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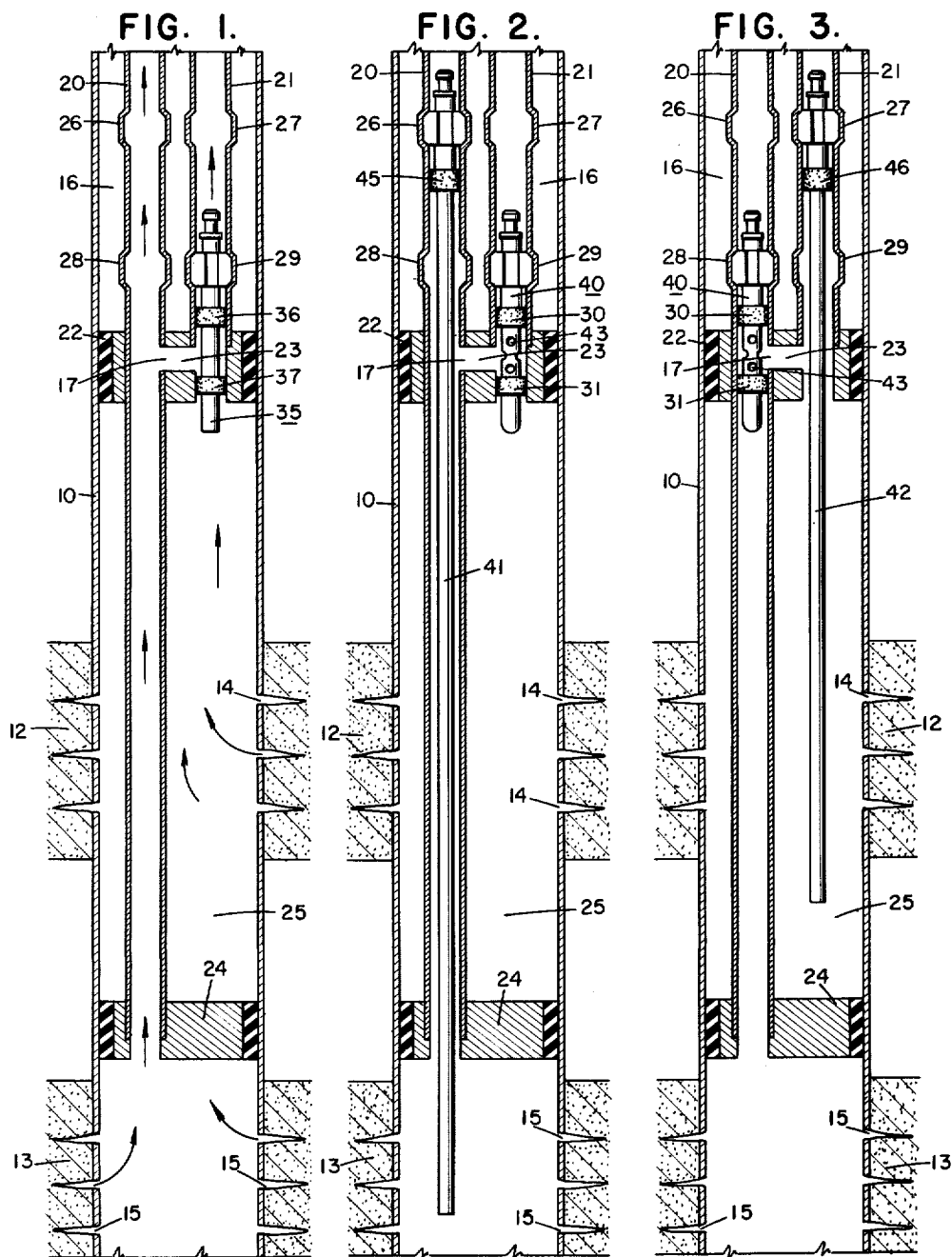
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PERMANENT WELL COMPLETION APPARATUS

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1

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PERMANENT WELL COMPLETION APPARATUS
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This invention is directed to a permanent well completion apparatus for working over and servicing a plurality of spaced-apart hydrocarbon productive zones or intervals.

