United States Patent

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[72] Inventor George L. Griffith
Coopersburg, Pa.
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[73] Assignee Commercial Solvents Corporation
Terre Haute, Ind.

[54] **TIMED SEQUENCE BLASTING ASSEMBLY FOR INITIATING EXPLOSIVE CHARGES AND METHOD**
3 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **102/22,** 102/28, 102/70.2
[51] **Int. Cl.** **F42d 1/06**
[50] **Field of Search** 102/28, 70.2, 22; 317/80

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Primary Examiner—Verlin R. Pendegrass
Attorney—Janes & Chapman

ABSTRACT: A blasting assembly for timed sequence blasting is provided in which a blasting cap and an electronic timing device are interconnected for detonating a series of explosive charges in sequence. The timing device includes a pulse discharge circuit and a silicon-controlled rectifier which, in combination, receive, store, and then after a predetermined delay, permit current to flow to the blasting cap and detonate it and any explosive charges associated with it.

A method for a timed delay blasting is also provided, in which an electrical charge is established and temporarily stored in a timing device, and released to a blasting cap after a predetermined delay.

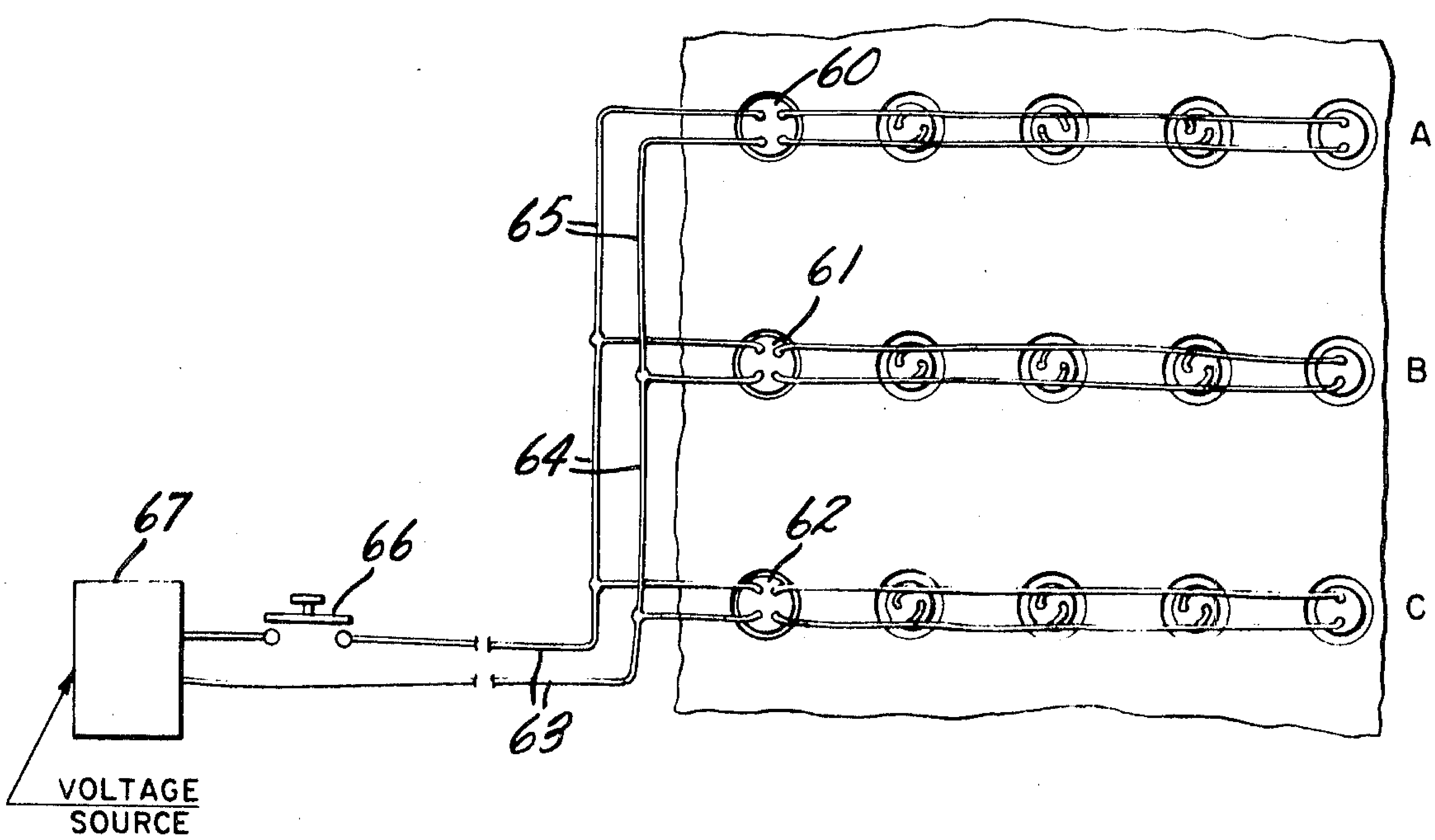


FIG. 1

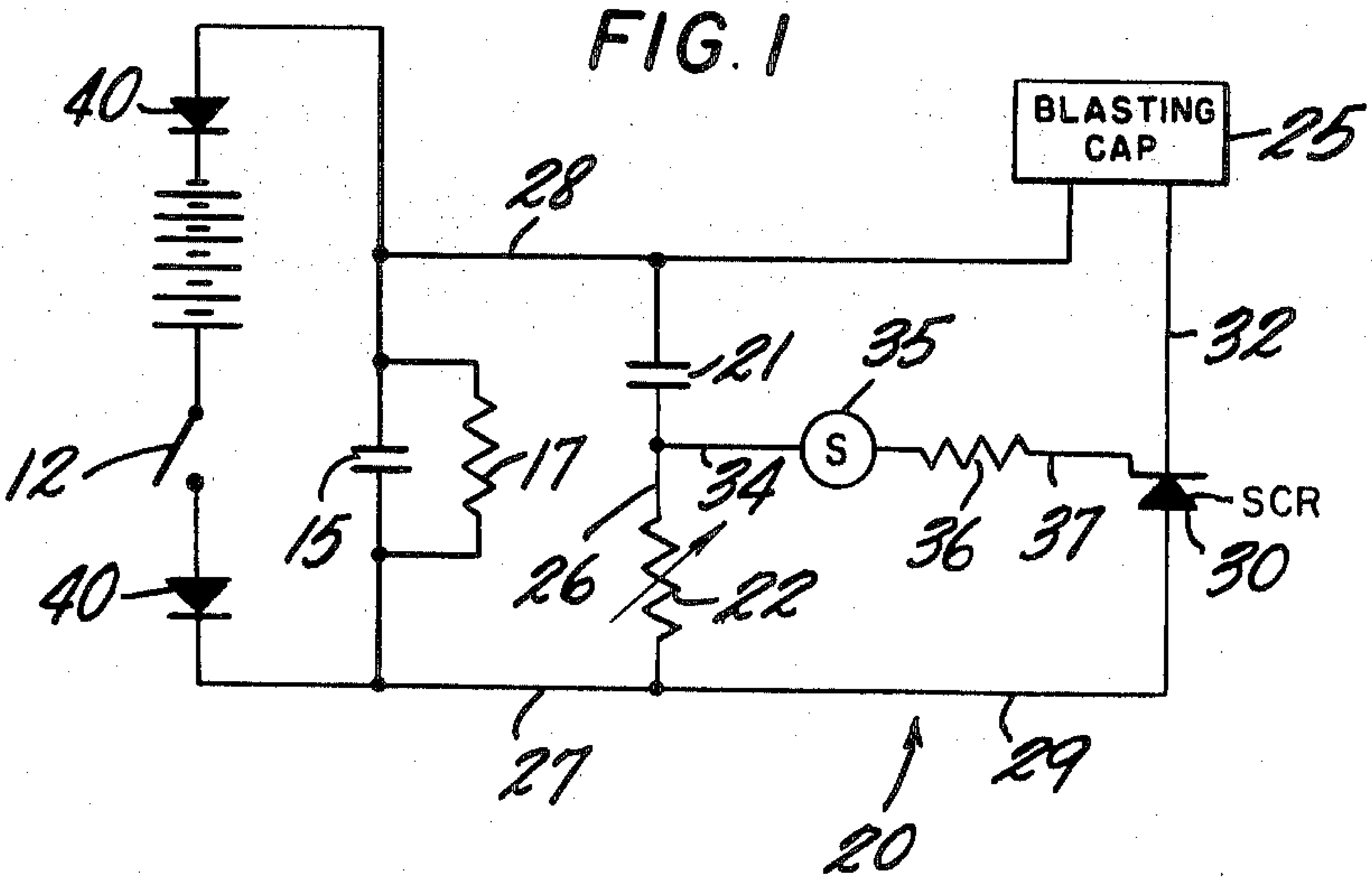


FIG. 2

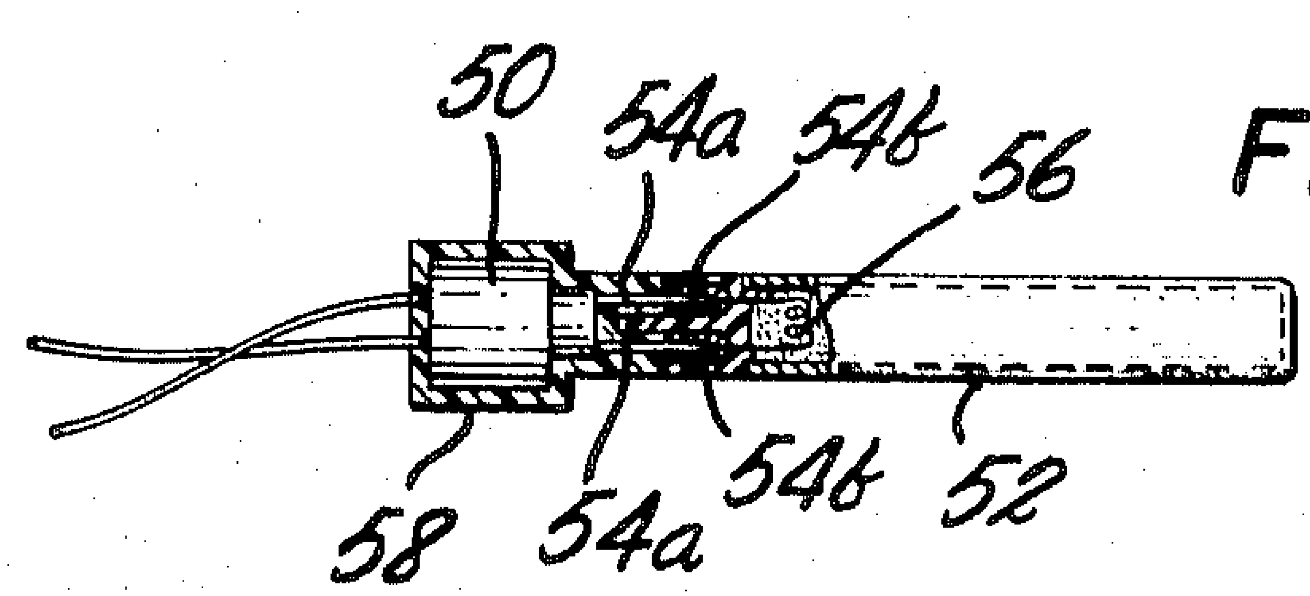
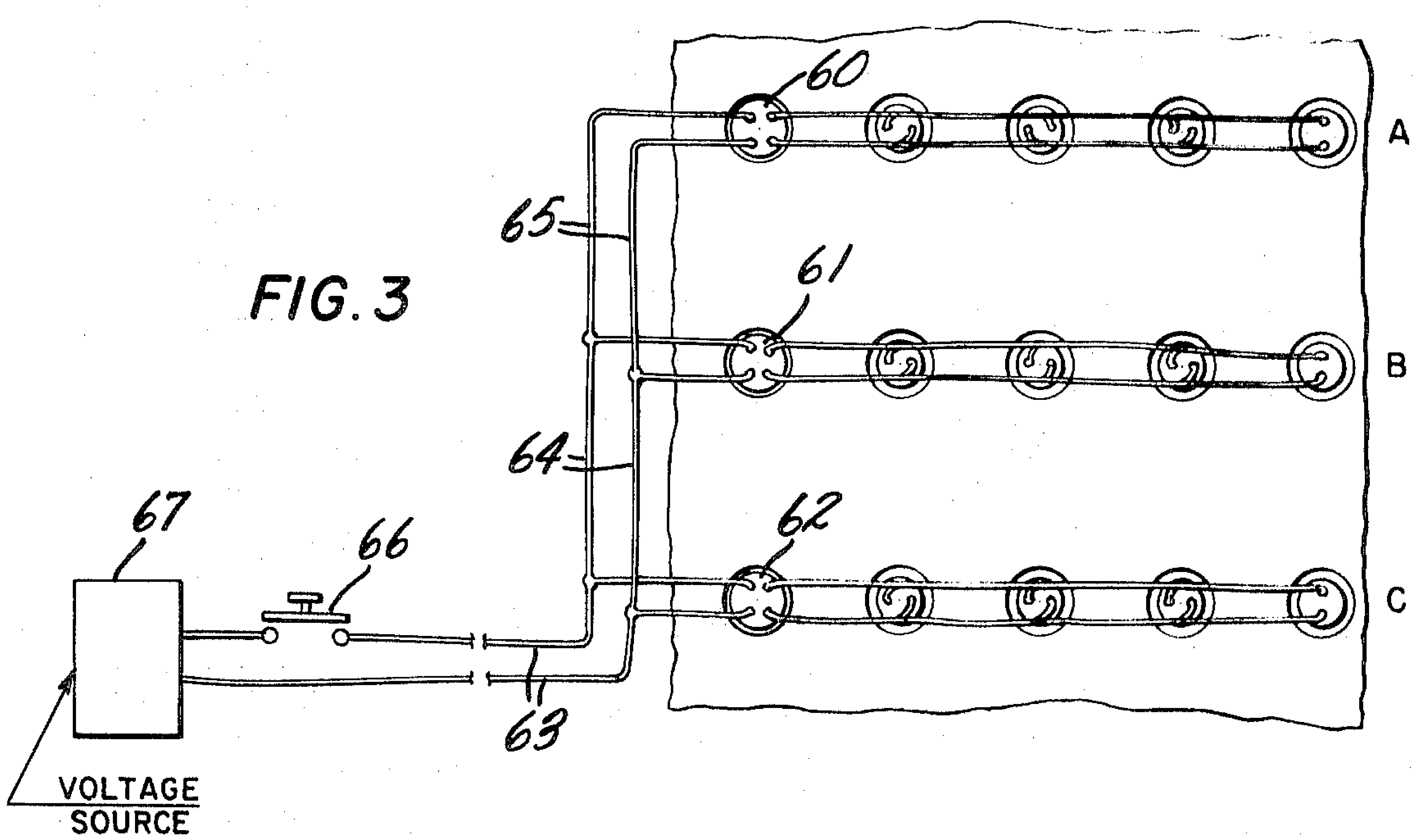


