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BY A. P. C.

M. SCHLUMBERGER
GUN FIRING APPARATUS
Original Filed Jan. 23, 1940

Serial No.
403,649
2 Sheets-Sheet 1

Fig. 1

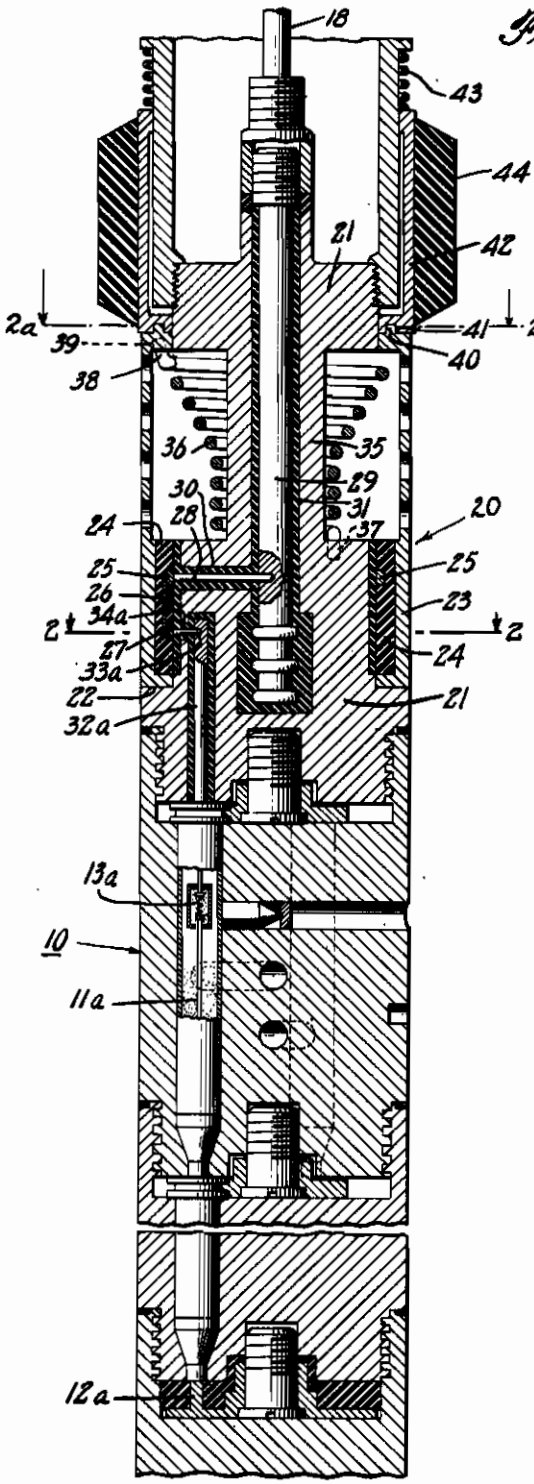
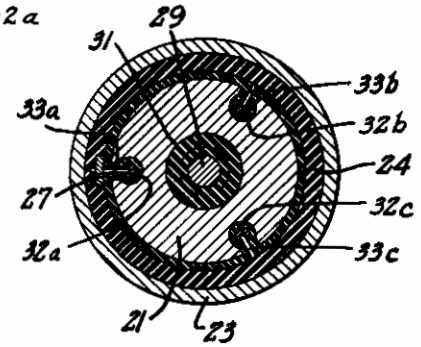