In permanent well completion operations tubing strings are set permanently during the life of the well and various producing, workover, and servicing operations are performed through these permanently set tubing strings. The workover and servicing operations generally performed on permanently completed wells include squeeze cementing operations wherein existing perforations below the lower end of the tubing are cemented off, perforating or re-perforating by means of wire line guns at the same or different producing zones or intervals, sand washing operations, acidizing operations and other remedial work.

A full discussion of permanent well completion operations is described in "Permanent Type Completions and Wire Line Work Overs," The Petroleum Engineer, September, 1956.

This invention relates primarily to one type of permanent well completion termed dual completion wherein two spaced-apart productive intervals are completed at the same time.

Briefly, the invention comprises apparatus for working over and servicing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals including first and second eccentric spaced-apart tubing strings arranged in the borehole, the lower open end of the first tubing string being positioned above the uppermost of said hydrocarbon productive intervals, a first packer arranged on the first and second tubing strings adjacent the lower end of the first tubing string adapted to close off the space between the tubing strings and the casing, a second packer arranged on the second tubing string below said uppermost interval adapted to close off the annulus between the second tubing string and the casing, means providing a passage fluidly communicating the first and second tubing strings and means arranged in the tubing strings adapted to control fluid flow employed in the workover and servicing operations.

The tubing strings may be provided with closable openings above the first packer for the purpose of fluidly communicating the interiors of the tubing strings and the annulus between the tubing strings and the casing whenever it is desired to utilize the annulus as a flow path.

An object of this invention is to provide improved apparatus for use in working over and servicing a plurality of hydrocarbon productive intervals of a dually completed well.

This and other objects of the invention will be apparent from the following description of the invention taken in conjunction with the drawings wherein:

FIG. 1 is a cross-sectional view of a well bore with the dual completion apparatus of the invention arranged therein for producing operations;

FIG. 2 is a cross-sectional view of a well bore with the dual completion apparatus of the invention arranged therein for working over and servicing a lower productive interval;

FIG. 3 is a cross-sectional view of a well bore with the dual completion apparatus of the invention arranged

2

therein for working over and servicing an upper productive interval;

FIG. 4 is a cross-sectional view of a well bore with dual completion apparatus of the invention arranged therein for working over and servicing a lower productive interval and producing an upper productive interval; and

FIG. 5 is a cross-sectional view of a well bore with the modified dual completion apparatus of the invention arranged therein for working over and servicing an upper productive interval and producing a lower productive interval.

Referring more particularly to the drawings wherein identical numerals designate identical parts:

FIGS. 1 through 5 show a casing 10 arranged in a borehole and penetrating a plurality of hydrocarbon productive intervals 12 and 13. Casing 10 is perforated adjacent intervals 12 and 13 as indicated at 14 and 15, respectively. Two parallel, eccentric tubing strings 20 and 21 are arranged in casing 10. The lower end of tubing string 20 extends to below upper productive interval 12 and the lower open end of tubing string 21 extends to above upper productive interval 12. The upper ends of tubing strings 20 and 21 are suspended from a dual well head assembly, not shown, arranged on the surface of the earth. A dual bore packer 22 is arranged on tubing strings 20 and 21 adjacent the lower open end of tubing string 21 and seals off the annulus or space 16 formed between tubing strings 20 and 21 and casing 10. Tubing string 20 is formed to provide an opening 17 adjacent packer 22 which, in turn, is formed to provide a lateral passage 23 which fluidly communicates the interior of tubing string 21 and opening 17. A packer 24 is arranged on tubing string 20 adjacent the lower open end thereof and seals off the annulus 25 between tubing string 20 and casing 10.

Tubing strings 20 and 21 are each provided with landing nipples 26 and 27, respectively. These landing nipples may be of any desirable type for supporting tubular extension members. Also, tubing strings 20 and 21 are provided with landing nipples 28 and 29, respectively. These latter landing nipples are adapted to support flow directing chokes to be described.

Also, tubing strings 20 and 21 may be provided with openings 50 and 51, respectively, fluidly communicating the interiors of the tubing strings and annulus 16. Opening 50 is arranged between landing nipples 26 and 28 and may be provided with a removable closure member 53 (FIG. 5). Opening 51 is arranged between landing nipples 27 and 29 and may be provided with a removable closure member 52 (FIG. 4).