FIG. 3



TIMED SEQUENCE BLASTING ASSEMBLY FOR INITIATING EXPLOSIVE CHARGES AND METHOD

This invention relates to a blasting assembly for initiating explosive charges in a timed sequence, and to a method for electrically timing the firing sequence of a series of explosive initiators in a safe and reliable manner.

The timed sequential initiation of a series of explosive charges has normally been carried out in either of two ways. One is to provide each explosive charge in the series with a blasting cap having a delay element incorporated into it, and use delay elements of appropriate delay times with each charge. Since explosive charges are usually initiated by blasting caps, this has proved to be a convenient way of providing a specified delay for each explosive charge and thereby ensure that the charges are detonated in the proper sequence.

The delay element is composed of a predetermined amount of combustible material which is compacted to a selected density. When the combustible material in the blasting cap is ignited, as, for example, by the closing of an electric circuit, the combustible material burns at a specified rate until the combustion reaches the explosive composition in the blasting cap and initiates it. The rate at which the combustible material burns is determined by the particular material and its density. Thus, for any selected combustible material of a given density the amount of the material used determines the delay. Using this technique, it has been possible to provide delay blasting caps which provide delays of from about 25 milliseconds to about 12 seconds.

Delay blasting caps, however, have been found to have serious drawbacks. Firstly, it is extremely difficult to precisely control the density of the combustible material in the blasting cap so as to ensure an accurate delay, since even a slight variation in density can significantly vary the burning rate of the combustible material. Since in most cases the delay desired is only a fraction of a second, even a small variation in the burning rate can cause quite a large percentage difference in the actual delay obtained. This problem is quite acute when delay caps are used to initiate in sequence one row of explosive charges after another within a few milliseconds of each other. When it is desired to initiate rows of charges in sequence, it is necessary to provide each charge in the row with a delay blasting cap providing the same delay. Each charge in the next row in the sequence is provided with a delay cap of a slightly longer delay. In such a procedure, it is quite possible that since the actual delay provided can vary significantly, the sequence in which the explosive charges are to be detonated is altered due to the fact that a charge in one row may detonate before all the charges in the preceding row detonate.

In instances when a long delay is desired, delay blasting caps of the type described above have a tendency to "cut-off" and not fire at all. In addition, long delay blasting caps are relatively large, and relatively expensive.

