Dec. 3, 1957 J. C. R. CANCE 2,814,991

ART OF DELAY ELECTRIC SHOT-FIRING OF BLASTING EXPLOSIVE CHARGES AND APPLIANCES SUITABLE FOR USE IN DELAY ELECTRIC SHOT-FIRING CIRCUITS

Filed April 30, 1953 3 Sheets-Sheet 1

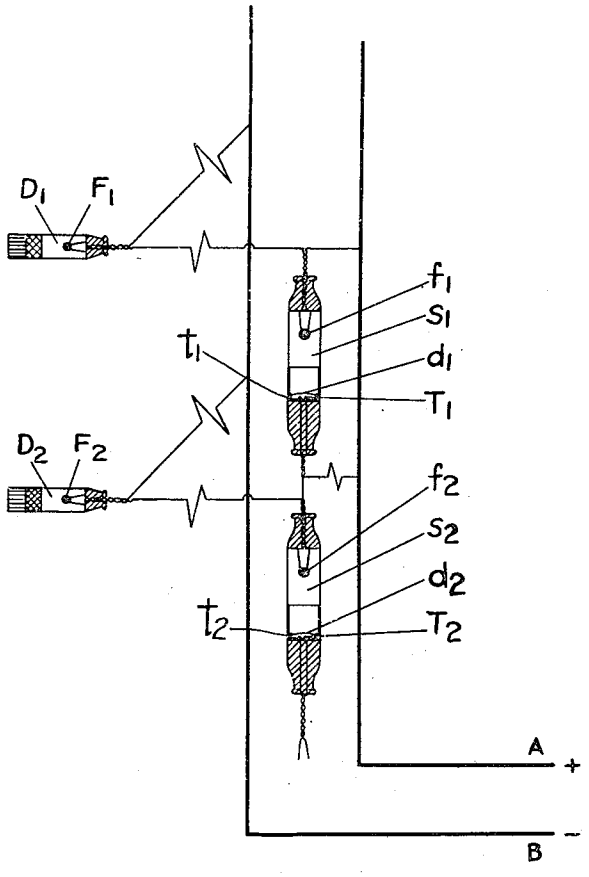


FIG. 1

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Filed April 30, 1953 3 Sheets-Sheet 2

