PERFORATOR INITIATING DEVICE

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1 Claim. (Cl. 166—55.1)

This invention relates to an improved wire line tool to be run through oil and gas well tubing and for perforating the tubing wall at a preselected depth.

At various times throughout the life of a producing well, there will be occasions to perforate or to install an office button at some given depth in the tubing wall to establish communication between opposite sides of the tubing wall. Common practice is to employ a perforator tool whose actuating power is supplied by an explosive charge and to lower the tool into the tubing to approximately the desired perforating location on a flexible line which can be manipulated for a jarring action to fire the charge. Misfiring from attempts to fire a stuck tool, with sudden changes in line tension, and accidental jarring often open the tubing wall at an undesired location and necessitate costly remedial measures and in any event there are many well equipment conditions which make for difficult, if not impossible, locating the conventional perforating tools at the point to be perforated.

An object of the present invention is to provide an improved means for precisely positioning perforations and within as little as one-half inch from the selected depth point and at regions spaced from tubing end connections.

A further object is to provide the tubing string with marker stations at known depths and which offer no interference to well tool passage but which can be preselected to effect automatic response of the tool equipment incident to traverse of the particular station.

Another object is to provide a tubing perforator tool which is insensitive to both upward and downward jarring and to banging laterally against the tubing wall so that perforation control is better assured even in coked and partially obstructed tubing.

A still further object is to provide a tool comprised of separable subassemblies frangibly joined in end to end succession, one as a perforator unit and the other as a marker responsive running tool unit, so that if the more simple and less costly perforator unit should become stuck, its disconnection at the frangible joint will enable the separated and more valuable running tool to be retrieved and then accommodate fishing operations to recover the stuck lower portion.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings, wherein:

FIG. 1 is a vertical section of a portion of a well tubing in which is being run the perforating equipment of which parts are shown in section and in elevation respectively;
FIG. 2 is a view similar to FIG. 1 but with the parts shown immediately following completion of a perforating operation;
FIG. 3 is a view like FIGS. 1 and 2 but shows the perforating tool being run upwardly in the tubing and also embodying certain modifications;
FIGS. 4A and 4B are companion vertical sectional views illustrating a fragmentary part of the tool shown in FIG. 1 immediately adjoining the reassemblability coupled ends of the two separable subassemblies and on a larger scale; and
FIGS. 5A and 5B are companion vertical sectional views of a fragment of the modified tool of FIG. 3 and on a larger scale.

In FIGS. 1 and 2 there is illustrated a wire line suspended tool equipment consisting of a lower perforator subassembly unit P and an upper running tool subassembly unit R releasably coupled in end to end succession for travel through a well tubing string T to a selected depth at which the tubing wall is to be pierced into the surrounding annular space between the tubing and the well bore wall which usually is lined by tubular casing C.

The perforator unit is made up of a hollow tubular main body 1 housing a longitudinally slidable driver rod 2 terminating downwardly in an inclined wedge face co-operatively fitted to the back of a laterally projectable piston 3 which is movable outwardly through a mating opening in the wall of the tubing 1. Optionally, the piston 3 may be locked by a shearing element, not shown, in the retracted position illustrated in FIG. 1 and it has releasably fitted to its forward face a punch or orifice button 4. Above the slidable wedge pin 2 there is mounted within the top of the housing 1 a cartridge 5 containing an explosive charge of powder and a detonator cap. Firing of the charge, as by a downwardly directed hammer blow on the detonator cap, will release the stored energy of the charge in the form of a rapidly expanding gas and push the wedge pin 2 downwardly for projecting the piston 3 to drive the punch or orifice button 4 through the tubing wall. An instantaneous action occurs and thereafter further movement of the piston 3 breaks its mounting connection with the orifice button 4.

The expendable cartridge 5 has an external locating top flange 1a, as best seen in FIG. 4B, and is held against an upwardly facing shoulder of an internally threaded counterbore upper end portion of the main body 1 by means of a fitting 1a threaded downwardly within the counterbore end portion. This end fitting 1a terminates upwardly in a reduced diameter projection having a threaded and headed fishing formation 1b.

At the time of final assembly of the units P and R, a bottom terminal skirt portion 6 is sealed over the fishing head end portion 1b and the interfitted parts are releasably secured together by one or more frangible elements or shear pins 7.

Located within the hollow fitting 1a is a short length firing pin 8 for transmitting downward force on the firing cap of the cartridge 5 and also slidably located within the fitting 1a and in end to end abutment with the firing pin 8 is the lower end of a motion transmitting pin or plunger 9. This plunger extends upwardly into and forms a part of the running tool R and terminates upwardly in a head 9a and has a slight lost motion slot and pin connection 10 with a tubular sleeve portion 11 which forms a downward continuation of and has a screw threaded connection with the lower end of a plunger stem 11a. A shear pin 12 initially joins the plunger sleeve 11 with the tubular housing 6a which is a sectional part of the main body or housing of the running tool R. This shear pin connection 12 is effective to immobilize the plunger assembly including the parts 9, 11 and 11a against slide movement and the imposition of unintentional downward force on the firing pin 8. The shear pin 12 will yield or be broken under stress imposed in opposite directions on the main body of the tool and on the upper end of the plunger stem 11a upon the firing of an explosive charge contained within the cartridge 13 located within the housing immediately above the upper end of the plunger 11a. By reason of the lost motion connection 10, down travel of the lower plunger section 9 in unison with the upper plunger section 11a for firing the cartridge 5 is delayed until after the shear pin 12 has first been broken.

The cartridge 13 contains an electrically actuated detonator or squib contained within an electric circuit which includes batteries and control switches protectively en-
closed within the upper portion of the main body of the running tool \( R \) together with control means which upon presentation within a magnetic field will be actuated and effect the closing of the normally open electric circuit containing the switch whereby to fire the cartridge 13 and thereby depress the slide plunger assembly after first breaking the flint pin 12 and thereafter delivering the necessary hammer blow through the lost motion connection 10 to the firing pin 8 for effecting the perforating operation. The circuitry under control of the magnetic field sensing means is more fully disclosed in Patent No. 3,105,547. Accordingly, there is shown in FIGS. 1 and 2 in broken lines a pair of field sensing or magneto devices 14 and 15 enclosed within the housing of the running tool \( R \) in longitudinally spaced apart relation. The pole pieces of the magneto devices are aligned with field extender plugs fixedly carried in the wall of the running tool and there are a group of several longitudinally spaced apart field extenders, such as shown at 16. The lowermost magneto device 15 can be considered as being fixedly positioned while the uppermost magneto device is mounted for longitudinal adjustment to present its poles selectively with any horizontal row of field extender plugs 16. Each magneto device when influenced by a magnetic field, remaining in a plane of normal switch contacts and both sets of switch contacts are in series circuit relation so that the circuit involved will remain open except when both magneto devices are concurrently influenced by magnetic fields.

The elements of an actuating circuit for a perforating operation can take place only at a selected location within in the tubing and as related to a marker containing station forming a part of the tubing string. Thus, there is contemplated that the tubing string will be made up with a number of special nipples 17 each having a counterbored internal pocket to receive a stack of rings 18 as best seen in FIG. 5A. The stack of rings includes two rings of nonmagnetic material, in each of which are located a pair of longitudinally spaced apart rows of circularly spaced apart magnets 19. The magnets will be arranged so that the inner faces of magnets in one open will be of opposite polarity to the inner faces of the magnets in the other row for the protrusion of a fairly strong magnetic field interior of the tubing string. The remaining rings of the stack will be spacers and will enable the longitudinal spacing between the two magnet carrying rings to be varied in each of the nipples 17. Thus a pair of inwardly protruding magnetic fields provide a marker station at each of the several nipples incorporated in the tubing string and the fields will be separated longitudinally at distances differing from one another at the several stations. Accordingly, when a perforation is to be made in the tubing string below any one nipple whose depth is known, the magneto devices 14 and 15 of the running tool will be adjusted to a spaced apart relation which corresponds to whatever the field spacing is in the particular nipple. In FIGS. 1 and 2 the magneto devices have their spacing selectively set to correspond to the spacing of the magnetic fields of the nipple shown. Accordingly, when the tool is lowered into the tubing string and as each magneto device traverses any magnetic field, the switch contacts controlled by that magneto device will close. Inasmuch as the switch- es are thus closed in series, their circuit will remain open until both magneto devices concurrently traverse the magnetic fields to which the selected spacing is coded or in correspondence. Immediately that happens, the cartridge 13 will be fired and furnish the necessary jet to detonate the cartridge 5 and power the perforating tool for the perforating operation.

