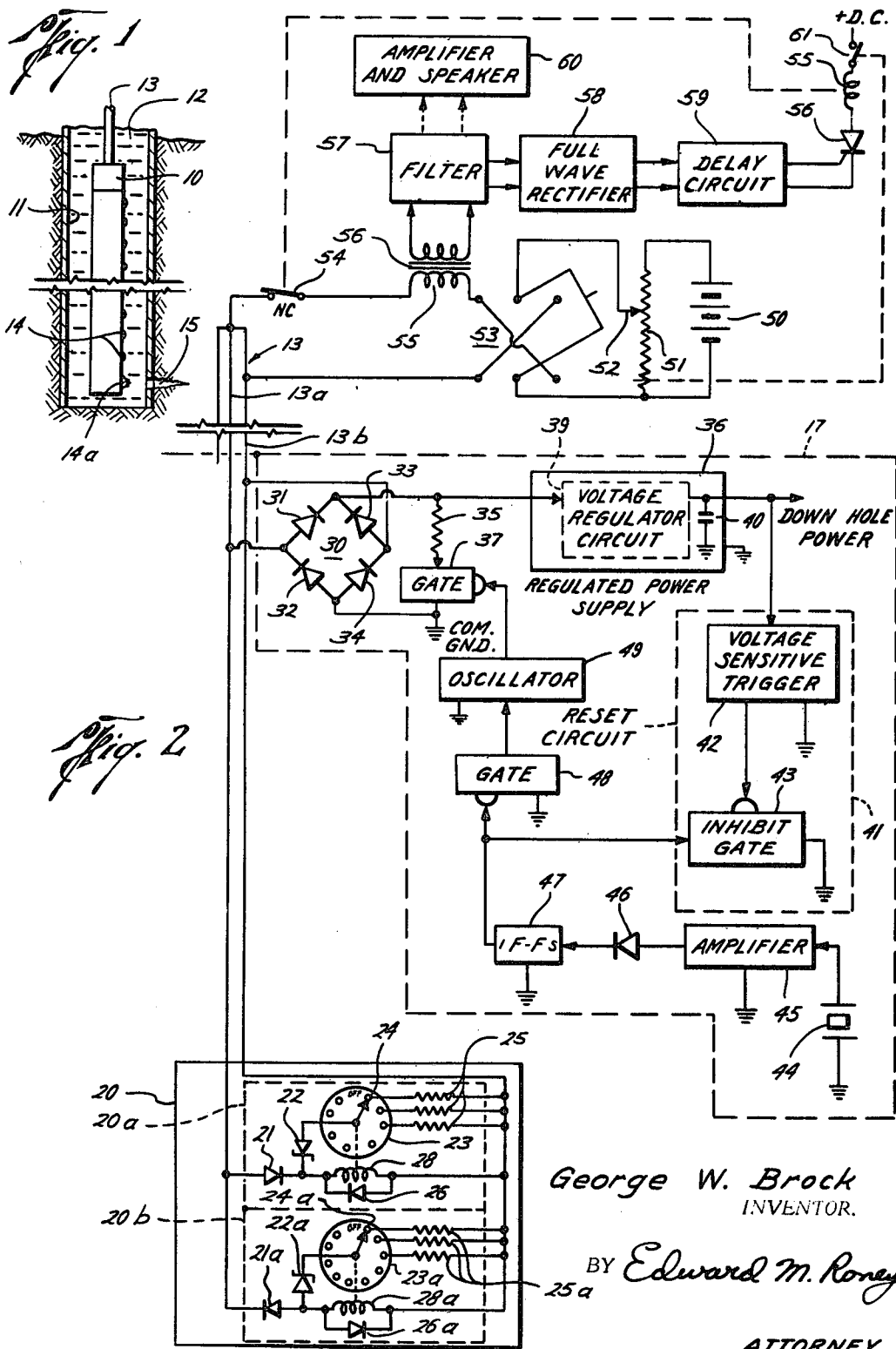


Feb. 10, 1970

G. W. BROCK
METHODS AND APPARATUS FOR DETECTING THE SUDDEN
MOVEMENT OF A TOOL IN A WELL
Original Filed Aug. 1, 1966

3,495,212



1

3,495,212

METHODS AND APPARATUS FOR DETECTING THE SUDDEN MOVEMENT OF A TOOL IN A WELL

George W. Brock, Houston, Tex., assignor to Schlumberger Technology Corporation, New York, N.Y., a corporation of Texas

Continuation of application Ser. No. 569,316, Aug. 1, 1966. This application Sept. 5, 1968, Ser. No. 768,582

Int. Cl. G01v 1/22, 1/26, 1/40

U.S. Cl. 340—18

26 Claims

ABSTRACT OF THE DISCLOSURE

A downhole relay system is associated with a perforator for initiating and indicating sequential operations. Power is supplied via a pair of conductors to the relay system. As the power is increased, a downhole relay is actuated to step a switch and connect an explosive means to the conductors. At a greater power level, the explosive means is detonated. In a downhole signaling system, the power is operative to enable the system and motion of the tool upon firing is detected to operate a frequency device to place a frequency signal on the conductors. The downhole systems can be selectively operated by positive and negative potentials. In the surface equipment, the frequency signal is detected to operate a drop-out switch and indicate initiation of the explosive means.

