Sept. 3, 1963 M. H. NAESETH 3,102,476

ELECTRIC CIRCUIT FOR FIRING DETONATORS CONSECUTIVELY

Filed April 24, 1961

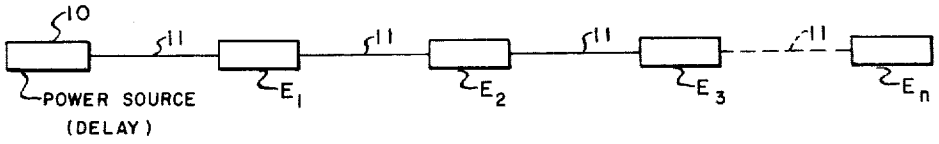

FIG. 1

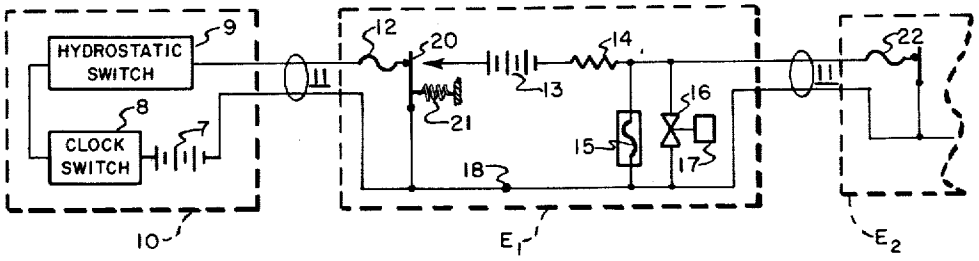

FIG. 2

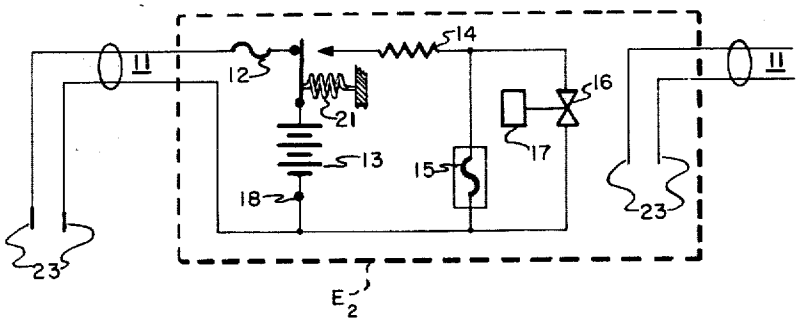

FIG. 3

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United States Patent Office 3,102,476 Patented Sept. 3, 1963

3,102,476
ELECTRIC CIRCUIT FOR FIRING DETONATORS CONSECUTIVELY

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Filed Apr. 24, 1961, Ser. No. 105,239
2 Claims. (Cl. 102—22)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to electrical circuit arrangements for firing consecutively a plurality of explosive charges and more particularly to circuit arrangements for firing explosive charges in sequence with predetermined intervals of time between explosions.

While the present invention may be advantageously employed for various purposes, such as short period delay blasting and in seismic exploration, it is of special utility in producing in a body of water a desired acoustic wave pattern.

Delay electric detonators graded according to the time intervals desired and instantaneous electric detonators fired by a sequence switch mechanism are among the methods utilized for carrying out short period delay blasting and the like.

It is known to be difficult in repetitive manufacturing operations to produce within the desired tolerances delay electric detonators (blasting caps) graded in fractions of seconds up to relatively large time intervals. Also, the use of a sequence switch mechanism generally requires an inconvenient length of leading wires.

An object of the present invention is to provide electrical means for consecutively energizing a plurality of electrically actuated elements.

Another object of the invention is to provide a plurality of separate detonating units connected in cascade so that as each unit is detonated it initiates the actuation of the next succeeding unit.

A further object of the invention is the provision of means in an explosive array of the character indicated whereby the detonation of one unit will actuate the next succeeding unit only when the array is immersed in a conducting medium.

These as well as other objects of the invention will become evident to those skilled in the art by reference to the following description and the annexed drawing which respectively describe and illustrate preferred embodiments of the invention.

