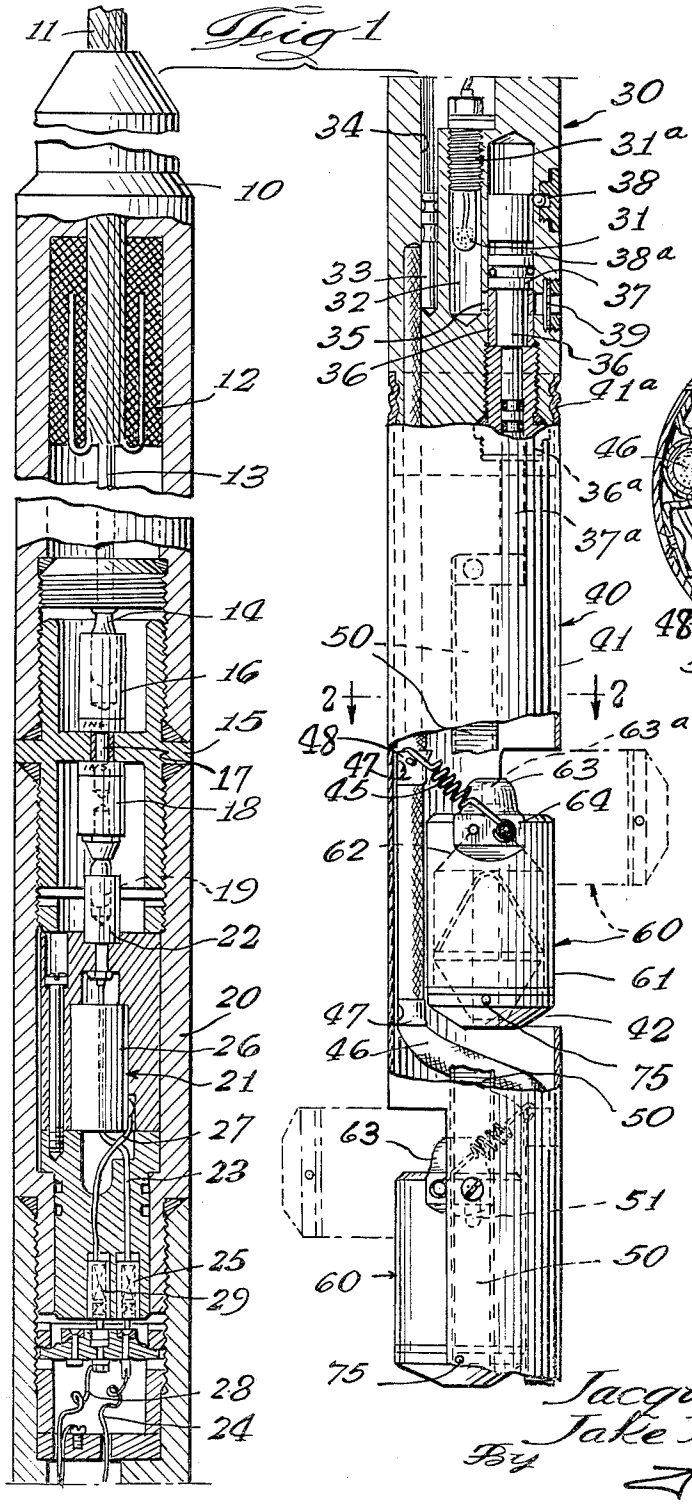
Jan. 1, 1963 J. H. CASTEL ETAL 3,071,072

PERFORATING APPARATUS

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Fig. 1



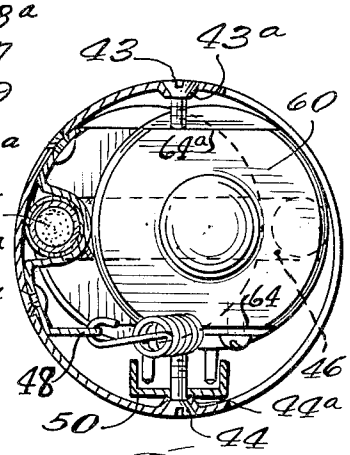


Fig. 2.

Inventors
Jacques H. Castel
Jake H. Le Bus
By
Attorney

Jan. 1, 1963 J. H. CASTEL ETAL 3,071,072

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Fig. 3.

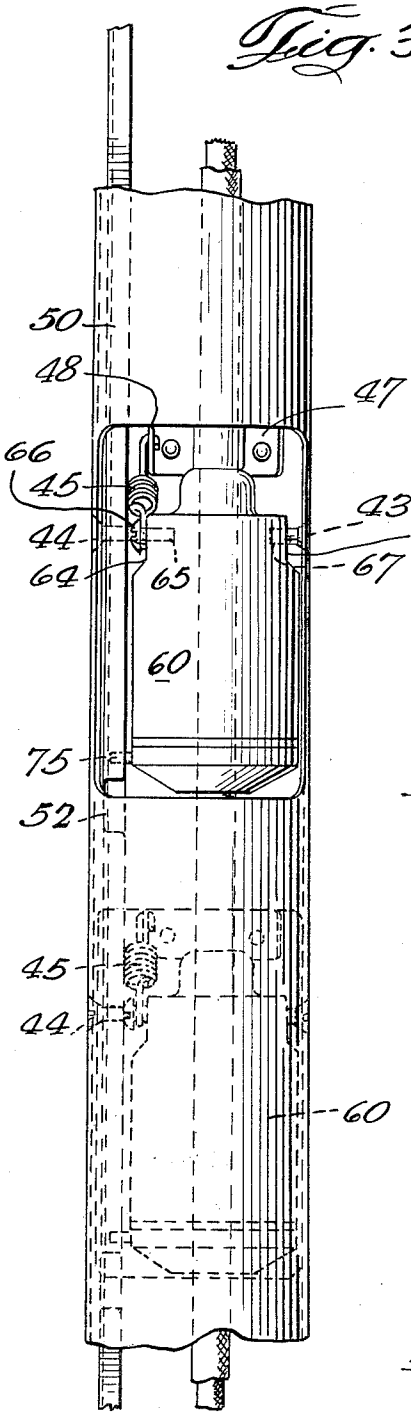


Fig. 4.