FIG. 1 discloses the apparatus arranged for producing from both productive intervals 12 and 13. The arrows indicate the direction of fluid flow. A flow directing choke 35 is supportingly arranged in tubing string 21 on landing nipple 29. Choke 35 is a small tubular member open at the upper and lower ends and provided with upper and lower sealing means or elements 36 and 37 which are adapted to seal off the annulus between choke 35 and tubing string 21 above and below, respectively, passage 23.

Thus, production from lower interval 13 enters casing 10 through perforations 15 and passes upwardly through the lower end of tubing string 20 and through tubing string 20 to the surface of the earth. Flow from tubing string 20 into tubing string 21 or casing 10 by way of passage 23 is prevented by sealing means 36 and 37 on choke 35. Production from upper interval 12 passes through perforations 14 into casing 10 and flows upwardly through choke 35 into tubing string 21 and upwardly to the surface of the earth.

3

FIG. 2 discloses apparatus for working over the lower interval 13. A flow directing choke 40 is supportingly arranged in tubing string 21 on landing nipple 29 in place of choke 35. Choke 40 is closed at the lower end, open at the upper end and formed to provide openings 43 intermediate the upper and lower ends. Intermediate openings 43 fluidly communicate with passage 23. Choke 40 is provided also with upper and lower sealing means or elements 30 and 31, respectively, for sealing off the annulus between choke 40 and tubing string 21 above and below passage 23 and openings 43. An open-ended extension 41 is supported in tubing string 20 on landing nipple 26. Sealing means 45 is arranged on tubular extension 41 for sealing off the annulus between tubular extension 41 and tubing string 20 above opening 17. Tubular extension 41 extends through the lower open end of tubing string 20 to adjacent perforations 15 in lower interval 13.

When it is desired to work over or service the lower interval, a fluid as for example a cement slurry, may be flowed down tubing string 20 and through open ended tubular extension 41 to adjacent lower interval 13. When it is desired to reverse circulate the excess cement from adjacent interval 13 according to permanent well completion practices, fluid may be flowed down tubing string 21 through the open upper end of choke 40, through openings 43 and passage 23 into the annulus between tubular extension 41 and tubing string 20 and into the casing-annulus below packer 24 and then up tubular extension 41 and tubing string 20 to the surface of the earth.

FIG. 3 illustrates the apparatus arranged for workover or servicing upper interval 12. In this arrangement choke 40 is supported on landing nipple 28 in tubing string 20. Sealing means or elements 30 and 31 seal off the annulus between choke 40 and tubing string 20 above and below opening 17, respectively. A tubular extension 42 is supportingly arranged in tubing string 21 on landing nipple 27. Sealing means 46 is arranged on tubular extension 42 for sealing off the annulus between tubular extension 42 and tubing string 21 above passage 23.

In working over the upper zone a fluid as for example a cement slurry, may be pumped down tubing string 21 through the open upper end of tubular extension 42 and spotted adjacent interval 12. When reverse circulating out the cement, fluid flow circulation may be down tubing string 20 through the open upper end of choke 40 through opening 17 and passage 23 into casing 10 and then up tubular extension 42 and up tubing string 21 to the surface of the earth.

FIG. 4 illustrates the apparatus arranged for workover or servicing lower intervals 13 while producing upper interval 12. In this arrangement choke 35 is supported on landing nipple 29 in tubing string 21 and sealing means 36 and 37 seal off the annulus between choke 35 and tubing string 21 above and below opening 23, respectively, as in the FIG. 1 embodiment. Open ended tubular extension 41 is supported on landing nipple 26 and sealing means 45 seals off the annulus between tubular extension 41 and tubing string 20 above opening 17 as in the FIG. 2 embodiment. Sealing means 45 is also located above opening 50 which opening fluidly communicates annulus 16 and the annulus formed between tubing string 20 and tubular extension 41. Opening 51 in tubing string 21 is closed as indicated by closure member 52 thereby preventing fluid communication between annulus 16 and tubing string 21.

Production and workover or servicing flow paths are as indicated by the arrows in FIG. 4. Thus, when producing the upper interval 12 the production fluids flow upwardly through open ended choke 35 and through tubing string 21 to the surface of the earth. When it is desired to workover or service the lower interval 13, a fluid such as a cement slurry may be flowed down tubing string 20 and through open ended tubular extension 41 to adja-

4

cent lower interval 13. To reverse circulate excess cement from adjacent interval 13, fluid may be flowed down annulus 16 through opening 50 down the annulus between tubular extension 41 and tubing string 20 into the casing annulus between packer 24 and then up tubular extension 41 and tubing string 20 to the surface of the earth.

