Nov. 12, 1957 J. C. R. CANCE ET AL 2,812,711

APPARATUS FOR FIRING EXPLOSIVE CHARGES

Filed Nov. 17, 1953 2 Sheets-Sheet 1

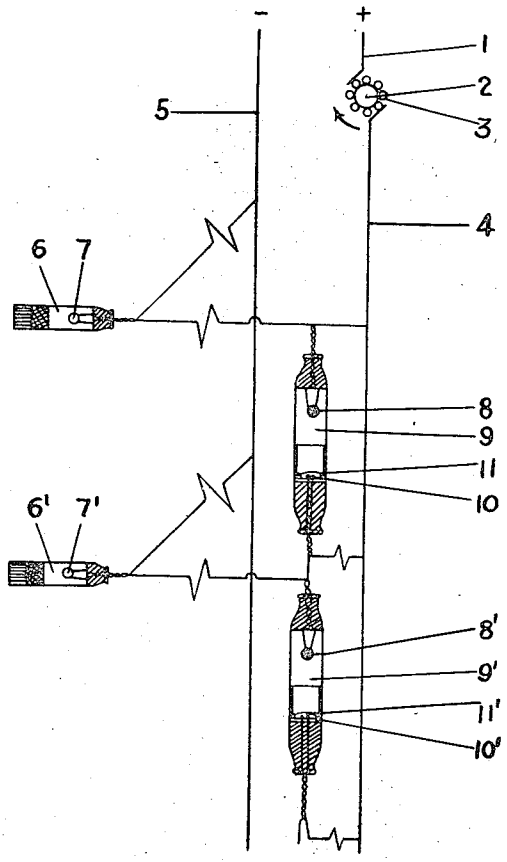


FIG. 1.

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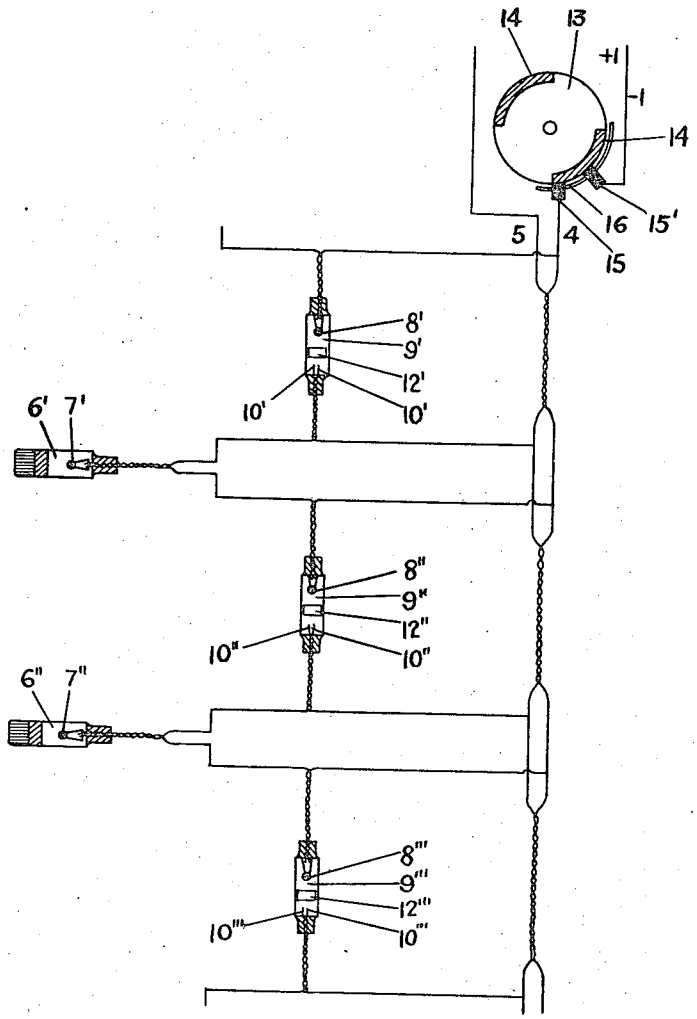


FIG. 2

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2,812,711

APPARATUS FOR FIRING EXPLOSIVE CHARGES

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Application November 17, 1953, Serial No. 392,658
Claims priority, application Great Britain November 28, 1952
2 Claims. (Cl. 102—22)

The present invention relates to an improvement in the art of delay blasting and especially short period delay blasting in quarries and other situations where it is required that a single setting-up of the wiring of a succession of electric detonators will result in the detonation of the explosive charges successively at time intervals which may be as low as only a millisecond apart, when the shot-firer performs a single manual operation.

