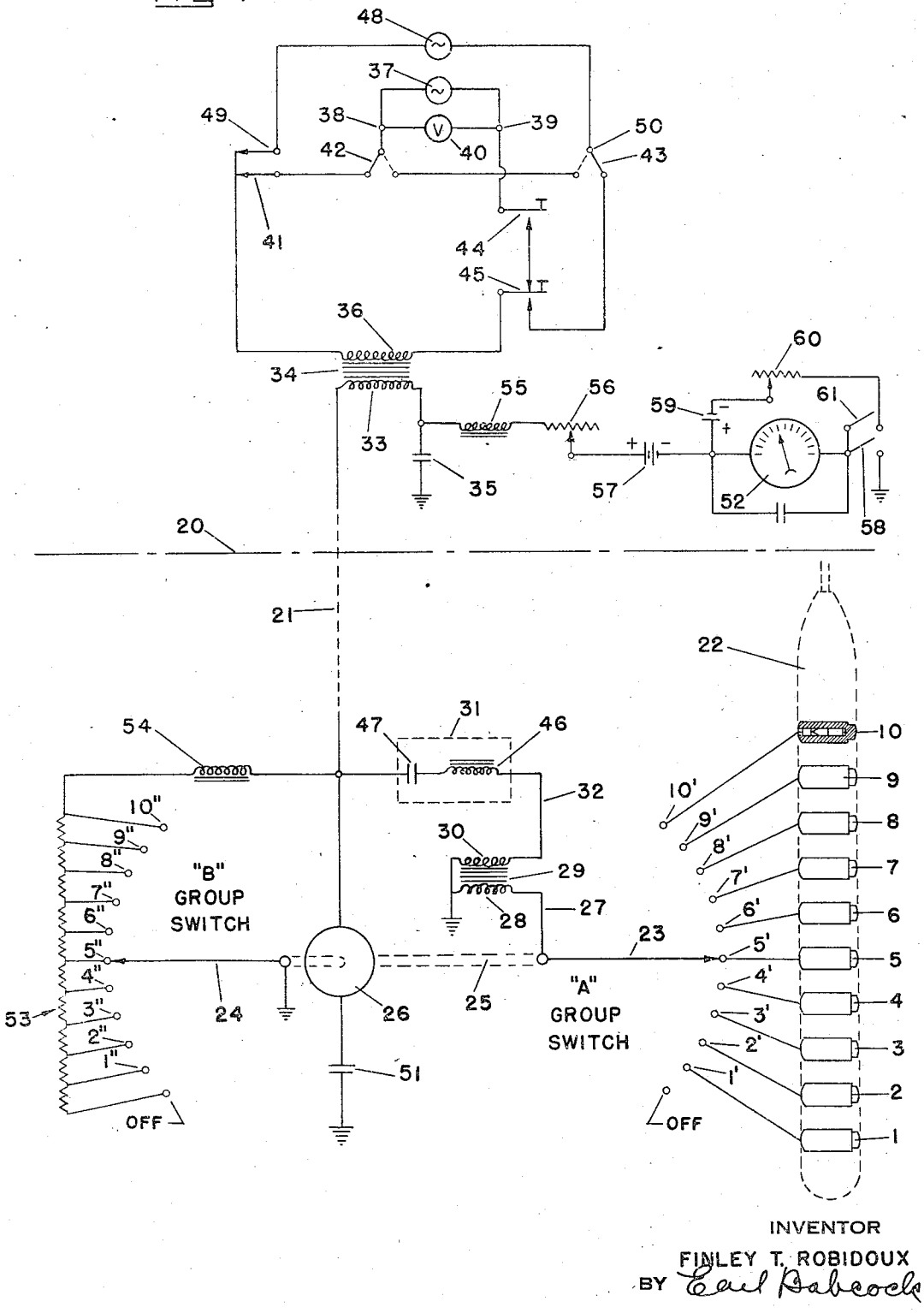
Jan. 11, 1944. F. T. ROBIDOUX 2,338,872

ELECTRICAL SYSTEM FOR FIRING GUNS

Filed Sept. 9, 1940 2 Sheets-Sheet 1

Fig 1



INVENTOR

FINLEY T. ROBIDOUX

BY Earl Babcock

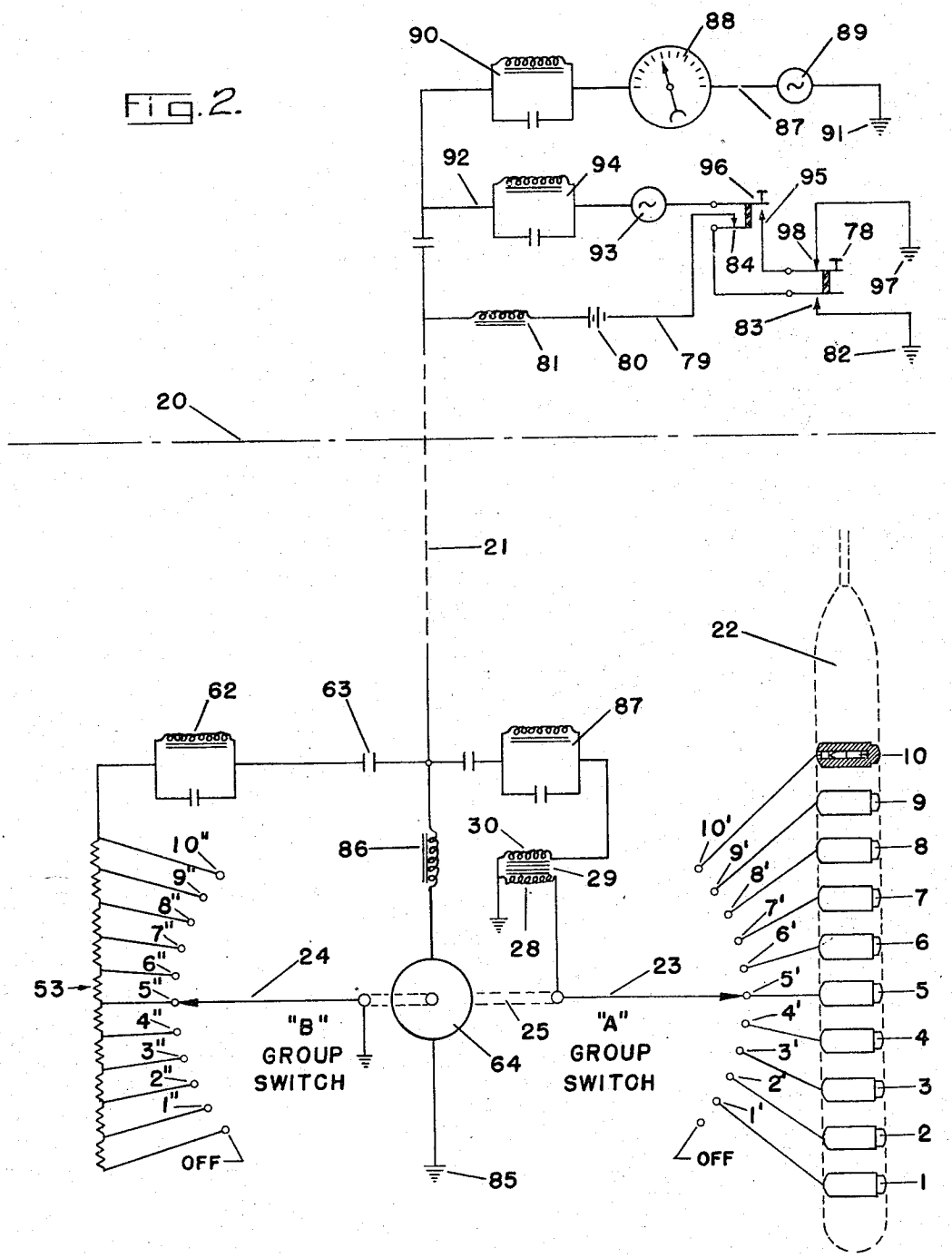
ATTORNEY

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ELECTRICAL SYSTEM FOR FIRING GUNS

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Fig. 2.



INVENTOR
FINLEY T. ROBIDOUX
BY Earl Babcock
ATTORNEY

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2,338,872

ELECTRICAL SYSTEM FOR FIRING GUNS

Finley T. Robidoux, Houston, Tex., assignor to Halliburton Oil Well Cementing Company, Duncan, Okla.