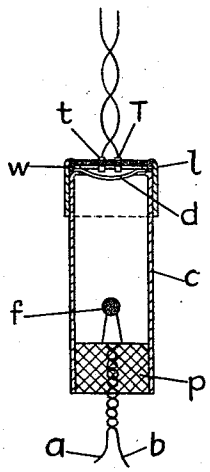


FIG. 2

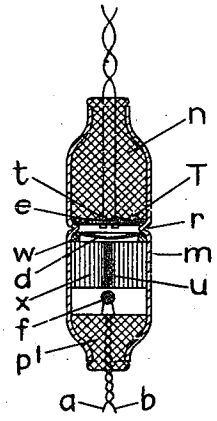


FIG. 6

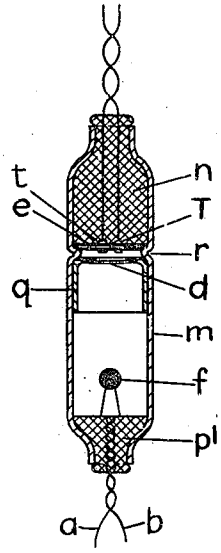


FIG. 3

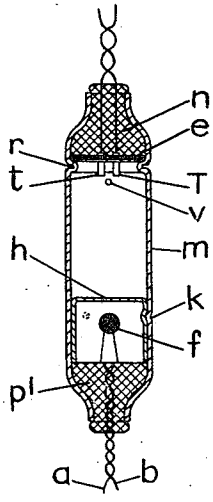


FIG. 4

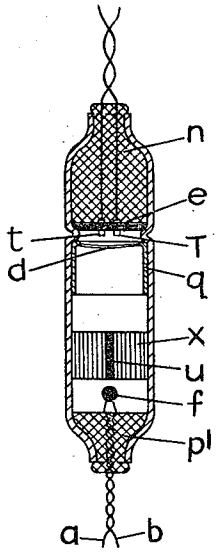


FIG. 7

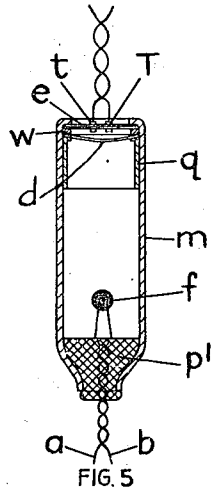


FIG. 5

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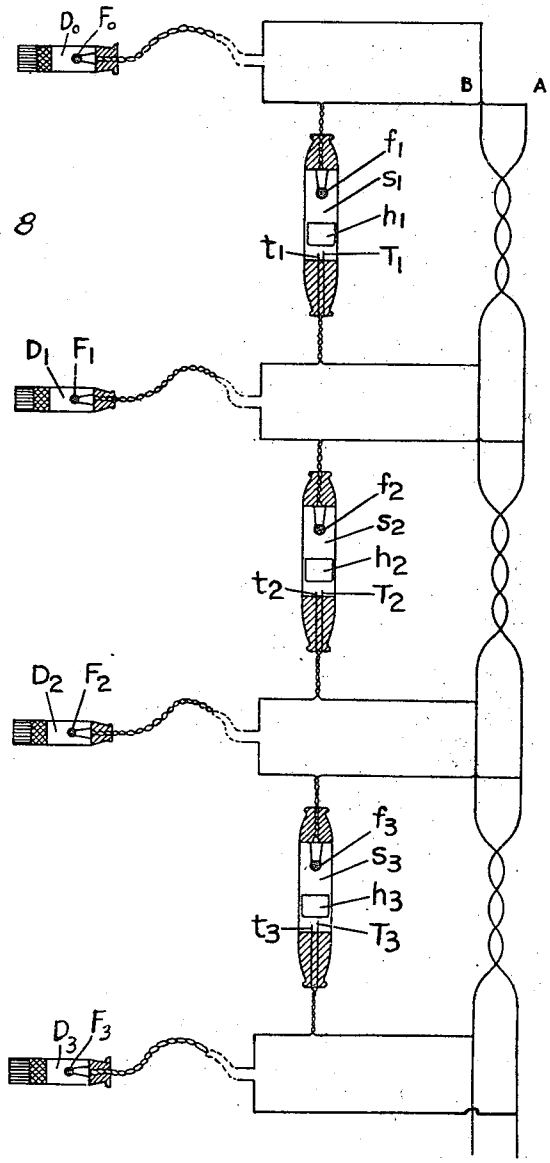
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FIG. 8



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ART OF DELAY ELECTRIC SHOT-FIRING OF BLASTING EXPLOSIVE CHARGES AND APPLIANCES SUITABLE FOR USE IN DELAY ELECTRIC SHOT-FIRING CIRCUITS

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Application April 30, 1953, Serial No. 352,128

Claims priority, application Great Britain May 21, 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 shotfirer performs a single manual operation.

Short period delay blasting has in certain circumstances advantages that are well recognised over simultaneous blasting, that is to say the firing of a series of shots in such a manner that the explosive charges of all the electric detonators in the round of shots occurs simultaneously, 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 rotary 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 intervals 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 efficient operation of a rotary switch mechanism requires a speed-governed motor and since each electric detonator in the round must be wired to a separate contact of the rotary switch mechanism and the latter must be situated at a safe distance from the blasting position, 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 rotary switch mechanism becomes increasingly inconvenient. In practice the number of successive intervals that has been obtained by using electric detonators with a rotary switch mechanism has not substantially exceeded 16, and using short period delay 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.

The object of the present invention is to provide a short delay blasting method and equipment by which the possibility of the shots firing out of their proper order is eliminated and which is capable of operation so as to fire any desired number of shots in a round.

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 arranging that an 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 the 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.

