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APPARATUS FOR COMPLETION IN A PLURALITY
OF HYDROCARBON PRODUCTIVE STRATA

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FIG. 1.

FIG. 2.

FIG. 3.

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APPARATUS FOR COMPLETION IN A PLURALITY OF HYDROCARBON PRODUCTIVE STRATA

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The present invention is directed to method and apparatus for use in completion in a plurality of hydrocarbon productive strata. More particularly the invention has to do with dual completion in a plurality of hydrocarbon strata in which the tubing string is permanently located in a casing well. In its more specific aspects, the invention is directed to completion in a plurality of formations in which the tubing string is permanently affixed in the well casing at a particular point above hydrocarbon productive strata and completion operations are conducted through the tubing string.

The invention may be briefly described as involving apparatus for use in completion in a plurality of hydrocarbon productive strata and adapted to be connected to a tubing string which is permanently arranged in a well casing. The apparatus comprises a tubular member having a port fluidly communicating the interior of the tubular member with the exterior thereof. At least one by-pass nipple is arranged in the tubular member. The tubular member has arranged on the exterior thereof first and second spaced apart packing members which are arranged above and below the by-pass nipple. A removable flow tube is arranged in the tubular member for separately directing flow through the tubing string and through the port. A packing member is carried by the flow tube for packing off at least a portion of the space between the flow tube and the tubular member. The tubular member is adapted to be located in a casing above a second hydrocarbon productive stratum and below or adjacent to the first hydrocarbon productive stratum. The removable flow tube may be open-ended to allow free flow through the flow tube or the flow tube may be open on a first end and closed on a second end and provided with at least one lateral port for flow through the flow tube. The flow tube may be of sufficient length to extend a substantial distance below the open end of the tubular member. The flow tube may also be provided with valve means for closing and opening the port in the tubular member.

The tubular member or the flow tube may carry a packing member to pack off the space between the flow tube and the tubular member or specifically pack off the space between the flow tube and the by-pass nipple, depending on the type of flow tube which is employed.

The tubular member is provided with means adjacent an upper end for supporting the flow tube. This supporting means may be a landing nipple, latch dogs, pipe slips and any other means well known to the art for supporting one member inside of a pipe and the like.

The invention also contemplates a method for producing hydrocarbons from a plurality of hydrocarbon productive strata pierced by a well in which hydrocarbon production is simultaneously had from two of said strata. In the particular invention, the tubing string is permanently arranged in the casing in the well with its open lower end below a first of said strata but above a second stratum. The first stratum may suitably be a large hydrocarbon reservoir while the second stratum may be one or a series of smaller reservoirs from which hydrocarbons may be obtained. In the invention, hydrocarbons are separately flowed through separate perforations in the casing from the first and second hydrocarbon productive strata with one path of flow being through the tubing and the second path of flow being through the casing. The flow of hydrocarbon is continued until the amount of hydrocarbon produced from the second stratum becomes uneconomical due to depletion and/or production or large amounts of undesirable fluids, such as, in the case where a stratum originally produced oil, by encroachment of gas and/or water. The flow from the first and second strata is then discontinued and a body of low water loss fluid cement is located adjacent the second stratum in the casing. The cement is squeezed into the perforations by imposing pressure on same to form filter cake in the perforations and seal off said second stratum from the casing. Excess fluid cement is then removed from the casing by reverse circulation and perforations are then made in the casing adjacent a third hydrocarbon productive lower down in the well or vertically displaced from the second stratum. Thereafter hydrocarbons are again flowed from the first stratum and hydrocarbons are obtained from the third stratum.

The present invention will be further illustrated by reference to the drawing in which Figs. 1 to 7 illustrate a stepwise arrangement of apparatus and a preferred mode of practicing the invention; and Figs. 8 to 11, inclusive, illustrate an arrangement of apparatus for employing the present invention using gas lift.

Referring now to the drawing, in which identical numerals will be employed to designate identical parts and especially to Fig. 1, numeral 11 designates a well in which a casing 12 has been arranged and which has been cemented in place with cement 13. A tubular member 14 is attached to and forms part of a tubing string 15, the tubular member 14 being attached to the tubing string 15 by means of a suitable threaded connection 16. The tubular member 14 is provided with ports 17 which allow fluid communication from the interior of the tubular member 14 to the annulus A between the casing 12 and the tubular member 14. Forming part of the tubular member 14 is a section 18 of larger internal diameter than the tubular member 14, the purpose of the section 18 being described in more detail hereinafter. The tubular member 14 is provided with by-pass nipples 19 which allow communication through passageways 20 with the annulus A. Spaced on each side of the by-pass nipple 19 are packers 21 and 22 which serve to isolate a hydrocarbon productive stratum 23 which is in communication with the annulus A by means of perforations 24 which have been formed in the casing 12 by firing gun perforator 70 lowered on wire line 71 as shown. The tubular member 14 has arranged in it adjacent its upper end a landing nipple 25 and is provided adjacent the lower open end 26 with a constricttion 27, the purpose of which will be described further hereinafter.

