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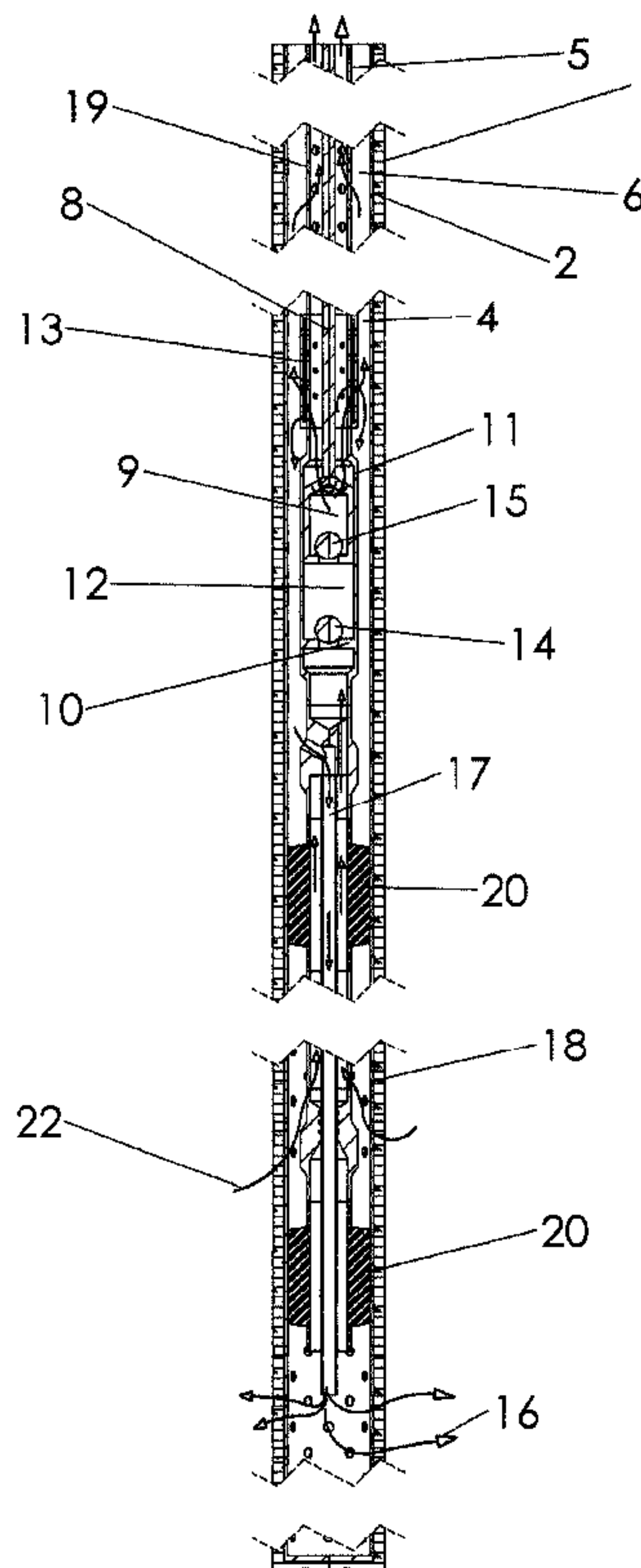
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(54) **Titre : PROCEDE ET APPAREIL SERVANT A SEPARER LE PETROLE ET L'EAU EN FOND DE Puits ET A REINJECTER L'EAU AINSI SEPARÉE**

(54) **Title: A METHOD AND APPARATUS FOR SEPARATING DOWNHOLE OIL AND WATER AND REINJECTING SEPARATED WATER**



(57) **Abrégé/Abstract:**

A method and apparatus for the downhole separation and reinjection of the water component of an oil/water mixture or an oil/water/gas mixture produced from a hydrocarbon well. The fluid mixture from the production zone is delivered to the wellbore at



(57) Abrégé(suite)/Abstract(continued):

the production zone through perforations in the casing and tubing string and delivered through check valves into the annulus formed between the casing and the tubing string. The hydrocarbons are then produced to surface under formation or pump pressure and water is discharged into a selected disposal horizon. The annulus between the casing and the tubing string comprises the separation means over its effective length to surface, the water separating by gravity in the separator and discharging into the water reinjection horizon and the hydrocarbons being delivered to surface.