This application is a continuation of applicant's co-pending application Ser. No. 569,316, filed Aug. 1, 1966. The co-pending application Ser. No. 569,316 has been abandoned.

This invention relates to methods and apparatus for detecting the sudden movement of a tool in a well and providing in indication thereof to the surface of the earth, and more particularly, to methods and apparatus for detecting the detonation of explosive charges set off by a tool in a well wherein a monocable is utilized both to carry current to a detonating means in the tool and to provide the indication of that detonation to the surface of the earth.

The invention has special utility in detecting the detonation of those explosive charges known as shaped charges by a well perforating tool. In well perforating, a number of perforations are placed at carefully selected points in a well. To accomplish this, apparatus carrying a number of shaped charges is lowered into a well to a particular depth where a perforation is to be placed. The first shaped charge is then detonated and the apparatus is repositioned to another depth for the detonation of another shaped charge. This procedure is repeated throughout the well.

Each of the shaped charges must have a separate detonator and be isolated from the detonator of other shaped charges so as to allow the selective detonation thereof. In the usual shaped charge systems, a so-called monocable supports the perforating tool in the well and supplies current through a single conductor contained within the cable to the explosive charge detonating means in the tool, the current returning through the armor on the outer portion of the cable to the surface of the earth. Thus, since only one conductor pair is utilized, a control system must be included in the detonating means at the tool to guarantee that the shaped charges are detonated in the designated sequential manner.

It is desirable when running a tool in the well for detonating shaped charges to be able to detonate as many charges in one trip into the well as may be desired and to detonate these charges in a predetermined sequence

2

to avoid perforating the well at an undesired depth. To accomplish this, a switching means within the detonating means at the tool is necessitated for switching between the various shaped charges in a sequential manner. However, when utilizing such a switching means, a danger arises in the possibility of erroneously switching from shaped charge to shaped charge before it is desired to do so if the power remains on the monocable for an extended period of time.

It has been found that not all of the shaped charges will be detonated when current is applied through the monocable to the individual shaped charges in the tool. Several systems have been proposed for determining when these shaped charges fail to detonate. One such method is to measure the current passing through the monocable to the detonating means, on the basis that there will be a sudden change in current when the detonator of the shaped charge is detonated. This is based on the fact that the detonator which is electrically coupled to the monocable will disintegrate with the detonation, thus hopefully causing a change in impedance across the detonator of the shaped charge. However, it has been found that there is not always a current change when the shaped charge is detonated due to such things as conductive gases being present in the vicinity of the detonator for a short period of time after detonation, and the drilling mud contained in the borehole rushing into the detonator area immediately after detonation. Also, there is a possibility that spurious signals will be generated on the monocable line before or after the explosive charge is detonated.

Other systems have utilized concussion switches at the tool to break contact with the current supplying means at the surface of the earth due to the shock or sudden movement of the tool, and thus provide an indication of the detonation of the explosive charge. However, the problem still remains of spurious signals being momentarily generated on the monocable line. Additionally, there is a danger in such a concussion switch arrangement of the switching means within the detonation means continuously stepping between several ones of the shaped charges.

It is therefore an object of the invention to provide new and improved methods and apparatus for detecting the sudden movement of a tool in a well.

In accordance with one feature of the methods and apparatus of the present invention, the sudden movement or acceleration of a tool on a well cable is detected and a control signal indicative of such an acceleration is generated. A signal at a predetermined frequency is then generated for transmission to the surface of the earth in response to the control signal. At the surface of the earth, the frequency signal can then be detected to thereby indicate the acceleration of the tool. This acceleration detection is especially desirable for use with well perforators for detecting whenever an explosive charge has been detonated.

In accordance with another feature of the present invention, apparatus in the tool for generating the frequency signal can take the form of a variable impedance means directly or nonreactively coupled across input terminals which can be connected to the cable conductors. Upon the occurrence of an acceleration of the tool, a changing means operating at a predetermined frequency changes the impedance of the variable impedance means to modulate an electrical parameter, such as current, already existing in the cable conductors. By so doing, the magnitude of the modulated parameter will vary without reversing polarity. This is especially desirable in well perforating systems which utilize opposite polarity control techniques

wherein the frequency signal will not cause an undesirable polarity inversion.