In accordance with one embodiment of the invention, the firing of a succession of individually packaged explosive charges by firing their associated electric detonators with delay periods therebetween is accomplished by connecting across a source of current in parallel with the first detonator to be fired a fuse element in the next succeeding charge package, the arrangement being that the detonator is fired only after the fuse element is burned out and the burning out of the fuse element, which provides at least part of the delay, enables the closing of a delay firing circuit in such succeeding package which in turn burns out the fuse element in the adjacent package before firing its own detonator.

In accordance with another embodiment of the invention, the fuse element in each succeeding individual firing circuit is connected in series with the local source of current, and through leads, with two spaced terminals immersed in a nonconductive medium in the immediately preceding charge package and so disposed that when its host package is exploded in a conducting medium such as sea water these terminals are brought into conductive

relationship to thereby complete the circuit through the fuse and the source of current.

Also in accordance with the invention, the delays which may be introduced by the electroresponsive detonator and the fuse element (indicating fuse) are preferably supplemented by an electric delay component, preferably a fuse, connected in parallel with the electric detonator and designed so that it must burn out before an actuating current will flow through the electric detonator. In the first above-mentioned embodiment, this delay component burns first, thereafter the indicating fuse in the succeeding package burns and then the electric detonator is actuated. In the second embodiment mentioned above, the indicating fuse is burned out after the two spaced terminals are brought into conductive relationship by sea water, which results in connecting the current source across the delay component, thereafter the delay component burns out to permit actuating current to flow through the electric detonator. Exemplary time intervals between explosions range between 100 to 600 milliseconds.

In the annexed drawing:

FIG. 1 is a schematic diagram of an explosive assembly which may be utilized in practicing the invention; and

FIGS. 2 and 3 are circuit diagrams of electrical circuits adapted to be employed in the assembly of FIG. 1.

The explosive assembly or array is shown in FIG. 1 as comprising an initiating device **10** and a plurality of individually packaged explosive units E_1, E_2 . . . E_n serially connected together by conductor cables **11** and adapted to be fired in timed sequence as will be described in connection with FIGS. 2 and 3. The length of the cables **11** is such that explosive units are spaced far enough apart to constitute separate charges, i.e., the firing of one unit does not sympathetically fire another unit. The value of n may be up to 20 or more.

FIG. 2 illustrates diagrammatically a preferred electric circuit to be used for selectively firing the various explosive units at the desired intervals between explosions. The initiating device **10** preferably comprises a delay arming circuit which may consist of a source of electric current such as a battery **7**, a clock switch **8** for introducing the required delay and, when the array is to be exploded under water, a hydrostatic switch **9** adapted to be closed only after the device **10** has submerged to a certain depth. The leads in the cable **11** connect the battery **7** and the two switches **8** and **9** in series with an indicating fuse **12** located in the adjacent explosive unit E_1 so that after both switches **8** and **9** are closed the indicating fuse **12** burns out. The indicating fuse **12** holds in open position a switch **20** against the tension of a spring **21** biasing the switch **20** to closed position. The switch **20** is connected in series with a source of current **13**, a current limiting resistance **14** and a parallel circuit consisting of a fuse **15**, a detonator **16** for an explosive charge **17** and, through the outgoing cable **11**, an indicating fuse **22** in the succeeding explosive unit E_2. A pressure arming switch such as a hydrostatic switch **18** is shown included in series with the switch **20** as a safety device when the explosive array is to be utilized under water.

In operation, the clock switch **8** is set with the desired time delay and the whole array is jettisoned in the sea where it sinks to a depth at which the hydrostatic switch **9** arms the initiating device **10** so that when the clock switch **8** completes the circuit the indicating fuse **12** is, after a short delay, burned out to enable the switch **20** to be closed by the biasing spring **21**. The fuse **15**, the detonator **16**, which may be an electric blasting cap, and the indicating fuse **22** in the next succeeding explosive unit E_2 are provided with properties such that when the switch **20** completes the circuit through the source of current **13**, the fuse **15** burns out first, then the indicat-

ing fuse **22** fuses, after which the detonator **16** is actuated to explode the explosive charge **17**. The time delay between the closing of the switch **20** and the firing of the explosive **17** is determined by the burning time of the fuse **15**, the burning time of the indicating fuse **22** and, if desired, by a short delay in the detonator **16**. It will be understood that the entire delay time may be provided by the burning out time of the indicating fuse **22** although it is preferred that the delay time be divided between the fuse **22** and the fuse **15**. Each of the succeeding units E_2 . . . E_n are identical with the explosive unit E_1 except, of course, that in the terminal unit E_n the cable **11** is closed within the unit E_n by an indicating fuse or equivalent time delay fuse.

