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H. A. LEWIS ET AL
BLASTING EXPLOSIVE DEVICE

2,736,263

Filed April 17, 1951

FIG. 1.

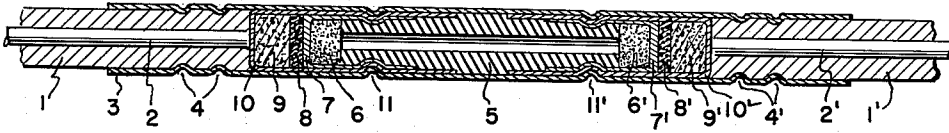


FIG. 2.

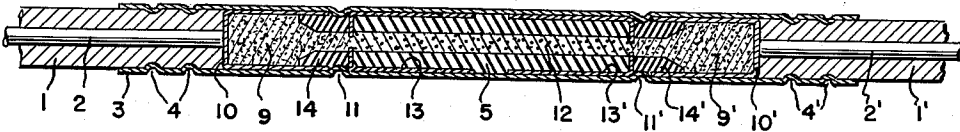


FIG. 3.

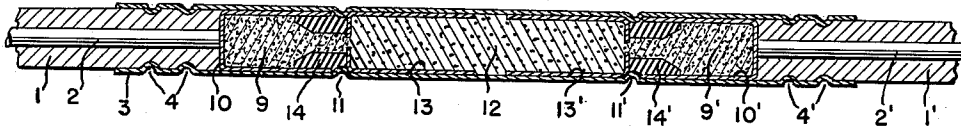


FIG. 4.

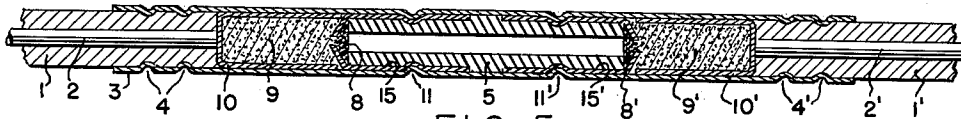


FIG. 5.

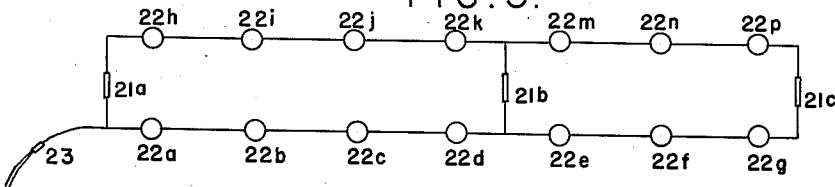
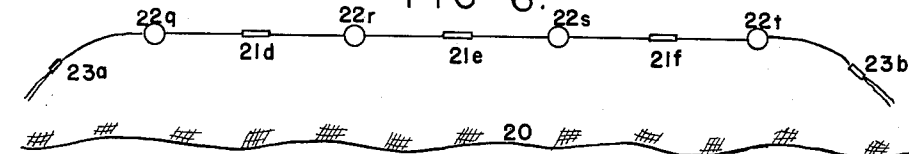


FIG. 6.



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2,736,263

BLASTING EXPLOSIVE DEVICE

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4 Claims. (Cl. 102—27)

This invention relates to a novel method of blasting where a number of explosive charges are to be fired and more particularly to the use of a new type of detonating device in the firing of explosives.

A common practice in the production of limestone and other raw materials is to drill deep vertical holes in accordance with a predetermined pattern or arrangement, and to load these with the desired amount of explosives. Such vertical holes usually range from about 25 feet to 250 feet or more in depth and from about 15 feet to about 40 feet or more apart. In such blasts, it is customary to shoot various numbers of drill holes from a few up to several hundred on occasion. The general practice is to arrange these holes according to a predetermined uniform pattern which may consist of a single row or several rows essentially parallel to each other.

