Oct. 5, 1965 M. P. LEBOURG 3,209,828

PERFORATING APPARATUS

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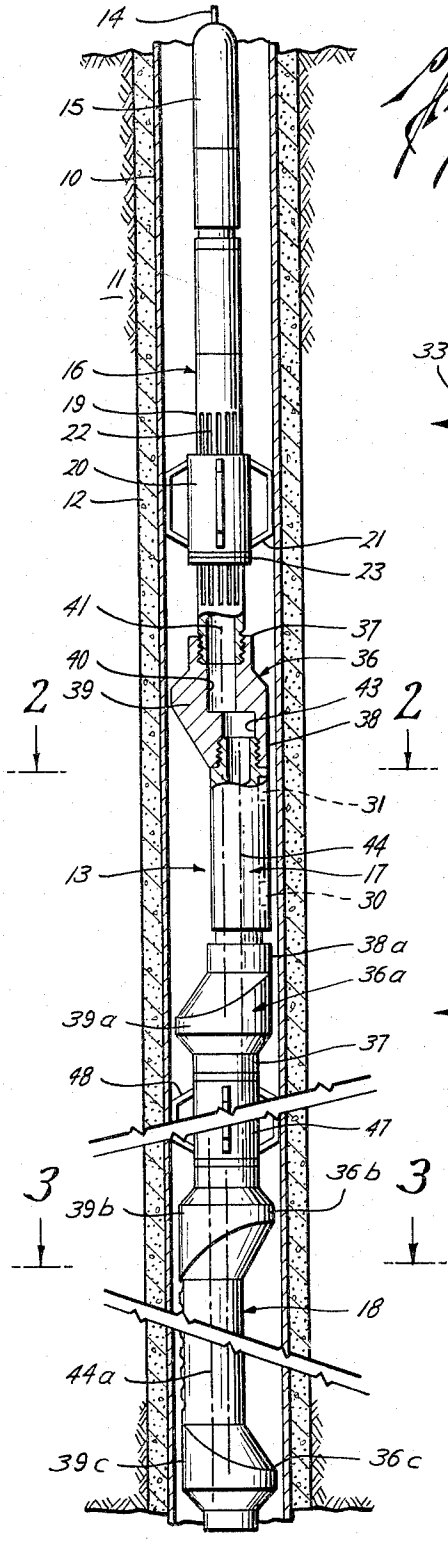

Fig. 1

Fig. 2

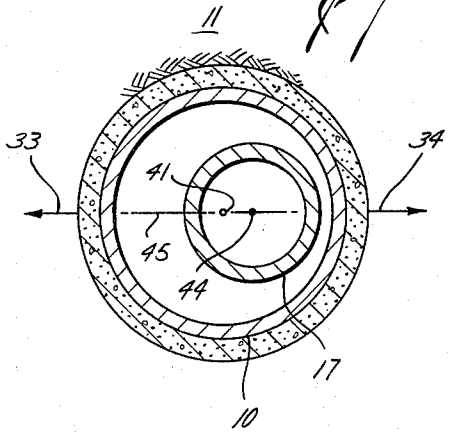

Fig. 3

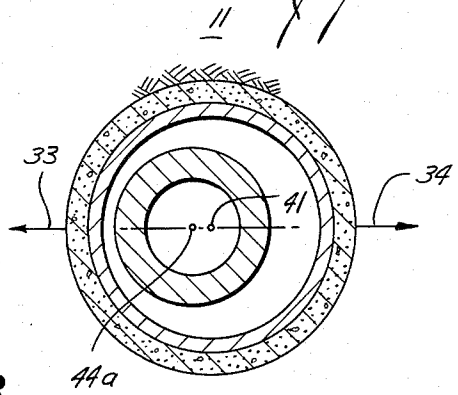

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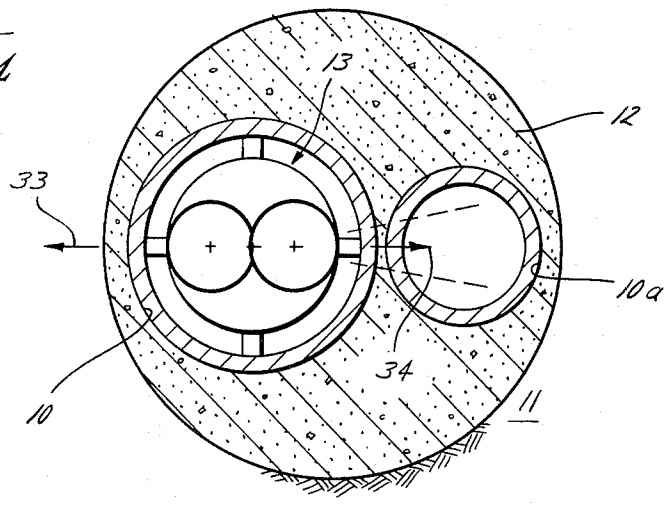
Fig. 4