A second conventional mechanism for providing a timed sequence of detonation for a series of charges has been to employ a stepping switch. In a stepping switch, a rotor revolves at a given rate across a number of electrical contacts. The explosive charge is timed by connecting the electric line leading to the blasting caps to one of the contacts at a predetermined number of contacts from the main terminal of the switch. Thus, since the rate at which the rotor switch moves across the contacts is known, it is possible to select a delay merely by connecting the lines to the blasting caps to the appropriate contacts.

Stepping switches are quite accurate, and have proved suitable for timing a series of detonations, but they are also bulky and quite expensive. Thus, they are normally placed far from the blast site, in order to avoid the possibility of damage from the explosion or from flying debris. Since it is necessary to run the electrical cables from the stepping switch to each series of charges to be initiated, the expense of the cables and the time consumed in laying the cable often makes the use of a stepping switch quite inconvenient.

In accordance with this invention there is provided a timed electronic-blasting assembly for the timed sequential initiation of a series of explosive charges which is compact, inexpensive and quite accurate. The electronic-timing device which is a part of the assembly is small enough to be made modular as will be explained hereinafter and capable of being plugged into, or otherwise combined with, a conventional electric blasting cap. It can be made inexpensively enough to be disposable, and it is extremely reliable, and provides accurate timing with little chance of error, even in a small fraction of a second.

The timed sequence blasting assembly of this invention comprises, in combination, an electric blasting cap; and electrically connected in series therewith an electronic timing device for connection to a source of direct current between the positive and negative lines thereof. The electronic-timing device comprises a controlled rectifier, preferably a silicon-controlled rectifier, connected in series with the blasting cap and between the positive and negative lines. The controlled rectifier normally blocks current to the blasting cap but permits current to flow to the blasting cap when a pulse of electrical energy is supplied to the gate of the rectifier. The electronic-timing device also includes a pulse-discharge circuit connected to the gate of the rectifier and across the anode-cathode of said rectifier. The circuit after connection to the source of direct current is adapted to progressively accumulate a predetermined amount of electrical charge. The time required to accumulate the charge determines the length of the predetermined delay. When the predetermined charge is reached, it is released as a pulse of electrical energy to the gate of the rectifier, thereby permitting current to flow through the rectifier to detonate the blasting cap.

The method for timed blasting of this invention comprises interposing an electronic sequence timing device before an electric blasting cap leading to an explosive charge; accumulating and temporarily storing an electrical charge in the device; and releasing the charge as an electrical pulse to the blasting cap, after a predetermined delay, thereby detonating the blasting cap and the explosive charge.

This invention also further provides an electronic sequence timer for connecting between positive and negative lines of a direct current source and in series with a blasting cap and especially adapted to be used to detonate a blasting cap and an explosive charge at the blast site, comprising, in combination, a controlled rectifier for connection in series with a blasting cap and between the positive and negative lines, said rectifier normally blocking current flow to the blasting cap, but permitting current to flow to the blasting cap when a pulse of electrical energy is supplied to the gate of the rectifier; a pulse-discharge circuit connected across the anode-cathode of the controlled rectifier and for supplying a pulse of current to the gate of the said rectifier to permit current to flow from the anode to the cathode of the rectifier and thence to the blasting cap; said pulse-discharge circuit comprising a threshold voltage switch connected to the gate of the rectifier and adapted to permit current to flow to the gate of the rectifier whenever there is a predetermined voltage across said switch; a resistor connected between said switch and one of said lines; a capacitor connected between said switch and the other of said lines and in series with said resistor; and a second capacitor connected in series with both of said resistor and capacitor and between said positive and negative lines, said second capacitor being charged upon connection to said power source and thereafter acting as an alternate voltage source.

The circuit of the timed sequence blasting assembly of this invention can be composed of a few relatively small sturdy components. For example, the circuit is normally made up of capacitors, resistors, a controlled rectifier and a switch which can be a diode, a transistor switch, a unijunction transistor or the like. One suitable transistor switch is G.E. transistor switch No. D13D1.

Since such components are quite small, the circuit can be extremely compact. By enclosing the circuit in a small rugged metal or plastic housing, it is possible to connect the timing device of the invention directly to the blasting cap at the blast site and recover the timing circuit undamaged after detonation of the blasting cap. However, since the instant-blasting sequence-timing circuit can be made quite inexpensively, it need not be recovered. Furthermore, due to its compact size, the timing circuit of the blast assembly can be incorporated into its own separate housing and formed as a modular component that can attach to the blasting cap as a separate component which mates with the blasting cap to form a unitary blasting assembly. For example, the timing circuit can have a housing formed with male connectors. The blasting cap can be formed with a female receptacle such as shown in U.S. Pat. No. 3,179,050 to Griffith and thus the timing circuit can be plugged directly into the blasting cap. In this manner, the timing circuit can be easily attached to and detached from the blasting cap as a separate modular component of the blasting assembly.

Normally, blasting sequence timers are employed to detonate rows of charges in sequence, with all the charges in each row detonated simultaneously. If such a procedure is desired, it is merely necessary to interconnect the electric blasting caps for each charge to a common terminal and connect that terminal in series with the sequence-timing circuit of the invention. Thus, only one blast sequence-timing device would be required for each row. Furthermore, although the power source may be located at quite a distance from the blast site, each row need not be connected back to the power source but can be connected to the blast sequence-timing device in the preceding row of charges. In this manner, a substantial amount of cable is saved. As indicated, the electronic-timing device includes a controlled rectifier and a pulse-discharge circuit. The controlled rectifier is a solid state device and preferably is a silicon-controlled rectifier but it can also be a germanium- or selenium-controlled rectifier. Such rectifiers control current flow therethrough by blocking current flow from the anode to the cathode until a gating current (which can be quite small) actuates the gate of the rectifier and which then permits current to flow from the anode to the cathode and to the load. Any similar electronic solid state device which operates in the same manner can be employed and is within the term "controlled rectifier."

The pulse discharge circuit can be any circuit adapted to produce a pulse of current at the gate of the controlled rectifier after a predetermined delay. A preferred pulse discharge circuit is described hereinafter. Another suitable circuit is shown in U.S. Pat. No. 3,162,772 to Smith, Jr. Such circuits provide a pulse of electrical energy after a predetermined delay by employing a resistor and capacitor in series with the source of direct current, and a threshold voltage switch connected between the resistor and the capacitor and the gate of the rectifier. The threshold voltage switch which can be a zener diode, a transistor switch, a unijunction transistor or the like, permits current to flow to the gate of the rectifier only when a predetermined voltage is present across it. The switch thereby provides a pulse of electrical current as soon as the threshold voltage is reached.

The timing of the circuit is primarily controlled by the resistor and capacitor, and their resistance and capacitance, respectively, are therefore selected to give the length of delay desired. When the circuit is connected to a direct current power source, the capacitor is charged at a rate determined by the amount of resistance provided by the resistor and when the charge on the capacitor, without exceeding the capacitance of the capacitor, reaches the threshold voltage of the switch, an electrical pulse is discharged. Since the rate is determined by the resistance of the resistor, the length of the delay provided after the power source is connected into the circuit can be adjusted by selecting a resistor whose resistance is such or can be varied to be such that the desired delay is obtained. The amount of capacitance of the capacitor and the threshold voltage of the switch, as well as the voltage of the power source all affect the length of the delay but the capacitance and threshold voltages are easily fixed, for a given circuit, and the delay obtained is adjusted by varying the amount of resistance of the resistor in series with the capacitor according to the delay desired. This is most easily done by use of a variable resistor. The circuit preferably employs only resistors, capacitors, and a solid-state-switching mechanism, and this is quite compact.

In the preferred embodiment of the timing circuit of this invention, an additional capacitor is provided as a component of the circuit. The additional capacitor acts as a storage capacitor and is connected into the circuit in parallel to the power source. After the switch is closed, the storage capacitor is charged and each charged timing device is then operative according to its predetermined delay, independently of the others. Thus, the operation of the blasting device does not depend on whether a connection to the power source or to any other circuit is maintained. Therefore, even if a wire should be broken by flying debris, the initiation of the subsequent rows of charges will not be prevented and the sequence will not be altered.

IN THE DRAWINGS

FIG. 1 is a circuit diagram of the electronic sequence-timing circuit in accordance with this invention for connection to an electric blasting cap.

FIG. 2 is a cross-sectional view of an electronic sequence-blasting assembly of the invention showing a blasting cap and the timing circuit shown in FIG. 1.

FIG. 3 is a schematic view of a blasting system incorporating the electronic sequence timing assembly of the invention.