Blast holes such as the above range from about 3 inches in diameter to as much as 12 inches and are loaded with the desired amount of explosives in cartridge diameters suited to the respective diameters of the holes. A safe and convenient method of detonating such charges of explosive is by use of detonating fuse, which consists of a core of high-velocity explosive enclosed in an outer casing of fabric or metal. Such fuse under the influence of a blasting cap detonates at a velocity of more than 20,000 feet per second. With a bore-hole loaded with explosive, the introduction of a length of detonating fuse to the bottom of the hole alongside the cartridges insures the practically instantaneous detonation of all the explosive.

A common method of firing a blast of this type is by connecting all the holes with detonating fuse. Such a practice is followed when firing a single row of holes or several rows of holes. In the latter case the trunk lines of the several rows are joined together by connecting lines of detonating fuse. With the large number of blast holes usually involved and the large quantity of explosives the simultaneous explosion of all the charges may cause an undesirable degree of earth vibration. When such explosions are fired successively at relatively short intervals of time such excessive vibration is materially reduced. It is usually advantageous from the standpoint of blasting execution to have the front row of holes shoot first, followed at the proper time interval by the second row, and so forth.

A means has been proposed (U. S. 2,475,875) for accomplishing successive rather than simultaneous explosion of a number of charges when the charges are joined

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together by connecting lines of detonating fuse. This means comprises the insertion of explosion-retarding devices in the connecting lines of detonating fuse, said explosion-retarding devices being such as to propagate explosion after a time interval between two lengths of detonating fuse, the detonation proceeding from the first to the second length of fuse unidirectionally. This means for obtaining delayed time intervals between successive blasts has the disadvantage that failure of the detonation to propagate through the explosion-retarding devices or failure of propagation for any other reason at any location in the connected lines of detonating fuse will result in failure of one or more shots in the connected series.

It should be emphasized that in the art of firing charges with detonating fuse it has been the standard practice for many years to so arrange the detonating fuse layout that the detonation will reach each charge from at least two directions. Due to the fact that the device described above propagates in one direction only, it does not insure this highly desirable feature.

There is also the disadvantage that personnel having the duty of connecting the lines of detonating fuse and the unidirectional delay connectors therebetween might inadvertently introduce one of the connectors in the opposite direction from that in which detonation would propagate to the connected line of detonating fuse. An occurrence of this kind would also cause failure of the shots in the circuit. Such failures result in a serious hazard since undetonated explosive material remains, in lack of success of the blast, and in costly and time-consuming interruption of blasting operations.

Although the workers in the prior art have appreciated the desirability of firing successive charges at predetermined minute time intervals, for example, of the order of magnitude of 10 to 25 milliseconds, it is important to note that up to the present time no simple effective practical means has been devised for achieving this result with detonating fuse.

An object of the present invention is an improved method of blasting by means of detonating fuse wherein successive charges may be fired effectively at some minute time interval of predetermined magnitude. A further object is an explosion-retarding device adapted to be inserted in the lines connecting the various holes for successive firing. Another object is an explosive assembly comprising such an arrangement of lines of detonating fuse and explosion-retarding, or delay, devices adapted to accomplish the aforesaid successive firing of charges. A further object is an explosion-retarding device which may be activated from either end whereby the foregoing objectives are achieved. A further object is such an assembly wherein the lines of detonating fuse and delay devices are arranged in a closed layout adapted to be activated at any point in the layout. Additional objects will be disclosed as the invention is described with greater exactness and detail in the following.

Our invention is a delay device for connecting two lengths of detonating fuse comprising at least one delay element interposed between two detonating elements. All of the foregoing objectives are satisfactorily achieved by means of this type of device.

A greatly preferred embodiment of this invention com-

prises a cylindrical shell of rigid material containing a delay element disposed in the central portion thereof, with heat sensitive charges disposed at either end of said delay element, and detonating charges disposed beyond and adjacent to each of said heat sensitive charges, and an open space at each end of said shell adapted to receive detonating fuse.

The accompanying drawing will serve to illustrate specific embodiments of our invention, in order that its utility and functioning will be thoroughly appreciated. It will be understood, however, that these are by way of illustration only and are not to be taken as limiting the invention in any way. Figures 1, 2, 3 and 4 are views of suitable delay devices in accordance with our invention interposed each between two lines of detonating fuse. Figures 5 and 6 are diagrammatic representations of layouts of typical open-face blasts, showing the position of the blast holes with reference to the quarry face, schemes for connecting said holes, and the places of introduction of the delay connectors.

