March 17, 1942. L. C. MILLER 2,276,544

PERFORATING DEVICE

Filed Feb. 6, 1939

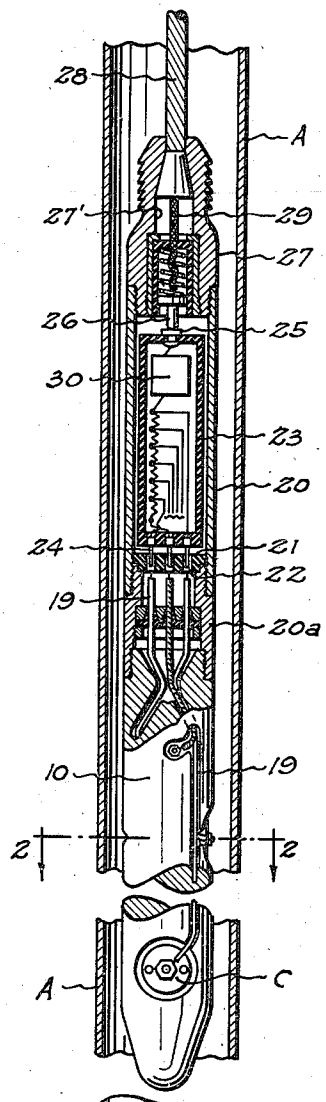


Fig. 1.

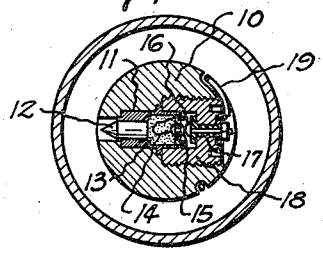


Fig. 2.

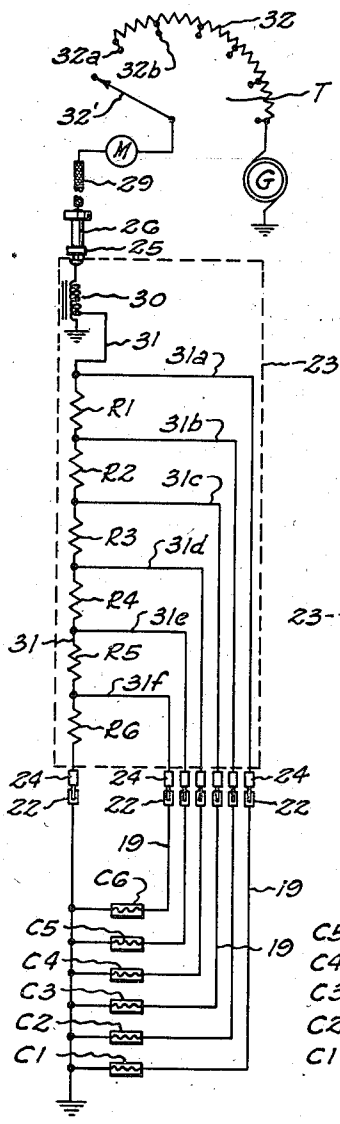


Fig. 3.

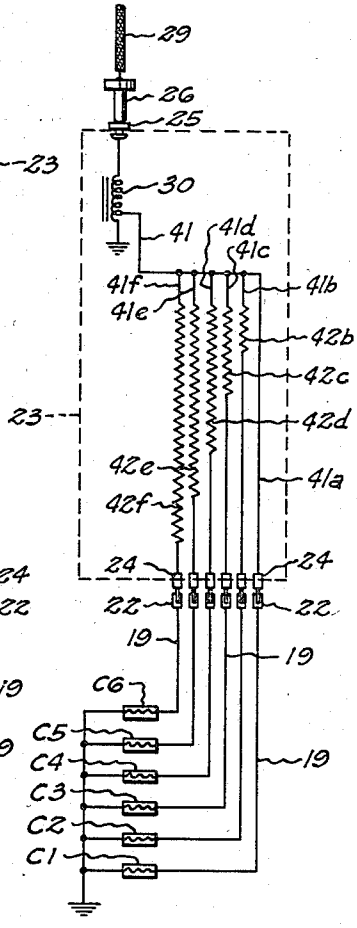


Fig. 4.