FIG. 5 illustrates the apparatus arranged for workover or servicing upper interval 12 while producing lower interval 13. In this arrangement choke 35 is supported on landing nipple 28 in tubing string 20 and sealing means 36 and 37 seal off the annulus between choke 35 and tubing string 20 above and below opening 23, respectively. Open ended tubular extension 42 is supported on landing nipple 27 in tubing string 21 and sealing means 46 seals off the annulus between tubular extension 42 and tubing string 21 above passage 23. Sealing means 46 is also located above opening 50 which opening fluidly communicates annulus 16 and the annulus formed between tubing string 21 and tubular extension 42. Opening 50 in tubing string 20 is closed, as indicated by closure member 53, thereby preventing fluid communication between annulus 16 and tubing string 20.

Production and workover or servicing flow paths are as indicated by the arrows in FIG. 5. Thus, when producing the lower interval 13 the production fluids flow upwardly through the lower open end of tubing string 20 through open ended choke 35 and upwardly through tubing string 20 to the surface of the earth. When it is desired to work over or service the upper interval 12 a fluid such as a cement slurry may be flowed down tubing string 21 and through open ended tubular extension 42 to adjacent upper interval 12. To reverse circulate excess cement from adjacent interval 12, fluid may be flowed down annulus 16 through opening 51 down the annulus between tubular extension 42 and tubing string 21 into the casing annulus between packers 22 and 24 and then up tubular extension 42 and tubing string 21 to the surface of the earth.

Each of the chokes 35 and 40 and each of the tubular extensions 41 and 42 are provided with a fishing head, not designated, to which is connected a wireline, not shown, for insertion into and removal from the tubing strings.

Having fully described the nature, objects and operation of our invention, we claim:

1. Apparatus for working over and servicing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals comprising spaced-apart first and second tubing strings arranged in said casing, the lower open end of said first tubing string being positioned above an upper hydrocarbon productive interval, the lower open end of said second tubing string being positioned below said upper hydrocarbon productive interval and above a lower productive interval, a first packer arranged on said tubing strings adjacent the lower end of said first tubing string adapted to close off the space between said tubing strings and said casing, a second packer arranged on said second tubing string between said upper and lower productive intervals adapted to close off the annulus between said second tubing string and said casing, means interconnecting said tubing strings providing a flow passage between said tubing strings isolated from the annulus between said tubing strings and said casing, said first and second tubing strings being provided with closable openings above said passage, and a tubular extension arranged in one of said tubing strings and choke means arranged in said other tubing string for controlling fluid flow employed in said workover and servicing operations.

2. Apparatus for working over and servicing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals comprising spaced-apart first and second tubing strings arranged in said casing, the

5

6

lower open end of said first tubing string being positioned above an upper hydrocarbon productive interval, the lower open end of said second tubing string being positioned below said upper hydrocarbon productive interval and above a lower productive interval, a first packer arranged on said tubing strings adjacent the lower end of said first tubing string adapted to close off the space between said tubing strings and said casing, a second packer arranged on said second tubing string between said upper and lower productive intervals adapted to close off the annulus between said second tubing string and said casing, means interconnecting said tubing strings providing a flow passage between said tubing strings isolated from the annulus between said tubing strings and said casing, an open ended tubular extension arranged in said second tubing string extending from above said passage to below said second packer, sealing means arranged on said tubular extension adapted to seal off the annulus between said tubular extension and said second tubing string above said passage, and choke means open at the upper end, closed at the lower end and open intermediate said upper and lower ends arranged in said first tubing string adjacent said passage, the interior of said choke means fluidly communicating with said passage, said choke means being provided with sealing means adapted to seal off the annulus between said first tubing string and said choke means below said passage and below the intermediate opening in said choke means whereby said upper interval is isolated between said first and second packers and a fluid circulation flow path between the earth's surface and said lower interval is established through the upper portion of said second tubing string, said tubular extension, the lower portion of said second tubing string, said passage, said choke means, and said first tubing string.