In Figure 1, which shows in longitudinal section one form of the preferred 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 said fuse being held within the open ends of a tubular brass shell 3 by means of crimps 4 and 4'. Within the shell between the two ends of detonating fuse is a thick-walled lead tube 5. At each end of said tube are charges 6 and 6' of a like exothermic mixture of pulverulent oxidizing and reducing agents held in position against said lead tube 5 by means of blind metal capsules 7 and 7', each having a base approximately four times as thick as the side walls of the capsule at the open end thereof. Adjoining the outside of each of these capsules are heat-sensitive charges 8 and 8' of the same kind, and adjacent thereto are detonating charges 9 and 9', also alike. These detonating charges 9 and 9' are enclosed in metal capsules 10 and 10' which extend also over the heat-sensitive charges 8, 8' and the capsules 7, 7' which enclose the exothermic charges 6, 6'. The capsules 10, 10' and 7, 7' are crimped about the ends of the lead tube 5, as indicated by indentations 11, 11'. The empty lead tube and the series of enclosed charges at each end thereof fill the space in shell 3 between the end of detonating fuse 1, 1', and said fuse ends abut against the metal capsules 10 and 10'.

The functioning of the delay connector illustrated in Figure 1 is as follows. When detonating fuse 1, detonates at capsule 10, detonating charge 9 explodes, and the resulting impact indents, but does not perforate, capsule 7. The impact, which passes through heat-sensitive charge 8 to the blind capsule 7, creates pressure within tube 5. This pressure ignites exothermic charges 6 and 6' essentially simultaneously and forces a part of charge 6 through the tube to charge 6'. The burning of both exothermic charges 6 and 6' evolves sufficient heat to ignite heat-sensitive charge 8', after a delay interval, but without burning open capsule 7'. After the heat-sensitive charge 8' ignites, it in turn initiates the detonating charge 9', which then initiates detonating fuse 1'. It is evident, since the delay connector contains the same sequence of charges at each end, that the connector can equally well be activated by fuse 1' to detonate detonating charge 9'. The impact of this detonation, passing through heat-sensitive charge 8' to capsule 7' would create pressure within the lead tube 5, thereby activating exothermic charges 6' and 6 enclosed in capsules 7' and 7, resulting in the initiation, after a delay interval, of heat-sensitive charge 8, which would then cause detonating charge 9 to detonate, thereby initiating detonating fuse 1.

Figure 2 illustrates another form of delay connector in accordance with the invention. In this figure, 1 and 1' are also lengths of detonating fuse each having a core 2 and 2' of detonating explosive and being held within

tubular shell 3 by means of crimps 4 and 4'. In this form of the delay connector, however, the thick-walled lead tube 5 contains a slow-burning delay composition 12 comprising a pulverulent mixture of oxidizing and reducing agents which produce little or no gas on burning. Retaining the delay composition 12 within the lead tube are singly perforated metal capsules 13 and 13'. Adjacent to the bases of capsules 13 and 13' are lead washers 14 and 14'. Within the perforations of the washers 14 and 14' and adjacent to the external ends of the washers 14 and 14' are detonating charges 9 and 9' of the same kind, and at the end of each of the detonating charges 9 and 9' is a metal capsule 10 and 10', in detonation-propagation relationship with which capsules 10 and 10' the two lengths of detonating fuse 1 and 1' are held.

The functioning of the delay connector of Figure 2 follows the pattern of that of Figure 1, except that the delay interval is greater because of the presence of the delay composition throughout the length of tube 5. When detonating fuse 1 detonates at capsule 10, detonating charge 9 explodes, and the resulting detonation, exerted under the confinement of washer 14 through the perforation of capsule 13, initiates the delay composition 12 which burns to the detonating charge 9' and initiates its detonation, which, in turn, initiates detonating fuse 1'. As in the case of the delay connector illustrated in Figure 1, this connector also can be initiated equally well by detonating fuse 1', at the opposite end of the connector, since like means of initiation are provided at each end of the lead tube 5.