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PERFORATING DEVICE

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10 Claims. (Cl. 164—0.5)

This invention relates to new and useful improvements in perforating devices.

As is well known, it has become the practice in the petroleum industry to lower a plurality of explosive charges into a well bore and to fire said charges in a predetermined order and at various elevations, whereby the force of the charges is directed radially outwardly of the bore. Such firing of explosive charges may be for the purpose of perforating the well casing, if such casing is in the well, or it may be for the purpose of obtaining cores or samples of the formations at various elevations in the bore. Irrespective of the purpose for which the charges are fired, it is essential, for practical purposes, that the firing of the charges, as well as the order of firing, be controlled from the surface.

It is one object of this invention to provide an improved perforating device having explosive charges adapted to be controlled from the surface of the well bore so as to be fired in a predetermined, desired order.

An important object of the invention is to provide an improved device, of the character described, wherein a plurality of explosive charges are arranged to be fired by electrical means; the electrical circuit including means for controlling the flow of current to each explosive charge, whereby an electrical current of predetermined intensity is required for each charge, thus making it possible to fire the charges in any predetermined order by varying the intensity of the transmitted electrical current.

Another object of the invention is to provide an improved device, of the character described, wherein a plurality of electrical resistances are connected in an electrical supply wire and are so arranged that as each charge is fired, an additional resistance is interposed in the path of current flow, whereby each subsequent charge requires a current of increased intensity as compared to the current which fired the previous charge.

A particular object of the invention is to provide an improved device for firing explosive charges, wherein a plurality of electrical resistances of varying capacities are connected in the circuit, each resistance being associated with one of the explosive charges so as to control the intensity of the current necessary to fire that charge; the arrangement being such that each charge is fired by a current of an intensity different from the current required to fire the other charges, thus making it possible to readily control the order of firing of said charges.

Another object of the invention is to provide an improved device for electrically controlling the firing of a plurality of explosive charges in a predetermined order and having means for preventing the conductive mud in the well bore from grounding the circuit to create a "short" after one or more charges have been fired, thereby obviating the danger of said mud interfering with the firing of the subsequent charges.

A construction designed to carry out the invention will be hereinafter described, together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawing, in which an example of the invention is shown, and wherein:

Figure 1 is a view, partly in section and partly in elevation of a perforating device, constructed in accordance with the invention,

Figure 2 is a horizontal, cross-sectional view, taken on the line 2—2 of Figure 1,

Figure 3 is a wiring diagram of the improved control, and

Figure 4 is a wiring diagram of a modified form of control.

In the drawing, the numeral 10 designates a substantially cylindrical body which houses a plurality of explosive charges C. Each charge is mounted in a diametrically extending opening 11 (Figure 2) in the body and includes a perforating bullet 12. A powder chamber 13 is located behind the bullet and has the explosive powder therein, with a fusible wire 14 extending therethrough. Electrical connection is made with the wire 14 through a contact 15 which is engaged by a contact pin 16. The pin extends through an electrical insulating sleeve 17 which is mounted in a plug 18 arranged to be threaded into one end of the opening 11 to close the same. An electrical lead wire 19, which is suitably insulated, has one end connected to the contact pin and extends upwardly through grooves and openings provided in the body. As will be explained, this wire conducts electrical current to the pin 16, contact 15 and wire 14, whereby said wire fires the explosive powder to expel or eject the bullet or projectile 12. It is particularly pointed out that the construction of the body 10 and the explosive charges mounted therein form no part of the present invention and these parts are, therefore, subject to variation. So long as the charges C are adapted to be fired by electrical current, the purposes of the invention may be accomplished.

An elongate sleeve or casing 20 has its lower end connected to the upper end of the body 10 by a coupling 20a and a transversely extending connecting base or electrical receptacle 21 is disposed within the lower end of this sleeve, being preferably secured to the top of the body 10. The base is constructed of electrical insulating material and has a plurality of electrical sockets 22 therein. Each socket is connected to one of the lead wires 19 extending from the explosive charges C, whereby a direct electrical connection is had between these parts.

For conducting electrical current to the sockets 22, an elongated plug 23 is insertable within the sleeve 20 and is provided with contact prongs 24, which depend therefrom and which are engageable within the sockets so as to make electrical connection therewith. The number of prongs corresponds to the number of sockets. The plug 23 houses the control means for controlling the firing of the charges C and such means will be hereinafter explained. The plug is readily removable from the sleeve 20 and has an axial contact 25 in its top, said contact being adapted to be engaged by a spring-pressed plunger 26 which is mounted in a cap member 27. The cap member is threaded into the upper end of the sleeve 20, thereby closing the same and has the lower end of a cable or wire line 28 connected thereto. The cable is utilized for lowering the device through the well casing A, or through the well bore and is constructed of an electrical insulating material, whereby an electrical conductor or wire 29 may extend downwardly therethrough from the surface of the well. The lower end of the conductor passes through an axial opening 27' in the cap member and is connected with the plunger 26. Manifestly, electrical current from the surface may flow downwardly from the surface through the conductor 29, plunger 26, contact 25, plug 23, prongs 24, sockets 22 and finally through wires 19 to the explosive charges C to fire the same.

For controlling the flow of current to the various charges, the control means which is mounted in the plug 23 is provided and this means is clearly illustrated in the wiring diagram. Figure 3. The contact 25 which is located in the top of the plug is connected to the primary winding of a transformer 30 which is suitably mounted within the plug. A wire 31 leads from the transformer and a resistance R1 is connected therein. Between the resistance and the transformer a lead wire 31a is connected and the other end of this wire is connected to one of the prongs 24 of the plug. This plug has connection with one of the sockets 22, which, in turn, has connection with one of the explosive charges C1. With this arrangement, an electrical current which is conducted through the wire 29 to the transformer passes through the transformer and then to the wire 31. Upon flowing through the wire 31, the current passes through the wire 31a, prong 24, socket 22, wire 19 and to the charge C1 to fire the same. The resistance R1 is of such size and the intensity of the transmitted current is such that sufficient current cannot pass said resistance to fire any of the other charges which are connected to the wire 31 beyond said resistance, as will now be explained.

Immediately beyond the resistance R1, a wire 31b is connected to the supply wire 31 and this wire has connection with a prong 24 which supplies current to a second explosive charge C2. A second resistance R2 is connected in the supply wire 31 beyond the wire 31b. Wires 31c, 31d, 31e and 31f are also connected to the supply wire for conducting current to the other explosive charges C3, C4, C5 and C6 respectively. Between the wires 31c and 31d, a resistance R3 is connected in the wire 31, while a similar resistance R4 is located between wires 31d and 31e and a resistance R5 is disposed between wires 31e and 31f. Beyond the wire 31f, a resistance R6 is connected and the lower end of the supply wire 31 leads to one of the prongs 24 which engages one of the sockets 22. The socket to which the supply wire is connected leads to ground. All of the resistances R1 to R6 are shown as of the same capacity and, therefore, set up the same electrical resistance to the flow of current. However, they could be of varying capacities.

In the operation of the device, a suitable variable transmitter T, or other device for transmitting a variable current, is mounted at the surface of the well bore and has connection with the upper end of the wire 29. This transmitter has been shown as a generator G associated with a variable resistance 32 having contact points therealong, whereby current of varying intensity may be transmitted. A suitable visible indicator, such as an ammeter M may be connected in the transmitting circuit. For the purposes of this description, it will be assumed that a two amp. current will fire each charge, but it is to be understood that this figure is selected arbitrarily and is subject to wide variation.