**A Method and Apparatus for Separating Downhole Hydrocarbons from Water and
Reinjecting the Separated Water**

ABSTRACT

A method and apparatus for the downhole separation and reinjection of the water component of an oil/water mixture or an oil/water/gas mixture produced from a hydrocarbon well. The fluid mixture from the production zone is delivered to the wellbore at the production zone through perforations in the casing and tubing string and delivered through check valves into the annulus formed between the casing and the tubing string. The hydrocarbons are then produced to surface under formation or pump pressure and water is discharged into a selected disposal horizon. The annulus between the casing and the tubing string comprises the separation means over its effective length to surface, the water separating by gravity in the separator and discharging into the water reinjection horizon and the hydrocarbons being delivered to surface.

A Method and Apparatus For Separating Downhole Oil and Water and Reinjecting Separated Water

This invention relates to downhole hydrocarbon - water separation of oilwell fluid mixtures. Downhole hydrocarbon - water separators eliminate the need and associated costs of bringing produced water to the surface, and permit direct downhole water disposal. Differing approaches have been developed for downhole separation of oil and water, and the gravity method appears to have been dominant, taking advantage of the difference in density of oil, gas and water. US Patent 6,719,048 B1 depicts a separation method employing gravity, in which the produced oil-water mixture is retained in the downhole body of an inclined separator for a relatively short dwell-time followed by pumping the oil/gas to surface and disposing separated water to a discharge zone in the separator body, after which the water is pumped into a selected underground formation to additionally assist in repressuring the oil/gas bearing formation. Detectors are shown as positioned at the inlets to the separator to distinguish between the oil and water components in order to provide early separation. US Patent 6,868,907 B2 illustrates a downhole gravity separator in which the separator chamber is inclined in the downhole producing portion of the wellbore in order to take advantage of the density differences of the oil and water.

US Patent 6,691,781 B2 depicts a production fluid separation and apparatus comprising a gravity-driven downhole fluid separator having gas/liquid separator and oil/water separator in which the separated gas is remingled with the separated oil and the gas and oil flow together to the surface, while the separated water is reinjected into the formation; turbine driven pumps are required which are powered by power liquids under pressure from surface. US Patent 7,389,816 B2 discloses a three-phase oil/gas/water separator in which the inlet oil, gas and water are introduced into the separator above an isolation packer separating the downhole assembly into what is defined as a "first vertical length" and a "second vertical length", the separation occurring immediately below a downhole pump. The gas is permitted to separate from the oil/water mixture in the "first vertical length" when it will bubble to surface within the casing. The oil/water mixture is pumped at high pressure into the "second vertical length" of the assembly below the isolation packer where gravity separation of the oil and water takes place, the oil being pumped to surface within the tubing in the "first vertical length" downhole assembly.

The present invention overcomes the deficiencies of the prior art.

A Method and Apparatus for Separating Downhole Hydrocarbons from Water and Reinjecting the Separated Water

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Summary of the Invention

The invention described in this disclosure is unique in that the oil/gas/water separation occurs in an annulus in the wellbore between the production tubing and the well borehole (whether cased or open hole) over the full length of the annulus from production horizon to surface. While the production of fluids in an oil well typically comprise oil and water, it will be recognized that hydrocarbon wells having a larger production of natural gas will readily be accommodated, with the separation of gas herein described.