Figure 3 illustrates still another construction of delay connector in accordance with the invention. This connector is similar to that of Figure 2, except that the delay composition is confined by heavy-walled, singly-perforated capsules at each end instead of being held in a tube provided with perforated capsules at each end. The delay connector of this figure functions in a manner similar to that of Figure 2, and can likewise be initiated from either end.

A further form of delay connector in accordance with the invention is shown in Figure 4. In this figure, capsules 10 and 10' enclose detonating charges 9 and 9'. Between these charges is an empty lead tube 5, at each end of which is a small charge 8 and 8' of a heat-sensitive composition such as a 30/35/35 mixture of magnesium, barium peroxide, and selenium. The heat-sensitive charges 8 and 8' are held against the tube 5 by means of a capsule 15 having a coned end provided with a small perforation at the apex of the cone.

When the detonating charge 9 of Figure 4 is detonated, the conical portion of the capsules 15 collapses, thus closing the perforation at its apex and confining the heat-sensitive charge 8, which, at the same time, is ignited. The resultant pressure and heat causes the heat-sensitive charge 8' at the opposite end of the tube 5 to become ignited, and this reaction, after a delay interval, initiates detonating charge 9', and, in turn, detonating fuse 1'. Like the delay connectors illustrated in Figures 1-3, the delay connector of Figure 4 is capable of initiation from either end, since the trains of charges are alike at each end.

In Figure 5, 20 represents a face back of which are drilled vertical holes 22a, 22b, 22c, 22d, 22e, 22f, 22g, 22h, 22i, 22j, 22k, 22m, 22n, 22p, approximately 6 inches in diameter and of suitable depth. A row of 7 holes 22a, 22b, 22c, 22d, 22e, 22f, and 22g parallels the face, about 20 feet back from said face and are spaced about 16 feet apart. A second row of 7 holes 22h, 22i, 22j, 22k, 22m, 22n, 22p is still farther back from the face. These holes are loaded with a suitable explosive, for example 60% ammonia gelatin dynamite, using the desired amount per hole. A trunk line of detonating fuse connects the holes of each row in a line, and branch lines of this same fuse

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run to the bottom of each hole, being held in contact with the individual explosive cartridges in such a way that the detonation of the fuse will cause the substantially instantaneous detonation of all the explosive. Connecting lines of detonating fuse lead off from the main trunk line in advance of the first hole 22a and beyond the last hole 22g. These lines connect the second row of holes to the first row of holes. In addition, a connecting line of fuse is placed at an intermediate position connecting the two trunk lines of detonating fuse at points between holes 22d and 22e and between holes 22k and 22m. Interposed in each line leading from the front row of holes to the second row of holes are delay elements 21a, 21b, and 21c of the "two-way" type described which contain delay elements adapted to cause the explosive charges in the second row to fire at a later time than the explosive charges in the first row. Three connecting lines are shown in the drawing as extending from the front row of holes to the second, and will ordinarily be employed as assurance against failures, although only one is actually required.

In the layout as shown in Figure 5 by the use of delay devices between the two rows of holes, time intervals of a few thousandths of a second are effected between the times of detonation of the two rows. The detonating fuse commonly used, "Primacord," explodes at a velocity of about 23,000 feet per second. Consequently, when this fuse is initiated by means of an electric blasting cap 23, on application of electric current, the charges in the holes in the front row detonate almost instantaneously and simultaneously. This causes the blasted rock to move away from the face. After a suitable delay interval, charges in the second row of holes, 22h, 22i, 22j, 22k, 22m, 22n, 22p, detonate. Since the rock blasted by the second row of holes moves at a brief interval after the movement occasioned by the blast of the front row, the vibrational effects of the multiple blast are reduced appreciably, and the fragmentation of the rock by the blast is improved.