Fig. 2



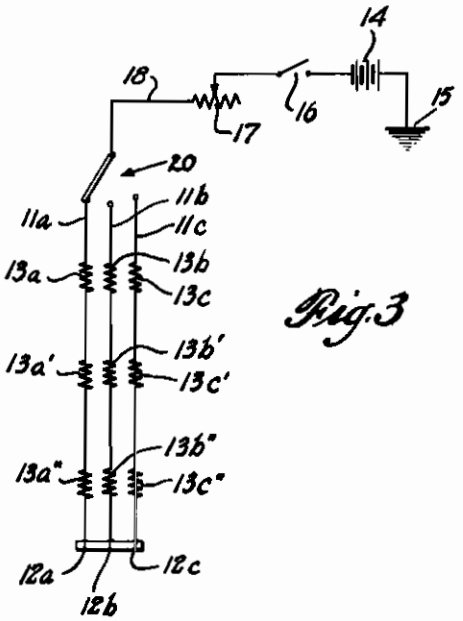


Fig. 3

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Fig. 4

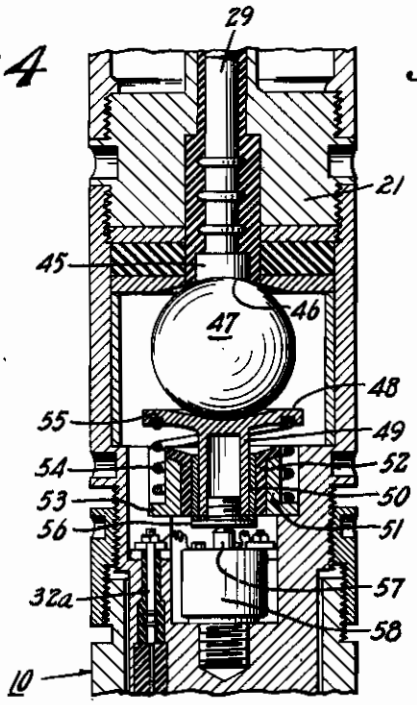


Fig. 2a

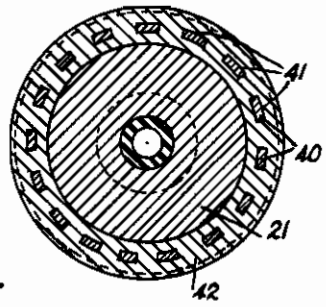
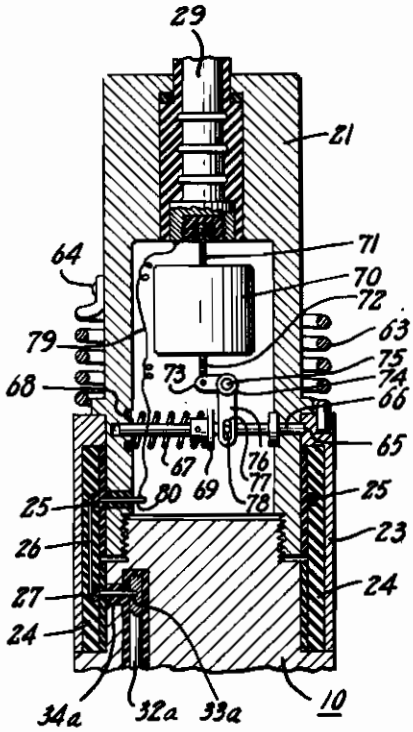


Fig. 6



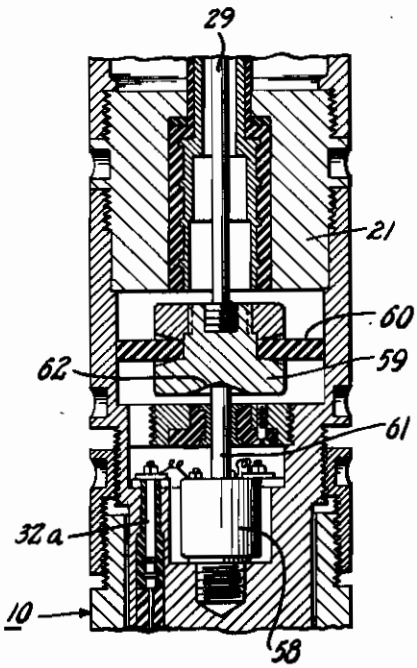


Fig. 5

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ALIEN PROPERTY CUSTODIAN

GUN FIRING APPARATUS

Marcel Schlumberger, St. Gaudens, Haute Garonne, France; vested in the Alien Property Custodian

Application filed July 23, 1941

The present invention relates to apparatus for controlling the firing of a plurality of explosive charges in a body such as a well casing perforator, for example, which is adapted to be located in a relatively inaccessible place.