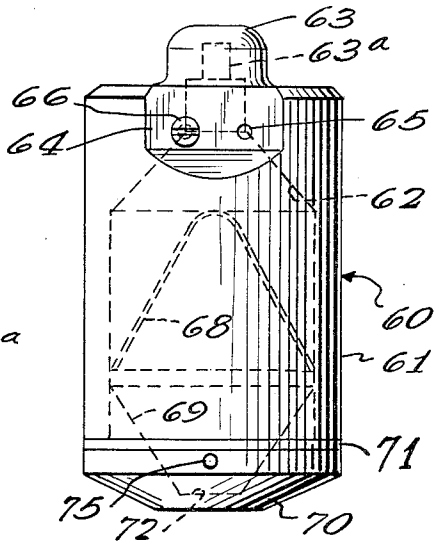
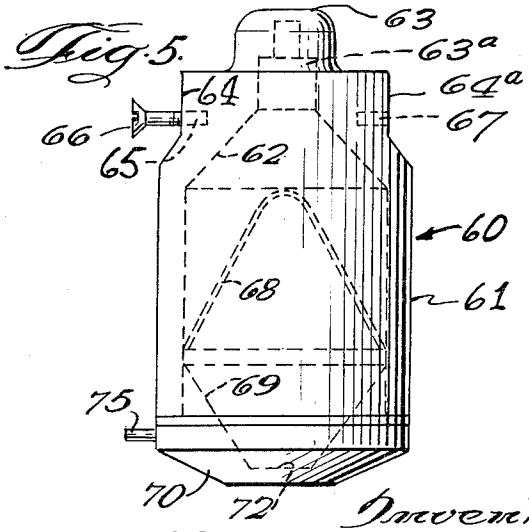


Fig. 5.



Inventors
Jacques H. Castel
Jake H. LeBus
By Hoyton
Attorney

Jan. 1, 1963 J. H. CASTEL ETAL 3,071,072

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Fig. 6.

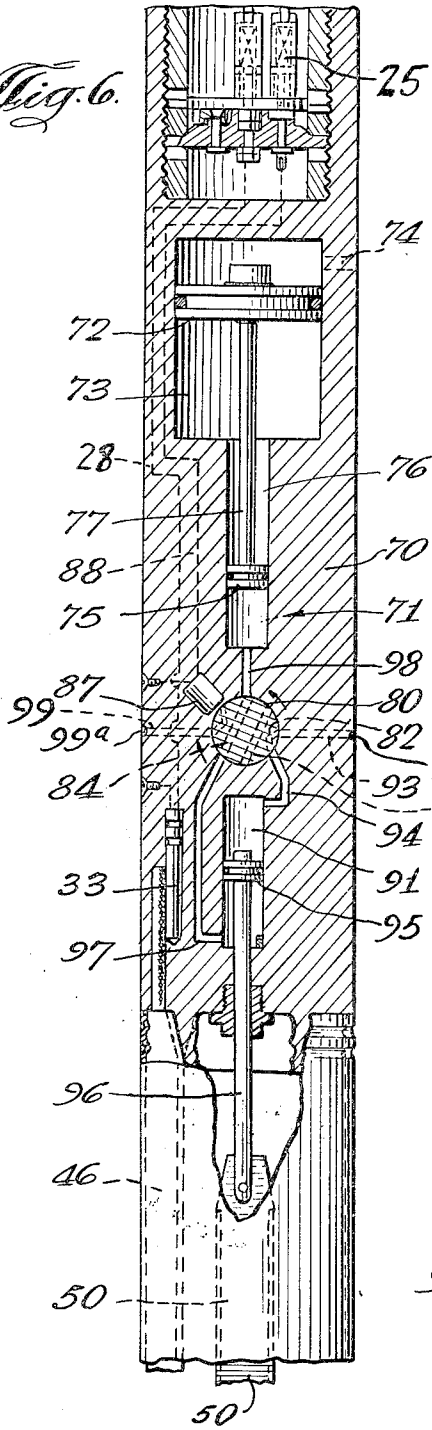


Fig. 7.

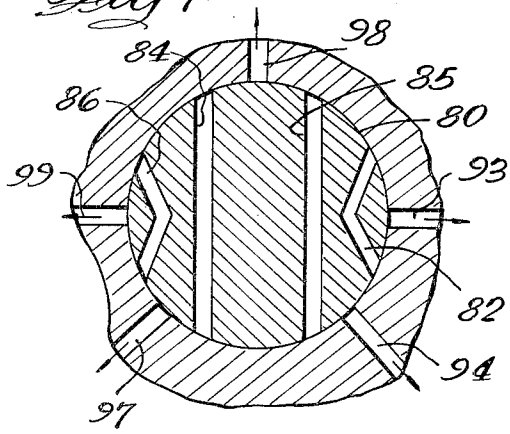


Fig. 8.