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 connectable to one pole of a source of electricity 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 and the other leading wire of the electrically actuable portion to another common conducting element connectable to the other pole of the source of electricity, connecting one lead wire of the next detonator to be fired to the common conducting element connectable to the first mentioned pole of the source of electricity and the other lead wire to the leading wire of an electrically actuable portion, for example an electric fusehead, of a second electrically actuable delay switch as well as connecting one leading wire of one of the terminals of the first electrically actuable switch 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 connectable to the other pole of the source of electricity, and so on, and thereafter permitting an electric current to pass from said source of electricity through said first detonator and electrically actuable portion of said first electrically actuable delay switch and then 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 connectable to one pole of a source of electricity 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 and the other leading wire of the electrically actuable portion to another common conducting element connectable to the other pole of the source of electricity, connecting the leading wire of one of the terminals of said switch to one of said common conducting elements and the leading wire of the other terminal of said switch to a lead wire of the second detonator to be fired connecting the other lead wire of said second detonator 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, and thereafter permitting an electric current to pass from said source of electricity through said first detonator and electrically actuable portion of said first electrically actuable delay switch and then 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 current of an order sufficient only for the firing of two electric fuseheads at a time.

A layout for firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots according to the invention comprises 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 the electric firing current to pass through the fusehead of the succeeding detonator.

More specifically a layout according to one embodiment of the invention for firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots is one wherein one lead wire of the first detonator to be fired is connected to a common conducting element connectable to one pole of a source of electricity and the other lead wire is connected to a leading wire of the electrically actuable portion, for example an electric fusehead, of an electrically actuable delay switch and the other leading wire of the electrically actuable delay portion to another common conducting element connectable to the other pole of the source of electricity, wherein one lead wire of the next detonator to be fired is connected to the common conducting element connectable to the first mentioned pole of the source of electricity and the other lead wire to a leading wire of the electrically actuable portion of a second electric switch and wherein also one leading wire of one of the terminals of the first electric switch is connected to the other leading wire of the electrically actuable portion of the second electric switch and the leading wire of the other terminal of the first electric switch to the common conducting element connectable to the other pole of electricity and so on.

More specifically a layout according to another embodiment of the invention for firing a succession of shots by the firing of their corresponding electric detonators with a delay period between successive shots is one wherein one lead wire of the first detonator to be fired is connected to a common conducting element connectable to one pole of a source of electricity and the othr lead wire is connected to a leading wire of the electrically actuable portion, for example an electric fusehead, of an electrically actuable delay switch and the other leading wire of the electrically actuable portion to another common conducting element connectable to the other pole of the source of electricity, wherein one leading wire 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 is connected to a lead wire of the second detonator to be fired, and wherein the other lead wire of the second detonator to be fired 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 is connected to the other common conducting element, and so on.

Preferably instantaneous electric detonators are used in the carrying out of the invention but delay electric detonators can be used if it is desired to control the number of detonators to be initiated before any particular one is allowed to fire.

An assembly according to one embodiment of the invention comprises two common conducting lengths each connectable to a pole of a source of electricity and a number of spaced electrically actuable delay switches, wherein one common conducting length has a number of spaced accessible portions each for electrical connection to one lead wire of a detonator, wherein one leading wire of the electrically actuable portion of the first electrically actuable delay switch to be fired is connected to the other common conducting length and the other lead wire is free for electrical connection to the other lead wire of the first detonator to be fired, wherein one circuit making terminal of said first delay switch is electrically connected to said second common conducting length and the other circuit making terminal of said first delay switch is electrically connected to one of the leading wires of the second electrically actuable delay switch to be fired, and wherein 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.

An assembly according to another embodiment of the invention comprises two insulated wires each connectable to a pole of a source of 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, wherein said other insulated wire has an accessible portion for electrical connection to the other lead wire of the first detonator to be fired, wherein 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 wherein 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.

The electrically actuable delay switch for use for the carrying out of the invention can take several forms. 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 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 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 position and the inertia of the metal partition element.

The partition element of the electrically actuable delay switch may for instance take the form of a hollow cup that can be moved bodily, by the gas pressure developed, towards the end of the tubular body at which at least one of the terminals to be connected is situated. Sometimes

it may be necessary to provide a vent hole in the tubular body between the terminals and the movable metal cap. Alternatively, the metal partition element may be a diaphragm held in the vicinity of at least one of the terminals required to be connected wherein only the central portion of the diaphragm is free to move into contact with the terminal under the gas pressure developed. For this modification a vent hole is not usually required.