In copending application Serial No. 315,157, filed January 23, 1940, for Gun perforator, of which this application is a division, there is disclosed well casing perforating apparatus having a plurality of guns, the axes of which lie in different horizontal planes and are angularly spaced about the longitudinal axis of the apparatus. The guns are adapted to be fired by a plurality of ignition circuits extending along the perforator, which are grounded to the perforator body at one end, and which are connected at the other end to corresponding conductors in the cable supporting the apparatus in the bore hole. The igniting circuits are adapted to be energized by a source of electrical energy located at the surface of the earth, one terminal of which is grounded to earth and the other terminal of which is connected through conventional switching means to the conductors in the cable.

It is an object of the present invention to provide new and improved switching means for connecting each of the ignition circuits in a gun perforator of the above character selectively to a single conductor in the supporting cable, whereby a mono-conductor cable may be used for carrying out perforating operations in a bore hole.

Another object of the invention is to provide new and improved switching means of the above character which is adapted to be actuated when a gun in the perforator is fired.

A further object of the invention is to provide new and improved switching means of the above character which is adapted to be actuated by the shock produced when one of the guns of the perforator is fired.

Additional objects of the invention will become apparent from the following detailed description of several embodiments taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic diagram illustrating switching means constructed according to the present invention in a gun perforator circuit;

Fig. 2 is a cross sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is a schematic diagram of the igniting circuits for the gun perforator shown in Fig. 1; and

Figs. 4, 5 and 6 are views in longitudinal section of modified forms of switching means constructed according to the invention.

In Figs. 1 and 2, the switching means of this invention is shown as embodied in a gun perforator of the type disclosed in the above mentioned copending application. The gun perforator 10 includes a plurality of igniting circuits 11*a*, 11*b* and 11*c* which are grounded to the body of the perforator 10 at the points 12*a*, 12*b* and 12*c* (Fig. 3). The ignition circuit 11*a* includes a plurality of igniting filaments 13*a*, 13*a*′ and 13*a*″ for firing the corresponding guns (not shown) in the perforator 10.

The igniting filaments 13*a*, 13*a*′ and 13*a*″ require different current values to bring them to red heat and means (not shown) is provided for grounding the free end of the next filament when one filament has been destroyed by the firing of the gun corresponding thereto, as disclosed in the above mentioned copending application, so that the guns in the perforator 10 may be fired successively by controlling the value of the current flowing through the igniting circuit 11*a*.

In similar fashion, the igniting circuit 11*b* includes a plurality of igniting filaments 13*b*, 13*b*′ and 13*b*″, and the igniting circuit 11*c* includes a plurality of igniting filaments 13*c*, 13*c*′ and 13*c*″ which may be energized successively by controlling the values of the currents flowing through the circuits 11*b* and 11*c*, respectively.

At the surface of the earth is disposed a source of electrical energy 14, one terminal of which is grounded to earth at the point 15 and the other terminal of which is connected through a conventional switch 16 and variable resistance 17 to a conductor 18 in the cable (not shown) on which the perforator 10 is supported in the bore hole. By means of the switching means 20 of this invention, the connections between the conductor 18 in the cable and the igniting circuits 11*a*, 11*b* and 11*c* are changed each time a gun is fired in the perforator 10.

The switching means 20 comprises a connector element 21 formed with a shouldered portion 22 on which a metallic sleeve 23 is adapted to be rotatably mounted. Within the lower portion of the sleeve 23 is disposed an insulating sleeve 24 in which is embedded a conducting ring 25. The conducting ring 25 is electrically connected through a conductor 26 to a conducting sector 27 which is also embedded in the insulating material 24.