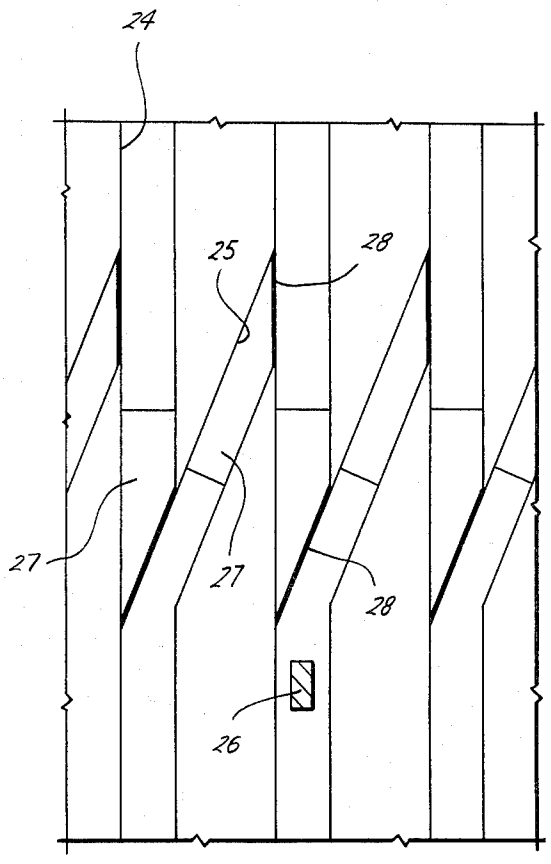


Fig. 5

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United States Patent Office

3,209,828
Patented Oct. 5, 1965

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3,209,828

PERFORATING APPARATUS

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Filed Nov. 1, 1962, Ser. No. 234,783
3 Claims. (Cl. 166—55.1)

This invention relates to apparatus useful for independent completion of one or more co-extensively extending tubing strings which are disposed in a common oil well borehole. In particular, this invention relates to new and improved apparatus for locating adjacent strings of tubing from a given large diameter string of tubing in a well bore with a greater degree of accuracy, and perforating the given string of tubing in a selected direction of orientation.

The technique of multiple completion involves the positioning of co-extending strings of tubing in a common borehole, cementing the strings in place in the borehole, and using orienting perforating apparatus to selectively perforate one or more of the tubing strings. The orienting perforating apparatus generally includes a pipe or tubing locating apparatus, an indexing device and a directional perforating device which are lowered into one string of tubing to a depth where perforations are desired. The adjacent tubing strings are located by indexing the pipe locating apparatus and the directional perforator is then oriented relative to the co-extending strings of tubing so as to fire in a selected direction, typically away from the other strings of tubing. Each string of tubing is completed in this manner. Heretofore, multiple completion of wells has been limited to tubing strings having a small diameter, say 2 or 2½ inches, and oriented perforator apparatus is correspondingly sized for operation in this small diameter tubing. However, where the string of pipe has a substantially larger diameter, say 4½ inches, the small diameter orienting perforating apparatus is generally inadequate for several reasons. First of all, the apparatus, when centered in the large diameter casing, has a large standoff distance thereby reducing the performance of the perforating apparatus. The pipe or tubing locating apparatus, which generally is a radioactivity device, has a tremendously decreased sensitivity because of the large standoff spacing and it is, in fact, extremely difficult to detect the presence of adjacent strings of tubing because of this large standoff.

An obvious solution to this problem is, of course, to increase the diameter of the orienting perforating apparatus to a size comparable to the large diameter casing. But, such a solution requires duplicate tools in a range of sizes, and larger diameter tools correspondingly have increased weight and raise difficulties in orienting the apparatus successfully.

Accordingly, the present invention is to provide new and improved small diameter orienting perforating apparatus for use in large diameter strings of tubing.

Another object of the present invention is to provide new and improved small diameter orienting perforating apparatus for use in a range of different diameter tubing strings.

A still further object of the present invention is to provide new and improved small diameter orienting perforating apparatus providing increased accuracy of orientation and perforating performance in large diameter well bores.

