PERMANENT WELL COMPLETION APPARATUS

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Application December 13, 1957, Serial No. 702,555

4 Claims. (Cl. 166—192)

This invention is directed to permanent well completion apparatus for producing, working over and servicing a plurality of hydrocarbon productive intervals. More particularly, the invention is directed to a tubular plug tool especially adaptable for use in permanent well completion operations.

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 reperforating operations by means of wire line tools 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 appears in "Permanent Type Completion and Wire Line Workovers," The Petroleum Engineer, September 1956. The retrievable plugging tool of the invention is especially adaptable for use in operations of this nature. For example, it may be used to plug off the well bore between two productive zones in a manner described later herein.

Referring to the drawings:
Fig. 1 is a cross-section of a well bore showing apparatus arranged therein for working over an upper productive interval;
Fig. 2 is a vertical, sectional view of a plugging tool adapted for use in the arrangement of apparatus of Fig. 1 showing the tool in one position, and Fig. 3 is a vertical, sectional view illustrating the plugging tool of Fig. 2 in another position.

Referring more particularly to the drawings wherein identical numerals designate identical parts:
Fig. 1 shows a borehole 10 penetrating a plurality of productive intervals 11 and 12. Casing 13 extends through productive intervals 11 and 12 and is cemented therein by means of cement 14. A single bore casing packer 15 is positioned in the well bore between upper and lower productive intervals 11 and 12. A dual bore casing packer 20 is positioned in the well bore above the uppermost productive interval 11. Dual well head equipment, not shown, is positioned at the surface of the earth and has connected thereto two parallelly extending eccentric tubing strings 23 and 24 which are permanently set in the well according to permanent well completion practice. Tubing strings 23 and 24 may be of the same size but are preferably of different dimensions, as shown, in order that various rates of production may be more efficiently controlled. These tubing strings are set in the well bore with the dual bore packer 20 positioned adjacent the lower ends which seal off the space or annulus A between the tubing strings and casing 13. Packer 20 is provided with a laterally extending passageway 25, which fluidly communicates the lower open end of tubing string 24 and the lower open end of tubing string 23. The latter tubing string is provided with a landing nipple 26 which may be of any desirable type for supporting a tubular extension member such as the landing nipple described in the Composite Catalog, vol. 1, 52—53, 19th ed., page 4063. Tubing string 23 is provided with an opening 32 above the upper packer 20, which opening fluidly communicates annulus A and the interior of tubing string 23. A tubular extension 35 is provided with anchoring means 36 and packing 37, 38, 39, and 40. Extension 35 includes a plug member, generally designated 41 and more clearly seen in Figs. 2 and 3 to be described. Plug member 41 is provided with openings 43, which openings fluidly communicate production zone 11 and the interior of tubular extension 35.

In the operation for working over the upper zone, fluid, such as cement, may be injected into tubing string 23 from the earth's surface; the fluid injected flowing downwardly through tubular extension 35 and out openings 43 to adjacent interval 11. The circulation of fluid is accomplished by the fluid passing upwardly through the annulus 44 into laterally extending passage 25 and thence upwardly through the tubing string 24 to the earth's surface. Reverse circulation is effected by flowing fluid downwardly through tubing string 24 through passage 25, openings 43 and upwardly through tubular extension 35 and tubing string 23.

Plugging tool 41, as seen in Figs. 2 and 3, includes a mandrel 50 having thereon spaced-apart upper and lower chevron packing 39 and 40, respectively. Also, mandrel 50 is formed to provide an opening 48 fluidly communicating the interior and exterior of the mandrel. A "no-go" ring 55, having a diameter greater than the diameter of the bore of packer 15 but less than the diameter of tubing string 23, is arranged on the upper end of mandrel 50 and functions to prevent mandrel 50 from passing through the bore of packer 15. A tubular member 56 is movably arranged in and extends through mandrel 50. The tubular member is formed to provide circulation ports 43 arranged above mandrel 50, an opening 58 located intermediate the length of tubular member 56, a by-pass slot 51, and a shoulder 59 positioned below mandrel 50. Also, adjacent the lower interior surface of tubular member 56 a plurality of teeth 60 are provided. The upper end of tubular member 56, above mandrel 50, is provided with an enlarged portion 61, on the exterior surface of which is formed a shoulder 62 adapted to engage the upper end of mandrel 50 and one end of the sealing surface 57 which is adapted to engage with surface 52 of tubular
member 56. In the position of piston 70, shown in Figs. 2 and 3, sealing means 72 seals off the annulus between tubular member 56 and piston 70 above and below said sealing ports 43, respectively. Sealing means 73 seals off the annulus between tubular member 64 and piston 70 above opening 58 when the piston is in each of the Fig. 2 and Fig. 3 positions. Sealing means 74 seals off the annulus between tubular member 56 and piston 70 above opening 58 when piston 70 is in each of the Fig. 2 and Fig. 3 positions, respectively. Sealing means 75 seals off the annulus between tubular member 56 and piston 70 below opening 58 when piston 70 is in each of the Fig. 2 and Fig. 3 positions.

Thus, when piston 70 is in the Fig. 2 position, fluid passage 71 fluidly communicates with opening 58. However, when the piston is in the Fig. 3 position, fluid passage 71 is sealed off from fluid communication with opening 58. Piston 70 has formed on the lower end thereof a split finger grab 76 which latter structure is engaged with teeth 60 formed on tubular member 56. The purpose of the split finger grab 76 is to lock piston 70 in the Fig. 2 and Fig. 3 positions to prevent upward movement thereof. Sealing means 63, 64, and 72 through 75 may be suitably O-rings whereas the sealing elements 39 and 40 are preferably chevron packing. A shear pin 77 releasably joins mandrel 50 to tubular member 56 and tubular member 56 to piston 70. When the apparatus is in operative position as seen in Fig. 1, packing 39 and the various sealing means 63, 64, 72, 73, 74 and 75 may be tested by applying fluid pressure through tubular extension 35. Tubular member 56 and piston 70 at this time are in their Fig. 2 positions. Any leakage will be evidenced by fluid in tubing string 24 or by a pressure drop in tubular extension 35. Packing 39 adjacent upper packer 20 may be pressure tested by applying fluid pressure through tubing 24 when leakage is evidenced by fluid in annulus A. Piston 70 remains in the upper or Fig. 2 position because fluid pressure entering tubular member 56 through ports 43 exerts an upward force against surface 57 thereof. Thus, circulating ports 43 are not in fluid communication with tubular extension 35 above piston 70.

When it is desired to treat the upper zone 11 additional fluid pressure of a treating fluid such as cement within tubular member 56 acts upon the upper end of piston 70. This force fractures the shear pin 77 connection between piston 70 and tubular member 56 and moves piston 70 downward thereby exposing circulating ports 43. Also downward movement of piston 70 seals off fluid communication between fluid passage 71 and opening 58 by means of sealing means 74. Opening 58 releases fluid trapped below surface 57 when sealing means 72 moves below ports 43. Movement of piston 70 downwardly causes split finger grab 76 to engage the teeth 60 on the lower portion of tubular member 56 to lock piston 70 in the Fig. 3 position.

When treating operations have been completed and it is desired to remove tubular extension 35 from the well bore a suitable wire line tool is lowered to engage with the flaring head of tubular extension 35. Then, upward force applied to the wire line moves tubular extension 35 and connected plumbing tool 41 upwardly. If the frictional forces restraining packing 39 and 40 are sufficiently large or if the hydrostatic pressure acting downwardly against mandrel 50 is sufficiently large to prevent upward movement of mandrel 50 then upward movement of tubular extension 35 causes the shear pin 77 connection between tubular member 56 and mandrel 50 to fracture which permits tubular member 56 to move upwardly relative to mandrel 50. Movement upwardly of tubular member 56 equalsizes the pressures above and below packer 15 because sealing means 63 moves out of sealing engagement with mandrel 50 and by means of by-pass 51 tubular member 56 moves out of sealing engagement with sealing means 64. Thus, the spaces above and below packer 15 are in fluid communication through the annulus between tubular member 56 and mandrel 50. It is desirable to provide such fluid communication since the pressure below mandrel 50 may be less than the pressure above mandrel 50 and within tubular member 56 thereby requiring application of greater force to remove the plugging tool than would otherwise be necessary. Consequently, it is desirable to first equalize the pressures within and outside of tubular member 56 above said packer below mandrel 50. Further, upward movement of tubular member 56 causes shoulder 59 of tubular member 56 to engage the lower end of mandrel 50. Upon engagement thereof removal of the tubular extension 35 removes connected tubular member 56 and engaged mandrel 56.

Thus, the plugging tool permits testing of the lower packer and permits retrieving of the lower packer prior to the hardening of any cement or plastic used in the well. For illustrative purposes the use of the plugging tool has been shown and described in conjunction with a particular arrangement of permanent well completion apparatus. However, since its use with other types of apparatus is contemplated the scope of the invention is not to be considered limited thereto.

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

1. A retrievable plugging tool adapted to plug the bore of a packer comprising a mandrel extensible through said packer bore and provided with an opening intermediate the length thereof; spaced apart first sealing means arranged on said mandrel adapted to seal off the annulus between said mandrel and said packer bore wall above and below said mandrel opening; a tubular member having first and second positions slidably arranged on said mandrel and adapted to be connected to said packer bore wall by means of said packer being provided with spaced-apart first and second openings and a shoulder; said tubular member second opening fluidly communicating with said mandrel opening when said tubular member is in said first position; upper and lower second sealing means adapted to seal off the annulus between said tubular member and said mandrel above and below, respectively, said tubular member second opening when said tubular member is in said first position; by-pass means provided on said tubular member adapted to fluidly communicate said tubular member-mandrel annulus above and below said lower second sealing means when said tubular member is in said second position, said upper second sealing means being above said mandrel when said tubular member is in said second position whereby pressures are equalized and below said packer when said tubular member is in said second position; a fluid pressure movable piston having first and second positions slidably arranged in said tubular member; said piston being provided with a fluid passage-way fluidly communicating the upper end exterior and the exterior intermediate the length thereof; third sealing means arranged on said piston adapted to seal off the annulus between said piston and said tubular member and positioned so that fluid circulation through said piston first opening is prevented and fluid communication between said fluid passageway and said tubular member second opening is permitted when said piston is in said first position and fluid circulation through said tubular member first opening is permitted and said fluid communication between said fluid passageway and said tubular member second opening is prevented when said piston is in said second position; frangible means interconnecting said tubular member and said mandrel and said tubular member and said packer adapted to releasably secure said tubular member in said first position and said packer in said first position; means arranged on said piston and said tubular member cooperating to lock said piston in said second position; stop means arranged on said mandrel above said packer bore adapted to prevent movement of
said mandrel through said bore; said tubular member being provided with a fluid passageway fluidly communicating the interior and exterior thereof below said tubular member first opening and above said mandrel to permit release of fluid trapped between said piston and said tubular member when said piston moves from said first to said second position; and said shoulder energetically connecting with the lower end of said mandrel upon fracture of the frangible connection between said tubular member and said mandrel and upward movement of the tubular member to its second position for removing said plugging tool from said packer bore.

2. A retrievable plugging tool adapted to plug the bore of a packer comprising a mandrel extensible through said packer bore and provided with an opening intermediate the length thereof; first sealing means arranged on said mandrel adapted to seal off the annulus between said mandrel and said packer bore wall above and below said mandrel opening; a member having first and second positions slidably arranged in said mandrel and adapted to be connected to a tubing, said member being provided with spaced-apart first and second openings, said member second opening fluidly communicating with said mandrel opening when said member is in said first position, upper and lower second sealing means adapted to seal off the space between said member and said mandrel above and below, respectively, said member second opening when said member is in said first position, said member being provided with means adapted to fluidly communicate the space between said member and said mandrel and said mandrel above and said lower second sealing means when said member is in said second position whereby pressures are equalized above and below said packer when said member is in said second position; fluid pressure movable means having first and second positions arranged in said member and provided with a fluid passageway; third sealing means arranged on said movable means adapted to seal off the space between said movable means and said member and positioned so that fluid circulation through said member first opening is prevented and fluid communication between said fluid passageway and said movable means in said first position and fluid circulation through said member first opening is permitted when said movable means are in said first position and fluid circulation through said member second opening is prevented when said movable means are in said second position; means releasably interconnecting said member and said mandrel adapted to secure said member in said first position; means releasably interconnecting said member and said mandrel means adapted to secure said movable means in said second position; means arranged on said mandrel above said packer bore adapted to prevent movement of said mandrel through said bore; means provided on said member adapted to permit release of fluid trapped between said movable means and said member when said movable means moves from said first to said second position; and means engagingly connecting with the lower end of said mandrel for removing said plugging tool from said packer bore.

3. A retrievable plugging tool comprising a mandrel; a tubular member having first and second positions slidably arranged in said mandrel and adapted to be connected to a tubing; said tubular member being provided with a circulation port; upper and lower sealing means adapted to seal off the annulus between said tubular member and said mandrel when said tubular member is in said first position; said tubular member being provided with means adapted to fluidly communicate said tubular member-mandrel annulus above and below said lower sealing means when said tubular member is in said second position, said upper sealing means being above said mandrel when said tubular member is in said second position whereby fluid communication above and below said mandrel is effected when said tubular member is in said second position; a fluid pressure movable piston having first and second positions arranged in said tubular member; sealing means adapted to seal off the space between said tubular member and said piston whereby fluid communication through said circulation port is prevented and permitted when said piston is in said first and second positions, respectively; frangible means interconnecting said tubular member and said mandrel and said tubular member and said piston adapted to releasably secure said tubular member in said first position and said piston in said first position; means arranged on said piston and said tubular member cooperating to lock said piston in said second position; and said tubular member being provided with means for permitting release of fluid trapped between said piston and said tubular member when said piston moves from said first to said second position.

4. A retrievable plugging tool comprising a mandrel; a member having first and second positions slidably arranged in said mandrel and adapted to be connected to a tubing; said member being provided with a circulation port; upper and lower sealing means adapted to seal off the space between said member and said mandrel when said member is in said first position, said member being provided with means adapted to fluidly communicate the space between said member and said mandrel and said mandrel above and below said lower sealing means when said member is in said second position whereby fluid communication above and below said mandrel is effected when said member is in said second position; fluid pressure movable means having first and second positions arranged in said member; sealing means adapted to seal off the space between said member and said movable means whereby fluid communication through said circulation port is prevented and permitted when said movable means is in said first and second positions, respectively; means releasably interconnecting said member and said mandrel, means releasably interconnecting said member and said movable means; means on said movable means and said member cooperating to lock said movable means in said second position; and means for permitting release of fluid trapped between said member and said movable means when said movable means moves from said first to said second position.

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