In accordance with another feature of the present invention, apparatus at the surface of the earth for receiving this frequency signal can take the form of an input terminal adapted for connection with the cable conductors and a receiving means for receiving a frequency signal from the input terminal. This frequency signal can then be used to disconnect the receiving means from the input terminal. Desirably, this disconnection process is delayed for a sufficient time interval to insure that the frequency signal is genuine. Thus, by supplying power to the receiving means to power the well tool, the frequency signal will operate to remove power from the well tool each time the frequency signal is received. This is especially desirable in well perforator systems because, by removing power after a detonation, the possibility of inadvertently detonating another explosive charge will be substantially eliminated.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, the scope of the invention being pointed out in the appended claims.

Referring to the drawings:

FIGURE 1 shows typical perforating apparatus of the type utilized with the present invention in the well bore; and

FIGURE 2 illustrates shaped charge detonating means along with a circuit for detecting a sudden movement or acceleration of the tool within the well bore in accordance with the present invention.

Looking now at FIGURE 1, there is shown a perforating tool 10 within a well bore 11. The well bore 11 contains a conductive drilling fluid or mud 12. The perforating tool 10 is supported in the well bore by a monocable 13. The perforating tool 10 includes a plurality of shaped charges 14, the bottom shaped charge 14a having already been detonated so as to produce a perforation 15. The tool 10 is now ready to be moved to another depth to detonate another shaped charge 14.

Looking now at FIGURE 2, there is shown a schematic representation of the apparatus for detecting a sudden movement of the tool after the detonation of an explosive charge. An example of an explosive charge detonation means which could be used with the detecting apparatus of the present invention is designated 20. The monocable 13, along with supporting the tool 10 in the well bore, connects the electrical circuitry at the surface of the earth to the electrical circuitry contained within the fluid-tight housing portion (not shown) of tool 10. The monocable 13 comprises a central electrical conductor 13a and the outer armor portion 13b.

Looking at a first portion 20a of the explosive charge detonating means 20, the central conductor 13a is connected to the anode of a diode 21, the cathode of diode 21 being connected through the solenoid 28 to the armor 13b of monocable 13 and to the cathode of a Zener diode 22, the anode thereof being connected to the switch contact arm of a rotary switch wafer 23 having plurality switch contacts 24. These switch contacts 24 on wafer 23 are individually connected through a plurality of explosive charges 25 to the armor 13b. Each explosive charge 25 is shown as a resistor, signifying the electrical significance of the explosive charge. In most cases, this resistor would comprise a detonator of the explosive charge.

Although there are other suitable mechanisms that could be used, the switch mechanism for moving the switch contact actuated by solenoid 28 has a pawl (not shown) that indexes a rotatable ratchet wheel (not shown) each time the solenoid 28 is energized and remains in engagement therewith so long as the solenoid 28 is energized. Then when the solenoid 28 is de-energized, the pawl returns and engages the next turn on the ratchet wheel. Thus, by successively energizing and re-energizing the solenoid 28, the contact arm is advanced one position at a time around switch wafer 23.

The apparatus shown within the portion 20b of explosive charge detonating means 20 is identical with the apparatus of portion 20a with the exception that the diodes are reversed. The center conductor 13a is connected to the cathode of diode 21a, the anode thereof being connected to solenoid 28 and the anode of a Zener diode 22a. The cathode of Zener diode 22a is connected to the switch contact arm of switch 23a, the contacts 24a being connected to explosive charges 25a. Explosive charges 25a and solenoid 28a are returned to the armor 13b. Diodes 26 and 26a are standard arc suppression diodes.

Looking now at the downhole detection circuitry 17, the center conductor 13a and armor 13b are connected across a full-wave rectifier circuit 30. The center conductor 13a is connected to the anode of a diode 31 and the cathode of a diode 32 and the armor 13b is connected to the anode of a diode 33 and the cathode of a diode 34. The cathodes of diodes 31 and 33 are connected to one side of a relatively low impedance resistor 35 and to the input of a regulated power supply 36. The anode of diodes 32 and 34 are connected to the common ground of the downhole detecting circuitry 17. This is the ground circuit designated throughout circuit 17. The other side of resistor 35 is connected across a gate 37 to ground.

The regulated power supply 36 includes a voltage regulator circuit 39, of standard design on the input thereof, for maintaining a constant voltage output. The regulated power supply 36 also includes a shunt capacitor 40 connected between the output of voltage regulator circuit 39 and ground. The output from voltage regulator circuit 39 is connected to the input of a reset circuit 41. Within reset circuit 41, this input is connected to the input of a voltage sensitive trigger 42, which comprises any standard type of circuit for generating an output signal whenever the input voltage attains a desired level, such as a Schmitt trigger. The output from voltage sensitive trigger 42 is connected to the control terminal of an inhibit gate 43. The output from regulated power supply 36 is also supplied to the various circuits within downhole detecting circuitry 17 for supplying power thereto. If desired, regulated power supplies could be utilized at various points in the network supplying power to the circuits within downhole detecting circuitry 17 to provide isolation between the various circuits.