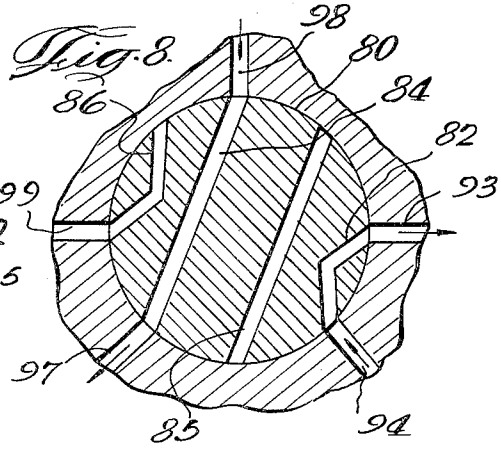
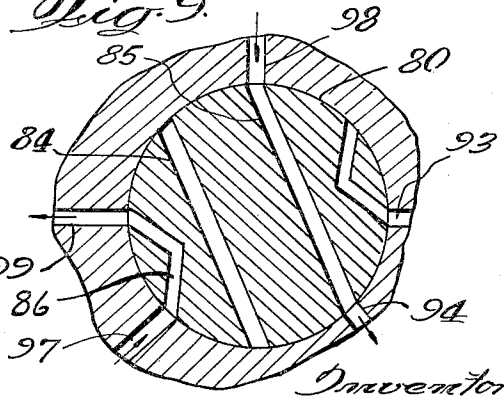


Fig. 9.



Inventors
Jacques H. Castel
Jake H. Le Bus
By Attorney

United States Patent Office 3,071,072 Patented Jan. 1, 1963

3,071,072

PERFORATING APPARATUS

Jacques H. Castel and Jake H. Le Bus, Houston, Tex., assignors, by mesne assignments, to PGAC Development Company, Houston, Tex., a corporation of Texas

Filed Aug. 11, 1954, Ser. No. 449,201
12 Claims. (Cl. 102—20)

The present invention relates to well tools and more particularly to perforating guns adapted for perforating well casing, cement or bore formations from boreholes.

Specifically, this invention concerns a so-called tubing jet perforating gun, named because it is comparatively small in diameter, permitting it to be lowered into a borehole through a string of tubing already in place therein.

As is well recognized in the art, in order to make an effective jet charge penetration, the jet stream axis of the charge upon detonation must be either at right angles to the longitudinal axis of its gun or carrier, or at least transverse thereto. If the jet charges of such a gun are to be fixedly mounted within such a gun, the maximum length of the jet charges to be employed must, of necessity, be limited to something in the neighborhood of the diameter of the gun, which, unfortunately, in the case of a tubing gun, must be of the order of about 1¾". In order to overcome this difficulty and to provide charges of a more substantial size, it has heretofore been proposed to initially position the jet charges axially of the tubing gun for movement through the tubing whereby charges of considerably greater length than the diameter of the gun may be employed. As a tubing gun is never fired in the string of tubing itself, but only after it has passed out of the tubing and is positioned in the portion of the borehole below the tubing, it has been proposed to include in the gun means operable from the surface to rotate the charges into firing positions in which their jet stream axes are transverse to the longitudinal axis of the gun.

It will immediately be appreciated that two major problems are involved in the operation of such a gun:

(1) The means for rotating the charges to firing position must be simple, yet completely dependable so that the well is in no way damaged by the firing of a charge not properly positioned. The charges should likewise be retractable if for some reason it is desired to withdraw the gun from the borehole before it is fired.

(2) The means for detonating the charges after the latter have been rotated to their firing positions must be positive and yet should provide a foolproof safety device against misfire when the charges are in any position but the extended or firing attitude.

The present invention solves these problems and is an improvement over a perforating gun in which the jet charges are rotatable to firing position by means controlled at the surface and disclosed in co-pending application Serial No. 370,990, filed July 29, 1953, now Patent No. 3,018,730 to which reference may be had for certain structural details of the gun per se.

Briefly, in the patent application referred to above, there is disclosed a perforating gun of very small outside diameter so constructed as to be capable of being run through small diameter openings or tubing in a well without sacrificing the efficiency and effectiveness of a larger diameter gun of currently conventional design. This is accomplished in accordance with the principles of the invention by initially maintaining the charges of the device in axial alignment with the gun for its ready passage through the narrower restrictions in the borehole, while providing an improved and novel means for rotating the charges through an arc or arcs from the latter position to the operative or firing position whereby the charge axes are substantially normal to the longitudinal axes of

the gun and the borehole. The rotation of the charges is effected by a slidable bar and cam means after the gun has been passed through the narrow and restricted portions of the well bore and is again situated in a less confined area of the borehole below the end of the well tubing, in which area production is sought.

In the referred to patent application, a number of mechanisms were disclosed, both automatically and selectively operable to position the charges into firing position. In that application, selective operation of the charges to the firing position was accomplished by electrically setting off a small body of slow burning explosive material, the high pressure gases generated thereby being utilized to release a locking means via a piston operated by the gas generated pressure. In addition, several arrangements to accomplish positive detonation of the charges in their operative positions were disclosed.

This invention constitutes an improvement and refinement over the foregoing by providing hydraulically operable means for releasing the referred to locking means by utilization of hydraulic pressures exerted by the well fluids and drilling muds, all at the selection of an operator at the earth's surface, as well as an improved arrangement for detonating the charges whereby detonation of the charges is positively prevented at all times other than when the charges are in firing position or attitude, that is, extended with their jet stream axes transverse to the longitudinal axis of the gun.

It is, accordingly, a principal object of this invention to provide an hydraulically operable device controllable from the earth's surface to actuate or release mechanism in a perforating gun or other well tool suspended in a borehole far below the earth's surface.

Another principal object of this invention is to provide an improved arrangement for detonating the charges of the gun only after said charges have been rotated or extended to their operative positions.

Another object of this invention is the provision of a simple electrical control operable from the earth's surface to actuate hydraulically operable mechanism suspended in a borehole below the earth's surface.

A feature of the invention resides in the simplicity of the electrical control by which both the hydraulic mechanism and the perforating charges are selectively operated and detonated respectively by electrical current over a single conductor.

Another feature of the invention resides in the separability of the improved detonating means whereby positive assurance against firing (or misfiring) is provided when the charges are not in the firing position.

These objects and additional features and advantages will become apparent as the following description proceeds, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a longitudinal sectional view of a portion of a perforating gun embodying gas operated charge rotating mechanism for use in connection with the novel and improved means and arrangement for detonating the shaped or jet charges only after they have attained their firing positions.

FIG. 2 is a sectional view along line 2—2 in FIG. 1.

FIG. 3 is a fragmentary view of a portion of the gun of FIG. 1 and rotated 90 degrees.

FIGS. 4 and 5 are plan views of charges for use in the gun of FIGS. 1, 2 and 3 and rotated 90 degrees to one another.

FIG. 6 is a longitudinal sectional view of a portion of a perforating gun as illustrated in FIG. 1 and provided with an hydraulic charge rotating actuating means.

FIGS. 7, 8 and 9 are schematic views of the hydraulic valve mechanism of FIG. 6 in various positions.

Referring now more particularly to the drawings, in

FIG. 1 a fishing head or bell 10 is secured to the lower end of a cable 11 by means of a well-known rope socket 12. The cable 11 is metal sheathed, the ends of the wires or strands comprising the sheathing being embedded in babbitt or the like within the rope socket. A single insulated conductor 13 from from the cable terminates at the lower end of the fishing bell in a male electrical connector member or plug 14. A connecting sub assembly 15 threadedly connects the lower end of the fishing head or bell 10 to a circuit component sub assembly 20.

The cable conductor 13 is electrically extended through the connecting sub assembly 15 by way of a female socket 16 into which the plug 14 fits, the insulated wire 17, insulated contacts 18 and male connector or plug 19 for connection to a suitable socket or female electrical member in the next adjacent sub assembly.

The circuit component sub assembly 20 contains a condenser 21, preferably of the coaxial type, the axial electrode of which is connected to a female socket connector 22 into which the male connector 19 from the connecting sub 15 fits. The central electrode is connected by means of wires 23 and 24 and an insulated connector 25 to a slow burning powder charge 31 in a cavity 32 in the detonating subassembly 30.

The detonating sub assembly 30 is, of course, threadedly connected to the lower end of the circuit component sub assembly 20. The external or concentric electrode 26 of the condenser 21 is connected by wires 27 and 28 and a suitable insulated connector 29 to a blasting cap 33 within another cavity 34 in the detonating sub 30.

The firing sub assembly 40 of the gun comprises a thin tubular shell 41, preferably of a readily frangible metal, such as aluminum, secured by crimping, or any other suitable means, to the lower end of the detonating sub 30 as indicated at 41*a*. Within this tubular shell 41, a series of shaped explosive jet forming charges 60 are pivotally mounted.

Referring specifically to FIGS. 4 and 5, one of the charges 60 is shown in detail. The charges 60 each comprise an outer cylindrical cartridge-like casing 61. The casing 61 is internally hollow, the inner rear portion preferably tapering at 62 to a central aperture into which a detonating booster charge 63*a* is inserted. The booster charge preferably extends outwardly beyond the casing 61 and is externally sealed by a cap 63 of any suitable material.

Externally, opposite sides of the rear portion of the casing 61 form flat parallel planes indicated at 64 and 64*a*.

One of the flat portions 64 of each of the charge casings 61 is provided with a tapped bore 65 for receiving a pivot screw. Spaced equidistant from bore 65, on the other side of the longitudinal center line of the flat surface 64, there is provided a pin or stud 66. The opposite flat surface 64*a* of the charge 61 is provided with a tapped bore 67 in alignment with the bore 65 for receiving another pivot screw or trunnion, more fully described hereinafter in connection with the mounting of the charges 60 in the firing sub assembly 40 of the gun. The interior of the charge casing 61 is provided with a suitable detonating explosive material shaped with a conical cavity outwardly flaring toward the forward or jet forming end of the charge. This cavity, as is conventional practice, preferably contains a suitable conical liner 68 of relatively soft metal, such as copper, well-known in the art. In order to provide the necessary stand-off for the shaped explosive charge, inverted over the mouth of the conical liner 68, and between it and a cap member or closure 70, there is provided a frustroconical element 69 open at both ends and which may comprise any suitable material, such as light metal, plastic, cardboard, etc. This charge casing itself is closed by the cap 70. This cap 70 is snugly seated about the forward or jet forming end of the charge casing 61, and may be secured

thereto by any suitable means, but is preferably secured in such manner that the detonating material is hermetically sealed within the casing 61. The central portion 72 of the cap 70 is of substantially lesser thickness than the remainder of the cap element so that the jet stream will not be in any way substantially impeded in its emergence therethrough. This section 72, however, is of such diameter, thickness and strength as to withstand whatever pressures may be encountered in the well. The frustroconical stand-off member 69 is arranged so that its end of lesser diameter seats in the annulus provided by the central portion 72 of the cap 70.

Radially projecting from the cap 70, and for positioning in longitudinal alignment between the tapped bore 65 and stud 66, is a charge lock pin 75, the purpose of which will more fully appear hereinafter.

In recapitulation, I have, therefore, provided a sealed shaped charge of substantially new external design. The rear portion is provided with a pair of parallel flat surfaces 64 and 64*a*, whereon laterally off center, but in axial alignment, two tapped bores are provided for receiving pivot screws or trunnions. One of the flat surfaces, 64, is also provided with a projecting stud 66, the purpose of which will be described hereinafter. Between the parallel flat surfaces 64 and 64*a* at the rear of each charge, a booster charge 63*a* with a suitable external hermetically sealing cap or cover 63 of thin metallic material is inserted so that the thin metallic cap projects rearwardly from the rear portion of the charge casing 61 proper. The forward, or jet forming end of the charge is provided with a cap element 70, the central portion 72 of which is of lesser thickness than the remainder of the cap, and which preferably completes the hermetical sealing of the detonating material within the charge casing. Finally, a charge locking pin 75 projects radially from the cap element 70 and is positioned on a longitudinal line between the stud 66 and the tapped trunnion bore 65. The charge casing 61 and the cap 70 may be made of any suitable readily frangible material, such as "Bakelite" plastic, glass, aluminum or other light metal, or the like.