Application September 9, 1940, Serial No. 355,953

3 Claims. (Cl. 177—353)

This invention relates to electrical systems for firing guns, and more particularly to systems for use with gun perforators in oil wells.

It is an object of the present invention to provide a simple and reliable electrical circuit for use in connection with a gun perforator having several guns or gun units, by which an operator, at the surface, can select, indicate and fire any gun of the perforator in a well.

A further object is to provide a selecting, indicating and firing circuit arrangement requiring a cable having but one conductor so as to reduce cable cost and bulk to a minimum—while at the same time restricting to a minimum, the size, weight and cost of the cable-handling equipment.

The invention is characterized by the employment of a direct current source and two alternating electric current sources of distinguishable frequencies, all arranged to supply current, as desired, to a single conductor cable supporting a gun perforator in a well, together with means for causing each current to perform one, and only one of the three functions of selecting, indicating and firing the guns.

Referring to the drawings which accompany this specification:

Figure 1 is a circuit diagram illustrating the preferred embodiment of the invention wherein a single-conductor cable is employed;

Figure 2 is a circuit diagram of a modified arrangement utilizing a single conductor cable.

In the circuit diagram, Figure 1, which represents the preferred embodiment of the invention, the dot-dash line 20 serves to segregate parts and circuit connections above ground from those which are incorporated in the gun body which is situated at some point in the well hole at which the perforating operation is to be performed. The parts and connections shown above line 20 are usually mounted in a service truck at the well derrick, whereas the parts and connections below line 20 are included within the gun body, or closely adjacent thereto—except for the cable conductor 21 which serves to interconnect the above-ground and below-ground equipment.

A gun perforator body is shown in dotted outline and identified by reference numeral 22. The body 22 constitutes the supporting structure and enclosure for all the elements shown below dot-dash line 20 including ten gun-units numbered 1 to 10 inclusive. Each of the gun-units comprises a gun barrel having an explosive chamber for the reception of a charge of gun powder and a bore to receive and guide a steel projectile which, when the gun-unit is fired, punctures the well casing and penetrates the formation—thus producing an aperture in the casing through which oil or gas can flow. Each of the gun units 1 to 10 is electrically grounded through the body 22.

Three major functions are performed by the circuit arrangement of Figure 1. These are: (1) pre-selection, under control of the operator, of the gun-unit next to be fired; (2) electrically firing the pre-selected gun-unit individually; and (3) indicating to the operator that the gun-unit which he has selected has actually been connected to the firing circuit in readiness for firing.

It is thought to be conducive to a more ready comprehension of the circuit diagram and its functions to describe first the firing circuit arrangement and its mode of operation and to follow that with a description of the gun-unit selecting circuit and, thereafter, a description of the indicating circuit.

Enclosed within the body of the gun are two rotary multiple-contact switches—one being identified as the "A" group switch and the other as the "B" group switch. These two switches each have a rotating contactor marked, respectively, 23 and 24, which are mounted on a common shaft 25, which is driven at very slow speed by a motor 26. In practice the motor 26 is a stock electric clock motor designed to operate on 60 cycles A. C. and the shaft 25 is geared to the motor armature shaft to rotate at one revolution per minute.

The "A" group switch includes eleven fixed contacts, one of which is marked "off" and the others identified by reference numerals 1' to 10' inclusive, to correspond to the identification of the gun-units to which said fixed contacts are individually connected. The "B" group switch has an equal number of fixed contacts—one being marked "off" and the others 1'' to 10'' inclusive, in correspondence, respectively, to fixed contacts 1' to 10' of the "A" group switch and also to correspond with the identification of the several gun-units. The fixed contacts of each rotary switch are preferably arranged in a complete circle instead of an arc, as shown, but it is more convenient for the present purpose to show them arranged in an arc. Manifestly, the contactors 23 and 24 rotate synchronously and always engage corresponding fixed contacts. They are shown in engagement with the 5' and 5'' fixed contacts—which is purely arbitrary.

The explosive charges are fired one at a time by means of a conductive filament which is embedded in the powder and heated by the passage therethrough of electric current. In practice a 500 cycle alternating current is employed as the firing current, but that frequency is entirely arbitrary—it being essential only that the firing current frequency be such as to render it practicable to isolate the 60 cycle or other gun-unit selecting current from that branch of the firing circuit which includes the gun-units—thus insuring against the possibility of the gun being accidentally fired by the wrong current.

The firing circuit for gun-unit 5—which has been preselected—includes fixed contact 5', contactor 23, conductor 27, secondary winding 28 of step-down transformer 29—which secondary winding is energized by primary winding 30, which is connected in series with a filter 31 through conductor 32 and in series with secondary winding 33 of transformer 34, through conductor 21, which is enclosed within the cable supporting the gun. The cable, per se, exclusive of the enclosed and insulated conductor 21 preferably provides the return path for all parts indicated as being grounded. Condenser 35 functions as a by-pass to ground for both 500 cycle and 60 cycle current. When 500 cycle current is induced into secondary 33, gun-unit 5 will be fired.

Transformer 34 is designed to pass both 60 cycle and 500 cycle current and an explanation is now in order with respect to the application of 500 cycle current to the primary 36 of transformer 34. Current of that frequency is supplied by a generator 37, which is connected across terminals 38 and 39, bridged by a voltmeter 40. A main power switch 41 is shown closed and there are two double throw switches 42 and 43, which for the moment will be considered as being in the positions indicated in full lines. There are also two manually operable, self-restoring keys, or push-button switches 44 and 45, which normally assume the conditions of operation illustrated. That is to say, the contact of key 44 is normally open while the back contact of key 45 is normally open and its front contact normally closed. It will be evident that with key 45 at normal, a closure of the contact of key 44 will connect the 500 cycle generator 37 to the primary winding 36 of transformer 34. It follows that an operation of key 44 will fire any gun-unit which happens to be selected and loaded. Key 45 serves to operate the gun-unit selecting circuit and it will be observed that it functions to break the 500 cycle circuit whenever it is depressed to close the 60 cycle circuit—thus ordinarily insuring against current of both frequencies being applied simultaneously. Filter 31 comprises an inductance coil 46 and a condenser 47 in series. The values of inductance and capacity are so chosen as to tune the firing circuit branch path in which they are included to resonate at about 500 cycles. Such a tuned path offers little impedance to the 500 cycle current while serving substantially to block 60 cycle current. It is essential, of course, that 60 cycle current be blocked out of the branch path which includes filter 31 to a sufficient extent to preclude all possibility of the gun being fired by current of that frequency; but it is not necessary that every trace of 60 cycle current be excluded.

Filter 31 need not be of the type shown but may be of any well known type.

The next step in the description deals with preselection of the gun-units under control of the operator. The selecting is accomplished by moving contactor 23 into engagement with the appropriate fixed contact of the "A" group switch, and this is brought about by energizing the 60 cycle motor 26 which drives shaft 25 at a slow speed. Current of 60 cycle frequency is provided by a generator 48 connected to terminals 49 and 50. Depressing key 45 closes its back contact and completes a circuit for the 60 cycle current to the primary 36 of transformer 34—while at the same time opening its front contact and breaking the 500 cycle path. The secondary 60 cycle path includes condenser 35, secondary winding 33, cable conductor 21, the winding of motor 26 and condenser 51 in series. The latter is provided mainly to block the flow of direct current but may advantageously be selected to tune the motor path to 60 cycles. If the motor does not provide sufficient reactance to the 500 cycle current, additional inductance should be inserted in series therewith.

As long as the operator continues to hold down key 45, motor 26 will run and the contactors 23 and 24 will continue to sweep over their fixed contacts; but in the absence of some suitable indication, the operator would not be informed as to whether the contactors were making contact or with which pair of contacts, if any, they happened to be engaged. And without such provision the operator could not select the gun-units at will, but would be limited to firing them either at random or in sequence.

It is the function of the "B" group switch, in conjunction with other instruments and connections about to be described, to indicate to the operator at all times which fixed contact of the "A" group switch is engaged by contactor 23 and, in consequence, which of the individual gun-units is connected to the firing circuit. The indication as to which gun-unit is ready for firing is given by an electro-responsive instrument 52, which may conveniently be a milliammeter having a dial specially calibrated to show the number of the gun-unit ready for firing, and, additionally, as a matter of preference, an indicia corresponding to the "off" contact of the "A" group switch. The "off" contact of the "A" switch serves as a safe-guard against the possibility of inadvertent firing; and the "off" contact of the "B" switch serves, as will presently appear, to afford a positive indication that the "A" switch is on the "off" contact. In other words, the system does not rely upon the absence of deflection of the indicator needle to show that the gun is safe, because total absence of needle deflection might result from a break in the indicator circuit or a dead battery.

The circuit of indicating instrument 52 includes grounded contactor 24 and all or a portion of the series-connected resistance elements 53—depending upon the position of contactor 24. When the latter engages the "off" contact of the "B" group, all the resistance elements 53 are connected in, but when it engages contact 10'' all the resistances are cut out of circuit. It will be plain that the path extending from resistance elements 53 to indicating instrument 52 embraces a choke coil 54, the cable conductor 21, transformer secondary winding 33, choke coil 55, rheostat 56 and battery 57. The other side of the instrument 52 is grounded through a switch 58 which is kept open when the instrument is not in use, in order to conserve battery 57.

Bridged across indicating instrument 52 are a battery 59, rheostat 60 and switch 61—the latter being kept open when the instrument is not in use in order to conserve battery 59. When the device is in use, switches 58 and 61 are kept closed. The circuit just described is a direct current path having two choke coils 54 and 55 functioning to impede the 60 cycle and 500 cycle alternating current and thus confine those currents to their proper paths. Manifestly, the needle of indicator 52 will respond to current from battery 57 flowing through the path just described, and it will be apparent that the deflection of the needle will be in conformity with the amount of resistance 53 included in circuit. Hence, it will be seen that indicator 52 is capable of showing by the deflection of its needle with which of the fixed contacts the contactors 23 and 24 are engaged. And it follows that the indicator will show which gun-unit is ready for firing. It will be observed that the indications are positive in that they do not occur until the switching operation at the gun itself has actually taken place. This is what is known as a "flash back" signal—the term being derived from the fact that the signal is dependent upon the selecting operation actually having been performed.

Rheostats 56 and 60 serve to adjust the indicator 52 to compensate for differences in cable resistance. With contactor 24 on its "off" contact, rheostat 56 is adjusted to bring the indicator needle into registration with the "off" reading on the dial. Then motor 26 is put in motion until a maximum reading is observed—which necessarily corresponds to a setting of contactor 24 on contact "10". Then rheostat 60 is adjusted to bring the needle into registration with the No. 10 indicia—it being noted that battery 59 is a bucking battery connected to oppose battery 57. When the two rheostats 56 and 60 have been adjusted so that the needle correctly registers at both ends of the scale, it will read correctly at all other points because the dial is calibrated in consonance with the values of resistance elements 53.

Whenever all the gun-units are to be fired and the order of fire is immaterial, they may be fired in sequence and no selection is necessary. In such event, switches 42 and 43 are thrown to the positions indicated by dotted lines and the key 44 is held down long enough to complete the firing of all gun-units. Key 45 then performs no function and it is left in its normal position, as shown, with its front contact closed. Current from both the 60 cycle generator and the 500 cycle generator is conducted at the same time through key 44 to the primary 36 of transformer 34. Motor 26 is then set in motion and as contactor 23 engages its fixed contacts in succession, the corresponding gun-units are fired by the 500 cycle current. One revolution of shaft 25 serves to fire all the gun-units. With switches 42 and 43 in their dotted positions, the path of the 60 cycle current includes the 500 cycle generator in series with key 44 and primary 36.

In Figure 2 there is illustrated a modified arrangement utilizing a single conductor cable and in which direct current is employed to operate the selector switch motor, while alternating current of low and high frequencies, respectively, are employed to energize the indicator and firing circuits. As in Figure 1, the conductor cable interconnecting the gun with the remote-control station is identified by reference numeral 21. The firing circuit branch path and selector switch arrangement are substantially the same as shown in Figure 1, differing therefrom only in that the filter 87 is of the parallel, tank circuit type instead of the series resonant type of Figure 1. The indicator circuit branch path at the gun is identical with that of Figure 1, except for the inclusion of a tank circuit 62, which is tuned to the higher frequency, and a blocking condenser 63 which serves to prevent the flow of direct current in that path. Motor 64 corresponds in function to motor 26 of Figure 1 but is a direct current motor. Connected in series with motor 64 is a choke coil 86 which serves to block the flow of alternating current in the motor branch path.