A transducer means 44 is connected between ground and the input to an amplifier 45. Transducer means 44 comprises any known type of device for generating an electrical signal in response to a mechanical shock or acceleration. In this case, transducer means 44 is of the type which internally generates an electrical signal, but could comprise any other type of shock or acceleration sensing means wherein a parameter, such as resistance, is changed in response to shock, thus requiring an external voltage source. The output of amplifier 45 is connected through forward biased diode 46 to the set input of a flip-flop 47. The "1" output from flip-flop 47 is connected to the control terminal of a gate 48 and to the input to the inhibit gate 43, the output of inhibit gate 43 being connected to ground. The gate 48 is connected to the initiate input of an oscillator 49 in a suitable manner. For example, the energization of gate 48 could provide power from power supply 36 to oscillator 49, to enable oscillator 49 to provide an output signal. Alternatively, gate 48 could connect a suitable point within oscillator 49 to ground (or the source of power) so as to inhibit the operation of oscillator 49 until gate 48 is energized, etc. Oscillator 49 could generate any type of output signal, e.g., sinusoidal, square wave, etc.

The output from oscillator 49 is connected to the control terminal of the gate 37. Gates 37 and 48 are of the standard enable type gate wherein a signal applied to the control terminal thereof will cause a very low impedance across the gate. On the other hand, the inhibit gate 43 will allow the input applied thereto to pass through to the output thereof until a signal is applied to its control

5

terminal, at which time the input is inhibited from reaching the output thereof.

Looking now at the circuitry at the surface of the earth, a battery 50 is connected across the resistance portion of a potentiometer 51. The wiper arm 52 of potentiometer 51 and one side of the resistance portion thereof are connected to the common terminals of a suitable polarity reversing switch 53. Thus, the magnitude and polarity of the current to monocable 13 can be controlled by this means. The center conductor 13a of monocable 13 is connected through a normally closed switch 54 to the primary winding 55 of a transformer 56. The other side of primary winding 55 and the armor 13b of monocable 13 are connected to the polarity reversing switch 53 in a suitable manner.

The secondary winding of transformer 56 is connected to the input of a filter 57 which is designed to pass the frequency of oscillator 49. The output from filter 57 is connected to a full-wave rectifier 58, the output of which is connected to the input of delay circuit 59. Delay circuit 59 is of the well known type wherein a voltage must be present on the input for a given period of time before a signal is generated from the output thereof. If the voltage on the input of delay circuit 59 is erased before the given time interval, there will be no output signal present. One side of the output of delay circuit 59 is connected to the gate or control input of silicon controlled rectifier 56 and the other output is connected to the cathode of silicon controlled rectifier 56. The anode of silicon controlled rectifier 56 is connected through a relay solenoid 55 and a normally closed mechanically interlocked switch 61 to a DC voltage source. The normally closed switch 61 is mechanically coupled to potentiometer 51 in such a manner that switch 61 will open when wiper arm 52 approaches the zero position of potentiometer 51 and will close when wiper arm 52 moves upward. This switch 61 is a standard type, for example, a V3-1 switch manufactured by Microswitch, Inc. Alternatively, the relay solenoid 55 could be electrically connected to wiper arm 52.

Now concerning the operation of the explosive charge detonating portion of FIGURE 2, the switch contact arms of the rotary switch wafers 23 and 23a, are initially in the "off" position and the wiper arm 52 of potentiometer 51 is initially in the zero position. To detonate one of the explosive charges 25, within the first portion 20a, the polarity reversing switch 53 is thrown to the left thus causing center conductor 13a of monocable 13 to be positive with respect to the armor 13b. The wiper arm 52 of potentiometer 51 is then moved upward from the zero position of potentiometer 51 thus increasing the magnitude of voltage across the monocable conductors 13a and 13b. With this positive polarity, diode 21 only will conduct. When the current through solenoid 28 is great enough, solenoid 28 is actuated and will cause the switch contact arm of wafer 23 to move one step. This puts the switch contact arm of wafer 23 in the position shown in FIGURE 2, which is the first contact of wafer 23.

Then, movement of the wiper arm 52 is continued upwardly, thus increasing the voltage across the conductors of monocable 13. At the Zener voltage of Zener diode 22 (which is safely higher than the line voltage required to energize solenoid 28), current will pass through the first switch contact 24 to the first explosive charge 25 to effect detonation. After detection of this detonation (to be described later), switch 54 opens. The procedure is repeated for the detonation of the next explosive charge 25. After all of explosive charges 25 associated with wafer 23 have been detonated, polarity reversing switch 53 is thrown to the right and the same process is repeated for portion 20b of detonating means 20.