In the modified embodiment of FIGS. 3, 5A and 5B, provision is made for providing a much longer over-all wire line tool for effecting a perforating operation at considerable distance below a marker station. The perforator subassembly, including the tubular housing 1, the slidable wedge 2 and the laterally projectable piston 3, is slightly modified at its upper end in that the fishing head portion 21 encloses a conductor 22 enclosed within an insulator sleeve 23 and provided at opposite ends with sockets for electrical connections. The lowermost connection is joined to an electrically responsive squib for detonating the cartridge of the perforator in accordance with Patent No. 3,105,547. The firing of the cartridge 24 provides the force for driving the wedge 2 downwardly and the transference of that motion to the piston 3 in order to set the oriifice button 4 in the wall of the tubing.

Current is delivered to the cartridge 24 through a long conductor tube 25 having detachable connection at its lower end with the conductor 22 and connection at its upper end with a bulkhead conductor 25A and the long length cable is protectively enclosed within an elongate spacer tube 26 of a length unlimited except for practical consideration, such as the distance between succeeding marker stations in the tubing string. At its lower end, the spacer tube 26 carries a tubular skirt 27 which is sleeved on the fishing head 21 of the perforator unit and is releasably secured thereto by one or more frangible or shear pins 28. At its upper end, the spacer tube 26 is joined to the tubular housing 29 of the running tool and which also carry switch contacts and are batteries and the circuit control devices. FIG. 5A shows a pair of magnetic field sensing devices protectively housed within a nonmagnetic wall portion of the running tool and constructed in accordance with the disclosure in Patent No. 3,105,550. The pair of devices can be variously spaced apart to match the spaced fields of any selected tubing nipple, by insertion between them of interchangeable spacers 30 of proper length.

Each sensing device involves a pair of longitudinally spaced apart pole pieces 31, shown in FIG. 5A as being in alignment with two sets of nipple mounted magnets so as to be simultaneously within the respective magnetic fields for concurrently closing a pair of series connected switches and effecting instantaneous firing of the cartridge 24. Between each pair of pole pieces is located a permanent magnet 32 pivoted on a transverse rocker axis intermediate the ends of the bar magnet. The bar axis is closer to one of the pole pieces 31 than to the other and hence magnetic attraction acts to bias or rock the magnet to a rest position, but should the pole pieces move into the influence of a magnetic field of opposite polarity, the magnet will rock away from its position of rest. One arm of each rockable magnet carries a switch contact which is in opening relation with a fixed contact at rest position of the pivoted magnet. Magnet swing away from rest closes the switch contacts. Completion of the electric circuit necessitates that both serially connected magneto devices be concurrently under magnetic field influence.

While the above description has been limited to the specific structure shown in the drawings, it will be understood that the invention can be embodied in various modified forms as come within the scope of the appended claims.

What is claimed is:

In combination, a tubing string having marker means providing an inwardly protruding magnetic field, perforating equipment to be lowered in the tubing string and including an electrically responsive squib for detonating means mounted by the housing means and carrying a push, a force transmitting wedge engageable with the member, means for imposing force on said wedge including a first explosive charge positioned by the housing means to be fired for furnishing said force, another explosive charge in the housing means, a first plunger slidably fitted within the housing means and exposed to direct action thereon of the explosive force of the second mentioned charge upon firing of the same, a fragile member initially anchoring said plunger to the housing means, a second plunger slidably fitted within the housing
means for transmitting force to fire the first mentioned charge, a lost motion connection joining said plungers and compelling breakage of said frangible member in advance of unison slide travel of said plungers, electrically actuated means to fire said second mentioned charge including a normally open electric connection, a connection closing switch and a magneto device operative on the switch to close the same and positioned by the housing for operation under influence of said magnetic field upon traverse thereof.