Returning now to the firing sub assembly 40 which, as stated previously, comprises a thin tubular shell 41, there are arranged in the shell 41 a series of elongated apertures 42 formed by the removal of sections of the cylindrical wall. The apertures 42 are each slightly longer than the length of one of the charges 60, and in width are less than the diameter of the firing sub 40 but slightly greater in width than the diameter of the charges. The diameter of the shell 41 is greater than the diameter of the charges by an amount at least equal to the diameter or thickness of the detonating material for setting off the charges. This detonating explosive material preferably takes the form of a column of detonating material, such as, for instance, Primacord, well known in the art. The apertures 42 are, moreover, longitudinally spaced and staggered on diametrically opposite sides of the shell 41 throughout its length.

One of the charges 60 is mounted within the firing sub 40 adjacent each of the apertures 42 in the following manner:

Screws 43 and 44 (FIG. 3) forming trunnions are radially inserted in diametrically opposite bores 43*a* and 44*a* in the shell 41, which bores are adjacent the longitudinal edges of the apertures 42 in the shell 41 and equally spaced therefrom in a plane running longitudinally through the center of the shell 41 and parallel to the longitudinal sides of the apertures 42. The screws 43 and 44 are threaded into the tapped bores 67 and 65 respectively of the charges 60 and thereby form trunnions about which the charges 60 may be rotated. It will be apparent that although the axes of the trunnions 43 and 44 lie in a diametral plane of the shell 41, they are eccentric with respect to the longitudinal axes of the charges 60 themselves.

The impetus necessary to rotate the charges 60 from their longitudinal or rest positions within the shell 41 adjacent the apertures 42 to a position wherein the longitudinal and jet stream axes of the charges 60 extend radially with respect to the firing sub 40, is provided by spring members 45 attached to each of the charges 60 with one end of each secured to studs 66 laterally offset from the pivot axes of the charges 60, the opposite end of each of the springs 45 being secured to the inner wall of the shell 41. The springs 45 are arranged under tension and it will be understood, therefore, that unless restrained, they will exert a turning moment about the trunnions 43 and 44 whereby the charges 60 are rotated to their operative or firing positions with their longitudinal and jet forming axes radially extending from the shell 41 through the apertures 42.

The detonating means for these charges, as stated before, may comprise a detonating column or cord 46, such as Primacord, which extends from its terminus adjacent the blasting cap 33 in the sub assembly 30 longitudinally along the inside wall of the shell 41 opposite from the apertures 42 and adjacent the longitudinal sides of the charges 60 in somewhat serpentine fashion.

In order to insure the proper positioning of the detonating cord 46, the cord is fastened at suitable intervals to the inner wall of the shell 41 by clamp members 47 so that whenever the charges 60 are rotated into their operative positions, the thin shell 63 covering the booster charges 63*a* will snugly abut the portion of the detonating cord 46 adjacent thereto. In the preferred embodiment illustrated in the drawings, the clamps 47 comprise small metallic brads or straps secured by any suitable means, such as rivets, to the inner wall of the shell 41 opposite the apertures 42, and these clamps 47 are preferably also provided at one end with an ear 48 provided with a suitable aperture to which one end of the respective operating springs 45 may be secured.

In order that the charges 60 may be releasably maintained in their inoperative or rest positions, that is, positioned longitudinally within the tubular firing sub assembly 40, until such time as it is desired to rotate them into their operative or firing positions, an operating bar member 50 is provided which extends longitudinally adjacent each of the charges 60. The operating bar 50, as illustrated, preferably comprises a channel shaped member having suitably spaced slots 51 which are slidable over the respective trunnions 44. The rails of the operating bar 50 are in turn provided with spaced slots 52 which are arranged so that in one extreme position of the operating bar 50, that is with the trunnion screws 44 all occupying the uppermost positions of the slots as seen in FIG. 1, the lock pins 75 on the caps 70 of each of the charges 60 lie beneath, or within, the rails of the operating bar 50 closely adjacent slots 52. When the operating bar is moved by means to be described hereinafter, to its other extreme position, that is, to the position wherein the trunnion screws 44 occupy the lowermost position in the slots 51, as seen in FIG. 1, the slots 52 are placed in register with the lock pins 75 whereby the charges 60 are released and are free to rotate automatically to their operative or firing positions under the impetus of their respective springs 45.

The operation of the actuator mechanism for rotating or permitting rotation of the charges to their operative or firing positions through the medium of the operating bar 50 is as follows:

At such time as it is desired to release the charges 60 for rotation to their operative or firing positions, which position is shown in the phantom lines in FIG. 1 of the drawings, direct current electrical energy may be passed down the single insulated conductor 13 of the cable, through the center electrode of the condenser 21, and by way of wire 23, connector 25, and wire 24 to an igniter 31*a* for the slow burning charge 31 within the chamber 32 of the firing sub assembly 30 previously referred to. The igniter contains a charge of slow burning powder 31 which, when fired, causes the products of combustion in the form of gases to expand in the closed chamber 32 and into the connecting port 35 into chamber 36. The chamber 36 is provided with a piston 37 connected to the upper end of the operating bar 50 by means of a rigid connecting rod 37*a*. The lower end of the piston chamber 36 is closed by a suitably packed gland nut 36*a* through which the connecting rod 37*a* is slidably operable. The expanding gases in chamber 36 cause the piston to move upward as viewed in FIG. 1 to a point where a spring loaded detent or pin 38 drops into a groove 38*a* provided for that purpose in the periphery of the piston 37, locking the piston into its operated position. The expansion chamber 36 is also provided with a safety shear plate or diaphragm 39, which is ruptured when the gas pressure has exceeded a predetermined value after the piston has been moved to its operative position. The movement of the piston 37 produces a corresponding movement of the attached connecting rod 37*a* moving the channel operating bar 50 upwardly as viewed in FIG. 1. The movement of the channel operating bar 50 places the slots 52 in the rail portions of the channel adjacent each of the locking pins 75, whereupon, as described above, the charges 60 then are each free to rotate to their operating or firing position under the impetus of their respective tensioned operating springs 45. When, and only when the charges 60 are in their operative or firing positions, and the base or capped portion 63 of their respective booster charges 63*a* abut the detonating cord 46, may detonation of the charges 60 take place. Detonation of the detonating cord 46, and consequent detonation of the charges 60, may then be accomplished by sending an alternating electric current over the cable conductor 13, which alternating current will bridge the coaxial condenser 21 and follow leads 27 and 28 through connector 29 to the blasting cap 33, to detonate the blasting cap 33, in turn detonating the adjacent end of the detonating cord 46 and substantially simultaneously therewith detonating each of the shaped charges 60. In this connection, it has been found preferable to encase the detonating column, or Primacord, 46 in a flexible covering of material, such as plastic or the like, so that the detonating cord itself is not in any way impaired or fouled by the well fluids which, of course, have free access to the interior of the tubular casing portion 41 of the firing sub 40 through the elongated apertures 42 provided for the rotation of the charges 60 to their operative firing positions.

The entire gun assembly below the detonating sub 30, which, of course, includes the tubular firing sub assembly 40, the detonating cord 46, its clamping members 47, the charges 60 and their associated operating mechanisms, including the pivot trunnions 43 and 44, springs 45, and the operating channel bar 50, is all considered expandable and largely disintegrates upon detonation, leaving a minimum of debris or "junk" in the hole.

Referring now to the embodiment shown in FIG. 6, there is substituted for the detonating and the charge actuating sub 30, a detonating and actuating sub assembly 70 which illustrates an alternative hydraulically operable means for causing rotation of the shaped charges 60 to their operating or firing positions. The hydraulic actuating device in the sub assembly 70 is generally indicated at 71, and provides a reciprocating actuator which can be used both for extending and retracting the charges. For use with the gun illustrated, it is necessary to actuate the charges 60 in one direction only, that is, to the operative or firing position. However, for use with other types of guns, dual operation, that is, including retraction, is valuable. The cable, fishing bell or head and connector block firing mechanism, and the charge case assemblies are all exactly as described above with reference to the embodiment of the gun illustrated in FIGS. 1, 2 and 3.

The hydraulic actuator arrangement 71 comprises a piston 72 operable within a cylindrical chamber 73 within the actuator sub 70. The piston 72 is of substantial diameter and is operable by the hydrostatic pressure from the well fluid within the borehole permitted to enter through a port 74 in the wall of the sub assembly 70 communicating with the upper portion of the cylindrical chamber 73. The lower portion, that is, the portion of the cylindrical chamber 73 normally below the piston 72, merely contains air at atmospheric pressure. The piston 72 is rigidly connected by a connecting rod 77 to a smaller diameter piston 75 in a cylindrical chamber 76 formed as an extension of the larger cylindrical chamber 73. The lower portion of chamber 76 is filled with an incompressible fluid for hydraulic operation, and is connected with a multi-position valve 80 by a passage 98. While the gun is being run through the tubing, and prior to reaching the firing location, the charges 60 remain locked in the inoperative position as described above, and the multi-position valve 80 is set in the position illustrated in FIG. 7. In this position, passage 98 is closed and piston 72 is thus held against movement in either direction. When the gun has reached the location in the borehole below the tubing where perforation is desired, the valve body 80 is rotated to the position illustrated in FIG. 8. The means for rotating the valve body 80 will be described subsequently.

It will be noted that when the valve body 80 is in the position illustrated in FIG. 8, the passage 84 places the lower portion of cylindrical chamber 76 in communication with the lower portion of cylindrical chamber 91 through passages 97 and 98. Simultaneously, passage 82 of the valve body 80 places the upper portion of chamber 91 in communication with the well fluid through port 92 and passages 93 and 94. Since the large piston 72 has substantially greater surface area than the smaller piston 95, the hydrostatic pressure of the well fluid entering the upper portion of cylindrical chamber 73 through the port 74 will cause the piston 72 to be depressed so that its connected piston 75 will in turn urge the substantially incompressible hydraulic actuating fluid in the lower portion of chamber 76 through passages 98 and 97 and valve passage 84 in valve body 80 into the lower portion of chamber 91, whereby the piston 95 will be moved upwardly, displacing ahead of it the well fluid which is vented through passages 93 and 94 and valve passage 82 to the external port 92. As the piston 95 moves upwardly, its connecting rod 96 causes the operating bar 50 connected thereto to move upwardly to a position where the charges 60 are released, and are free to rotate to their respective firing positions under the impetus of their individual springs 45.