As can be seen from Figure 5, failure of a line of detonating fuse to transmit detonation from one explosive charge to another is not likely to result in failure of any of the charges in the blast, because, since the delay devices 21 can be activated from either end, the detonation can be transmitted in either direction in either loop of detonating fuse. For example, if the front trunk line should fail to transmit the detonation after charge 22b had been initiated, the detonation impulse would travel via connector 21a in the normal direction to holes 22h, 22i, 22j, 22k, 22m, 22n, and 22p and from this second row in the reverse direction through connectors 21b and 21c, thereby detonating holes 22d and 22c and holes 22e, 22f, and 22g. Likewise, if detonation should fail to be transmitted from hole 22f to 22g, for example, detonation would follow a path through connectors 21a and 21b in the normal direction to holes 22h, 22i, 22j, 22k, 22m, 22n, and 22p, and from these through connector 21c in the reverse direction to hole 22g, thus covering the complete loop. Although, in a blasting arrangement such as is illustrated in Figure 5, it is advantageous to have all the holes in the front row detonate before the holes in the second row, the delay afforded by the connectors traversed by the detonating impulse in the reverse direction in the event of failure of a hole in the front row nevertheless prevents the charges in the second and first rows from detonating simultaneously. Later detonation of a portion of the front row is greatly to be preferred to failure of detonation altogether. If, in the blasting arrangement illustrated in Figure 5, unidirectional delay connectors had been used to join the trunk lines of fuse in a direction from the first row to the second, failure of detonation to be transmitted from any one of the charges in the first row would result in failure of the blasting charges in the remaining holes of that row since there would be no means whereby the detonation impulse could return to the front row. Thus,

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the probability of the firing of all charges in any one layout is greatly increased by the use of two-directional delay connectors, and the hazard resulting from the leaving of undetonated charges in a borehole is correspondingly reduced.

Figure 6 shows another method of connecting holes containing explosive charges where delay intervals are desired between each, thus lessening earth vibration even more. In this figure, 20 represents a face in which vertical drill holes 22q, 22r, 22s, 22t are arranged in a single row. Interposed between each of the holes 22 are delay connectors 21d, 21e, 21f. In this figure, each end of this line of fuse is initiated by an electric blasting cap as shown at 23a and 23b. Consequently, if detonation should fail between any two holes, detonation would be transmitted from the opposite end of the line of detonating fuse to the remaining holes. If unidirectional connectors were to be used in a series of blasting charges connected in this manner, advantage could not be taken of the added safety factor of initiation of the second end. The blasting arrangement of Figure 6 likewise shows clearly the hazard, inherent in unidirectional connectors, of the possibility of their being connected in the wrong direction. If a unidirectional delay connector were inadvertently connected with its detonating charge toward the initiating line of fuse instead of in the opposite, correct, direction, and this mischance of connection could readily occur, even though a distinguishing mark were made on the exterior of the connector, detonation would fail to be transmitted through the connector and all succeeding holes following the end hole would fail.

In carrying out the present invention, any type of detonating fuse is applicable. The specific example has shown the use of "Primacord," which is a detonating fuse having an explosive core of pentaerythritol tetranitrate contained within a waterproof sheath overlaid by reinforcing coverings. It has a velocity of detonation of about 23,000 feet per second. Cordeau, a lead-wrapped fuse having a core of trinitrotoluene and a velocity of detonation of about 17,500 feet per second, is also applicable. Detonating fuse having a core of cyclotrimethylenetrinitramine may also be used. Detonating fuse is usually of a diameter of about 0.22 inch.

The tubular shell of the connector may be of any desired metal, such as brass, for example. The shell is of a diameter which will permit it to be crimped tightly to the detonating fuse.

Considerable variation may exist in the various charges and compositions used in the delay connectors and in the structure and materials of construction of the delay elements. Small variations in both type and amount of the charges and compositions and in the construction and materials of construction of the delay elements result in appreciable changes in the delay times of the delay connectors according to the invention.

The explosive of the detonating charge may comprise any detonating composition capable of being detonated by a detonating impulse as from detonating fuse; for example, lead azide, mercury fulminate, diazodinitrophenol, and other sensitive explosive compounds or compositions.