The timing circuit, shown in FIG. 1, is composed of a direct current voltage source such as a 48-volt dry cell battery connected in series to a switch **12** and a 100 μf. storage capacitor **15**. A resistor **17** is connected in parallel to the capacitor **15**. The function of the resistor **17** and the capacitor **15** will be explained more particularly hereinafter. The voltage source is also connected in series with a pulse-discharge circuit **20**, which is connected to a blasting cap **25** via a silicon-controlled rectifier **30**. The pulse-discharge circuit has a capacitor **21**, and a resistor **22**, connected in series with each other. The resistor **22** and the capacitor **21** can be variable. The resistor **22** and capacitor **21** control the timing of the circuit. The time required to charge the capacitor **21** determines the delay provided by the circuit. Thus, the timing of the pulse discharge can be varied according to the amount of resistance provided by the resistor **22**, or the capacity of the capacitor **21**. These values can be varied each time the circuit is used if desired. The resistor **22** and the capacitor **21** are connected to each other by a line **26** and are connected to the voltage source via lines **27** and **28** respectively.

The resistor **22** is connected to the anode of the silicon-controlled rectifier **30** by line **29**. The silicon-controlled rectifier is connected in series with the blasting cap **25**, via line **32**. The blasting cap **25** is also connected in series with the voltage source through line **28**. Since normally the silicon-controlled rectifier **30** does not pass current through the line **32**, the blasting cap is not initiated. The gate of the silicon-controlled rectifier **30** is connected to a switch **35**, through a current-limiting resistor **36** and the line **37**. The current-limiting resistor **36** has been found to improve the accuracy and reliability of the timing circuit, but it can be omitted. The switch **35** in turn is connected to the line **26** between the capacitor **21** and the resistor **22**. The switch **35** can be a transistor switch, a Zener diode, or any compact switch mechanism which operates upon the development of a threshold voltage across it, prior to which current will not pass current through it. The switch **35**, for example, can be a unijunction transistor, in which case the line **34** would be connected to the emitter of the transistor, and the line **37** would be connected to one of the bases. In addition, the two bases would each be connected into the circuit via unequal resistors to provide a reference voltage between the bases, such as shown in U.S. Pat. No. 3,162,777 to Smith.

Diodes 40 are provided in the circuit to isolate the circuit from any feedback from other pulse-discharge circuits which may be connected in parallel to the circuit 20, and from any other possible sources of electrical energy which could possibly affect the operation of the circuit.

Operation of the circuit is as follows: When the switch 12 is closed, current flows through the diodes 40, charging the storage capacitor 15 and the capacitor 21. Once the capacitor 15 has been charged (which occurs immediately), the voltage source can effectively be removed from the circuit, since the capacitor will then serve as the voltage source.

The resistor 17 is provided to drain the charge from the storage capacitor 15 after a predetermined time, so that if for some reason the explosive connected to the circuit is not detonated, there is no possibility that it can detonate at a later time, when such detonation is not desired.

The capacitor 21 is charged through the variable resistor 22, and as indicated above, the amount of the resistance provided by the resistor 22 determines the length of time required to charge the capacitor 21. When a sufficient charge has developed on the capacitor 21 to reach and exceed the threshold voltage of the switch 35, the switch 35 permits current to flow through the resistor 36, to the gate of the silicon-controlled rectifier 30. This reverses the polarity of the gate, and permits current to flow through the line 32, thus detonating the blasting cap.

As indicated above, the timing assembly can be made extremely compact, due to the fact that it employs few and small components, such as a transistor switch and silicon-controlled rectifier.

The instant timing device can also be made to plug into or otherwise attach in a modular manner directly to a blasting cap, such as shown in FIG. 2.

In FIG. 2, a blast sequence timing assembly of this invention is shown. It comprises a timing circuit 50 as described in connection with FIG. 1 connected to a blasting cap 52. The timing circuit is housed in a blasting casing 58 and is plugged into the blasting cap 52 by means of a mating plug 54*a* and receptacle 54*b* connection on the timing circuit housing 58 and blasting cap 52. The receptacle 54*b* in the blasting cap 52 is connected to a wire 56 which passes through the explosive in the blasting cap for detonation of the explosive when current passes through the wire.

The importance of the provision of the capacitor 15 and the resistor 17 can be appreciated by reference to FIG. 3, in which a blast-sequence-timing system is shown. In the blast system shown in FIG. 3, it is desired that the rows A, B, and C of explosive charges be initiated in sequence, and that a delay be provided for the first row, A, after the switch is closed. Each row is provided with timing assemblies 60, 61, 62, comprising a timing circuit as shown in FIG. 1 connected to a blasting cap in the manner similar to that shown in FIG. 2.