It is to be noted that the casing 13 extends through a hydrocarbon productive stratum 28 and a third hydrocarbon productive stratum 29.

Referring now to Fig. 2, it is to be noted that the tubular member 14 has arranged in it a straight flow tube 30 which has been landed with its upper end in the landing nipple 25 and is supported by the same, the straight flow tube 30 having been lowered into the tubing 15 and into the tubular member 14 by means of a wire line, not shown, connected to a fishing head or spear 31 on the upper end of the flow tube 30. It is to be noted that the flow tube 30 and landing nipple 25 are provided with a chevron packing 32 to provide a seal.

It is to be noted further that the flow tube 30 carries...
a packing member 33 adjacent its lower end which suitably may also be a chevron packing to provide a seal between the tube 34 and the flow tube 30 in effect closing the annulus A'.

Referring now to Fig. 3, a tubular member 14 has been arranged to fit into a slightly different type of flow tube 40 which has a closed lower end 41 with at least one lateral port 42 which is in fluid communication with passageway 23. The flow tube 40, like flow tube 30, may have an upper end carrying a fishing head 31 and is provided with chevron packing 32. The lower end of the flow tube 40 carries a packing member, such as chevron packing 43, which serves to provide a seal between the landing nipple 19 and the flow tube 40 but still allows for passage through the passageway 20 to the interior of the flow tube 40.

Referring now to Fig. 4, a different type of flow tube 50, which is similar to flow tube 30 is employed in the tubular member 14. The flow tube 50 is identical to flow tube 30 but has a sufficient length to extend a substantial distance below the open end 26 of the tubular member 14. Like flow tubes 30 and 40, flow tube 50 is provided with a fishing neck 31 and chevron packing 32 to seal with the landing nipple 25. Flow tube 50 carries a packing 51 which serves to seal off the landing nipple 19 including the passageway 26.

Referring now to Figs. 5 and 6, it will be seen that a flow tube 60 is arranged in the tubular member 14 and, like flow tubes 30, 40 and 50, is landed in landing nipple 25 and is provided with packing 32. The flow tube 60 is provided with a shoulder 61 and a slidable annular member 62 which serves to close the port 17 when the slidable annular member 62 is in a first position. The slidable annular member 62 is normally urged in the first position by means of a biasing member, such as a coil spring 63, which bears frictionally against the annular member 62 and the shoulder 61. Like the other flow tubes, flow tube 60 is provided with a fishing head or neck 31 for lowering and raising the flow tube from the tubular member by means of a wire line. It is to be noted also that the flow tube 60 extends a substantial distance below the open end 26 of the tubular member 14, the purpose of which will be described hereinafter.

Referring now to Fig. 7, it will be noted that the flow tube 60 has been pulled from the tubular member 14 and a gun perforator, such as a small gun perforator 70, is lowered through the tubular member 14 by means of a wire line 71 and operated to cause perforations 72 in the casing 12 to penetrate the stratum or sand 29 to allow production to be had therefrom. Referring now to Figs. 8 and 9, it will be seen that the apparatus is identical to the apparatus of Figs. 2 and 3 with the exception that the tubing 15 is provided with gas lift mandrels 90, 81, and 82. The gas lift mandrels 80, 81 and 82 each are provided with a port 83, 84 and 85, respectively, which communicate the interior of the tubing with the annulus A.

In the embodiments of Figs. 8 and 9, the ports 83, 84 and 85 are closed by equipping the mandrels 80, 81 and 82 with dummy wire line gas lift valves. In short, the dummy wire line gas lift valves 86, 87 and 88 serve to close the tubular member 14. It will be apparent that other means besides dummy valves may be used for closing these ports, such as a slidable valve which may be opened as desired or any other means. In the embodiment and mode of Figs. 8 and 9, the operation is identical to the operation of Figs. 2 and 3 as has been described. When the strata or reservoirs 23 and 24 cannot be produced by the pressure in the strata due to gas or water drive, it may be desirable to place production from these strata on artificial lift, such as by gas lift. Under these conditions, the dummy valves 86, 87 and 88 in the mandrels 80, 81 and 82 will be replaced by wire line gas lift valves 90, 91 and 92 and the casing annulus A pressurized with gas to serve as a gas lift gas reservoir or flow path to allow artificial lift of the producing interval as will be described.

In Fig. 10 the flow tube, such as 30, is provided with an annular valve means 62, such as described in Figs. 5 and 6, to close the port 17, the space between the flow tube 30 and the mandrel 14 being closed by packing 33 as has been described. With the annulus A' closed off due to the closing of the port 17, the gas lift valve member 62 can only be had from the stratum 28 through perforations 25, up through flow tube 30 into mandrel 14 and tubing 15, gas being introduced into the tubing 15 through ports 83, 84 and 85 by gas lift valves 90, 91 and 92. The gas lift valves 90, 91 and 92 are conventional equipment and are detailed in the Composite Catalogue on page 1059 of the 1952-1953 edition. Since the operation of such gas lift valve is well known and is also described in the Composite Catalogue supra, further description thereof will not be given.

When it is desired to produce from the stratum 23 employing artificial lift, a flow tube, such as 40, is provided with annular valve means, such as 62, to close the port 17 and the gas lift valves 90, 91 and 92 are employed to lift artificially hydrocarbons from the stratum 23 through perforations 24, the flow being as described with respect to stratum 23 as shown by the arrows and as also indicated in Fig. 3 with the flow from the stratum or formation 28 through the perforations 25 being cut off to facilitate the passage of the stratum 23 below the virtual of closing the port 17 by the annular valve member 62. After the formation or stratum, such as 28, may no longer produce commercial quantities of oil, it may be desirable to seal off stratum 28 and then perform operations as have been described with respect to Figs. 4 to 7 and recomplete in another zone or reservoir or strata as the case may be.

With the apparatus of Figs. 8 to 11, as has been described, it is possible to produce by artificial lift from one stratum for a 15-day producing period in one month and for a 15-day producing period in another month, making a total of 30 production days in two months and then change the flow tube, as has been described, and produce from another stratum for another 30-day period divided in two calendar months to conform to proration regulations. Thus a flow tube need be replaced or changed only once every 30 days.

The present invention operates in the following manner:

Referring again to the drawing and to Fig. 1, it will be noted that the tubular member 14 has been attached to the tubing string 15 and has been lowered in the well until the lower end 26 is below the oil stratum 23 and is a substantial distance above oil stratum 28 and 29. Under the conditions of Fig. 1, the well is under control by means of having been closed in or provided with a column of heavy fluid, such as drilling mud.

In Fig. 2 a flow tube, such as flow tube 30, has been landed in landing nipple 25 and the well has been brought in by swabbing and the like, perforations 35 having been formed in the stratum 28 by lowering a tubing gun perforator of the well known type through the tubing 15 and tubing member 14 on a wire line, such as shown in Fig. 7, and operated to cause the perforations 35. After the well has been brought in and with the flow tube, such as 30, in place, flow may be had from the stratum 23 and the stratum 28, the flow from the strata 23 being through the by-pass nipple 19 and passageway 20 into the annulus A', and thence through the ports 17 into the annulus A and up the annulus A to the surface; flow from the stratum 28 being introduced in and with the flow tube, such as 30, in place, and the tubular member 14 and up through the flow tube 30, the tubular member 14 and up the tubing string 15 to the surface.

In the embodiment and mode of Fig. 3 the well has been brought in after forming perforations 35 and after a flow tube 40 has been landed in the landing nipple 25. In this particular instance, the flow from stratum 23 is
through perforations 24 and passageway 20 in by-pass nipple 19 into the lateral passageway 42 of flow tube 40 and thence up flow tube 40 into the tubular member 14 and up the tubing 15 to the surface. The flow from stratum 28 is through the perforations 35, up the open end 26 of the tubular member 14, thence through the annulus A' and through port 17 into the annulus A and up the annulus A through the casing.

After the stratum 28 has ceased to produce economical amounts of hydrocarbon due to water and/or gas encroachment or for other reasons and strata 23 is still productive, the stratum 28 may be sealed off and production had from a lower stratum in the well. In these particular instances, flow tubes, such as 30 and 40 as the case may be, are pulled and replaced by a flow tube, such as 56, which is of sufficient length to extend a substantial distance below the open end 26. It will be noted in this instance that the flow nipples 19 have been sealed off and that flow may be had down through the tubing 15 to the tubular member 14, flow tube 50 and thence up the open end 26 of the tubular member into annulus A' and through port 17 into annulus A.

In this operation when the stratum 28 is to be sealed, a body of low water loss fluid cement such as described by Salathiel in U. S. Patent 2,582,459 or any other low water loss cement such as oil-emulsion cements and other low water loss cements available on the market, are deposited adjacent the perforations 35 in stratum 28 through the flow tube 50 by flowing down through the tubing 15, tubular member 14 and flow tube 50. A bradenhead squeeze is then put on the body of cement 55 to cause filter cake 56 to form in the perforations 35 to seal the perforations. If the cementing job is for plugging off the stratum 28 from production a flow tube 50 having a length shown by the full lines in Fig. 4 will be employed without excess fluid cement being reversed out by flow down the tubing 15, tubular member 14 and flow tube 50 and up the annulus A' into the annulus A except as shown by the arrows. However, it is desired to recomplete in stratum 29, then the flow tube 50 will have a length, such as shown by the dotted lines, to reverse out all of the body of fluid cement 55 remaining in the casing 12 after forming the filter cake 56 in the perforations 35. Thereafter a gun perforator may be employed, such as shown in Figs 1 and 7, to form perforations 72 in the casing 12 and stratum 29 and production had therefrom, such as shown in Figs 2 and 3.

Figs. 5 and 6 illustrate an apparatus employed when a high pressure squeeze is to be used in sealing off the perforations 35 in stratum 28. Like the Fig. 4, a body of cement 55 is deposited through the flow tube 60 with the flow tube being set in the position shown by the full lines or in the position as shown by the dotted lines, the determination of which will depend on whether or not the stratum 28 is to be sealed completely and production had only from stratum 23 or it is desired to have production from stratum 23 and strata 29. In any event, the apparatus, such as in Figs. 5 and 6, will be used with the ports 17 closed by the annular valve member 62, pressure being imposed down through the tubular member 14 and flow tube 60 with fluid escaping out in the stratum 28 and cement forming a filter cake, such as 56c in the perforations 35.

In the operation as described with respect to Fig. 6, the excess fluid cement 55 is circulated out by flowing fluid down through the annulus A through the port 17, fluid pressure serving to compress the spring 63 and to cause annular member 62 to move down into section 18 which is of larger inner diameter than tubular member 14 and to open the port 17 allowing fluid to pass from ports 17 into annulus A', down through the open end 26 and up through the flow tube 60 into tubular member 14 and up the tubing string 15. Thereafter, as shown in Fig. 7, the flow tube 60 is withdrawn by means of a wire line, such as 71, and a gun perforator, such as 70, from the perforations 72. Thereafter production may be had from the stratum 29, such as illustrated with respect to Figs. 2 and 3.

It is contemplated that the operation may be conducted from two hydrocarbon productive strata where one may be a gas producing stratum and the other an oil producing stratum. In those instances it may be desirable to have the gas stratum producing through the casing and the oil stratum producing through the tubing. Where the stratum is a high pressure gas stratum, it may be more desirable to produce same through the tubing whereas a low pressure oil stratum may be allowed to produce through the casing. In general, a high pressure fluid well is desired to be produced through the tubing while the low pressure fluid would be produced through the casing. The tubing string may be used as a preferred high pressure flow channel and the casing string as a preferred low pressure flow channel.

The present invention is quite useful in allowing the completion and production from two zones simultaneously. It is possible with the apparatus and method of the present invention to change direction of flow of either the upper or lower completion interval through the tubing or through the casing to prolong the flowing life of the interval. With the present invention it is possible to complete where a large reservoir overlies a number of small reservoirs or strata. The lower reservoirs may then be depleted individually using the aforedescribed technique. In the present invention it is possible to produce from two zones or intervals at the same time and obtain the full allowable of oil and/or gas production from each zone or interval.

While I have illustrated the present invention by sealing off a first of a series of strata and going to the next of the series of strata and producing from same, it is possible, in accordance with the present invention, to perforate in a lower of a series of strata and produce from same along with production from the large reservoir and then seal off the lower strata and go up the hole to another stratum vertically spaced from the exhausted oil stratum. In short, my invention is susceptible to many modifications and use.

The invention is also useful, especially the embodiment of Figs. 4 to 6, in removing sand and other debris from the well. The invention is also quite useful when other fluid material is employed for treating a well for or for injecting into a formation, such as injecting acid, acid gel, and other materials, such as plastic and the like, in a well.