Short period delay blasting has in certain circumstances advantages that are well recognised over simultaneous blasting, as occurs when instantaneous electric detonators are used in the normal manner. Among these advantages are reduction in the amount of backbreak (i. e. the undesirable cracking of rock which occurs behind and is caused by the firing or blasting of a row of vertical shot holes) and of vibration, and facilitation of fragmentation of the rock to the desired size. Hitherto short period delay blasting has been carried out either by using a graded series of short period delay electric detonators, or by firing each of a sequence of instantaneous electric detonators in a properly wired shot-firing circuit through a sequence switch mechanism.

In practice, however, it is difficult in repetitive manufacturing operations to produce short period delay electric detonators whose individual delay periods are sufficiently close to their respective average delay periods to obviate the possibility that in a round the detonators will not always fire in the desired order, especially when the time interval required between the successive shots in the round is relatively small, as is frequently desirable. When the number of shots in the round is large and the delay period of the slowest detonator is relatively long, either the lengths of some of the delay elements and consequently of the short period delay electric detonators containing them tend to become excessive, or a variety of delay compositions have to be used in the series, which adds to the difficulty and expense of the production of the short period delay electric detonators. On the other hand the use of a sequence switch mechanism has required heretofore that each electric detonator in the round is to be wired to a separate contact of the sequence switch mechanism so that the total length of leading wire required and the inconvenience of handling it increases considerably with the number of shots to be fired. Also the accommodation of the required number of switch contacts in the sequence switch mechanism becomes increasingly inconvenient. In practice the number of successive intervals that has been obtained by using electric detonators with a sequence switch mechanism has not substantially exceeded 16, and using short delay period detonators the number of successive intervals attained has been much the same. It would, however, be desirable to provide a short delay blasting method and equipment that would enable a considerably larger number of delay intervals to be obtained in a round.

In British application No. 12,832/52, U. S. application Serial No. 352,128, filed April 30, 1953, there is described and claimed inter alia a method of firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots which comprises arranging that a direct electric firing current is

passed through the fusehead of each succeeding detonator by way of an electrically actuable delay switch which is interposed between it and its preceding detonator so as to permit the electric firing current to pass through said fusehead when a closed circuit is formed by the actuation of said switch.

Application No. 12,832/52, U. S. application Serial No. 352,128, also describes and claims inter alia a layout for firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots comprising an electrically actuable delay switch which is interposed between the fusehead of each succeeding detonator and its preceding detonator and which is adapted to form the closed circuit required after the preceding detonator has fired thereby to permit direct electric firing current to pass through the fusehead of the succeeding detonator.

Application No. 12,832/52, U. S. application Serial No. 352,128, furthermore describes and claims an assembly comprising two insulated wires each connected to a pole of a source of D. C. electricity and a number of spaced electrically actuable delay switches wherein one leading wire of the electrically actuable portion of the first electrically actuable delay switch to be fired is connected to one of said insulated wires and the other leading wire of said electrically actuable portion is free for connection to a lead wire of the first detonator to be fired, and wherein said other insulated wire has an accessible portion for electrical connection to the other lead wire of the first detonator to be fired. The one circuit-making terminal of said first delay switch is electrically connected to one of said insulated wires and the other circuit-making terminal of said first delay switch is free for connection to a lead wire of the second detonator to be fired, and one leading wire of the actuable portion of the second electrically actuable delay switch to be fired is electrically connected to the other of said insulated wires, and the other leading wire of the actuable portion of said second electrically actuable delay switch is free for electrical connection to the other leading wire of the second detonator to be fired, and so on.

In application No. 12,832/52, U. S. application Serial No. 352,128, there is also described and claimed inter alia an electrically actuable delay switch comprising a tubular body containing within it an electric fusehead, two terminals at least one of which is insulated from the tubular body, and a metal partition element positioned between said fusehead and terminals and adapted to be displaced to form a metallic bridge at least momentarily between said terminals on creation of a gas pressure on that side of it facing said electric fusehead, wherein said fusehead comprises an electric resistance wire and a combustible delay composition element adapted to ignite to yield hot gases when an electric current is passed through said wire.

However to date it has not been found convenient to manufacture electrically actuable delay switches of the kind described and claimed in application No. 12,832/52, U. S. application Serial No. 352,128, which will have uniform delay times greater than 12 milliseconds. This is because of the impracticability of increasing the effective volume of the switches.

Accordingly, the object of the present invention is to provide a short delay blasting method and equipment which permits an appropriate choice of a uniform delay time between, for instance, 10 and 100 milliseconds, to be obtained from electrically actuable delay switches of the kind described heretofore, which have only a uniform lower delay time as for instance between 1 millisecond and 12 milliseconds, and which excludes the possibility of the shots firing out of their proper order. This object is accomplished by the use of pulsating electric current as described below.

In connection with the description of the present invention, the use of the phrases "lead wire" and "leading wire" are noted. Of course, it can be appreciated that "lead wire" refers to the wires of the detonator, while "leading wire" refers to the wires of the electrically actuable portion of the electrically actuable delay switch.

According to the present invention the method of firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots comprises passing a single impulse of electric firing current through the fusehead of each succeeding detonator by way of an electrically actuable delay switch which is interposed between it and its preceding detonator and which only permits the electric firing current to pass through said fusehead when a closed circuit is formed by its actuation. The electric firing current for each detonator and its associated delay switch is supplied by way of a series of single impulses from a pulsating electric current in which the period of time between the electric impulses is the same as the delay period desired between successive shots and in which the duration of each of said impulses is less than the delay period of a delay switch and is longer than the period of time required to fire a detonator and its associated delay switch.

In accordance with one embodiment of the invention the method of firing a succession of shots by the firing of their corresponding electric detonators with a short delay period between successive firings comprises connecting one lead wire of the first detonator to be fired to a common conducting element connected to one terminal of a source of pulsating electric current, and the other lead wire to a leading wire of the electrically actuable portion, for example an electric fusehead, of an electrically actuable delay switch. The other leading wire of the electrically actuable portion goes to another common conducting element connected to the other terminal of the source of pulsating electric current, the said source of pulsating electric current being such that the period of time between the electric impulses is the same as the delay period desired between successive shots and in which the duration of each of said impulses is less than the delay period of a delay switch and is longer than the period of time required to fire a detonator and its associated delay switch. One lead wire of the next detonator to be fired is connected to the common conducting element attached to the first mentioned terminal of the source of pulsating electric current as noted heretofore and the other lead wire is attached to the leading wire of an electrically actuable portion, for example an electric fusehead, of a second electrically actuable delay switch. In addition, one leading wire of one of the terminals of the first electrically actuable delay switch is connected to the other leading wire of the electrically actuable portion of the second electrically actuable delay switch and the leading wire of the other terminal of the first electrically actuable delay switch to the common conducting element attached to the other terminal of a source of pulsating electric current, and so on. This method of firing permits an electric impulse to pass from said source of pulsating electric current through said first detonator and electrically actuable portion of said first electrically actuable delay switch and then another electric impulse through said second detonator and electrically actuable portion of said second electrically actuable delay switch, and so on.

More particularly in accordance with another embodiment of the invention the method of firing a succession of shots by the firing of their corresponding electric detonators with a short delay period between successive firings comprises connecting one lead wire of the first detonator to be fired to a common conducting element connected to one terminal of a source of pulsating electric current and the other lead wire to a leading wire of the electrically actuable portion, for example an electric fusehead, of an electrically actuable delay switch. The other leading wire of the electrically actuable portion goes to another common conducting element connected to the other terminal of the source of pulsating electric current, the said source of pulsating electric current being such that the period of time between the electric impulses is the same as the delay period desired between successive shots and in which the duration of each of said impulses is less than the delay period of a delay switch and is longer than the period of time required to fire a detonator and its associated delay switch. One leading wire of one of the terminals of said switch is connected to one of said common conducting elements and the leading wire of the other terminal of said switch to the lead wire of the second detonator to be fired. The other lead wire of the second detonator is connected to a leading wire of the electrically actuable portion of the second electrically actuable delay switch to be fired and the other leading wire of the electrically actuable portion of said second delay switch to the other common conducting element, and so on. Thus, when an initial electric impulse is applied, it passes from said source of pulsating electric current through said first detonator and electrically actuable portion of said first electrically actuable delay switch and then another electric impulse through the terminal portion of said first delay switch, said second detonator and electrically actuable portion of said second electrically actuable delay switch, and so on.

The method of the present invention enables a round of any desired number of shots to be fired with an electric impulse of an order sufficient only for the firing of two electric fuseheads at a time.

It can be appreciated that, in accordance with the method described heretofore, a layout for firing a succession of shots can be achieved by the firing of their corresponding electric detonators with a delay period between successive shots. This layout, of course, would include a series of electrically actuable delay switches of the type noted heretofore interposed between the fuseheads of successive detonators. Thereafter, by application of a pulsating electric firing current, the firing of a succession of shots would be achieved.

It will be understood that in accordance with the method of the invention the delay period between successive shots is given by the period of time between the electric impulses from the source of pulsating electric current and that in the simple layout of the invention each electrically actuable delay switch prevents any one electric impulse from initiating all the detonators in the round simultaneously and so it is essential that the duration of each of said impulses should be less than the delay period of an electrically actuable delay switch. A special advantage of the present invention is that a layout made from electrically actuable delay switches of any particular delay period can be used for delay periods between successive shots exceeding this particular delay period.

As noted heretofore, the electrically actuable delay switch for use for the carrying out of the invention can take for instance any of the forms described and claimed in application No. 12,832/52, U. S. application Serial No. 352,128. A preferred form of electrically actuable delay switch comprises a tubular body containing within it an electric fusehead, two terminals at least one of which is insulated from the tubular body, and a metal partition element positioned between said fusehead and terminals and adapted to be displaced to form a metallic bridge between said terminals on creation of a gas pressure on that side of it passing said electric fusehead, wherein said fusehead comprises an electric resistant wire and a combustible composition element adapted to ignite to yield hot gases when an electric current is passed through said wire. If desired the tubular body may contain only one terminal as the tubular body itself if of conducting material may act as the other terminal.

The period of time to displace said metal partition element at least momentarily to form a metallic bridge between said terminals can be predetermined and depends

inter alia upon the burning characteristics of the combustible composition element, the free space in the tubular body between said composition and said terminal or terminals, the composition, and the inertia of the metal partition element.

Any suitable means may be used for providing a pulsating electric current as for example directly by mechanical devices for example by a magneto designed to give a pulsating electrical current, by a combination of mechanical and electrical devices by which a steady source of current is interrupted mechanically to give a required pulsating current, or by purely electrical devices in which for example a steady source of electric current is interrupted or controlled by electronic means.

By way of example a portion of a detonator firing circuit for short period delay blasting in accordance with one embodiment of the invention, showing two instantaneous electric detonators and their associated expendable gas pressure closable electric switches out of a considerably greater number is illustrated diagrammatically in the diagrammatic drawing accompanying the specification, referred to as Fig. 1.