Although, as stated previously, it is normally not necessary in the type of gun illustrated to provide means for returning the charges 60 to their inoperative or retracted positions after they have been once rotated to firing position, this ordinarily can be accomplished by merely withdrawing the entire gun back into the tubing whereby the charges 60 are literally wiped back into their retracted positions within the shell 41. After the charges 60 have been thus retracted, unfired, within the shell 41, the actuating mechanism of FIG. 6 can be employed to lock them in place by rotating the valve body 80 to its third position as illustrated in FIG. 9. In this position, passages 98 and 94 are placed in communication, and passage 97 is placed in communication with passage 99 which terminates in port 99*a*. Thus, well fluid entering port 74 depresses piston 72 further, whereby the hydraulic fluid in the lower portion of chamber 76 is urged by connected piston 75 through passage 98, valve passage 85 and passage 94 into the upper portion of the chamber 91 above the piston 95, which is thereby depressed. Well fluid below piston 95 is vented into the well bore through passage 97, valve passage 86, passage 99 and port 99*a*. This movement of the piston 95 in turn moves the operating bar 50 downwardly so that the upper ends of the slots 51 engage the charge trunnion pins 43 and 44 and the rails of the bar 50 are again in position over the charge pins 75 restraining the charges 60 against the rotating force of springs 45.

It will also be apparent that where movement of the charges 60 is required in one direction only, the hydraulic valve body and actuating mechanism may be substantially simplified by the elimination of the chambers 73 and 76 and the pistons 72 and 75. Actually, all that need remain are passages 99, 97 and the cylindrical chamber 91 for operating a piston such as 95, of suitable area. The upper portion of the chamber 91 would then be closed and would contain only air or other compressible gas at atmospheric pressure. At the selected firing position, the valve body 80, which would then require only one curved passage, such as 86, shown in FIG. 9, would be rotated so that passages 97 and 99 are in communication, whereby the hydraulic pressure of the well fluid admitted through these passages into the lower portion of chamber 91 would urge the piston 95 upwardly so that the operating bar 50 would likewise be raised to release the charges 60 for rotation into their firing positions.

Rotation of the valve body 80 may be accomplished by actuation through a small electric motor 87 suitably geared to the valve body 80, or, for that matter, by any other appropriate electrical device, such as a solenoid and ratchet arrangement. As illustrated in FIG. 6, the motor 87 is energized by direct current supplied through an insulated lead 88 connected to the direct current connector plug 25 in the connecting sub 20. The motor 87 is, of course, grounded to the body of the actuating sub 70 which is in turn electrically connected to the external metal sheath of the cable forming the ground return for the entire electrical system.

Although only certain preferred embodiments of the invention have been illustrated and described, it will be obvious to those skilled in the art that the invention is capable of being carried out by numerous modifications and arrangements of apparatus and it is, therefore, intended that all such modifications and other arrangements of apparatus coming within the spirit of the invention be included within its scope as defined by the appended claims.

We claim:

1. A perforating gun comprising a fishing head, a cable having at least one insulated conductor for suspending said fishing head in a borehole, an operating sub assembly suspended from said fishing head, a tubular shell provided with at least one aperture suspended from said operating sub assembly, at least one cartridge containing a charge of jet forming, shaped explosive material pivotally mounted in said shell adjacent said aperture, means biasing said cartridge to a position wherein it projects through said aperture, means controlled from the earth's surface for releasably restraining said cartridge within said shell against said bias, means maintained out of effective contact with the explosive charge until the latter has been pivoted to its projecting position for detonating said charge, at least one hydraulically operable piston within a chamber in said operating sub assembly connected to said restraining means, and valve means controlled over said conductor from the earth's surface for causing well fluid under pressure to be admitted to said chamber to move said piston to operate said means for releasably restraining said cartridge whereby the cartridge is released from said restraining means.

2. A perforating gun as claimed in claim 1, in which said means for releasably restraining said cartridge comprises a member slidable transverse to the pivot axis of said cartridge, a radial projection on said cartridge adapted for engagement with said member in one slidable position and for disengagement in another slidable position of said member, in which latter position said cartridge is free to rotate to its projecting position under

the impetus of said bias, said well fluid on admission to said chamber causing said piston to move said member from said one position to the other.

3. A perforating gun comprising a fishing head, a cable having at least one insulated conductor for suspending said fishing head in a borehole, an operating sub assembly suspended from said fishing head, a tubular shell provided with at least one aperture suspended from said operating sub assembly, at least one cartridge containing a charge of jet forming, shaped explosive material pivotally mounted in said shell adjacent said aperture, means biasing said cartridge to a position wherein it projects through said aperture, means controlled from the earth's surface for releasably restraining said cartridge within said shell against said bias, means maintained out of effective contact with the explosive charge until the latter has been pivoted to its projecting position for detonating said charge, a plurality of pistons each mounted in individual chambers within said operating sub assembly, two of said pistons being connected, one of said chambers containing a transmission fluid, a fluid path between said chamber and another of said chambers, a valve, said path normally closed by said valve, a port admitting well fluid to still another of said chambers for exerting a pressure on one of said connected pistons ineffective to move said one connected piston when said fluid path is closed, and motor means controlled over said conductor from the earth's surface for adjusting the position of said valve to open said fluid path whereby the pressure of said well fluid is rendered effective to move the piston in said third chamber to exert a force through said transmission fluid to move another of said pistons to operate said means for releasably restraining said cartridge whereby the cartridge is released from said restraining means.

4. A perforating gun as claimed in claim 3, in which said piston against which the pressure of the well fluid is directly exerted is of larger diameter than the piston connected thereto.

5. A perforating gun as claimed in claim 4, in which said means for releasably restraining said cartridge comprises a member slidable transverse to the pivot axis of said cartridge between two positions, a radial projection on said cartridge, said member being formed and arranged for engagement with said projection in one slidable position and for disengagement in another slidable position of said member, in which latter position said cartridge is free to rotate to its projecting position under the impetus of said bias, said well fluid on admission to said chamber causing said piston to move said member from said one slidable position to the other said slidable position.

6. A perforating gun as claimed in claim 5, including additional fluid paths in said operating subassembly normally closed by said valve, said valve being adjustable to a second position opening said fluid paths wherein said pistons reoperate said member to a position restraining said cartridge.