The conducting ring 25 is maintained in engagement with a contact rod 28 which is electri-

cally connected to an axial conducting rod **29** connected to its upper extremity to the conductor **18**. The conducting rod **28** is insulated from the body of the perforator **10** by an insulating sleeve **30** and the axial conducting rod **29** is insulated in a similar manner by an analogous insulating sleeve **31**.

Each of the igniting circuits is electrically connected to a contact member which is adapted to be moved into engagement with the conducting sector **27** embedded in the insulating material **24**. Thus the igniting circuit **11***a* is connected to an insulated conducting rod **32***a* which has secured thereto a radially extending contact rod **33***a* which is disposed within an insulating sleeve **34***a* and which is adapted to engage the contact sector **27** as the sleeve **23** is rotated with respect to the connector element **21**. In similar fashion, the igniting circuits **11***b* and **11***c* are connected through insulated conductors **32***b* and **32***c*, respectively, to radially extending contact rods **33***b* and **33***c*, respectively, which are also adapted to engage the contact sector **27** when the sleeve **23** is rotated (Fig. 2).

The connector element **21** is provided with a portion **35** of reduced diameter on which is disposed a coil spring **36**, one end of which is secured to the connector element **21** at the point **37** and the other end of which is secured to a link **38** which is connected to the rotatable sleeve **23** at the point **39**. The rotatable sleeve **23** is provided with a plurality of longitudinally extending teeth **40** which are adapted to be received in corresponding recesses **41** formed in a sleeve **42** which is carried on the connector element **21** so as to be slidable axially thereupon without rotation.

The sleeve **42** is normally urged downwardly by means of a coil spring **43**, thereby engaging the teeth **40** on the sleeve **23** in the recesses **41** provided in the sleeve **42** and locking the sleeve **23** in position. Mounted on the sleeve **42** is a ring **44** made of flexible material, such as rubber, for example, and which is of substantially the same diameter as the bore hole casing into which the perforator **10** is to be lowered.

Before any of the igniting circuits may be energized, the position of the sleeve **23** with respect to the connector element **21** must be such that one of the contact rods **33***a*, **33***b* or **33***c* is in engagement with the sector **27**. If, for example, the conducting sector **27** is in engagement with the contact rod **33***a*, a circuit is completed from the ground point **15** at the surface of the earth through the source of electrical energy **14**, the switch **16**, the variable resistance **17**, the conductor **18**, the conducting rod **29**, the contact rod **28** engaging contact ring **25**, the conductor **26**, the conducting segment **27** engaging contact rod **33***a*, the contact rod **32***a* and the igniting circuit **11***a* to the ground point **12***a* on the perforator **10**, the circuit being completed through the liquid in the bore hole and the intervening earth formations.

In order to ignite the lowermost filament **13***a''*, the switch **16** is closed and the variable resistor **17** is adjusted to give the required current value to accomplish this. As indicated above, the electrical characteristics of the igniting filaments **13***a* and **13***a'* are such that they will not ignite at this value of current.

The igniting of the filament **13***a''* fires the gun corresponding thereto, and the powder gases issuing from the corresponding gun barrel exert an upward thrust on the ring **44**, thereby causing the teeth **40** to become disengaged from the recesses **41** and permitting the sleeve **23** to rotate with respect to the connector element **21**. As soon as the energy in the gases has been dissipated, the spring **43** returns the sleeve **42** to its normal position, engaging the teeth **40** in the recesses **41** and again holding the sleeve **23** in fixed position.

The tensions in the springs **36** and **43** are so adjusted as to permit the sleeve **23** to rotate through a sufficient angle after it has been released to move the sector **27** out of engagement with the rod **33***a* and into engagement with the rod **33***b* in the igniting circuit **11***b*. The lowermost filament **13***b''* may then be ignited as indicated above in connection with the igniting filament **13***a''* and by continuing the operations in this fashion the guns in the perforator may be fired successively.

