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W. L. KITSMAN

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PERFORATING METHOD AND APPARATUS

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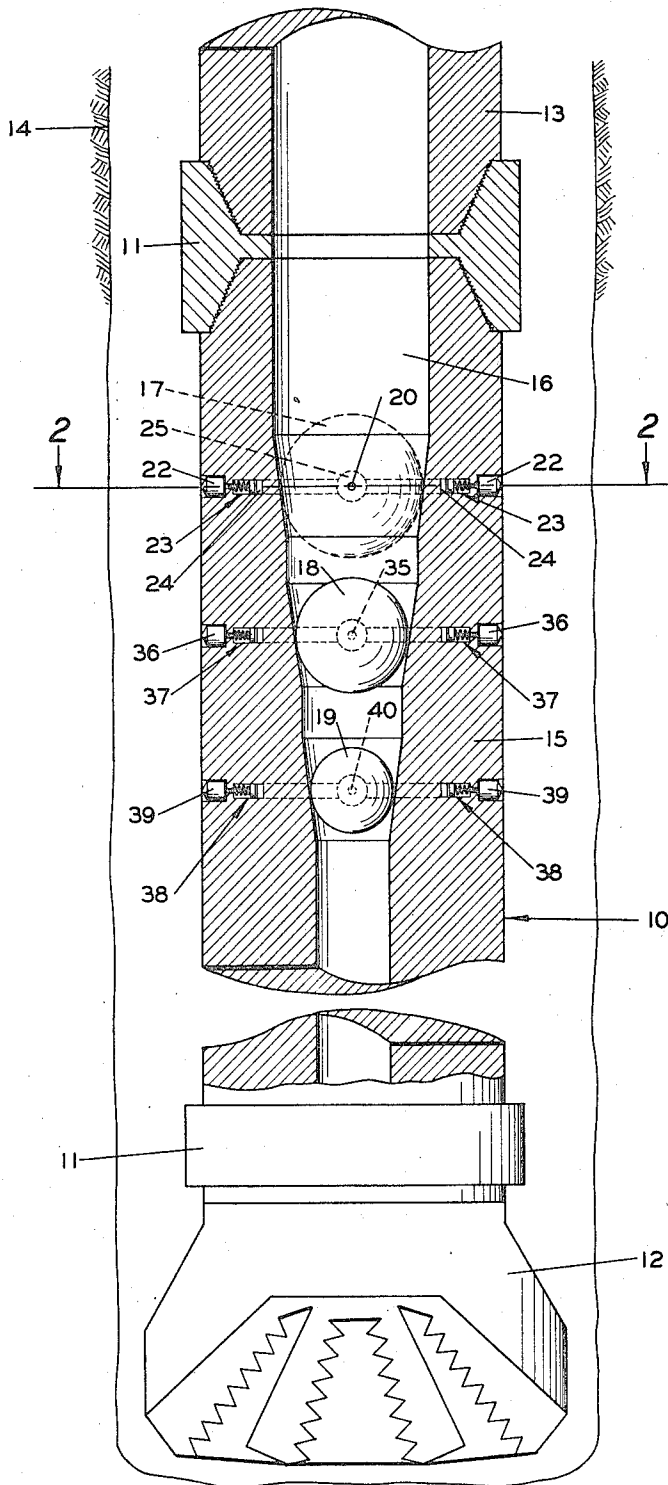


FIG. 1

INVENTOR
W. L. KITSMAN

BY
Hudson, Young, Shaulley & Ginger
ATTORNEY

UNITED STATES PATENT OFFICE

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PERFORATING METHOD AND APPARATUS

William L. Kitsman, Bartlesville, Okla., assignor
to Phillips Petroleum Company, a corporation
of Delaware

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8 Claims. (Cl. 164—0.5)

This invention relates to a method and apparatus for perforating casing and the like, and for inserting marking materials in various strata penetrated by a well bore.

Present day developments in the art of completing hydrocarbon wells by gun-perforating the casing opposite the productive zone are well known in the petroleum industry. The recompletion of wells by perforating the casing opposite a productive zone subsequent to plugging back from a lower depleted zone is also well known in the petroleum industry. Another application for gun perforating devices is the marking of possible productive hydrocarbon-bearing strata with a material, which can be detected by suitable apparatus at a later date. In this connection, a gun-perforating device is usually lowered to the zone to be marked, where a bullet containing a radio active or other detectable substance is fired from the gun and embedded in the strata. This permanent marker can then be accurately located without depending on the accuracy of any previous measurements made at the time of drilling the well.

The types of gun-perforating devices which are available at the present time to the petroleum industry are disadvantageous in several respects. Those devices which are adapted for use in conjunction with the rotary drilling system, require the removal of the drill pipe from the well bore prior to lowering the gun-perforating device into the bore hole. My instant invention incorporates a novel perforating gun with the rotary drill stem. I am able by the practice of my instant invention to effect selective firing of the perforating gun and thereby attain several distinct advantages which will be readily apparent to persons skilled in the art.

The primary object of my invention is to provide a method and apparatus for perforating casing and the like, and for inserting marking materials in the various strata penetrated by a well bore.

Another object of my invention is the provision of a gun-perforating device which can be selectively fired at the will of the operator.

A further object of my invention is the provision of a gun-perforating device which is incorporated with a rotary drill stem and which need not be withdrawn from the bore hole prior to or after firing.

These and additional objects and advantages will be readily apparent to persons skilled in the art by reference to the following description and annexed drawings, of which,

Figure 1 is an elevation view, partly in cross-section, of a preferred embodiment of my invention; and

Figure 2 is an enlarged sectional view along line 2—2 of Figure 1, partly in cross-section, with the firing elements removed.

Referring to Figure 1, numeral 10 generally designates a perforating gun, which I shall describe in detail further along in my specification. A pair of coupling means 11 is used for connecting the lower portion of the gun to a bit 12 and for connecting the upper portion of the gun to the lower end of a hollow rotary drill stem 13, which is suspended in a bore hole 14 that extends downwardly from the surface of the ground. The perforating gun thus constitutes an extension of the drill stem, and comprises a cylindrical member 15, which is smaller in external diameter than the diameter of bit 12, and which is provided with a passage 16 of gradating internal diameter. The passage is adapted to receive a plurality of firing elements 17, 18, and 19, which are preferably spherical and which decrease in size in the order enumerated. It is to be noted from the drawings that each of the firing elements has a corresponding lower limit of travel in passage 16, as defined by the relative size of each firing element and the diameter of the passage. Opposite the lower limit of travel for element 17 in passage 16 are firing pins 20 and 21 (see Figure 2) which detonate bullets 22 through the cooperation of a firing mechanism, generally designated by numeral 23. It will be noted that the firing mechanism consists essentially of a pair of identical semicircular fluid passages 24 which are oppositely disposed in member 15, a pair of fluid actuating cylinders 25 and 26, which contain an incompressible fluid, and a pair of detonation cylinders 27. Cylinder 25 communicates with passages 24 and contains a movable partition, such as a piston 28 which is connected to firing pin 20 and is positioned in the chamber intermediate the fluid and a compression spring 29 of desired strength. Cylinder 26 also connects with passages 24 and contains a second movable partition, such as a piston 30, which is connected to firing pin 21 and is positioned intermediate the fluid and a compression spring 31 that is identical to spring 29. Each detonation cylinder 27 communicates with passages 24 and contains a movable partition, such as a piston 32. This piston is secured to a plunger 33 which fires bullet 22, and is normally held in a predetermined position by a compression spring 34. Spring 34 is substantially strong-

er than either spring 29 or 31. In order to actuate the firing mechanism, firing element 17 is placed in hollow drill stem 13 at the surface of the ground. The element falls by gravity or it is carried downwardly by the drilling fluid, which is employed during the drilling of bore hole 14. As the firing element strikes pins 20 and 21, pistons 28 and 30 are respectively moved outwardly in cylinders 25 and 26, displacing the fluid therefrom. The displacement of fluid moves pistons 32 outwardly in cylinders 27 against the force of springs 34 until plungers 33 contact and fire bullets 22. If the impact of element 17 is not great enough to compress springs 34 sufficiently to allow plungers 33 to fire bullets 22, additional force may be transmitted to the firing element through the medium of the drilling fluid, which circulates downwardly through drill stem 13. As each spring 34 is greater in strength than either spring 29 or 31, both pins 20 and 21 must be depressed before bullets 22 can be fired. This feature makes my perforating gun selective in firing. For instance, should element 18, which is smaller in size than element 17, be dropped through the drill stem, bullets 22 would not fire although firing pin 20 or 21 be struck. If element 18 strikes firing pin 20, piston 28 moves outwardly, displacing the fluid from cylinder 25. Because spring 34 is stronger than spring 31, displacement of the fluid will cause piston 30 and pin 21 to move inwardly, compressing spring 31 without moving piston 32. When element 18 moves beyond pin 20, springs 29 and 31 immediately coact to readjust the relative positions of pistons 28 and 30 in cylinders 25 and 26, respectively. Although I have shown the firing mechanism adapted to firing two bullets, it is to be understood that any number of bullets may be detonated by the addition of detonation cylinders 27 to the mechanism. Moreover, by eliminating one of the semi-circular passages, or by eliminating the detonation chambers on one side, the mechanism will fire from one side only.

Opposite the lower limit of travel for element 18 in passage 16 are a pair of firing pins 35, which may be identical except for size to firing pins 20 and 21 and which detonate bullets 36 through the cooperation of a second firing mechanism 37, which may be identical to mechanism 23. Similarly, another firing mechanism 38, which may also be identical to mechanism 23, fires bullets 39 when firing element 19 contacts another pair of firing pins 40 at the lower limit of travel for the element in passage 16. These pins may also be similar to firing pins 20 and 21.

When it is desired to insert a marker in the formation, the desired firing element, such as element 19, is dropped through the drill stem to its lower limit of travel, where it fires bullets 39. In order to resume drilling, the element is retrieved by reversing the circulation of the drilling fluid, whereby it flows downwardly through the annular space between bore hole 14 and drill stem 13 and thence upwardly through bit 12, passage 16 in perforating gun 10 and drill stem 13. The drilling fluid carries element 19 out of the passage upwardly to the surface of the ground. When the firing element is retrieved, the circulation may be changed back to normal and the drilling continued. It is to be noted that a great flexibility in the spacing of perforations of the bore hole or insertion of markers can be obtained with my device without removing the drill stem from the bore hole in order to reload the perforating gun. This is accomplished by employ-

ing a plurality of firing mechanisms and firing elements, by the selectivity of firing order, and by the combining of the perforating gun with the drill stem. While I have described my invention with respect to its use as a part of a hollow drill stem, the device will work with equal success when adapted to any tubular member.

While the apparatus of this invention has been illustrated as simply as possible but with the intent to fully set forth the inventive concept of the present invention, it is to be understood that the construction of perforating gun 10 and of the firing cylinders is such as to permit of their construction and ready assemblage. It is considered that the mechanics involved in doing this will be readily apparent to persons skilled in the art. It is further to be understood that the size and weight of firing elements 17, 18, and 19 are in such relation to the density, pressure and other characteristics of the drilling fluid that while they are capable of effecting the discharge of the firing elements when the flow of the fluid is downward, they will also be capable of being brought to the surface by the liquid when its direction of flow is upward through tube 13. This is in accordance with the teachings of Stokes Law as indicated in "A Treatise on Physical Chemistry," by H. S. Taylor, vol. 2, published in 1925 by D. Van Nostrand.

From the foregoing, it is believed that the method and apparatus for practicing my instant invention will be readily comprehended by persons skilled in the art. It is to be borne in mind, however, that various changes in the apparatus herewith shown and described and in the method of practicing the invention as outlined above, may be resorted to without departing from the spirit of the invention as defined by the appended claims; and further that the theories of operation set out, although believed to be accurate, are not to be considered as the sole basis of the operativeness of this invention since this invention does operate successfully whether or not upon the principles referred to herein.

I claim:

1. In a method of the character described, the steps comprising disposing a plurality of firing mechanisms and corresponding explosive means at different elevations in a well bore, moving a device downwardly through the well bore and into engagement with at least one of the firing mechanisms, and actuating said one of the firing mechanisms upon further downward movement of the device to fire the corresponding explosive means without actuating at least one other firing mechanism that is located at a higher elevation sufficiently to fire the corresponding explosive means which is adapted to be fired upon predetermined actuation of said one other firing mechanism.

2. In a method of the character described, the steps comprising disposing a plurality of firing mechanisms and corresponding explosive means at different elevations in a well bore, moving a device downwardly through the well bore and into engagement with at least one of the firing mechanisms, actuating said one of the firing mechanisms upon further downward movement of the device to fire the corresponding explosive means without actuating at least one other firing mechanism that is located at a higher elevation sufficiently to fire the corresponding explosive means which is adapted to be fired upon predetermined actuation of said one other firing mechanism, and subsequently retrieving the device by

transmitting fluid upwardly through the well bore.

3. In apparatus of the character described, the combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means for firing the explosive means, said actuable means being carried by the member and extending within the inner surface thereof, and a substantially spherical member adapted to be moved along the passage in the member for engaging and actuating one of the actuable means to fire an explosive means that is disposed at one elevation without firing at least one other explosive means that is disposed at a higher elevation.

4. In apparatus of the character described, the combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means for firing the explosive means, said actuable means being carried by the member and extending within the inner surface thereof, and means comprising a substantially spherical member adapted to be moved downwardly through the conduit, said last mentioned means engaging and actuating one of the actuable means upon predetermined downward movement thereof to fire an explosive means that is disposed at one elevation without firing at least one other explosive means that is disposed at a higher elevation.

5. In apparatus of the character described, the combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means for firing the explosive means, said actuable means being carried at different elevations by the member and extending into the passage, and means comprising a substantially spherical member adapted to be moved downwardly through the conduit, said last mentioned means engaging and actuating an actuable means at one elevation to fire an explosive means without actuating at least one of the actuable means at a higher elevation.

6. In apparatus of the character described, the

combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means for firing the explosive means, said actuable means being carried by the member at a plurality of different elevations corresponding to the elevations of the explosive means and extending within the inner surface of the member, and means comprising a substantially spherical member adapted to be moved downwardly through the conduit, said last mentioned means engaging and actuating one of the actuable means upon predetermined downward movement thereof to fire the corresponding explosive means that is located at one elevation without firing at least one other explosive means that is located at a high elevation.

7. In apparatus of the character described, the combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means each including pin means for firing the explosive means, said actuable means being carried by the member and having the pin means extending into the passage at different elevations, and a substantially spherical member adapted to be moved along the passage in the member for actuating the pin means at one elevation to fire an explosive means without actuating at least one other pin means at a higher elevation.

8. In apparatus of the character described, the combination comprising a conduit adapted to be lowered into a well bore, a member disposed below the conduit and connected thereto, a passage in the member communicating with the conduit, a plurality of explosive means carried by the member and disposed at a plurality of different elevations, a plurality of actuable means each including a pair of oppositely disposed pins for firing the explosive means, said actuable means being carried by the member and having the pairs of pins extending into the passage at different elevations, and a substantially spherical member adapted to be moved along the passage in the member for actuating a pair of oppositely disposed pins at one elevation without actuating at least one other pair of oppositely disposed pins at a higher elevation.

WILLIAM L. KITSMAN.