In firing the charges, the arm 32' of the variable resistance is engaged with the first contact 32a of the resistance 32. The current flows from the generator, through the transformer and then through wires 31, 31a and 19 to the first charge C1 to fire the same. The transmitted current is of such intensity that sufficient current flows to this charge to fire the same. However, the resistance R1 is of such construction as to prevent sufficient current to pass to the next charge C2 through the wire 31b and, therefore, before the next charge can be fired, the intensity of the current must be increased at the transmitter. This is done by moving the arm 32' to the next contact point 32b of the resistance 32. Such movement of said arm increases the intensity of the transmitted current to a point whereby sufficient current flows past the resistance R1 to the wire 31b and thence to the charge C2. However, the resistance R2 blocks the current to the wire 31c and the next charge C3. Thus, in order to fire this next charge C3, the current must be again increased in intensity to overcome the resistances R1 and R2 connected in the supply wire 31. Obviously, upon each increase of the intensity of the current the next successive charge is fired. The charges may be connected in any desired order and to any of the lead wires 31a to 31f, whereby said charges may be fired in any predetermined desired order. Also, two or more charges may be fired simultaneously by properly arranging the connecting wires and resistances. It is pointed out that although six explosive charges have been shown and described, this number may be varied as desired.

The transformer 30 is connected in the circuit for the purpose of reducing the voltage, whereby the charges may be fired by a relatively low voltage. By utilizing a low voltage for setting off the charges, interference of the conductive mud or fluid in the well bore with the operation of the device is eliminated. It is manifest that when the first charge is fired, the conductive mud

in the well bore may enter the opening 11 in the body wherein the charge was mounted. This mud will, of course, contact the pin 16 which is connected in the electrical circuit by the wire 19. In effect, this mud sets up another resistance in the line and if a high voltage is employed for firing the charges, such resistance would be relatively low, as compared to the intensity of the current, with the result that the transmitted current for firing the subsequent charges would readily pass through the mud and the entire circuit grounded. Such an occurrence would prevent firing of the remaining charges.

The transformer T reduces the voltage and the charges are arranged to be fired by the relatively low voltage. Therefore, when the first charge is fired and the conductive mud enters the opening 11 and engages the pin 16, the resistance created by the mud is of a relatively high value, as compared to the voltage, with the result that the passage of current therethrough is defeated. This condition may also occur by the mud contacting the terminal connection between the wire 19 and pin 16. Thus, the current is directed through the supply wire 31 and the resistances therein, whereby the subsequent charges may be fired. In this manner, the entrance of the conductive mud into any of the openings 11 after the charge has been ejected does not effect the firing of the subsequent charges. It is pointed out that, under some conditions, there may be no danger of the mud, or other fluid, entering the openings 11 after discharge of the bullets, and in such event the transformer 30 may be eliminated, the current being conducted directly from the wire 29 to the wire 31.

From the foregoing, it will be seen that a simple and effective means for controlling the firing of the explosive charges is provided. By arranging the resistances and the connections from the supply wire 31 to the charges, said charges may be fired in any desired order. The capacity of the resistances may be, of course, varied to permit a current of any predetermined intensity to be utilized for firing the charges. The control is from the surface and may be manually actuated. The control mechanism is housed in the single plug 23, which may be readily removed for repair, or for any other reason, and it is manifest that by substituting a plug having resistances of different capacities and arranged in a different manner, for the plug 23, the order of firing may be changed.

In Figure 4, a slightly modified form of control mechanism is shown, wherein a plurality of resistances of varying capacities are employed in place of the resistances R1 to R6 which all have substantially the same capacity. In this form, a supply wire 41 leads from the transformer and a wire 41*a* leads from the supply to the prong 24 and socket 22 of the first explosive charge C1.

When current is directed over the wire 41*a*, the charge C1 is fired. The next charge C2 is connected to the supply wire 41 by a wire 41*b* and this latter wire has a resistance 42*b* connected therein. The current which is utilized to fire the first charge C1 is of insufficient intensity to pass the resistance 42*b* and, therefore, the first charge C1 may be fired without firing the second charge C2. The third charge C3 is connected to the supply through a wire 41*c* which has a resistance 42*c* connected therein. The resistance 42*c* is of a greater capacity than the resistance 42*b*, whereby a current of sufficient intensity to pass the resistance 42*b* and fire the charge C2 is not sufficient to pass the resistance 42*c*. Thus, the second charge may be fired without firing the third charge C3. Charges C4, C5 and C6 are also connected to the supply wire 41 by wires 41*d*, 41*e* and 41*f*, respectively, and the wires 41*d*, 41*e* and 41*f* have resistances 42*d*, 42*e* and 42*f* connected therein. These resistances are of progressively increasing capacities and, with such arrangement, it is manifest that a current of increased intensity must be employed for firing each subsequent charge. By properly arranging the resistances 42*b* to 42*f*, the charges may be fired in any desired order. The operation of this form is substantially the same as the form shown in Figure 3, wherein a plurality of resistances of the same capacities are connected in the supply wire 31 between the wires leading to the charges. In Figure 3, as each charge is fired, an additional resistance is, in effect, connected in the supply wire. Thus, in passing to the charge C2, the current need only flow through the one resistance R1, whereas in passing to the charge C6, the current must flow through the resistances R1 to R5, whereby the intensity of the current must be progressively increased to successively fire the charges. In Figure 4, resistances of varying capacities are connected in the individual lead wires and the current must be progressively increased, in the same manner, to fire the charges. In both forms, the control is from the surface and the charges may be exploded in any predetermined, desired manner.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What I claim and desire to secure by Letters Patent is:

1. A perforating device including, a body adapted to be lowered into a well bore, a plurality of explosive charges mounted in said body, means for conducting electrical current to the charges to fire the same, and means in the electrical circuit remote from the charges for controlling the current flowing to each charge, whereby a current of a predetermined intensity is required to fire each charge.

2. A perforating device including, a body adapted to be lowered into a well bore, a plurality of explosive charges mounted in said body, an electrical conductor extending from the surface for conducting electrical current to the charges, a plurality of resistances connected in the electrical circuit in advance of the explosive charges and associated therewith, whereby each charge is fired by electrical current of a predetermined intensity, and means at the surface of the bore for transmitting electric currents of progressively increasing intensities through the circuit.

3. An apparatus for electrically firing a plurality of explosive charges including, an electrical circuit, and a series of electrical resistances forming part of said circuit and being separate from and associated with the explosive charges whereby the charges are successively fired by electrical currents of different and progressively increasing intensities.

4. An apparatus for electrically firing a plurality of explosive charges including, an electrical circuit, a plurality of electrical resistances connected in the circuit, and means for automatically disposing an additional resistance in the

path of the flowing current after each charge is fired, whereby each subsequent charge requires a current of increased intensity as compared to the previous charge.

5. An apparatus for electrically firing a plurality of explosive charges including, an electrical circuit, a plurality of electrical resistances connected in the circuit, means for automatically disposing an additional resistance in the path of the flowing current after each charge is fired, whereby each subsequent charge requires a current of increased intensity as compared to the previous charge, and means at the surface of the well bore for transmitting electric currents of varying intensities through the circuit to fire the charges.

6. An apparatus for electrically firing at a distance a plurality of explosive charges including, means for successively firing the charges by transmitting electric currents of progressively increasing intensities to said charges, said means including a plurality of resistances connected in the circuit in advance of the charges and associated therewith so as to control the flow of current thereto.

7. An apparatus for electrically firing a plurality of explosive charges including, an electrical circuit, and a series of electrical resistances of varying capacities connected in the circuit remote from said charges, each resistance being associated with one of the charges so as to control the intensity of the current required to fire said charge.

8. A perforating device including, a body adapted to be lowered into a well bore, a plurality of explosive charges mounted in said body, an electrical conductor extending from the surface for conducting electrical current to the charges, control means removably mounted within the body and electrically connected in the conductor in advance of the charges, said means being arranged to control the passage of current to the charges, whereby each charge may be fired by electrical current of a predetermined intensity.

9. A perforating gun for boreholes comprising a gun body, bullets mounted for radial discharge from said gun body, a powder chamber arranged behind each bullet, a firing filament in each of said powder chambers, and a firing circuit including a source of power, a conductor connecting said source of power to said filament, a resistance arranged in parallel with said filament, and a conductor connecting said source of power to the ground through said resistance.

10. A perforating gun for boreholes comprising a gun body, bullets mounted for radial discharge from said gun body, a powder chamber arranged behind each bullet, an electrical firing means in each of said powder chambers, and a firing circuit including a source of power, a conductor connecting said source of power to said firing means, a resistance arranged in parallel with said firing means, and a conductor connecting said source of power to the ground through said resistance.

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