Now concerning the operation of the means for detecting when an explosive charge has been detonated, the downhole detecting means 17 detects a sudden movement in the tool 10 and provides a cyclic output signal through the conductors of the monocable 13, which cyclic output

6

signal is detected at the surface of the earth. Looking in detail at the downhole detecting means 17, the power supplied on monocable 13 is rectified by the full-wave rectifier 30 so that the polarity within the downhole detection circuit 17 will be the same regardless of the position of polarity reversing switch 53. The regulated power supply 36 supplies a constant voltage output regardless of the voltage on the conductors of the monocable 13, so long as it is greater than the regulated constant voltage output of circuit 39. Capacitor 40 maintains a relatively constant voltage output from regulated power supply 36 if transients are introduced into the downhole circuitry 17.

When one of the explosive charges 25 or 25a is detonated, the tool 10 will have a sudden movement. This sudden movement causes the accelerometer or shock device 44 to produce an output signal, which is amplified by amplifier 45. The positive output signal from amplifier 45 energizes the set input of flip-flop 47, thus causing a continuous control signal to be applied to gate 48. Diode 46 keeps a negative signal from turning flip-flop 47 back off. The gate 48 enables oscillator 49 which is desirably, but not limited to, a square wave generator. The oscillator 49 supplies a cyclic control signal to gate 37, turning gate 37 on and off in unison with the oscillator output signal. This on and off operation of gate 37 connects resistor 35, which is desirably, a relatively low impedance, to the common ground at intervals determined by the frequency of oscillator 49. This then, causes the total impedance applied across the center conductor 13a and armor 13b of monocable 13 to change at the frequency of oscillator 49, thus causing cyclic current changes through monocable 13 at the same frequency.

At all times during this operation, the polarity of center conductor 13a with respect to armor 13b of monocable 13 never changes from the polarity which was placed on monocable 13 from polarity reversing switch 53. Thus, there is very little chance of energizing the solenoid 28a, and detonating the explosive charges 25a associated therewith within portion 20b of detonating means 20 if the explosive charge 25 associated with portion 20a are presently being detonated, or vice versa. Also, since the current through solenoids 28 and 28a must be first dropped to near zero and then increased again for the switches to step to the next position, the fact that the current is always in the same direction will insure against an erroneous stepping of the switches.

This change in current on monocable 13 induces a signal into the secondary winding of transformer 56 at the surface of the earth. Filter 57 passes only the frequency of oscillator 49 and full-wave rectifier 58 applies a DC output signal to delay circuit 59. After a given time delay by delay circuit 59, the silicon controlled rectifier 56 is enabled, thus energizing relay 55 and opening switch 54. This opening of switch 54 withdraws power from monocable 13. The time delay of delay circuit 59 is great enough to insure that transients on monocable 13 will not cause an erroneous indication of a detonation. Desirably, the time delay of delay circuit 59 is less than the time for one of the solenoids 28, 28a, etc. to switch to the next position, thus insuring against the erroneous stepping of one of the stepping switches, caused by such things as spurious signals picked up on the monocable 13, or a loose contact, etc.

After switch 54 is opened, thus indicating a detonation, the wiper arm 52 of potentiometer 51 is now returned to the zero position. This causes relay solenoid 55 to become de-energized, thus closing switch 54 again, and resets silicon controlled rectifier 56 by opening switch 61. Now, as the wiper arm 52 is moved upward, thus increasing the voltage thereon, to energize solenoids 28 within detonation means 20 to step the switch arm of wafer 23 to the next contact 24, the voltage begins building up on the output of regulated power supply 36, thus applying power to the various downhole circuits.

To guarantee that flip-flop 47 will be set into the cor-

rect state, i.e., no voltage on the "1" output, the "1" output is tied to ground through inhibit gate 43, which has not been energized yet. (Alternatively the "S" input could be tied to ground.) After the output voltage from regulated power supply 36 attains a certain value, the flip-flop 47 will become positioned in the correct (reset) state due to the "1" output being tied to ground. At some higher voltage, voltage sensitive trigger 42 will supply an output signal to inhibit gate 43, thus removing ground from the "1" output and allowing flip-flop 47 to become energized from amplifier 45 when transducer 44 becomes energized.

At some still higher voltage, the solenoids 28 are energized, thus enabling the detonating means 20 to fire another explosive charge 25. This operation is repeated over and over again as each explosive charge 25 is fired. After all of explosive charges 25 within portion 20a of detonating means 20 are detonated, the polarity reversing switch 53 is thrown to detonate explosive charges 25a within portion 20b and the above procedure is repeated.

It can thus be seen that with the apparatus of FIGURE 2, a sudden movement of the tool 10 within the borehole caused by a detonation will be detected and a cyclic output signal supplied to the surface of the earth indicative of that sudden indication, which signal is detected and after a given delay, the power supplied to the monocable 13 is dropped. Since the signal supplied to the surface of the earth is generated by switching a low impedance in and out of the circuit connected to the monocable 13, any chance of erroneously stepping the switches within the detonating means is substantially minimized.

A speaker system could be used with the present invention, if desired, to obtain an audible tone upon the sudden movement of tool 10, but of course, is not necessary to the operation of the invention. This is shown in FIGURE 2 by the dotted lines connecting amplifier and speaker 60 to the output of filter 57.