At the remote-control station indicated above line 20 are three branch paths, the first of which numbered 87 includes the indicator 88 in series with a 60 cycle or other low frequency source 89 and a tank circuit 90 which is preferably tuned to 500 cycles in order to exclude the latter frequency from the indicator branch path. The branch path 87 is grounded at 91 and may include a switch, not shown, for opening the circuit.

Next below the branch path 87 is the firing circuit branch path identified by reference numeral 92. This path includes a 500 cycle, or other high frequency source 93 and a tank circuit 94, which is preferably tuned to 60 cycles or whatever may be the frequency of the source 89. A key 95 functions upon being manually depressed to close a contact 96 which establishes ground at 97 through the upper contact 98 of a second key 78—the latter being included in the motor actuating branch path 79. The last mentioned branch path includes a source of direct current 80 in series with choke coil 81 which latter functions to suppress alternating current of both the low and high frequencies and thus to prevent the same from being grounded at 82. Upon depressing key 78, a circuit is established from ground 82 through contact 83, contact 84, of key 78, battery 80, choke coil 81, cable conductor 21, choke coil 86 and motor 64, to ground at 85. Motor 64, which may be a series wound motor, is thus set into motion to operate the two rotary switches. The firing circuit is energized in the manner previously described and the indicating circuit operates as before, except that the indicating instrument 88 is designed to respond to alternating current instead of direct current. While only two embodiments of the invention have been shown and described herein, it is obvious that various changes may be made without departing from the spirit of the invention or the scope of the annexed claims.

I claim:

1. An electrical system for use with a single conductor cable and a multiple gun perforator in an oil well, comprising three separate and distinguishable sources of current located at the surface of the earth and there grounded, means for causing current from any of said sources to flow through the single conductor of the cable to the perforator in the well and thence to the ground, means including a group switch connected to one of said sources of current for selecting one of the guns of the perforator for firing, means including a second group switch driven in synchronism with said first mentioned group switch and connected to an indicator and to another of said sources of current for indicating which gun has been selected by said selecting means, means op-

erable in response to current from the third of said sources for firing the gun selected by said selecting means and indicated by said indicating means and means for controlling the flow of current from each of said sources to cause it solely to perform its particular, intended function independently of current from the other sources.

2. An electrical system for use with a single conductor cable and a multiple gun perforator in an oil well comprising three separate and distinguishable sources of current located at the surface of the earth and there grounded, one of said sources being direct, another alternating at sixty cycle frequency and the third alternating at a predetermined different frequency, means for causing current from any of said sources to flow through the single conductor of the cable to the perforator in the well and thence to the ground, means including a group switch connected to one of the first two mentioned sources of current for selecting one of the guns of the perforator for firing, means including a second group switch driven in synchronism with said first mentioned group switch and connected to an indicator and to the other of said first two mentioned sources of current for indicating which gun has been selected by said selecting means, means operable in response to current from said third mentioned source for firing the gun selected by said selecting means and indicated by said indicating means and means for controlling the flow of current from each of said sources to cause it solely to perform its particular, intended function independently of current from the other sources.

3. An electrical system for use with a single conductor cable and a multiple gun perforator in an oil well, comprising three separate and distinguishable sources of current located at the surface of the earth and there grounded, means for causing current from any of said sources to flow through the single conductor of the cable to the perforator in the well and thence to the ground, selective means associated with the perforator in the well and energized by one of said sources for individually connecting the guns thereof to another of said sources to fire the guns, said selective means including a multiple switch the fixed contacts of which are individually connected to the guns and the movable contact of which is connected to the conductor of the cable, indicating means for informing the operator as to which of the guns has been selectively connected to said firing source, said indicating means utilizing the third of said sources and having a portion associated with the perforator and a portion located at the surface of the earth, the portion associated with the perforator including a resistor and multiple switch connected in series between the conductor of the cable and the ground, the fixed contacts of the switch of the indicating means being connected at spaced points along said resistor and the movable contact of the switch of the indicating means completing the resistor circuit, the portion of said indicating means located at the surface of the earth including a device responsive to variations in resistance of the resistor circuit depending upon the position of the movable contact of the switch of said indicating means, and means for driving the movable contacts of both of said multiple switches in synchronism.

FINLEY T. ROBIDOUX.