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The present invention includes an assembly of small diameter perforating apparatus, radioactivity pipe locating apparatus and indexing means with interconnecting positioning means arranged to position the perforating apparatus and locating apparatus proximate to the wall of the tubing string in which it is positioned.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a view illustrating apparatus of the present invention disposed in a well bore;

FIG. 2 is a view in cross-section taken along line 2—2 of FIG. 1;

FIG. 3 is a view in cross-section taken along line 3—3 of FIG. 1;

FIG. 4 is a view in cross-section illustrating pipe strings in a well bore and apparatus in one pipe string; and

FIG. 5 is a partial plan view of indexing means.

Referring now to FIG. 4, a large diameter string of pipe 10 and small diameter string of pipe 10*a* are shown traversing the earth formations 11 and cemented in place by a column of cement 12. Shown positioned in the string of pipe 10 is orienting perforating apparatus 13 according to the present invention. The assembled apparatus 13 is adapted to be lowered into the pipe string 10 by means of an electric armored cable 14 (FIG. 1) spooled from a winch (not shown) at the earth's surface in a conventional manner. The pipe string 10 is typically filled with a well control fluid such as mud.

As shown in FIG. 1, the apparatus 13 includes a conventional casing collar locator 15 connected to an indexing device 16, a directional radioactivity pipe locating means 17 and a directional perforator 18. The elements 16–18 are sized to pass through a small diameter tubing which is the range of tubings in 2 and 2½ inch sizes.

The indexing device 16 generally includes a tubular mandrel 19 and a tubular cage 20 slidably received thereon. Cage 20 is sized to be passed through a small diameter tubing but has attached, peripherally spaced, bow springs 21 sized for frictional engagement with the pipe 10. Mandrel 19 has a slot system 22 in its outer surface while cage 20 has a follower 23 for the slot system. Follower 23 may, for example, be a spring clip ring with an end portion extending through the cage 20 into register with the slot, the end portion being resiliently movable inwardly and outwardly relative to the cage 20.

As shown in partial view in FIG. 5, the slot system 21 includes longitudinal slots 24 and transverse connecting slots 25. The end portion of the spring clip ring is shown at 26. The slots 24 and 25 have inclined portions 27 which extend from a bottom surface of a slot to a shoulder 28 to a point below the outer surface of the mandrel 19. In operation, if the end portion 26 is in a longitudinal slot, it will be guided up an inclined surface 27 and over a shoulder 28 when the mandrel is moved relative to the cage in an upward direction. Movement then in a downward direction will bring the end portion 26 into engagement with a shoulder 28, and end portion 26 will be guided into a transverse slot 25 to rotate the mandrel until the end portion 26 passes over a shoulder 28 of the longitudinal slot.

The directional radioactivity pipe locating means 17 includes a focussed source of radioactivity 30 and spaced therefrom a suitable distance a focussed detector of radioactivity 31. These devices may, for example, be a gamma radiation source such as Cs 137 and a Geiger-Mueller tube. These devices cooperate in a well-known manner so that radioactivity induced by the source is detected in a directional manner by the detector tube. The directional sensitivity is shown by the arrow 34 in FIGS. 2, 3. For optimized sensitivity, the source and detector should be located proximate to the wall of the tubing in which they are positioned.

The perforating apparatus 18 may, for example, be of the type illustrated in my Patent No. 3,048,102 where the shaped charges are all oriented to fire in a single direction as illustrated by the arrow 33 in FIGS. 2 and 3.

Interconnecting the indexing device 16 and the radioactivity pipe orienting device 17 is a coupling member 36 having a centered end 37, an eccentered end 38, and an intermediate centered portion 39. The centered end 37 has a first opening 40 about a first axis 41, the axis 41 being coextensive with the central axis of the pipe 10 when the apparatus is centered in the pipe 10. Opening 40 extends into the intermediate portion 39, the opening 40 having a threaded portion adapted to receive a threaded end of the indexing device 16. The intermediate portion 39 has an outer cylindrical surface which is concentrically arranged relative to the first opening 40 and sized to a diameter just slightly less than the diameter of the large diameter casing, say on the order of ½ inch. In the eccentered end 38 of the coupling member is a second opening 43 about a second axis 44 which is offset and parallel to axis 41. Opening 43 extends into the intermediate portion 39 and opens to the first opening 40. The second opening 43 also has a threaded portion adapted to receive a threaded end of the pipe locating apparatus 17. The common plane defined by the first and second axes 41, 44 is here defined as a plane or orientation and identified by the numeral 45. The directional sensitivity 34 of the pipe locating means 17 and the direction of firing 33 of the perforating apparatus 18 lie in plane 45 but face in opposite directions.