Although the sudden movement detecting circuit of the present invention has been shown together with the explosive charge detonation means 20 in FIGURE 2, it can be seen that it could be utilized with any other type of detonation means. For example, the detection circuitry of the present invention could be utilized with the detonating means shown in U.S. Patent No. 2,871,784 granted to W. B. Blair on Feb. 3, 1959 or, it could be used in the detonation means shown in FIGURE 2 of copending application Ser. No. 420,345 by John Harrigan filed on Dec. 22, 1964, now Patent No. 3,327,791. Alternatively, the detonation means 20 could comprise just a single explosive charge. Also, it is to be understood that the sudden movement detecting apparatus of the present invention has utility for detecting the sudden movement of any tool, and not just a tool used for shaped charges, or even just for detonation purposes. Also, the sudden movement detecting apparatus of the present invention could be used with other cable means than a monocable, or even transmitted without a cable.

While there has been described what is at present considered to be a preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:
 - a cable having conductor means and capable of supporting the tool in the well, the conductor means adapted to carry current to the explosive charge detonating means in the tool;
 - transducer means in the tool for detecting a sudden

movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the conductor means a predetermined frequency signal in response to an indication of sudden movement of the tool, the conductor means supplying such an output signal to the surface of the earth; and

means coupled to the conductor means at the surface of the earth and responsive to a predetermined frequency signal for indicating a sudden movement of the tool.

2. The apparatus of claim 1 and further including means responsive to the predetermined frequency signal for removing power from the cable conductor means.

3. Apparatus for detecting acceleration of a tool in a well, comprising:

transducer means located in a tool for detecting acceleration of the tool and providing an indication thereof;

means located in the tool and responsive to the indication of acceleration for generating a control signal; and

means located in the tool and responsive to a control signal for generating a predetermined frequency signal representative of an occurrence of acceleration of the tool.

4. A method of determining the occurrence of a sudden movement of a tool in a well, comprising:

detecting a sudden movement of the tool on a well cable and providing an indication thereof;

generating a continuous control signal in response to the sudden movement indication, the control signal continuing after the sudden movement indication has elapsed;

generating a predetermined frequency signal representative of the occurrence of a sudden movement of the tool in response to the control signal; and

detecting the predetermined frequency signal.

5. In an explosive charge detonating system supported by a tool in a well, a method of detecting a sudden movement of the tool after a detonation, comprising:

supplying current from the surface of the earth over conductor means to an explosive charge detonating means in the tool;

detecting sudden movement of the tool in response to actuation of the detonating means and providing an indication thereof;

supplying to the conductor means a predetermined frequency signal in response to the indication of the sudden movement of the tool, the conductor means supplying the predetermined frequency signal to the surface of the earth; and

deriving an indication of the sudden movement of the tool from the predetermined frequency signal.

6. The method of claim 5 and further including the step of removing current from the conductor means when the predetermined frequency signal is detected.

7. The method of claim 5 wherein the step of supplying to the conductor means a predetermined frequency signal includes:

generating a continuous control signal in response to the sudden movement indication and continuing the continuous control signal after the sudden movement indication has elapsed; and

generating the predetermined frequency signal in response to the continuous control signal.

8. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:

a cable having conductor means and capable of supporting the tool in the well, the conductor means adapted to carry current to the explosive charge detonating means in the tool;

transducer means in the tool for detecting a sudden movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the conductor means a cyclic output signal in response to an indication of sudden movement of the tool including means responsive to the sudden movement indication for generating a continuous control signal, the control signal continuing after a sudden movement indication has elapsed and means responsive to the continuous control signal for generating the cyclic output signal, the conductor means supplying such an output signal to the surface of the earth; and

means coupled to the conductor means at the surface of the earth and responsive to the cyclic output signal for obtaining an indication of the sudden movement of the tool.

9. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:

a cable having a pair of conductor means and capable of supporting the tool in the well, the pair of conductor means adapted to carry current to the explosive charge detonating means in the tool;

transducer means in the tool for detecting a sudden movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the pair of conductor means a cyclic output signal in response to an indication of the sudden movement of the tool including means responsive to a sudden movement indication for generating a continuous control signal, the control signal continuing after a sudden movement indication and means responsive to a continuous control signal for generating a cyclic output signal, the pair of conductor means supplying such an output signal to the surface of the earth; and

means coupled to the pair of conductor means at the surface of the earth and responsive to the cyclic output signal for obtaining an indication of the sudden movement of the tool.

10. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:

a cable having a pair of conductor means and capable of supporting the tool in the well, the pair of conductor means adapted to carry current to the explosive charge detonating means in the tool;

transducer means in the tool for detecting a sudden movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the pair of conductor means for transmission to the surface of the earth a cyclic output signal in response to an indication of the sudden movement of the tool including means responsive to the sudden movement indication for generating a continuous control signal, the control signal continuing after the sudden movement indication, oscillator means responsive to a continuous control signal for generating a cyclic output signal, and means responsive to a cyclic control signal for cyclically switching on and off a relatively low impedance across the pair of conductor means; and

means coupled to the pair of conductor means at the surface of the earth and responsive to the cyclic output signal for obtaining an indication of the sudden movement of the tool.

11. In an explosive charge detonating system, including an explosive charge detonating means supported by a

tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:

a cable having a pair of conductor means and capable of supporting the tool in the well, the pair of conductor means adapted to carry current to the explosive charge detonating means in the tool;

transducer means in the tool for detecting a sudden movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the pair of conductor means a cyclic output signal in response to an indication of the sudden movement of the tool including means responsive to a sudden movement indication for generating a continuous control signal, the control signal continuing after the sudden movement indication, and means responsive to a continuous control signal for generating a cyclic output signal, the pair of conductor means supplying such an output signal to the surface of the earth, and means for resetting the means for generating a continuous control signal into the state where no control signal is generated, in readiness for another sudden movement indication, and in the explosive charge detonating system, voltage divider means across the pair of conductor means for setting the voltage approximately zero after each detonation and progressively increasing the voltage from zero to provide for another detonation; and

means coupled to the pair of conductor means at the surface of the earth and responsive to the cyclic output signal for obtaining an indication of a sudden movement of the tool.

12. The apparatus of claim 11 wherein the means for generating a continuous control signal includes a flip-flop wherein the energization of the set input causes the continuous control signal to be generated, and the reset means includes:

holding means for holding the flip-flop in the reset state; and

means coupled to the pair of conductor means for de-energizing the holding means upon the voltage across the conductor pair attaining a given level, the flip-flop then being enabled for generating the continuous control signal in response to a sudden movement indication.

13. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the sudden movement of the tool after a detonation, comprising:

a cable having conductor means and capable of supporting the tool in the well, the conductor means adapted to carry current to the explosive charge detonating means in the tool;

transducer means in the tool for detecting a sudden movement of the tool after a detonation and providing an indication thereof;

means coupled to the transducer means for supplying to the conductor means a cyclic output signal in response to an indication of sudden movement of the tool, the conductor means supplying such an output signal to the surface of the earth; and

means coupled to the conductor means at the surface of the earth and responsive to the cyclic output signal for obtaining an indication of the sudden movement of the tool; and means responsive to a cyclic output signal for delaying the removal of power from the cable conductor means for a given interval of time so that if the cyclic output signal is not present at the surface of the earth for a specified time, the power will not be removed from the conductor means.

14. Apparatus for detecting the sudden movement of a tool in a well, comprising:

a cable having a pair of conductors and capable of supporting the tool in the well, the pair of conductors

11

- adapted to supply power to the tool;
 transducer means located at the tool for detecting the sudden movement of the tool and providing an indication thereof;
 means located at the tool and responsive to the indication of the sudden movement of the tool for generating a continuous control signal, the control signal continuing after the sudden movement indication has elapsed;
 means located at the tool and responsive to the control signal for generating a cyclic output signal representative of the occurrence of a sudden movement of the tool for application to the conductor pair;
 means located at the surface of the earth for detecting the cyclic output signal; and means responsive to a detected cyclic output signal for removing power from the pair of conductors after a sudden movement of the tool has occurred.
15. Apparatus for detecting acceleration of a well tool supported by a cable in a well bore comprising:
 a pair of input terminals adapted to be connected to at least two conductors of a cable for receiving a voltage potential from a cable;
 an impedance apparatus directly and non-reactively coupled across said input terminals and including means for changing the value of the impedance across said input terminals; and
 means responsive to acceleration of a tool for operating said changing means at a predetermined frequency to modulate an electrical parameter in a cable at said predetermined frequency whereby said modulated parameter will vary in amplitude without changing polarity.
16. The apparatus of claim 15 and further including means for inhibiting operation of said operating means until a predetermined voltage potential is applied to said input terminals.
17. The apparatus of claim 15 and further including means coupled to said input terminals for sensing a predetermined frequency and providing an indication of the occurrence of such a frequency.
18. Apparatus for detecting acceleration of a well tool supported by a cable in a well bore comprising:
 a pair of input terminals adapted to be connected to at least two conductors of a cable for receiving current from a cable;
 an impedance apparatus directly and non-reactively coupled across said input terminals and including means for changing the value of the impedance across said input terminals; and
 means responsive to acceleration of a tool for operating said changing means at a predetermined frequency to modulate said current flowing in a cable at said predetermined frequency.
19. A surface panel for operation of a tool in a well borehole comprising:
 an input terminal adapted for connection with a well tool which provides a signal at a predetermined frequency upon the occurrence of a given condition in a well tool;
 means for receiving said frequency signal from said input terminal and converting such a signal to a DC voltage; and
 means responsive to said DC voltage and operative after a predetermined time delay for disconnecting said receiving means from said input terminal, said predetermined time delay insuring that said frequency signal is received for a sufficient number of cycles to be genuine.
20. The apparatus of claim 19 and further including power supplying means coupled to said receiving means for applying power to a tool in a well bore, whereby the disconnection of said receiving means from said input terminal operates to remove power from a well tool.
21. A surface panel for operation of a tool in a well bore comprising:

12

- an input terminal adapted for connection with a well tool which provides a signal at a predetermined frequency upon the occurrence of a given condition in a well tool;
 means for receiving said frequency signal from said input terminal;
 delay means responsive to said frequency for generating an output signal after said frequency signal has been received for a given time interval; and
 means responsive to said output signal for disconnecting said receiving means from said input terminal, said time delay interval insuring that said frequency signal is received for a sufficient number of cycles to be genuine.
22. A shooting panel for a well perforator comprising:
 a source of variable potential connected by conductors to a pair of terminals which are adapted for applying power to a well perforator;
 a normally closed switch and a transformer winding connected in one of said conductors; and
 means coupled to said transformer winding for detecting a frequency signal indicative of a given condition of a well perforator and including means for opening said switch when said frequency signal is present to thereby remove power from said terminals.
23. A shooting panel for a well perforator comprising:
 a source of variable potential connected by conductors to a pair of terminals which are adapted for applying power to a well perforator;
 a normally closed switch and a transformer winding connected in one of said conductors;
 means coupled to said transformer winding for detecting a frequency signal indicative of a given condition of a well perforator and generating an output signal representative of such detection; and
 means responsive to said output signal and operative after a predetermined time delay for opening said switch to thereby remove power from said terminals.
24. In an explosive charge detonating system, including an explosive charge detonating means supported by a tool in a well, apparatus for detecting the reaction of the tool to a detonation, comprising:
 a cable having conductor means and capable of supporting the tool in the well, the conductor means adapted to carry current to the explosive charge detonating means in the tool;
 transducer means in the tool for detecting a reaction of the tool to a detonation and providing an indication thereof;
 means coupled to the transducer means for supplying to the conductor means a predetermined frequency signal in response to an indication of the reaction of the tool, the conductor means supplying such an output signal to the surface of the earth; and
 means coupled to the conductor means at the surface of the earth and responsive to a predetermined frequency signal for indicating a reaction of the tool to the detonation of an explosive charge.
25. In a well tool signaling system, the combination comprising:
 a well tool supported at one end of a cable in a borehole, the other end of said cable terminating at the surface of the earth;
 means located at the opposite end of said cable from applying a signal having a predetermined frequency to said cable for transmission to the other end of said cable;
 means located at the opposite end of said cable from said signaling means for receiving said signal;
 filter means for passing received signals at said predetermined frequency; and
 delay means responsive to signals from said filter means for generating an output signal if a signal at said predetermined frequency is continuously re-

13

ceived for a predetermined time interval, whereby said output signal will reliably indicate the reception of said predetermined frequency signal.

26. In a well tool signaling system, the combination comprising:

a well tool supported at one end of a cable in a borehole, the other end of said cable terminating at the surface of the earth;

signaling means located at one end of said cable for applying a signal having a predetermined frequency to said cable for transmission to the other end of said cable;

means located at the opposite end of said cable from said signaling means for receiving said signals;

filter means for passing received signals at said predetermined frequency;

means responsive to signals from said filter means for converting such signals to a DC voltage; and

delay means responsive to said DC voltage for generat-

14

ing an output signal if a signal at said predetermined frequency is continuously received for a predetermined time interval, whereby said output signal will reliably indicate the reception of said predetermined frequency signal.

References Cited

UNITED STATES PATENTS

2,732,518	1/1956	Bricaud	340—18	XR
3,028,528	4/1962	Ghiselin	317—80	
3,304,538	2/1967	Zill	340—18	

RICHARD A. FARLEY, Primary Examiner

C. E. WANDS, Assistant Examiner

U.S. Cl. X.R.

181—.5; 340—15.5

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,495,212 Dated February 10, 1970

Inventor(s) George W. Brock

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 59, "systems" should read -- system --.
Column 2, line 49, "aceleration" should read -- acceleration --.
Column 5, line 44, "wtihin" should read -- within --.
Column 6, line 40, "charge" should read -- charges --;
Column 6, line 52, "slicon" should read -- silicon --.
Column 7, line 23, "cylic" should read -- cyclic --;
Column 7, line 44, "in" (first occurrence) should read -- with --;
Column 7, line 61, "modifictions" should read -- modifications --.
Column 12, line 41, "reatcion" should read -- reaction --;
Column 12, line 64, "means . . . from" should read -- signaling
means located at one end of said cable for --.

SIGNED AND
SEALED
OCT 20 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents