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GUN PERFORATOR FOR WELL CASINGS

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This invention relates to gun perforators for well casings, and the objects of this invention are:

First, to provide a gun perforator of this character which is adapted to be lowered on a sand line and is so arranged as to incorporate a lost-motion linkage interposed between the gun and sand line, which forms a loosening jar to facilitate removal of the gun perforator should it hang up in the hole;

Second, to provide a gun perforator of this character which incorporates a plurality of gun units adapted to be operated consecutively by a controller incorporated in the gun perforator to form a self-contained unit which may be lowered into a well bore without electrical connection to the surface;

Third, to provide a gun perforator wherein each of the gun units are urged laterally outwardly from the gun body and into direct contact with the surrounding casing, whereby the bullet passes directly from the gun unit into the casing without passing through an appreciable layer of well fluid;

Fourth, to provide a gun perforator of this character which, by reason of direct contact between the muzzles of the several gun units and the surrounding well casing, materially reduces the retarding effect caused by the hydrostatic head of fluid in the well bore;

Fifth, to provide a gun perforator wherein the pressures within the gun perforator are at all times at least equal to the external hydrostatic pressure, and which during the firing operation is maintained above that of the external hydrostatic pressure, thus insuring against leakage of fluid into the working parts of the gun and eliminating the need of high pressure packing glands around the several laterally movable gun units;

Sixth, to provide a gun perforator of this character which may be locked in position in the gun bore during the firing operation and automatically releases itself when the firing operation is completed;

Seventh, to provide a gun perforator which incorporates a novel control apparatus which is operated electrically and designed to set into operation an electric motor which drives a gear pump for the purpose of forcing the several gun units hydraulically into position against the surrounding well casing, and thereafter cause sequential firing of the several gun units.

With the above and other objects in view, as

may hereinafter appear, reference is made to the accompanying drawing, in which:

Figure 1 is a longitudinal fragmentary sectional view of the gun perforator illustrating the upper end thereof;

Figure 2 is a similar longitudinal sectional view thereof illustrating the lower end of the gun perforator;

Figure 3 is an enlarged transverse sectional view through one of the gun units, with the gun unit shown extended and bearing against the well casing, this section being taken through 3-3 of Figure 1;

Figure 4 is another transverse sectional view through 4-4 of Figure 2 illustrating particularly the gear pump structure;

Figure 5 is a fragmentary longitudinal sectional view, on a slightly larger scale than Figure 1, illustrating a piston-controlled locking means which may be incorporated in the gun body to assist in holding the gun perforator in position during its operation; and

Figure 6 is a wiring diagram illustrating the technical mechanism within the controller and its association with the other electrical parts of the gun perforator.

The gun perforator is relatively long and of such diameter to fit into conventional well casings. The perforator includes a body member 1 in which are arranged a plurality of laterally directed sockets 2, each of which receives a gun unit 3. The outer end of each socket 2 is screw-threaded and inwardly thereof is relieved to form an annular channel 4. The several channels thus formed are connected by a central bore 5 extending longitudinally through the body member 1. The channels 4 and bore 5 serve to receive wires, not shown, whereby the several gun units may be electrically connected, as will be brought out hereinafter. Each gun unit comprises a sleeve 6 threaded to fit the corresponding socket 2. The sleeve 6 is constricted slightly at its outer portion, as indicated by 7, to receive slidably a chamber block 8. The chamber block 8 is provided with a flange 9 at its inner end and a spring 10 is interposed between this flange and the abutment formed by the reduced outer portion 7 of the sleeve. The spring 10 tends to hold the gun unit in its retracted position, as shown in Figure 1.

The chamber block 8 is provided with a screw-threaded bore 11 which receives a correspondingly threaded barrel 12. Inwardly from the bore 11 the chamber block 8 is provided with a cartridge chamber which receives a cartridge

13. The cartridge 13 is preferably of the type disclosed in Patent No. 2,092,317, that is, the cartridge is formed of insulating material and contains a fusible wire extending there-
 5 through whereby the powder charge may be ignited by heating the wire to incandescence. Between the cartridge 13 and the barrel 12 is fitted an explosive expansion-delaying disc 14, to which is attached a bullet 15, fitting the bore 16,
 10 out of the barrel 12. The outer end of the barrel 12 is closed by a sealing disc 17, while the connection between the barrel 12 and the bore 11 of the chamber block is sealed by a ring gasket 18.

15 The cartridge 13 is grounded against the expansion retarding disc 14 and is electrically connected at its other end to a pin 19, insulated from the chamber block 8, and having a terminal at the inner end of said block. The corresponding
 20 socket 2 is provided at its inner end with an insulating plate 20, upon which is mounted a contact spring 21 positioned to engage the terminal 19 when the gun unit is extended as shown in Figure 3, and to be out of engagement with the
 25 terminal 19 when the gun unit is retracted.

Each contact spring 21 is connected by wires passing through the channels 4 and bore 5 to the upper end of the gun body. Here the gun body is provided with a recess in which is clamped
 30 a suitable multiple contact connector member 22. The recess at the upper end of the gun body is internally threaded to receive the lower end of a controller housing 23, in which is mounted a controller 24 which contains the
 35 necessary battery and other devices for operating the gun, as will be brought out hereinafter. The lower end of the controller is provided with a multiple contact connector 25 which coacts with the connector 22.

40 The upper end of the controller housing 23 is closed by an adapter 26 having a reduced upper end in which is secured a stem 27. The stem 27 is provided at its upper end with a loosening jar element 28 which coacts with a complemen-
 45 tary loosening jar element 29 to form a loosening jar structure 30, this structure being in the form of a lost motion linkage between the members 28 and 29. The jar element 29 is secured to the lower end of a sand line, or other hoisting
 50 rope, R and also can act by a pull on R upwardly to hit sleeve 34 at 36. The function of the loosening jar structure 30 will be described hereinafter.

The stem 27 is provided with a small bore therein, in which is fitted a rod 31. The upper end of the rod extends into a transverse slot 32 provided in the stem 27 and said rod is provided therein with an apertured head portion.

Slidably fitting over the loosening jar structure and cable is a sleeve 34. The sleeve is of sufficient length to permit the necessary movement of the loosening jar member 29 without being affected thereby, that is, clearance is provided above the loosening jar member 29 so that
 65 member 29 may reciprocate with respect to member 28 without moving the sleeve. The upper end of the sleeve is provided with a constricted head portion 36 slidably fitting the cable and forming an anvil adapted to be engaged by a
 70 sleeve type go-devil 37. The purpose of the sleeve 34 is to transmit the impact of the go-devil 37 around the loosening jar structure and to the firing pin 31. This is accomplished by a safety bar 33 which fits in the aperture 32 and into
 75 holes provided in the sleeve 34. During loading

operations the bar 33 is withdrawn so that movement of the sleeve 34 cannot be transmitted to the pin 31. When the gun has been loaded and lowered into the top of the well so that only its upper end protrudes, the safety bar is inserted so that thereafter movement of the sleeve 34 will be transmitted to the firing pin 31. The sleeve and its firing pin are held upwardly by a shear pin 35 extending through the sleeve and through the stem 27. The pin 35 is so
 10 designed that the impact of the go-devil 37 upon the anvil 36 will be sufficient to shear the pin and permit movement of the sleeve 34, safety bar 33 and firing pin 31. Although the cable is inherently yieldable, the gun has sufficient inertia
 15 that an adequate blow is applied to the anvil 36 by the go-devil 37, even though the go-devil is dropped through liquid.

The firing pin 31 extends through a packing gland 38 and is adapted to engage a contact member 39 associated with the controller 24.

The lower end of the body member 1 is threaded to receive a motor 40, which motor may include an outer case equal to the diameter of the body member 1 and having externally
 25 threaded ends. Also, the motor is provided with a hollow shaft 41 so as to afford a fluid passage from the lower to the upper end thereof. Electrical connection is made between the motor and the controller by means of a wire 42a extending
 30 downwardly through the body member 1, terminating in a contact 42 and adapted to engage a spring contact 43 mounted at the upper end of the motor when the motor is assembled on
 35 the body member.

The lower end of the motor 40 is connected to a pump housing 44 in which is mounted a gear pump 45. The gear pump preferably comprises a central driving gear and a pair of idler gears, one on either side. Intake ports 46 leading upwardly from the lower side of the housing 44 and a discharge port 47 are directed upwardly therefrom into the space between the gear pump and the lower end of the motor 40.

The pump housing 44 is threaded to receive a reservoir chamber shell 48 which depends therefrom. The shell 48 is screw-threaded to an air chamber shell, or case, 49 of similar diameter. The case 49 is tapered to a point at its lower end and provided with ports 50 therein. The upper
 50 end of the case 49 carries a bellows diaphragm 51 which extends upwardly into the lower end of the reservoir chamber 48. The case 49 forms an air chamber, at the upper end of which air is compressed as the gun perforator is lowered
 55 into well fluids. The diaphragm transmits this pressure to the liquid contained within the gun perforator, it being intended that all of the cavities within the gun perforator be filled with a suitable electrically non-conducting liquid. Coal
 60 oil, low viscosity lubricating oil, transformer oil, glycerine, alcohol, and many other liquids, may be used.

The terminal 39 of the controller 24 is connected through an overload relay 52 and battery 53 to the motor 40. The other side of the motor is grounded, as is also the contact 39, when engaged by the rod 31. The overload relay 52 operates a switch 54 which, in turn, energizes a solenoid 55. The solenoid 55 controls an armature 56 which operates, through a ratchet and pawl mechanism 57, a sweeper arm 58. The sweeper arm 58 is adapted to engage a series of contacts 59, each connected by a lead wire to a cartridge 13 through the spring contact 21
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and terminal 19. The sweeper arm 58 is electrically connected with the switch 54 parallel with the solenoid 55. The armature 56 controlled by the solenoid 55 is adapted to engage and open a switch 60 each time it is raised, so as to break the circuit through the solenoid 55 and thereby cause the sweeper arm 58 to advance in stages around the series of contacts 59.

A cut-off switch 61 is interposed in the line between the battery 53 and the motor 40 and positioned to be engaged by the sweeper arm 58 after it has completed its firing of the several gun units, whereby the motor is automatically disconnected.

At either end, or both ends, or, if desired, intermediate the ends of the body member 1, there may be incorporated means to assist in securing the gun perforator in the casing during the firing operation—such an arrangement is illustrated in Figure 5. The body 1 is provided with a transverse bore 62, constricted slightly at its central portion to form an abutment facing each end and adapted to receive a pair of pistons 63. The outer ends of the pistons 63 are provided with teeth 64 adapted to engage the surrounding well casing. The pair of pistons 63 are connected by a spring 65 so that they normally occupy a retracted position within the boundaries of the body member 1.

Operation of the gun perforator is as follows: The several gun units are loaded and secured in position, the several springs 10 holding the gun units in their retracted position, as shown in Figure 1. The entire space within the gun perforator, including the reservoir within the shell 48, is filled with an electrically non-conducting liquid. Various parts of the controller are arranged as shown in Figure 6, that is, switch 54 is open as is also contact 39, and the sweeper arm 58 is in position to engage the first contact 59 communicating with one of the gun units 3. The sleeve 34 is positioned so that the shear pin 35 may be inserted, whereby the rod 31 is held upwardly from the contact 39. The gun perforator is then lowered into the well bore on the sand line R to the desired depth; thereupon the go-devil 37 is dropped, which causes the pin 35 to shear, allowing the sleeve 34 to drop and cause the rod 31 to engage contact 39, closing the circuit through the overload relay 52, battery 53 and motor 40. The motor 40 drives the pump 45, pumping the liquid from the chamber within the reservoir 48 upwardly behind each of the gun units and behind the pistons 63. When each of the gun units and pistons 63 have moved out into engagement with the casing, the liquid pressure within the body member builds up to a predetermined value, whereupon the load on the motor 40 increases to a point where the armature of the overload relay 52 causes switch 54 to close. When the switch 54 closes, the solenoid 55 and armature 56 advance the ratchet mechanism 57 and sweeper arm 58 so as to engage each of the contacts 59 in succession, thereby firing the gun units one at a time. As the sweeper arm completes its rotation it engages the switch 61 to open the same and thereby disconnect the motor 40 from the battery 53. When this occurs the liquid from within the body member tends to drain back into the reservoir and is urged to return by the several springs 10 and 65 which retract the gun unit 3 and pistons 63. In a moment after the cycle of operation is completed the gun units are retracted, as well as the pistons, and the gun perforator may be withdrawn from the well.

As an added safety measure, the battery 53 is so designed that its life within the well bore, particularly with the load of the motor thereon, is relatively short, so that should the controller fail to function, the power of the battery will diminish in a comparatively short time to a point where the motor can no longer maintain the pressure in the body member to overcome the effect of the springs 10 and 65, so that the gun unit and pistons are sure to return within the body member and in no manner interfere with its removal from the well bore.

The jar structure's principal function is to insure loosening of the gun after firing. Thus, should the gun become wedged by reason of inflowing sand through the perforations which it has made, or through failure of the gun unit to retract into the body, or should a bullet fail to penetrate, the cable may be slacked and jerked upward, causing the jar elements to hammer one against the other and work the gun free. Also, in lowering the gun prior to firing, should it become wedged in the casing, the jar elements function to aid in retrieving the gun or forcing it to pass the obstruction. It should be noted that operation of the jar structure prior to firing the gun has no effect on sleeve 34 and does not place a strain on the pin 35.

Though we have shown and described a particular embodiment of our invention, we do not wish to be limited thereto, but desire to include in the scope of our invention the constructions, combinations and arrangements substantially as set forth in the appended claims.

We claim:

1. The combination with an explosive device and a wire rope, of: a loosening jar structure connecting said explosive device and said wire rope to provide a predetermined lost-motion connection therebetween, whereby an upward or downward hammer action between the parts of said loosening jar structure may be effected; a firing mechanism for said explosive device, including a member projecting above said loosening jar structure and clearing the same to permit movement of said jar structure without affecting said member; and means other than said loosening jar structure engageable with said member to actuate said firing mechanism.

2. The combination with a gun perforator and wire rope, of: a loosening jar structure connecting said gun perforator and wire rope; a firing mechanism including a sleeve projecting above said jar structure; a shear pin restraining said sleeve; means operable upon shearing of said pin to fire said gun perforator; and means other than said jar structure engageable with said member to actuate said firing mechanism.

3. A gun perforator comprising: a gun body; a plurality of gun units carried thereby; a controller mechanism for firing said gun units in a predetermined sequence; a supporting cable; a loosening jar structure connecting said cable and gun body; and means operable by impact for instigating operation of said controller mechanism.

4. A gun perforator comprising: a gun body; a plurality of gun units carried thereby; a controller mechanism for firing said gun units in a predetermined sequence; a supporting cable; a loosening jar structure connecting said cable and gun body; means for instigating operation of said controller mechanism, including a member projecting above said jar structure; and a device adapted to engage said member by impact.

5. A gun perforator comprising: a gun body; a plurality of gun units carried thereby; a controller mechanism for firing said gun units in a predetermined sequence; a supporting cable; a loosening jar structure connecting said cable and gun body; a sleeve embracing said jar structure and extending thereabove; a means initially restraining said sleeve; link means operatively connecting said sleeve with said controller; and impact means engageable with said sleeve thereby to instigate operation of said controller.
6. A gun perforator comprising: a gun body; a plurality of laterally directed gun units; means for shifting said gun units laterally from said gun body into contact with a surrounding well casing; and means for firing said gun units.
7. A gun perforator comprising: a gun body; a laterally directed and laterally movable gun unit mounted in said gun body; means for urging said gun unit laterally from the gun body into contact with a surrounding well casing; and means for retracting said gun unit.
8. A gun perforator comprising: a gun body; a gun unit mounted for lateral displacement therein; hydraulic means for extending said gun unit laterally from the gun body into engagement with a surrounding well casing; and means for firing said gun unit while so extended.
9. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; and a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing.
10. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; and yieldable means tending to retract said gun unit into said gun body.
11. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; yieldable means tending to retract said gun unit into said gun body; an electrically responsive explosive charge carried by said gun unit; and means for supplying current to said explosive charge, including contact means in said chamber.
12. A gun perforator comprising: a gun body

having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; and an electrical controlling means for said gun.

13. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; an electrically responsive explosive charge carried by said gun unit; an electric motor for operating said pump; a controller for said motor and explosive charge, including means for operating said motor; and means operative upon lateral extension of said gun unit to discharge said explosive charge.

14. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; an electrically responsive explosive charge carried by said gun unit; an electric motor for operating said pump; a controller for said motor and explosive charge, including means for operating said motor; means operative upon lateral extension of said gun unit to discharge said explosive charge; a supporting cable for the gun body; a jar structure interposed between the gun body and cable to facilitate movement of the gun body should the same hang up in the well bore; mechanism for instigating operation of said controller, including a member protruding above the jar structure; and impact means slidable on said supporting cable for engaging said member.

15. A gun perforator comprising: a gun body having a laterally directed chamber; a gun unit forming a plunger filling said chamber; a pump adapted to introduce fluid into said chamber to urge said gun unit laterally outwardly into contact with a surrounding casing; an electrically responsive explosive charge carried by said gun unit; an electric motor for operating said pump; a controller for said motor and explosive charge, including means for operating said motor; means operative upon lateral extension of said gun unit to discharge said explosive charge; and means slidable with respect to said gun body for actuating said controller.

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