The tubular body may either be made of metal or of a non-conducting material and it is preferable that both of the terminals to be bridged by the movement of the metal partition should be accommodated near to one another at the end of the tube remote from the electric fusehead, which for a metal tube can conveniently be done by embedding leads to them in a plug of insulating material around which the metal can be crimped, so that only the terminals protrude from the plug. The electric fusehead can be similarly accommodated in a plug of insulated material around which the tube is crimped at the other end. It is, however, possible for one of the terminals to be in permanent electrical connection with the metal partition although in general this is a less convenient arrangement.

The delay period interposable between the successive detonations may be varied according to requirements. One very convenient way of doing this that need not involve a change in dimensions of the switch body or the inertia characteristics of the metal partition is to alter the nature and/or size of the combustible composition element. For example, for a relatively short delay period this may consist solely of an electric fusehead, while when a longer delay period is required there may be interposed between the electric fusehead and the metal partition a delay fuse element comprising a core of a combustible composition compressed into a tube of noncombustible material, for example metal, fixed in the tubular switch body so that one end of the core of combustible material is fixed in position in ignition contact with the fusehead, so that when the whole length of the core has burned the expanding gases can actuate the metal partition.

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 gas-pressure closeable expendable electric switches out of a considerably greater number is illustrated diagrammatically in Fig. 1 of the diagrammatic drawings accompanying the specification. Figs. 2 to 7 of said drawings illustrate in axial section various forms of expendable electric switches in accordance with the invention.

In Fig. 1 it will be seen that from the firing line A, denoted in the drawing as a positive line, the electric fusehead f_1 of the first expendable electric switch s_1 is wired in series with the electric fusehead F_1 of the first instantaneous electric detonator D_1 in the round, from which there is a return to the return firing line B, so that on completion of the firing circuit the fuseheads f_1 and F_1 fire simultaneously, and the detonator D_1 fires the first charge of explosive, not illustrated in the sketch. The pressure generated by the firing of the match composition of the fusehead f_1 in the expendable switch s_1 brings about the outward motion of the central part of the metal diaphragm d_1 in the first switch body and thus causes it to establish contact with terminals t_1 and T_1 normally insulated from the said diaphragm. Terminal T_1 is connected directly to the firing line A, and the terminal t_1 is connected through the electric fusehead f_2 of the next expendable switch s_2 in the round to the fusehead F_2 of the second instantaneous electric detonator D_2, from which there is a return branch to the firing line B. If this second expendable electric switch s_2 is identical with the expendable electric switch s_1 then when this diaphragm d_2 is moved into effective contact with the terminals T_2 and t_2, which are similarly connected to the firing line A and a third instantaneous electric detonator not shown in the drawing, this third electric detonator will fire in due course. There is

a small but definite period of delay between the instant at which the fusehead f_1 fired and the diaphragm d_1 contacts the terminals T_1 and t_1, this delay period depending on the burning characteristics of the matchhead composition of the fusehead f_1, the free space in the switch body between the fusehead and the diaphragm d_1 and the inertia of this diaphragm, so that the firing circuit through the fusehead F_2 of the second instantaneous detonator D_2 is only completed after a corresponding delay period, and it will be appreciated that similarly the firing of the next instantaneous electric detonator in the round will only occur after precisely the same period of delay from the instant at which this second electric detonator fires, and so forth.

It is by no means a necessary feature of the invention that the delay periods of the expendable electric fuses s_1, s_2, s_3 and so forth should be identical, but whatever the delay periods may be it will be appreciated that it is quite impossible for the second detonator in the round to fire before the first or the third before the second and so forth. Also, if one of the switches s_1, s_2, should fail to close satisfactorily, none of the subsequent detonators in the round connected through its terminals t_1 and T_2 will fire.

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 four of their associated instantaneous electric detonators out of a considerably greater number of detonators and switches is illustrated diagrammatically in Fig. 8 of the diagrammatic drawing attached hereto. Fig. 8 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 twisted wires A and B and showing the free leading wire of one terminal of the preceding delay switch and a free leading wire from the electric fuse of the succeeding delay switch each for subsequent connection to a lead wire of an instantaneous electric detonator which is to detonate after the firing of said preceding delay switch and is to permit the passage of the applied electric current through the electrically actuable portion of the succeeding electrically actuable delay switch.