The exothermic charge, or "hot mix," as shown at 6 and 6' in Figure 1, is a burning charge which is sensitive to initiation by shock and heat, such as by the pressure engendered by the detonation of the detonating composition, and preferably comprises a pulverulent mixture of solid oxidizing and reducing agents which burns with the evolution of little gas, but of large amounts of heat. Suitable mixtures, for example, are (1) mixtures of magnesium, barium peroxide, and selenium or (2) mixtures of bismuth, selenium, and potassium chlorate. We have found that a mixture containing 30 parts by weight of magnesium, 35 parts of barium peroxide, and 35 parts of selenium is particularly suitable. Likewise, a mixture of

40 parts by weight of bismuth, 40 parts of selenium, and 20 parts of potassium chlorate may be used.

Where a delay composition is used within the delay element, as shown at 12 in each of Figures 2 and 3, it is preferably a slow-burning composition such as a pulverulent mixture of solid oxidizing and reducing agents which burns with the evolution of little or no gas. Mixtures of boron with red lead and selenium with barium peroxide are examples of suitable delay compositions. For example, a mixture of 2 parts by weight of boron and 98 parts of red lead affords a satisfactory delay composition, as does a mixture of 80 parts by weight of barium peroxide and 20 parts of selenium.

The heat-sensitive charge, as shown at 8 and 8' in Figures 1 and 4, comprises a compound or mixture which is readily initiated by high temperatures. Suitable charges comprise, for example, mixtures of bismuth, selenium, and potassium chlorate, e. g., a 40/40/20 mixture of these ingredients in the order named, mixtures of aluminum, tetrazene, and mannitol hexanitrate, e. g., a 50/25/25 aluminum/tetrazene/mannitol hexanitrate mixture, mercury fulminate, diazodinitrophenol, or other compound or mixture of low ignition temperature. Heat-sensitive mixtures of high burning rate give short period delays, and, conversely, those of lower burning rate give delays of longer intervals.

If desired, the materials comprising the heat-sensitive charge may be mixed with the detonating charge, instead of being used as a separate charge.

As has been stated, considerable variation may also occur in the construction and in the materials used for the construction of the delay elements within the delay connectors of our invention. The tubular element, for example, illustrated at 5 in Figures 1, 2, and 4, and the washers illustrated at 14 and 14' in Figures 2 and 3 may be made of lead, as has been shown on those figures, since lead is a convenient material. They may also be made of any rigid, relatively non-combustible material such as another metal, brass, or aluminum, for example, or of some other rigid material, such as a rigid synthetic plastic, for example nylon. Although the washers shown in the figures have the portion of the perforation toward the detonating charge of larger diameter than the rest of the perforation, this is for convenience in loading only, and is not essential to the functioning of the delay connector. The length and the bore of the tubular element may be varied in order to attain the delay time desired. Tubes varying in length from 1/2 inch to 1 1/2 inches have been used and bore diameters varying between 0.046 and 0.135 inch. The capsules may be made of any desired metal, gilding metal being particularly suited to their fabrication. The size of the opening in the perforated capsules may be varied as desired, and the thickness of the capsule and the base thereof may be varied. The relationship of thickness of the base of the capsule to that of its cylindrical wall is of particular importance in the blind capsule shown at 7 and 7' in Figure 1. The base of the blind capsule illustrated in that figure is approximately four times as thick as the cylindrical wall of the capsule, and this is a satisfactory relationship. For example, a base thickness of 0.027 in. and a minimum wall thickness of 0.007 in. may be used. Somewhat thinner and somewhat thicker bases may also be used, but the base should be strong enough to resist perforation by the explosion of the detonating charge, and should not be so strong that a pressure impulse is not transmitted through the bore of the rigid tube within the delay element.

In the construction of the delay connectors of our invention, the parts forming the delay element are preferably crimped in place sharply as an aid to the proper functioning of the delay element.

If desired, delay compositions may be used in the tubular members shown at 5 in Figures 1 and 4. In the event of the use of delay compositions in these tubular members, greater delay, or explosion-retarding, intervals of

the delay element are obtained. When a delay composition is used in the tubular member of Figure 1, the delay composition is ignited by exothermic charge 6 or 6', as the case may be, and the exothermic charge at the opposite end is, in turn, ignited by the delay composition after its burning throughout the length of the tubular member has been effected.

Various examples of the delay times which may be attained with the "two-way" delay connector of the present invention, whether ignited from one end or the other, are given below:

Example 1

A delay connector made in accordance with Figure 1 containing detonating charges of 4 grains of lead azide each, heat-sensitive charges of 1.0 grain of 50/25/25 Al/tetrazene/mannitol hexanitrate each, exothermic charges of 1.5 grains of a 30/35/35 Mg/BaO₂/Se mixture each in blind capsules of gilding metal of 0.027 in. bottom thickness, and a lead tube 0.073 in. in internal diameter and 1 in. long gave a delay time of 17 milliseconds.

Example 2

A delay connector made in accordance with Figure 1 containing detonating charges of 4 grains of lead azide each, heat-sensitive charges of 1.0 grain of tetrazene each, exothermic charges of 0.5 grain of a 30/35/35 Mg/BaO₂/Se mixture each in blind capsules of gilding metal of 0.027 in. bottom thickness, and a lead tube 0.081 in. in internal diameter and 1 in. long gave a delay time of 3 milliseconds.

Example 3

A delay connector made in accordance with Figure 2 containing detonating charges of 2.5 grains of lead azide each, lead washers, a lead tube 1 1/4 inches long and 0.081 in. in internal diameter containing a 2/98 B/Pb₃O₄ mixture gave a delay time of 35 milliseconds.

Example 4

A delay connector made in accordance with Figure 3 containing detonating charges of 5 grains of pressed lead azide each, lead washers, heavy gilding-metal capsules each having holes 1/32 in. in diameter and together enclosing a delay composition comprising 15 grains of a 2/98 B/Pb₃O₄ mixture gave a delay time of 353 milliseconds.

Example 5

A delay connector made in accordance with Figure 4 containing detonating charges of 4 grains of lead azide each, heat-sensitive charges each consisting of 3.0 grains of a 30/35/35 Mg/BaO₂/Se mixture and a lead tube gave a delay time of 3 milliseconds.

Example 6

A delay connector made in accordance with Figure 1 containing detonating charges of 4 grains of lead azide each, heat-sensitive charges of 1 grain of a 50/25/25 Al/tetrazene/mannitol hexanitrate mixture each, exothermic charges of 1.75 grains of a 30/35/35 Mg/BaO₂/Se mixture each in blind capsules of gilding metal of 0.032 in. bottom thickness, and an aluminum tube 0.101 in. in internal diameter and 1 in. long gave a delay time of 17 milliseconds.

In addition to the foregoing examples, a tabulation is given below showing the delay times that can be expected in delay connectors made according to Figure 1 and containing detonating charges of 4 grains of lead azide each with the variations shown in the heat-sensitive charge, the metal capsule, the exothermic charge, and the lead tube:

Heat-Sensitive Charge		Thick- ness of bottom of capsule, in.	Exothermic Charge		Tube		Average Delay Time, ms.
Weight in Grains	Composition		Weight in Grains	Composition	I. D., in.	Length, in.	
1.0-----	50/25/25 Al/tetrazene/mannitol hex- anitate.	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.081	1	12
1.0-----	do-----	0.027	1.0	30/35/35 Mg/BaO ₂ /Se-----	0.081	1	6
0.5-----	50/50 Tetrazene/red lead-----	0.025	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.110	1	16
2.0-----	62/35/3 Cu/Se/KClO ₃ -----	0.025	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.110	1	72
1.0-----	80/20 BaO ₂ /Se-----	0.025	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.110	1	132
1.0-----	40/40/20 Bi/Se/KClO ₃ -----	0.027	1.5	20/60/20 Mg/BaO ₂ /Se-----	0.073	1.5	17
1.0-----	Lead Styphnate-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	23
1.0-----	Lead Salt of Dinitro-o-cresol-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	39
1.0-----	50/40/10 Pb(SCN) ₂ /KClO ₃ /S-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	23
5.0-----	95/5 Lead Azide/Nitrostarch-----	0.025	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.046	1.5	21
5.0-----	do-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	29
5.0-----	do-----	0.027	1.5	20/60/20 Mg/BaO ₂ /Se-----	0.073	1.5	18
1.0-----	50/25/25 Al/tetrazene/mannitol hex- anitate.	0.027	1.5	15/60/25 Mg/BaO ₂ /Se-----	0.093	1.5	14
1.0-----	do-----	0.027	1.5	30/70/0 Mg/BaO ₂ /Se-----	0.093	1.5	32
1.0-----	Mercury Fulminate-----	0.032	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.081	1.5	16
1.0-----	Diazodinitrophenol-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	13
1.0-----	Mannitol hexanitate-----	0.027	1.5	30/35/35 Mg/BaO ₂ /Se-----	0.073	1.5	8

