and **10'** and the capsules **11** and **11'** as a part of the detonating charge. The detonating charges usually amount to about from 2 to 10 grains. The exothermic mixture of "starter mix" shown as **7** and **7'** in FIGURE 1 is a burning charge which is sensitive to initiation by shock and heat and preferably comprises a pulverant mixture of solid oxidizing and reducing agents which burns with the evolution of little gas but of large amounts of heat. Examples of such mixtures include, for example, (1) mixtures of magnesium/barium peroxide/selenium, which preferably are substantially anhydrous, (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 of barium peroxide and 35 parts selenium is particularly suitable.

Heat-sensitive charges **9** and **9'** comprise compounds or physical mixtures which are readily initiated by high temperature, for example, mixtures of aluminum, nitromannite and tetracene; mixtures of lead azide and tetracene; mixtures of bismuth, selenium and potassium chlorate; mercury fulminate, diazodinitrophenol; or other compounds and mixtures of low ignition temperature.

When a delay charge is used as shown by **12** and **12'** in FIGURE 2, it is preferably a rapid-burning delay composition, such as a mixture of solid oxidizing and reducing agents which burns at a uniform rate with the evolution of little or no gas. Mixtures of silicon with red lead or mixtures of boron, silicon, and red lead are particularly preferred. However, other compositions which can be used include mixtures of magnesium, barium peroxide and selenium; mixtures of cupric oxide and aluminum; mixtures of aluminum and red lead; mixture of the sodium salt of TNT, barium peroxide, and dibasic lead phosphite; and mixture of boron and/or silicon with red lead.

Capsules **8** and **8'** when used as in FIGURE 1 serve as a barrier which when heated through by burning of the exothermic mixture initiates the heat sensitive mix. The bottom thickness of this capsule controls, to a large degree, the delay timing of the connector. The capsule may be made of any desired metal which is a good heat conductor. The bottom thickness of this capsule usually is from about 0.020 to about 0.050 inch. To preclude rupture of the capsule between the side and bottom walls, the thickness of the side walls of the capsule should not be unduly thin in comparison to this bottom thickness; generally the side walls will be 0.015 to 0.050 inch thick.

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

Example 1

Two-hundred connectors are prepared by plant assembly techniques resembling that of FIGURE 1. in each connector, the tubular shell **3** is of commercial bronze, 3.75 inches long, 0.235-inch inner diameter. In the midsection of each connector is a unit comprising a drawn lead tube **5**, 1.125 inch long and 0.190 inch outer diameter, containing in its 0.015-inch axial bore a relay element consisting of a column **6** of lead azide at a distribution of 2.6 grains per foot and a detonation velocity of about 3000 meters per second. On each side of the lead tube are exothermic charges **7** and **7'** of 1.5 grains of a 30/35/35 mixture of magnesium, barium peroxide, and selenium. Commercial bronze capsules **8** and **8'** are 0.562 inch long and have a bottom thickness of 0.034 inch. Heat-sensitive charges **9** and **9'** adjacent the commercial bronze capsules **8** and **8'** are 1.0 grain each of an 85/15 lead azide/tetracene mixture. Detonating charges **10** and **10'** are 4.8 grains of lead azide. Capsules **11** and **11'** are also of commercial bronze and are 1 inch long.

For comparative purposes an equal number of connectors are made identical to those above except that in the midsection of these connectors is an empty heavy-walled lead tube 0.190 inch in outer diameter, 0.067 inch in inner diameter and 1.15 inches long, the bore of these tubes being free of obstructions or imperfections.

To test performance of the connectors of both types when used at varying temperatures 140 of each type were tested under the conditions shown below.

(I) Connectors containing the empty lead tube:

	Test Environment			
	Warm Water, 80° F.	Ice Water, 32° F.	Air, Approx. 10–25° F.	Dry Ice, −40° F.
Number Tested	15	15	15	15
Delay, Milliseconds:				
High	11.0	18.9	18.9	37.4
Low	3.7	9.6	11.6	23.1
Avg	8.4	12.6	14.2	30.8

(II) Connectors containing the lead azide relay unit:

	Test Environment			
	Warm Water, 80° F.	Ice Water, 32° F.	Air, Approx. 10–25° F.	Dry Ice, −40° F.
Number Tested	15	15	15	15
Delay, milliseconds:				
High	9.2	14.7	12.8	23.1
Low	5.9	7.8	9.1	14.6
Avg	7.6	9.5	10.6	18.1

To test the effect of storage, connectors of each type are subjected to storage (1) under normal, ambient storage conditions, (2) at 100° F. at 80% relative humidity and (3) at 160° F. The results of this storage are shown below, the Type I connectors being those containing the relay unit and the Type II those containing the empty lead tube.

TABLE I

Time In Storage	Timing, milliseconds of Connectors Stored Under Normal Conditions				Timing, milliseconds of Connectors Stored at 100° F., 80% Humidity		Timing, milliseconds of Connectors Stored at 160° F.	
	When Tested in Air		When Tested in Water at 0° C.					
	Type I	Type II	Type I	Type II	Type I	Type II	Type I	Type II
0 months:								
High	12.8	18.9	9.2	11.0				
Low	9.1	11.6	5.9	3.7				
Avg	10.6	14.2	7.6	8.4				
1 month:								
High	10.5	16.6	7.9	15.8	10.9	18.0	12.6	13.8
Low	8.3	13.0	6.3	7.9	8.5	12.9	10.1	9.9
Avg	9.4	14.8	7.5	11.5	9.9	16.3	9.0	9.4
2 months:								
High	10.8	17.0	7.5	10.5	10.5	35.4	11.5	17.7
Low	7.3	9.5	6.2	7.9	8.2	17.3	9.7	10.0
Avg	9.2	15.7	7.1	9.0	9.8	22.7	10.5	11.7
3 months:								
High	10.5	13.0	7.8	9.6	10.5	49.6	9.3	13.7
Low	7.9	8.9	7.0	8.3	7.8	13.2	8.4	9.3
Avg	9.1	10.3	7.4	9.1	8.8	31.0	8.7	10.9
6 months:								
High	9.0	11.6	8.6	11.7	10.8	50.1	11.2	13.9
Low	7.3	9.2	6.6	7.0	8.6	27.6	7.7	2.0
Avg	8.2	10.1	7.5	9.3	9.9	39.7	9.0	10.1
12 months:								
High	11.4	17.2	9.1	10.6	13.8	100.7	13.2	29.7
Low	9.0	14.0	7.4	9.2	9.8	53.7	10.0	18.7
Avg	10.4	16.2	8.4	9.9	10.9	76.0	11.3	22.5

As can be seen from the table, there is a considerable spread of values for the timing of connectors containing the empty lead tubes (Type II) but the values for the connectors containing relay unit of this invention are relatively more uniform and unaffected by storage conditions.

Similar results are obtained when the column **6** of relay composition is an equal loading of (1) tetracene, (2) diazodinitrophenol, (3) a mixture of lead azide with metal powders such as aluminum, (4) lead styphnate.

Example 2

Two hundred delay connectors are prepared resembling that shown in FIGURE 2. In each connector charges **10** and **10′** are 4.8 grains of lead azide and delay charges **12** and **12′** are 1.3 grains of a 1.5/28.5/70 mixture of boron, silicon and red lead. Heavy-walled lead tube **5** is 0.210 inch in outer diameter and 1.25 inches long and contains a central column **6** of lead azide having a core loading grains/foot, a diameter of about 0.010 inch and a detonation velocity of about 3000 meters per second. When connectors of this type are tested in a storage program, as described in Example 1 the results are as shown in Table II below.

TABLE II

Original Timing Results	Test Environment			
	Air	80° F.	Ice Water	Dry Ice
No. Tested	10	10	10	10
Delay, milliseconds: High	29.4	26.8	27.7	28.4
Low	21.6	18.0	17.6	16.0
Avg.	26.0	24.0	23.2	22.7

STORAGE DATA

Time in Storage	Storage Environment			
	Normal	120° F.	160° F.	100° F.[1]
1 Month—Delay, millisec.: High	32.9	28.4	38.7	28.6
Low	9.6	23.7	31.2	23.1
Avg.	23.7	26.7	33.3	25.4
2 Month—Delay, millisec.: High	27.4	30.2	30.2	30.1
Low	24.0	25.7	25.7	23.6
Avg.	25.1	28.5	28.7	27.1

[1] At 85% humidity.

Similar results are obtained when an equal weight of (1) the double salt of lead nitrate and the lead salt of dinitro-o-cresol, (2) nitromannite, or (3) mercury fulminate is substituted for the lead azide column **6** used above.

We claim:

1. In bidirectional delay connectors comprising a shell containing two detonating charges each having a delay element adjacent thereto, each end of the shell adjacent the detonating charges being adapted to receive the end of an explosive cord, the improvement which comprises interposing between the delay elements associated with said each detonating charges, a relay element comprising a column of explosive having a loading of about from 0.5 to 5 grains per foot and a propagation velocity of at least about 300 meters per second.

2. A bidirectional connector of claim **1** wherein said relay element has a loading of about 1 to 4 grains per foot.

3. A bidirectional delay connector of claim **2** wherein said relay element comprises a column of explosive confined in a metallic tube.

4. A connector of claim **3** wherein said explosive comprises at least one explosive selected from the group consisting of lead azide, tetracene, lead styphnate, diazodinitrophenol, mercury fulminate, and the double salt of lead nitrate and lead dinitro-o-cresylate.

5. A connector of claim **3** wherein said explosive is a detonating explosive.

6. A connector of claim **5** wherein said explosive has a detonation velocity of about from 2000 to 5000 meters per second.

7. A connector of claim **3** wherein said relay element is a piece of uncountered lead azide low-energy detonating cord.

8. A connector of claim **3** wherein said relay element consists essentially of lead azide confined in a lead tube, and between each said detonating charge and the adjacent end of said relay element is a delay element comprising an exothermic charge adjacent said relay element, a heat-sensitive charge adjacent said detonating charge and a metal partition therebetween.

9. A connector of claim **3** wherein said relay element consists essentially of lead azide confined in a lead tube and said delay elements consist essentially of delay composition filling the space between said relay element and each said detonating charge.

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