In Fig. 8 one leading wire from the electric fusehead f_1 of the electrically actuable delay switch S_1 is connected to A and the other leading wire from the electric fusehead is shown connected to B through fusehead F_0 of the first to be fired detonator D_0 in the round. The lead wire of T_1 is joined to B and the lead wire of t_1 is joined to one of the two leading wires of F_1. The other lead wire of F_1 is joined to one of the two leading wires of f_2 and the other leading wire of f_2 is joined to A, and so on. The pressure generated by the firing of the matchhead composition of the fusehead f_1 in the electrically actuable delay switch S_1 effects the movement of the thin rigid cup h_1 fitting closely in the tube of said delay switch so as to make it touch the terminals t_1 and T_1. When this occurs an electric firing current passes from B to A, through T_1 and t_1, F_1, and f_2 of the electrically actuable delay switch S_2. There is a definite period of delay between the instant at which the fusehead f_2 fires and the cup h_2 contacts the terminals T_2 and t_2, this delay period depending inter alia on the burning characteristics of the matchhead composition of the fusehead f_2, the free space in the electrically actuable delay switch between the fusehead and the bottom or circuit making portion of the cup h_2, and the position and inertia of the cup h_2, so that the firing circuit through the fusehead F_2 is only completed after a corresponding delay period, and it will be appreciated that similarly the firing of the next instantaneous electric detonator in the round will only occur after precisely the same period of delay from the instant at which this second electric detonator fires, and so on through the last to be fired detonator, which in the illustration of Fig. 8 is detonator D_3.

Referring to Fig. 2, c is a thick walled cylindrical card-

board tube into one end of which there is cast around insulating leading wires *a* and *b*, leading to a low tension fusehead *f*, a sealing plug *p* of chlorinated naphthalene. The bared ends of another pair of insulated wires pass through the base of a cylindrical cardboard cap *l* at spaced positions near to and equidistant from its centre and are riveted in their positions above and below the thickness of the cardboard so that they form two terminals *t* and T insulated from one another, just projecting from the inner surface of the base of the cap. Into the base of the cap there is placed a spacing washer *w* on which there is superposed the circumferential portion of a thin metal diaphragm *d* dished outwardly away from the terminals. The outer surface of the wall of the tube *c* at its open end is provided with a coating of an adhesive not seen in the drawing and this end of the tube is pressed home into the cap *l*, whose internal diameter is just sufficient to enable a tight fit to be obtained. After the adhesive has set the resulting expendable fuse is coated with a waterproofing composition also not seen in the drawing. When the fusehead *f* is fired the hot gases from this matchhead composition build up a pressure in the free space between the plug *p* and the diaphragm *d* and after a short but measurable interval of time of the order of a few milliseconds from the firing of the fusehead the diaphragm *d* is forced out of its original shape into contact with the terminals *t* and T, the thickness of the washer *w* being insufficient to prevent good contact being made when the convexity of the diaphragm is reversed.

Referring to Fig. 3, *m* is an aluminium tube grooved at some distance from one end, as shown at *r* to form a cannelure. This tube is originally almost cylindrical in shape but has a slight taper towards the end shown in the drawing as the upper end. Into this tube there is inserted a similarly tapered almost cylindrical tube *q* of aluminium which is inwardly flanged at its narrower end. This flanged tube is a push fit within the tube *m*. To the outer surface of the flange of the tube *q* there is cemented a thin metal diaphragm of the same outer diameter as the flange. This diaphragm is disposed so that it is dished into cylinder *q* and the resulting assembly is pushed into the tube *m* until the circumferential portion of the diaphragm encounters the cannelure at *r*. *e* is a cardboard disc of greater diameter than the narrow portion of the tube at the cannelure. Near to and equidistant from the centre of this disc there are spread and riveted the bared ends of a pair of conducting wires, so as to form and locate projecting terminals *t* and T. Superposed on this disc is a cylindrical insulating plug *n* of soft polymerized chloroprene composition through parallel bores in which pass the conducting wires leading from the terminals *t* and T to be connected electrically by the action of the switch. The disc *e* and the plug *n* carrying these wires are now inserted into the tube *m* until the disc *e* encounters the cannelure, at which position the terminals *t* and T are still out of contact with the diaphragm but are sufficiently close to the diaphragm to enable contact to be made when it yields. The end of the tube *m* is crimped around the end of the plug *n*, which accordingly bulges at that end. An assembly consisting of a low tension fusehead with its leading wires *a* and *b* threaded through a shorter plug *p'* of soft polymerised chloroprene insulating composition is similarly crimped into the end of the tube *m* facing the convex surface of the diaphragm.

A small but definite time interval of the order of a few milliseconds occurs between the moment when the electric fusehead fires and the moment when the gas pressure built up in the space between the plug *p'* and the diaphragm *d* forces the latter into contact with the terminals *t* and T.

Referring to Fig. 4, the elements *m*, *n*, *e*, *t*, and *T*, *a*, *b*, *p'* and *f* have the same significance as in Fig. 3. *r* is a cannelure beyond the width of which the terminals *t*, T project when the disc *e* is in contact with it. *v* is a vent hole situated at a point close to the cannelure on the opposite side from the disc *e* and the plug *h*. *h* is a thin rigid metal cup fitting closely into the tube *m*, this cup being frictionally retained in its position around the fusehead *f* by inwardly directed equally spaced small indentations *k*. When the fusehead *f* is fired the gases accumulating under pressure within the cup *h* propel it against the frictional resistance of the indentations *k* and the slightly tapering unindented portion of the wall of the tube *m* until this cup contacts the terminals *t* and T, and so connects them together, the air in the tube *m* displaced by the cup *h* escaping through the vent *v* without creating any back pressure.

An electrically actuable delay switch in accordance with a modified form of the article illustrated in Fig. 4 comprising an aluminium tube *m* 60 mm. long and 6.7 mm. diameter, a cup *h* with a frictional fit positioned so that the distance between plug *p'* and the bottom of the cup *h* is 25 mm., terminals T and *t* located 5 mm. from the bottom of the cup *h* and a low tension fusehead *f* having an ignitable composition consisting of a collodion coated lead mononitroresorcinate, 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.

Referring to Fig. 5, the originally open and slightly tapering metal tube *m* has an inturned flange at its narrower end. A slightly tapering open metal tube *q* also has an inturned flange at its narrower end and is a press fit within the tube *m*. The circumferential portion of the dished thin metal diaphragm *d* is cemented on to the exterior surface of the flange of the tube *q* with its dished surface facing inwards, and a spacing washer *w* is superposed upon it. A cardboard disc *e*, in which the terminals *t* and T are located and spaced in the same manner as that in which they are located and spaced in the cap *l* of Fig. 2, is cemented on top of the spacing washer *w* so that the terminals *t* and T face the dished portion of the diaphragm. The thickness of the washer is sufficient to prevent the terminals from contacting the diaphragm in its undistorted position, but sufficient to prevent such contact when the diaphragm is distorted as by inversion of its concavity. The resulting assembly is inserted, wires first, into the flanged tube *m* and punched until it encounters the flange. The fusehead assembly consisting of the fusehead *f* and its leading wires *a* and *b* passing through the plug of soft polymerised chloroprene composition *p'* is next inserted into the tube *m* through the unflanged end of the tube *m*, which is then crimped around this plug in the usual manner. After the fusehead has been ignited there is a short interval before the pressure developed in the space between the plug *p'* and the diaphragm *d* moves the dished portion of the diaphragm into contact with the terminals *t* and T.

Referring to Fig. 6, the metal tube *m* is cannelured at *r* and the cardboard disc *e* bearing terminals *t* and T and the plug of soft polymerised chloroprene composition carrying the wires to these terminals is crimped into position as in Fig. 3. A spacing washer *w* is placed on one end of a delay fuse element consisting of a core of a rapid burning combustible fuse composition of relatively low gas yield characteristics *u* compressed into a rigid cylindrical metal sleeve *x*, and on top of the washer is placed a thin metal diaphragm *d* dished towards the sleeve. The resulting assembly is pressed into the tube *m*, in which the sleeve is a press fit, until the diaphragm *d* encounters the cannelure *r*. Close to the other end of the core *u* there is positioned a fusehead *f*, whose leading wires *a* and *b* pass through a plug of soft polymerised chloroprene insulating composition *p'*. This plug is crimped into the end of the tube *m* in the usual way. When the fusehead is fired the hot gases from it enter the space between plug *p'* and the delay sleeve *x* and ignite the fast burning combustible fuse composition *u*. The gases from the latter can only escape into the small space between the delay sleeve *x* and the diaphragm *d* when the composition *u*

has burned substantially right through to its end, whereupon the gas pressure moves the diaphragm into contact with the terminals *t* and T. In this case the delay period depends almost wholly on the time taken by the fast burning combustible fuse composition *u* to burn, and this form of construction enables delay switches of very much longer delay characteristics to be obtained in a convenient manner than any of the constructions illustrated in Figs. 2 to 5.