In the modification shown in Fig. 4, the conducting rod **29**, which is in electrical connection with the conductor **18**, terminates in an enlarged portion **45**, the lower surface of which is curved at **46** and is in engagement with a spherical conducting ball **47**. The conducting ball **47** rests upon a cup-shaped member **48** provided with a tubular shaft **49** which is movable axially in a bushing **50** secured within a tubular member **51** fixed to the connector element **21**, and insulated from the member **51** by an insulating sleeve **52**.

The tubular element **51** is provided with an outwardly extending flange **53** at the lower extremity thereof which is adapted to seat a compression spring **54**, the upper end of which is seated in an annular recess **55** formed in the lower face of the cup-shaped member **48**, thereby maintaining the spherical ball **47** in good electrical contact with the enlarged portion **45** of the conducting rod **29**.

At the lower end of the tubular portion **48** on the cup-shaped member **48** is fitted a contact plate **56** which is continuously engaged by the actuator **57** of a conventional type commutating switch **58**. The actuator **57** is made of conductive material and it serves to complete the circuit from the conducting plate **56** to one element of the switch **58**. The switch **58** is adapted to connect the conducting rod **29** selectively to the conductors **32***a*, **32***b* and **32***c* in the igniting circuits **11***a*, **11***b* and **11***c*, respectively.

In operation, the shock produced when one of the guns in the perforator **10** is fired moves the spherical ball **47** transversely within the perforator **10**, thereby moving the cup-shaped member **48** axially against the force of the compression spring **54**. This action depresses the actuator **57** of the switch **58**, connecting the conducting rod **29** to the next igniting circuit which is to be energized.

The modification illustrated in Fig. 5 is similar to that shown in Fig. 4, except that the spherical ball **47** is replaced by a cylindrical conducting mass **59** which is elastically suspended in the connector element **21** by suitable supports **60** made of resilient material, such as rubber, for example. In this modification, the switch **58** is provided with an extended actuator **61** which projects into a conical recess **62** formed in the lower face of the cylindrical mass **59**. As in the previous case, when one of the guns in the perforator **10** is fired, the latter is moved laterally with respect to the mass **59** and the inclined surface of the conical recess **62** therein depresses the switch actuator **61**, thereby disconnecting the conducting rod **29** from one igniting circuit and connecting it to a different igniting circuit.

The modification shown in Fig. 6 is similar to that shown in Fig. 1. In this embodiment, however, the sleeve 23 is adapted to be rotated with respect to the connector element 21 by means of a coil spring 63 which is secured on the connector element 21 at the point 64. The interior wall of the sleeve 23 is provided with a plurality of spaced recesses 65, within which a transversely extending rod 66 is adapted to be received for the purpose of holding the sleeve 23 in fixed position. The rod 66 is continuously urged into engagement with the recess 65 by means of a compression spring 67, one end of which is seated within an annular recess 68 formed in the wall of the connector element 21 and the other end of which is seated against a disc 69 secured to the rod 66.

A large mass 70 is suspended within the connector element 21 on a flexible cable 71 and it is connected at its lower end by means of a flexible cable 72 to one arm 73 of a bell crank mechanism 74 which is pivoted at 75. The other arm 76 of the bell crank mechanism 74 is provided with a slot 77 within which a pin 78 on the rod 66 is adapted to be received. The conducting rod 29 which supplies current to the igniting circuits is connected by means of a conductor 79 to an insulated conducting rod 60 which is maintained in engagement with the conducting ring 25 in the sleeve 24.

When one of the guns in the gun perforator 10 is fired, the shock imparted to the perforator assembly causes the latter to move laterally with respect to the mass 70, turning the bell crank mechanism 74 about the pivot point 75 and disengaging the rod 66 from the recess 65. This permits the sleeve 23 to rotate under the influence of the spring 63 through a sufficient angle to bring the conducting sector 27 into engagement with the conducting rod 32b corresponding to the next igniting circuit 11b. By this time the mass 70 has returned to its normal position and the rod 66 is again moved into engagement with one of the recesses 65 by means of the compression spring 67.

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