Each of the assemblies 60, 61, 62 is identical, with the exception that the value of the resistor 22 is different for each circuit, and thus provides a different delay. The resistor 22 for timing assembly 60 is 500 ohms, and in combination with a 25-μf. capacitor provides a 38 milliseconds delay after closing of the switch. Similarly, for timing assemblies 61 and 62, resistors of 4 k. ohms and 9 k. ohms are provided, thus producing 78 and 128 milliseconds delays, respectively. Delays of from about 10 milliseconds to about 30 seconds can be conveniently obtained by varying the values of the resistor 22 and capacitor 21.

The blast timing assembly 62 is connected via two lines 63, to a voltage source 67 and switch 66. Branch lines 64 and 65 connect the blast timing assemblies 61 and 62, respectively, to the main lines 63. Thus, since each row of explosive charges is provided with its own timing assembly, the wires connecting the timing devices 60, 61, 62 to the voltage source need not all extend back from the blast site to the voltage source 65 since they can be interconnected one to the other. Moreover, due to the provision of the capacitor 15, once the switch is closed, permitting the current to flow from the voltage source 65 to each of the blast timing assemblies 61, 62, each blast timing is then completely independent of the others as well as the voltage source. This is due to the fact that the storage capacitor 15 acts as the voltage source after being charged. Thus, if the lines 63, 64, or 65 are severed after the switch has been closed, for example, due to flying debris from the detonation of the first row in the series of charges, the sequence timing of the second row and third rows of charges is not affected.

In FIG. 1 a single-timing circuit is shown. However, a single modular unit can if desired incorporate several such circuits, with the output of each circuit providing a different delay. The circuits can be connected in parallel or in series. If the circuits are connected in parallel they will be independent of each other, and subsequent rows of charges will be detonated, although a malfunction in the firing of a preceding row may have occurred. It is also possible to connect the circuits in series such that the pulse that fires one row begins the timing of the next circuit. This can be accomplished by merely connecting pulse-discharge circuits in series with each other through the downline side of the silicon-controlled rectifier. In this manner it is assured that a subsequent detonation will not occur unless an earlier detonation in the series has taken place.

Having regard to the foregoing disclosure, the following is claimed as the inventive and patentable embodiments thereof:

1. A blasting assembly including a plurality of explosive charges arranged for initiation by groups in a timed sequence, comprising, in combination, a plurality of explosive charges arranged in series in at least two groups, each group having a built-in timed delay that is different from the timed delay of the other group or groups for initiation of each group separately in a timed sequence, the groups of explosive charges being connected together in an electric-timing circuit having positive and negative lines; a single voltage source, and a single switch in electrical connection therewith, controlling the flow of electric current to the groups of explosive charges via the positive and negative lines; a timing assembly for each group of explosive charges comprising, in combination, an electrically actuated blasting cap and, in electrical connection therewith, an electric-timing device comprising a controlled rectifier connected in series with the blasting cap between the positive and negative electric lines, the rectifier being adapted normally to block current from flowing to the blasting cap, but to permit current to flow to the blasting cap when a pulse of electrical energy is supplied to the gate of the rectifier, and a pulse-discharge circuit connected to the gate of the rectifier and across the anode-cathode of the rectifier, the pulse-discharge circuit being adapted upon flow of electric current thereto when the switch is closed to accumulate an electrical charge over a period of time corresponding to a predetermined delay until a desired amount of charge is reached, and then to release the charge as a pulse of electrical energy to the gate of the rectifier, thereby to permit current to flow through the rectifier to detonate the blasting cap, the pulse-discharge circuit in the controlled rectifiers of each group of explosive charges being arranged to progressively accumulate the electrical charge for different periods of time, corresponding to different predetermined delays, whereby after the switch has been closed, and current permitted to flow from the voltage source to each of the timing assemblies of each group, the timing delay in the detonation of the blasting cap thereby initiated for each group is independent of the others, as well as of the voltage source, and the explosive charges in each group are detonated in timed sequence automatically.

2. A blasting assembly in accordance with claim 1, in which the electronic-timing device is in modular form, and is mounted on the blasting cap to provide a unitary assembly, the timing device and the blasting cap each being provided with mating plug and receptacle connections providing for flow of the pulse-discharge from the timing device to the blasting cap when the timed delay has elapsed.

3. A blasting assembly in accordance with claim 1, in which the controlled rectifier is a silicon-controlled rectifier.

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