Fig. 7 illustrates a form of delay switch embodying a modification of the principle embodied in the delay switch of Fig. 6. In this case the space between the delay sleeve *x* and the diaphragm *d* is considerably greater than in the delay switch in Fig. 6, with the result that the time taken for the gas pressure to build up within this space after the fast burning combustible fuse composition *u* has burned through may contribute an appreciable fraction of the total delay period. This form of construction provides a convenient way of effecting minor variations in delay periods achieved by the use of delay sleeves containing fast burning combustible fuse compositions, since in general it is easier to bring about such a minor variation by varying the available free space than by varying the length of the delay fuse composition and sleeve. It will be seen that in Fig. 7 the washer *w* shown in Fig. 6 is replaced by a press fit metal tube *q* with an inturned flange and that the delay sleeve *x* containing the fast burning fuse composition *u* is pushed to a desired position in the tube *m*. It will also be appreciated that the tube *m* is longer than that shown in Fig. 6 so as to provide the necessary space between the end of the delay sleeve and the diaphragm. In other respects the construction is as in Fig. 6.

What I claim is:

1. In a system for firing detonators in a group thereof successively without any possibility of overlap in the firing of any two or more detonators, the system including a plurality of instantaneously fireable detonators making up said group, a plurality of delay switches each characterized by having a hollow body with a closure at each end and an air space in between the closures, a fusehead disposed at one end of said air space, a set of spaced apart contacts disposed at the other end of said air space, a metal partition element positioned between the fusehead and said contacts whereby current through said fusehead develops a gas pressure on the side of the partition element facing said fusehead causing displacement of the partition element so that said element forms a metallic bridge at least momentarily across said contacts, a source of electricity, means for coupling each of said detonators in parallel to said source, each of said means except that coupling the last to be fired detonator including a different switch fusehead in series with the detonator coupled thereby, each of said means except that coupling the first to be fired detonator also including a set of said spaced apart contacts in series with the detonator coupled thereby, the fusehead and spaced apart contacts connected in series with each detonator being in a different switch, the arrangement being such that as to any two of the plurality of detonators to be fired immediately successively the fusehead of the switch between said two detonators is in series with one of the two detonators and the spaced apart contacts of the in-between switch is in series with the other of said two detonators whereby said other detonator fires after said one detonator by a time predetermined by the delay time of the in-between switch.

2. In a system for firing detonators in a group thereof successively without any possibility of overlap in the firing of any two or more detonators, a system including a plurality of instantaneously fireable detonators making up said group, a plurality of delay switches, the second mentioned plurality being one less in number than the first mentioned plurality, each switch being characterized by having a hollow body with a closure at each end and an air space in-between the closures, a fusehead disposed at one end of said air space, said fusehead including an electric resistance wire and a combustible composition element adapted to ignite to yield hot gases when an electric current is passed through said wire, a set of spaced apart contacts disposed at the other end of said air space, a metal partition element positioned between the fusehead and said contacts whereby the pressure as developed by said hot gases on the side of the partition element facing said fusehead causes displacement of the partition element so that said element forms a metallic bridge at least momentarily across said contacts after a delay of less than ten milliseconds, a source of electricity, means for coupling each of said detonators in parallel to said source, each of said means except that coupling the last to be fired detonator including a different switch fusehead in series with the detonator coupled thereby, each of said means except that coupling the first to be fired detonator also including a set of spaced apart contacts in series with the detonator coupled thereby, the fusehead and spaced apart contacts connected in series with each detonator being in a different switch, the arrangement being such that as to any two of the plurality of detonators to be fired immediately successively, the fusehead of the switch between said two detonators is in series with one of the two detonators and the spaced apart contacts of the in-between switch is in series with the other of said two detonators whereby said other detonator fires after said one detonator by a time predetermined by the delay time of the in-between switch.

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