Another coupling member 36*a* interconnects the pipe locating apparatus 17 and a centralizer sub 47, the coupling member 36*a* being reversed in position relative to the coupling member 36 so that the axis of the opening in the eccentered end 38*a* coincides with the axis 44 of coupling 36 while the axis of the opening in the centered end 37 coincides with the central axis of the centralizer sub 47 and the central axis 41 of the pipe 10. The centralizer sub 47 has the usual bow springs 48 thereon for centering the apparatus in the pipe 10 and is constructed so that a mandrel is rotatable relative to the outer tubular cage which has the springs 48.

From the foregoing, it will be appreciated that coupling members 36, 36*a* are identical but reversed in position so that pipe locating device 17 is eccentered relative to the central axis 41 of the pipe 10, the pipe locating device, however, being within an imaginary cylindrical envelope defined by the cylindrical intermediate portions 39, 39*a* of the coupling members. The intermediate portions 39, 39*a* protect the device 17 from damage in the pipe while insuring the close positioning of the device 17 to the wall of the pipe.

At the lower end of the centralizer sub 47, another pair of coupling members 36*b*, 36*c* are reversely positioned and connected to the ends of the perforator 18 so that the axis 44*a* of the perforator is eccentered with respect to the central axis of the pipe 10, the perforator device, however, being within an imaginary cylindrical envelope defined by the intermediate portions 39*b*, 39*c* of the coupling members.

From the foregoing description it will be appreciated that the apparatus disclosed resembles a crankshaft where the apparatus is centered in a pipe but has components thereof displaced radially from the central axis of the apparatus to place such components proximate to the wall of the pipe.

In operation, the apparatus is lowered in the pipe to the level to be perforated. Bow springs 21 and 48 centralize the apparatus in the pipestring. The cable 14 is then lifted up a short distance to bring the index pin in the lower end of the slot system and lowered to original position, thus indexing tool to adjacent slot. Radioactivity measurements are made and the cable 14 reciprocated thereby rotating the radioactivity apparatus through the distance between adjacent slots of the slot system. Radioactivity measurements are taken for each rotative position through a 360° arc. From the radioactivity measurements, the location of the adjacent pipestring, or for that matter, any locatable object is determined and the preforator oriented as desired.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Perforator orienting apparatus for large diameter pipe strings comprising: radioactive pipe-locating means having a given radial direction of sensitivity; an indexing device including wall-engaging means to centralize the apparatus in such pipe string, and a member rotatable about a central axis of the apparatus relative to said wall-engaging means; perforator means having a given radial direction of fire; means coupling said radioactivity locating means, said rotatable member and said perforator means in fixed relation to one another, said coupling means including an interconnecting member above and coupled to said radioactivity locating means where said radioactivity locating means has a cross-sectional size substantially less than the cross-section of such pipe string, said interconnecting member having an axially offset portion arranged to eccenter said radioactivity locating means relative to the central axis of said apparatus and position said radioactivity locating means proximate to the wall of such pipestring.

2. Perforator orienting apparatus for large diameter pipestrings comprising: an indexing device including wall-engaging means for contact with the wall of a pipestring and a member rotatably mounted about a central axis relative to said wall-engaging means, radioactive pipe locating means having a given radial direction of sensitivity; perforating means having a given radial direction of fire; said pipe locating means and said perforating means having a cross-section sized for passage through a small-diameter tubing string; and means coupling said rotatable member, said pipe locating means and said perforating means in fixed relation to one another, said coupling means including a pair of interconnecting members having axially offset connecting portions for each of said pipe locating means and said perforating means arranged to displace said pipe locating means and said perforating means relative to said central axis, said pipe locating means and perforating means being arranged with their respective radial direction of sensitivity and radial direction of fire disposed in opposite directions.

3. As a subcombination, apparatus for use in a pipestring in a well bore having a central axis comprising: radioactivity-sensing means having a given radial direction of sensitivity; means for rotating said radioactivity-sensing means about said central axis; wall-engaging means for centralizing said rotating means along said central axis within the pipestring; and means dependently coupling said radioactivity-sensing means to said rotating means for eccentering said radioactivity-sensing means relative to said central axis; said coupling means including an axially

offset portion arranged to eccentrically displace said radioactivity-sensing means in said radial direction and into proximity with said pipestring.

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