The embodiment illustrated in FIG. 3 differs from the embodiment of FIG. 2 in that the explosive units E_2 . . . E_n are designed for use exclusively in a conducting liquid such as sea water and depends upon the destruction of the preceding unit to be armed. In this embodiment, the source of current **13** is located to be in both the circuit of the indicating fuse **22** and the switch **20** and the cable **11** originating in the preceding unit is provided with two spaced bare terminals **23** insulated from each other by a nonconductive fluid such as air contained in such explosive unit. When such explosive unit explodes, the terminals **23** are exposed to sea water which closes the circuit through the battery **13** and the indicating fuse **22** which results in fusing of the fuse **22** and the closing of the switch **20** by the action of the spring **21**. Closing of the switch **20** connects the battery **13** in series with the current limiting resistance **14** and the parallel circuit consisting of the fuse **15** and the detonator **16** so that the detonator **16** fires the explosive **17** after the delay required for the fuse **15** to burn out. Obviously in this embodiment the unit E_1 may also be identical with the units E_2 . . . E_n in which case the battery **7** in the initiating unit **10** may be omitted and the terminals **23** connected in series with the switches **8** and **9**.

Indicating fuses adapted to close an auxiliary circuit upon being burned out are on-the-shelf items and the term indicating fuse as used herein is for identification of its function and not a limitation to its structure.

While the preferred embodiments illustrated in FIGS. 2 and 3 have been described in detail, it will be understood that the time delay interval between the firing of the explosive units may be concentrated in a single delay element such as the indicating fuse or may be distributed between two or more delay elements such as the indicating fuse and the detonator with or without the fuse **15**. For the relatively short delays envisioned for the explosive arrays of the invention, delay electric detonators can be made with reasonable accuracy and thus be relied upon for providing at least a portion of the desired delay interval. This is especially true in the arrangement of the present invention since any small variation in one delay interval in no wise affects the preceding or following delay intervals as would be the case where successive firings depend upon ascending time intervals each operating independently of all the others.

Other embodiments and modifications thereof will be obvious to those skilled in the art and all such modifications are intended to be included within the scope of the appended claims.

What is claimed is:

1. Electrical circuit means for consecutively firing a plurality of detonators individually packaged with a plurality of separate explosive charges connected together serially by cables having two conductors, each package including

a switch biased to closed position,

a fuse connected across the two conductors entering the package adapted to hold said biased switch in open position and fusible by an electric current to enable said biased switch to close, and

a source of electric current and a current limiting resistance in series with said biased switch and with a parallel circuit comprising an electric detonator and the switch holding fuse of the next adjacent package and characterized by properties such that when said biased switch closes said fuse in said adjacent package is fused by current from said current source and thereafter the current actuates said detonator,

said parallel circuit being shunted by a second fuse in said package having a resistance such that the second fuse must burn before a fusing current will flow through said fuse in said adjacent package.

2. In electric circuit means for consecutively exploding a plurality of charges including in combination a plurality of serially connected explosive units each having a separate explosive charge, the combination in each of said units of

an electroresponsive detonating device for firing said explosive charge,

a switch biased to closed position,

a source of electric current connectable through said switch to establish an operating firing connection between said detonating device and said current source,

an indicating fuse for holding said switch in open position and fusible to permit said switch to close, and

means operative in the sequence of firing said explosive charge to provide a fusing current through the indicating fuse of the next succeeding explosive unit in the series,

said source of electric current being connected in series with said indicating fuse and with two spaced bare terminals in the immediately preseding explosive unit, and said spaced terminals being disposed so that they will be shorted when their host explosive unit is fired in a conducting fluid.

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