In Fig. 1, **1** is a positive wire connection to a source of supply of electric current, **2** is a rotary switch having diametrically opposite inter-connected contacts **3** positioned on its periphery, **4** is an electric supply line energised by the wire **1** through the rotary switch **2** and **5** is a negative connection to the electric supply. **6** is an electric detonator the fusehead **7** of which is connected in series with the electric fusehead **8** of an electrically actuable delay switch **9** provided with two contacts **10** and a press-fitted movable conducting partition **11**. One of the contacts **10** is connected to the wire **4** and the other to the fusehead **8'** of a switch **9'** which is provided with a press-fitted movable conduction partition **11'** and contacts **10'**. The fusehead **8'** is connected in series with the fusehead **7'** of the detonator **6'** to the wire **5**. The contacts **10'** can be connected up in a similar fashion to contacts **10** to continue the series. Thus, when the firing switch (not shown) is closed and the rotary switch closes the circuit, current passes through the fuseheads **7** and **8**, causing the detonator **6** to fire and the partition **11** to move into contact with the contacts **10**. Before partition **11** reaches contacts **10**, however, the rotary switch **2** breaks the circuit. When the rotary switch remakes the circuit current passes through the fuseheads **7'** and **8'** causing the detonator **6'** to fire and the partition **11'** to move into contact with the contacts **10'**. Again the rotary switch **2** breaks the circuit before partition **11'** makes contact with the contacts **10'** and this sequence of actions will continue throughout the whole series of detonators and electrically actuable delay switches. It will be apparent from the lay-out illustrated that it is impossible for any detonator in such a series to fire before any other earlier detonator in the series. Furthermore should any switch fail to close satisfactorily none of the subsequent detonators in the series will fire. In practice the leads from the fuseheads **8**, **8'** etc. to the firing line **4** may be of considerable length whereas the distance between the detonators and their corresponding switches may be made so small that the switches may suffer damage or destruction by blast from the explosive charges initiated by their respective detonators. If the delay interval is such that this would cause any switch to be destroyed before its corresponding detonator has been fired the switches may be wired so that they are close to the supply line and considerably removed from the previously fired charge.

If R is the rotational speed (revolutions per minute) of the rotary switch and d is the desired delay time in milliseconds and n is the number of times the circuit is made per revolution of the rotary switch, then

$$d=\frac{1000}{R/60\times n}$$

By way of example a portion of a detonator firing circuit for short period delay blasting in accordance with another embodiment of the invention showing three electrically actuable delay switches and two of their associated instantaneous detonators out of a considerably greater number of detonators and switches is given in Fig. 2 of the diagrammatic drawing attached hereto.

Fig. 2 also illustrates the assembly comprising three associated electrically actuable delay switches out of a considerably greater number of delay switches electrically connected to the insulated twin wires **1** and **5** and showing the free leading wire of one terminal of the preceding delay switch and a free leading wire from the electric fusehead of the succeeding delay switch each for subsequent connection to a lead wire of an electric detonator which is to detonate after the firing of said preceding delay switch and is to permit the passage of the applied electric impulse through the electrically actuable portion of the succeeding electrically actuable delay switch.

In Fig. 2 the motor operated rotary switch which provides a simple form of pulse generator when connected in series with a battery supply has a different construction to the one included in the detonator firing circuit illustrated in Fig. 1 and comprises a disc **13** of insulating material which is fitted with two brass inserts **14**, so that the circumference is divided into four alternate and equal sections of insulating material and brass, and two mounted soft carbon brushes **15'** so that, as the disc **13** rotates, the brass inserts **14** bridge the brushes **15'** twice per complete revolution. Brush **15'** is mounted on a radial slot **16** so that its position relative to brush **15** can be varied through a 90° arc. The duration of electrical contact between the brushes **15** and **15'** can be varied from zero at 90° to a maximum when the brushes are just free from touching.

The motor (not shown) for operating the radial switch can be a speed governed elastic motor in conjunction with a friction gear (not shown) which can be set to give rotational speeds from zero to 5,000 R. P. M. Since contact is made twice per revolution the period between pulses delivered by this switch rotating at 5,000 R. P. M. is 6 milliseconds. The duration of contact is a function of the rotational speed of the disc **13** and consequently the duration of each pulse varies with the rate of repetition of the pulses. This duration of contact, however, may be altered by altering the distance between the brushes **15** and **15'** for a given rotational speed of the disc **13**.

In the detonator firing circuit and assembly illustrated in Fig. 2 one leading wire from the electric fusehead **8''** of the electrically actuable delay switch **9'**, is connected to **4** and the other leading wire from the electric fusehead is shown free, but would have been connected to **5** if **8'** were the first electric fusehead to be fired in the row. One of the two leading wires of **10'** is joined to one of the two leading wires of **7'**, the other leading wire of **7'** is joined to one of the two leading wires of **8''** and the other leading wire of **8''** is joined to **4**, and so on. When the firing switch (not shown) is closed and one of the brass inserts **14** of the rotary switch closes the circuit, current passes through the fusehead **8'** of the electrically actuable delay switch **9'** and the pressure generated by the firing of the matchhead composition of the fusehead **8'** in the electrically actuable delay switch **9'** effects the movement of the thin rigid cup **12'** fitting closely in the tube of said delay switch so as to make it touch the terminals **10''** and **10''**, this delay period depending inter **10'**, however, the rotary switch breaks the circuit. When the rotary switch remakes the circuit an electric firing current passes from **5** to **4** through **10'** and **10'**, **7'** and **8''** of the electrically actuable delay switch **9''**. There is a definite period of delay between the instant at which the fusehead **8''** fires and the cup **12''** contacts the terminals **10''** and **10''**, this delay period depending inter-alia on the burning characteristics of the matchhead composition of the fusehead **8''**, the free space in the elec-

trically actuable delay switch between the fusehead and the bottom or circuit making portion of the cup 12'' and the position and inertia of the cup 12'', so that the firing circuit through the fusehead 7'' is only completed after a corresponding delay period. Once again, however, the rotary switch breaks the circuit before the partition 12'' reaches the terminals 10'' and this series of actions will continue throughout the whole series of detonators and electrically actuable delay switches.

As in the previous embodiment the desired delay time in milliseconds d is controlled by the rotational speed (revolutions per minute) R of the rotary switch and n the number of times the rotary circuit is made per revolution of the rotary switch and is given by the formula

$$d=\frac{1000}{R/60\times n}$$

An electrically actuable delay switch illustrated by way of example in Fig. 2 comprising an aluminium tube 60 mm. long and 6.7 mm. diameter, a cup 12'' with a frictional fit 25 mm. from the terminal end of the tube, terminals 10 located 5 mm. from the cup 12'' and a low tension fusehead 8 having an ignitable composition consisting of a collodion coated lead mono-nitroresorcinate, potassium chlorate and charcoal composition and which evolves approximately 7 ml. of gas at N. T. P., gives a delay time of approximately 7 milliseconds.

If desired in the method, layout and assembly of the present invention the electrically actuable delay switches can comprise a container having within it an electric fusehead comprising an electric resistance wire and combustible composition element adapted to ignite to yield hot gases when an electric current is passed through said wire and two terminals at least one of which is insulated from the container and so distanced from each other and the fusehead that on combustion of said combustible composition the space between the terminals becomes a conducting path for the difference of potential available between the terminals.

What we claim is:

1. A system for firing a series of detonators successively at predetermined intervals of time comprising a plurality of detonators each having an instantaneous fusehead, means for supplying a series of electric impulses at said predetermined intervals of time, means for coupling the fuseheads of said detonators in parallel to the impulse supplying means, the coupling means including a plurality of delay switches each having a set of spaced apart terminals and a fusehead whereby current through said fusehead develops gas to effect closure of said terminals at a delayed time, the delay time of said switch being less than said predetermined interval of time and the duration of said impulses being less than the delay time of said switches, said switches being connected respectively between successive detonators with each switch fusehead being in series with a different detonator while each associated set of terminals is in series with a different following detonator, the arrangement being such that successive electric impulses flow through the fuseheads of successive detonators respectively at said predetermined intervals of time whereby said detonators are fired successively.

2. A system as in claim 1 wherein the electric impulse supplying means includes a rotary switch having a plurality of alternate conductive and non-conductive portions thereon, two brushes for contacting said conductive portions, and a source of electricity, said brushes being separated a predetermined distance and connected in series between the source and each of the detonators when contacted by a conductive portion, said portions and brushes being relatively rotatable at a predetermined speed whereby said predetermined intervals of time are determined in accordance with said speed and the number of conductive portions of said switch.

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