3. Apparatus for working over and servicing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals comprising spaced-apart first and second tubing strings arranged in said casing, the lower open end of said first tubing string being positioned above an upper hydrocarbon productive interval, the lower open end of said second tubing string being positioned below said upper hydrocarbon productive interval and above a lower hydrocarbon productive interval, a first packer arranged on said tubing strings adjacent the lower end of said first tubing string adapted to close off the space between said tubing strings and said casing, a second packer arranged on said second tubing string between said upper and lower productive intervals adapted to close off the annulus between said second tubing string and said casing, means interconnecting said tubing strings providing a flow passage between said tubing strings isolated from the annulus between said tubing strings and said casing, an open ended tubular extension arranged in said first tubing string and extending from above said passage to adjacent said upper productive interval, sealing means arranged on said tubular extension for sealing off the annulus between said tubular extension and said first tubing string above said passage, and choke means closed at the lower end, open at the upper end, and open intermediate the upper and lower ends arranged in said second tubing string adjacent said passage, the interior of said choke means fluidly communicating with said passage, said choke means being provided with sealing means for sealing off the annulus between said second tubing string and said choke means below said passage and below the intermediate opening in said choke means whereby said lower interval is isolated from said upper interval and a fluid circulation flow path between the earth's surface and said upper interval is established through said first tubing string, said tubular extension, said passage, said choke means, and said second tubing string.

4. Apparatus for working over and servicing and for producing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals comprising spaced-apart first and second tubing strings arranged in said casing, the lower open end of said first tubing string being positioned above an upper hydrocarbon productive interval, the lower open end of said second tubing string being positioned below said upper hydrocarbon productive interval and above a lower hydrocarbon productive interval, a first packer arranged on said tubing strings adjacent the lower end of said first tubing string adapted to close off the space between said tubing strings and said casing, a second packer arranged on said second tubing string between said upper and lower productive intervals adapted to close off the annulus between said second tubing string and said casing, means interconnecting said tubing strings providing a flow passage between said tubing strings isolated from the annulus between said tubing strings and said casing, an open ended tubular extension arranged in said second tubing string extending from above said passage to below said second packer, said second tubing string being provided with an opening above said passage fluidly communicating said annulus and said second tubing string, sealing means arranged on said tubular extension for sealing off the annulus between said tubular extension and said second tubing string above the opening in said second tubing string, and an open ended choke means arranged in said first tubing string adjacent said passage, said choke means being provided with sealing means adapted to seal off the annulus between said choke means and said first tubing string above and below said passage whereby separate flow paths between the earth's surface and each interval are established, one flow path fluidly communicating the upper interval and the earth's surface through said choke means and said first tubing string and said second path permitting fluid circulation to said lower interval through said annulus, said second tubing string opening, the lower portion of said second tubing string, said tubular extension, and the upper portion of said second tubing string.

5. Apparatus for working over and servicing and for producing a cased borehole penetrating a plurality of spaced-apart hydrocarbon productive intervals comprising spaced-apart first and second tubing strings arranged in said casing, the lower open end of said first tubing string being positioned above an upper hydrocarbon productive interval, the lower open end of said second tubing string being positioned below said upper hydrocarbon productive interval and above a lower hydrocarbon productive interval, a first packer arranged on said tubing strings adjacent the lower end of said first tubing string adapted to close off the space between said tubing strings and said casing, a second packer arranged on said second tubing string between said upper and lower productive intervals adapted to close off the annulus between said second tubing string and said casing, means interconnecting said tubing strings providing a flow passage between said tubing strings isolated from the annulus between said tubing strings and said casing, an open ended tubular extension arranged in said first tubing string and extending from above said passage to adjacent said upper productive interval, said first tubing string being provided with an opening above said passage fluidly communicating said annulus and said first tubing string, sealing means arranged on said tubular extension adapted to seal off the annulus between said tubular extension and said first tubing string above the opening in said first tubing string, and an open ended choke means arranged in said second tubing string adjacent said passage, said choke means being provided with sealing means adapted to seal off the annulus between said choke means and said second tubing string above and below said passage whereby separate flow paths between the earth's surface and each interval are established, one path fluidly communicating the lower interval and the earth's surface

through the lower portion of said second tubing string, said choke means, and the upper portion of said second tubing string, the other path permitting fluid circulation to said upper interval from the earth's surface through the annulus, the opening in said first tubing string, the lower portion of said first tubing string, the tubular extension, and the upper portion of said first tubing string. 5

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