The nature and objects of the present invention having been completely described and illustrated, what I wish to claim as new and useful and to secure by Letters Patent is:

1. Apparatus for use in completion in a plurality of hydrocarbon productive strata adapted to be connected to a tubing string which is permanently arranged in a well casing which comprises a tubular member having a port fluidly communicating the interior of the tubular member with the exterior thereof, at least one by-pass nipple arranged in said tubular member, first and second spaced apart packing members arranged on said tubular member above and below said by-pass nipple, a removable flow tube provided with at least a port communicating with said by-pass nipple and having a closed lower end retrievably arranged in said tubular member for separately directing flow up said tubing string and through said port and up said casing from a first hydrocarbon productive stratum adjacent said by-pass nipple and from a second hydrocarbon productive stratum below the tubular member, means for closing and opening said port, a packing member carried by said flow tube for packing off the space between said flow tube and said by-pass nipple, said tubular member being adapted to be located in said casing above said second hydrocarbon productive stratum with its lower open end and said tubular member providing a
substantially full open passageway on retrieving said flow tube from said tubular member.

2. Apparatus for use in completion in a plurality of hydrocarbon productive strata adapted to be connected to a tubing string which is permanently arranged in a well casing which comprises a tubular member having a port fluidly communicating the interior of the tubular member with the exterior thereof, at least a by-pass nipple arranged in said tubular member, first and second spaced apart packing members arranged on said tubular member above and below said by-pass nipple, a removable flow tube retrievably arranged in said tubular member for separably directing flow from a first hydrocarbon productive stratum through said tubing string and through said port, means for closing and opening said port, and a packing member carried by said flow tube for packing off at least a portion of the space between said flow tube and said tubular member, said tubular member being adapted to be located in said casing above said second hydrocarbon productive stratum with its lower open end and said tubular member providing a substantially full open passageway on retrieving said flow tube from said tubular member.

3. Apparatus in accordance with claim 2 in which the means for closing and opening said port comprises a shoulder arranged on said flow tube and a spaced apart annular member slidably arranged on said flow tube, said annular member being normally urged into a position to close said port by a biasing means arranged between said shoulder and annular member.

4. Apparatus in accordance with claim 2 in which the flow tube extends a substantial distance below the open end of the tubular member.

5. Apparatus for use in completion in a plurality of hydrocarbon productive strata adapted to be connected to a tubing string which is permanently arranged in a well casing which comprises, a tubular member having a section with an internal diameter greater than the internal diameter of the tubular member and having a port arranged above said section fluidly communicating the interior of the tubular member with the exterior thereof, at least a by-pass nipple arranged in said tubular member, first and second spaced apart packing members arranged on said tubular member above and below said by-pass nipple, a removable flow tube retrievably arranged in said tubular member for separably directing flow from a first hydrocarbon productive stratum through said tubing string and through said port, means for closing and opening said port, and a packing member carried by said flow tube for packing off at least a portion of the space between said flow tube and said tubular member, said tubular member being adapted to be located in said casing with its lower open end above a second hydrocarbon productive stratum and said tubular member providing a substantially full open passageway on retrieving said flow tube from said tubular member, said flow tube having a sufficient length to extend a substantial distance below the open end of said tubular member.

6. Apparatus in accordance with claim 5 in which the means for closing and opening said port comprises a shoulder arranged on said flow tube and a spaced apart annular member slidably arranged on said flow tube, said annular member being normally urged into a position to close said port by a biasing means arranged between said shoulder and annular member.

7. Apparatus for use in completion in a plurality of hydrocarbon productive strata adapted to be connected to a tubing string which is permanently arranged in a well casing which comprises, a tubular member having a section with an internal diameter greater than the internal diameter of the tubular member and having a port arranged above said section fluidly communicating the interior of the tubular member with the exterior thereof, at least a by-pass nipple arranged in said tubular member, first and second spaced apart packing members arranged on said tubular member above and below said by-pass nipple, a removable flow tube retrievably arranged in said tubular member for separably directing flow from a first hydrocarbon productive stratum through said tubing string and through said port, means for closing and opening said port, and a packing member carried by said flow tube for packing off at least a portion of the space between said flow tube and said tubular member, said tubular member being adapted to be located in said casing with its lower open end above a second hydrocarbon productive stratum and said tubular member providing a substantially full open passageway on retrieving said flow tube from said tubular member, said flow tube having a sufficient length to extend a substantial distance below the open end of said tubular member.

8. Apparatus in accordance with claim 7 in which the means for closing and opening said port comprises a shoulder arranged on said flow tube and a spaced apart annular member slidably arranged on said flow tube, said annular member being normally urged into a position to close said port by a biasing means arranged between said shoulder and annular member.

References Cited in the file of this patent

UNITED STATES PATENTS

2,077,912 Van Voorhis .............. Apr. 20, 1937
2,173,034 Armentrout et al. .......... Sept. 12, 1939
2,512,801 Kinney et al. .............. June 27, 1950
2,537,066 Lewis .................. Jan. 9, 1951
2,649,916 Brown .................. Aug. 25, 1953
2,717,041 Brown .................. Sept. 6, 1955