7. A perforating gun as claimed in claim 3, including a sub assembly containing a coaxial condenser interposed between said fishing head and said operating sub assembly, said detonating means being connected to one lead of said condenser and said valve operating motor means being connected to the other lead of said condenser, said motor means being operated by an electrical current of one characteristic transmitted over said insulated conductor of said cable and said detonating material being detonated by an electrical current of another characteristic transmitted from the earth's surface over said insulated conductor of said cable.

8. A perforating gun as claimed in claim 3 in which said shell, detonating material, cartridge, pivotal mounting bias means, and releasable restraining means are expendable and are substantially disintegrated upon detonation of said explosive charge.

9. A perforating gun comprising a fishing head, a cable having at least one insulated conductor for suspending said fishing head in a borehole, an operating subassembly suspended from said fishing head, a tubular shell provided with at least one aperture suspended from said operating sub assembly, at least one cartridge containing a charge of jet forming, shaped explosive material pivotally mounted in said shell adjacent said aperture, means biasing said cartridge to a position wherein it projects through said apertures, means controlled from the earth's surface for releasably restraining said cartridge within said shell against said bias, means maintained out of effective contact with the explosive charge until the latter has been pivoted to its projecting position for detonating said charge, a gas pressure operable piston within said operating sub assembly, a charge of gas generating combustible material in a chamber adjacent said piston and in communication therewith, said piston being connected to said means for releasably restraining said cartridge, means controlled over said conductor from the earth's surface for igniting said gas generating combustible material wherein said gases expand within said chamber to move said piston to operate said means for releasably restraining said cartridge whereby the cartridge is released from said restraining means, and a sub assembly containing a coaxial condenser interposed between said fishing head and said operating sub assembly, said detonating means being connected to one lead of said condenser and said gas generating combustible material being connected to the other lead of said condenser, said gas generating material being ignited by an electrical current of one characteristic transmitted over said insulated conductor of said cable and said detonating material being detonated by an electrical current of another characteristic transmitted from the earth's surface over said insulated conductor of said cable.

10. In a gun for carrying out a perforating operation in a borehole having an outer casing and a longitudinal section of borehole tubing enclosed by the casing in an upper portion thereof, the combination comprising: a tubular shell provided with a plurality of longitudinally spaced apertures staggered on substantially opposite sides of said shell; a cable for moving and suspending said shell within a borehole, said cable having at least one insulated conductor therein; a plurality of jet cartridges each containing a jet forming shaped explosive charge respectively pivotally mounted adjacent said apertures within said shell; means biasing each of said cartridges to pivot toward a position wherein it projects outwardly from said shell through its adjacent aperture with its jet axis extending at a predetermined angle relative to said shell; means comprising a substantially rigid latch operable from the earth's surface within said lower portion for positively and releasably restraining each of the said cartridges against said bias in a retracted position in which each said cartridge is substantially enclosed by said shell lower portion; means comprising a piston actuated by gas pressure exerted independently of pressure within the borehole tubing and controlled over said cable from the earth's surface for releasing said restraining means; a detonating material within said shell maintained out of effective physical contact with the explosive charges in said cartridges until the latter have pivoted to their respective outwardly projecting positions; and means also controlled over said cable from the earth's surface for detonating said detonating material and said charges, said detonating means being operative in relation to said charges only when the respective cartridges have pivoted to their outwardly projecting positions.

11. A perforating gun comprising a tubular shell provided with a plurality of longitudinally spaced apertures located in staggered relationship in opposite portions of the sidewall of said shell, means to locate said shell within a borehole comprising a cable having at least one insulated conductor therein, a plurality of jet cartridges

each containing a jet forming shaped explosive charge respectively carried on pivotal mountings within said shell, the pivotal mounting of each said cartridge being near one of its ends and in a diametral plane of said tubular shell and in a plane parallel to and eccentric to the longitudinal axis of each said cartridge, each of said cartridges being thus mounted on the interior of said shell adjacent one of said apertures with the jet axis of each said cartridge being substantially parallel to the longitudinal axis of said tubular shell, a booster charge for each said explosive charge adjacent the end of each said cartridge at which it is pivotally mounted, means for pivoting each said cartridge to a position wherein the other end of the cartridge projects outwardly from said shell through its respective aperture including a substantially rigid latch controlled from the earth's surface and biasing means comprising a plurality of springs, each connected by one end to said shell and at the other end to a respective one of said charges at a point in a plane eccentric to the longitudinal axis of the charge and on the side of the longitudinal axis of said charge which is opposite that from which the charge is pivoted, said springs thus mounted being adapted to bias the charges with maximum efficiency for minimum tension into a pivoted position in which the ends opposite the booster charges project outwardly from said shell through said apertures, said latch releasably restraining each said cartridge against the bias of the respective springs within said shell, a column of detonating material arranged within said shell and normally out of effective physical contact with said booster charges, said eccentric pivotal mounting of each said cartridge permitting the inner diameter of said shell to be substantially equal to the sum of the diameters of one of the respective cartridges and the detonating column, said column of detonating material and said booster

charges being so arranged that effective physical contact therebetween is made only when the respective cartridges have been pivoted to their outwardly projecting positions, and means also controlled from the earth's surface for detonating said column of detonating material.

12. A perforating gun as claimed in claim 11, in which said restraining latch for said charges comprises a notched member mounted for limited reciprocating movement transverse to the respective pivot axes of the said charges and extends longitudinally along one of the sides of the respective charges, a radial projection rigidly mounted on each said cartridge adjacent the end opposite the booster charge and adapted for engagement with said member in one position of reciprocation of said member and for disengagement in another position of reciprocation of said member, in which latter position each projection is free to move through a notch of said member together with its cartridge to its projecting position under the impetus of said biasing means, and means for moving said bar member.

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