By initiating means is meant the train of components between the detonating fuse and the delay element, which train of components, at the end of the delay connector activated by the detonating fuse, initiates the delay element and thereby transmits the detonation impulse of the detonating fuse, traveling at high velocity, to the delay element, where the burning reaction occurs at lower velocity, and which train of components, at the other end, being activated by the delay element, serves to initiate the second length of detonating fuse.

In addition to the delay connectors illustrated and described, many other structures and compositions also lie within the scope of the invention. It is possible to use series of alternating delay and detonating elements within the connector provided that at least one delay element and two detonating elements are contained therein, and that the sequence of charges, whether detonating charges, delay charges, heat-sensitive charges, or exothermic charges, is the same at each end of the connector.

In carrying out the invention, it will be understood that it is not limited in any way by the type of explosive in the holes to be blasted, or elsewhere, except that they must be detonating explosives adapted for explosion by means of detonating fuse. In the case of such open blasting operations, such high explosives are commonly used as ammonia dynamites, straight dynamites, gelatin dynamites, blasting agents containing high percentages of ammonium nitrate and free from liquid explosive, and many others.

Many variations in exact procedures and details of assembly may be employed, therefore, without departure from the scope of the invention. While its use in such operations as quarry blasting and the like has been emphasized, it will be understood that it is applicable to all uses of explosives, whether commercial or military, where more than one explosive charge is to be fired by means of detonating fuse, and in fact to all firing of successive lengths of detonating fuse which are separated by delay elements of the type described. We intend to be limited only by the following claims.

We claim:

1. An explosive assembly wherein two lengths of detonating fuse are connected by a delay connector, said connector comprising a tubular shell of rigid material, each end of which is fastened about one end of each of

the two said lengths of detonating fuse, a delay element within said shell, at each end of said delay element a charge ignitable by high temperature, and adjacent to each of said charges ignitable by high temperature a detonating charge, each of said detonating charges being alike and in detonation-propagation relationship to one of the ends of said lengths of detonating fuse.

2. An explosive assembly wherein two lengths of detonating fuse are connected by a delay connector, said connector comprising a tubular shell of rigid material, each end of which is fastened about one end of each of said two lengths of detonating fuse, a delay element within said shell, said delay element comprising a thick-walled tube of rigid material having at each end a like exothermic mixture of solid oxidizing and reducing agents and at the external end of each of said mixtures a like solid metallic capsule, adjacent to each end of said delay element a like charge ignitable by high temperature, adjacent to the external end of each of said heat-sensitive charges a like detonating charge, and at the external end of each of said detonating charges and adjacent thereto a like metal capsule, each of said detonating charges enclosed in said metal capsules being in detonation-propagation relationship to one of the ends of one of the two lengths of detonating fuse.

3. A delay connector for connecting two lengths of detonating fuse comprising a tubular shell, an open space at each end of said shell adapted to receive detonating fuse, a like charge of a detonating explosive adjacent to each of said open spaces, a delay element centrally disposed within said shell, and a like charge ignitable by high temperature interposed between each of said detonating charges and said delay element.

4. A delay connector as claimed in claim 3, wherein said delay element contains an exothermic mixture of solid oxidizing and reducing agents disposed at least at each end of said delay element.

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