The method of this invention utilizes the entire length of the hydrocarbon/water column in the annulus from production horizon to surface, to take advantage of the density difference between the oil/gas and water produced, rather than the limited length of a downhole separator chamber as disclosed in the prior art, in order to more completely separate the components of oil and gas and to permit the water component to be discharged at the exit from the separator chamber into the water horizon selected. Operating costs of production are reduced by creating a relatively long distance over which separation will occur within the wellbore annulus, thereby to achieve production of clean oil and/or gas at surface, and reinjection of water into the water formation. The water, when separated, is maintained in separated condition and not allowed to re-emulsify with the oil and gas before discharge.

In accordance with one embodiment of the present invention, a method is disclosed of producing hydrocarbons from a wellbore to which an emulsion of oil, gas and water is delivered under downhole formation pressure and in which a previously determined water discharge horizon is known to be located below the hydrocarbon producing formation, this being the normally occurring geological structure encountered in hydrocarbon production.

In accordance with a second embodiment of this invention, in which the identified water injection formation is located above the hydrocarbon production zone, an altered embodiment of the structuring of the separation chamber is shown.

With the modern development of horizontal drilling and production technology, different embodiments of the technology of this invention are depicted, which do not depart from the inventive concept but illustrate its adaptation to horizontal completions. In each of these adaptations the separation chamber is positioned in a vertical portion of the wellbore, adjacent the horizontal wellbore. In each of these variations, the separation of the hydrocarbons and water takes place in the vertical portion of the wellbore, while water

reinjection will normally occur on discharge in the horizontal portion, as dictated by the geological conditions in that location.

Downhole oil/water separators are frequently designed with mechanically operated separator-assist devices such as cyclones, powered by downhole power drive means such as described in US Patent 6,080,312 and 6,336,504 B1. The invention herein disclosed relies on the entire length of the tubing string and casing annulus to effect the gravity driven hydrocarbon/water separation. With the pump positioned downhole at the production horizon, co-operating with a system of check valves in the pump chamber as herein described, and advantageously using the full length of the annulus between the tubing and the casing as the separator, effective hydrocarbon/water separation is accomplished as follows:

- On the pump upstroke, hydrocarbon and water from the production zone enter the pump chamber through the inlet check valve;
- On the following downstroke, this valve closes and the chamber wall - mounted check valves open to discharge the hydrocarbon/water emulsion into the surrounding annulus;
- Water then accumulates in the annulus and later in the tubing until it reaches a sufficient volume and commences descending by gravity within the annulus and the water-discharge by-pass to enter the water discharge horizon of the adjacent geological horizon;
- Gas and/or oil accumulating in the tubing and casing rise to the ground surface for recovery;
- Discharge of both the water and the hydrocarbon is achieved by formation or pump pressure developed in the separation assembly.

The gravity separation of this invention utilizes an annular height of fluid averaging from a few hundred feet to thousands of feet, within which the separation of hydrocarbons from the water takes place.

It has been found that the system herein described is suited for thousands of barrels of water per 24 hours and oil production at the rate of hundreds of barrels per day from depths of 1,000 to 20,000 plus feet. The foregoing described features will be apparent from the following figures, descriptions and claims.

Brief Description of the Drawings

FIG. 1 is a partially cross-sectional drawing of the system of the first embodiment for producing and separating hydrocarbon and embodied water from a vertical wellbore, in which the water reinjection zone has been identified as in a geological formation below and separated from the oil production zone;

FIG. 2 is a partially cross-sectional drawing of the system of the second embodiment, which will be seen as similar to the first embodiment except for the location of the water reinjection horizon, which is shown as being above the hydrocarbon production formation;

FIG. 3A is a partially cross-sectional view illustrating the system of the invention deployed in a vertical wellbore in which the borehole is initiated as a vertical borehole, then deviating at a predetermined depth into a horizontal borehole, within an oil and gas producing formation, the water reinjection horizon being downstream of the production zone;

FIG. 3B is a partially cross-sectional view of the system described in FIG. 3A in which the water reinjection horizon is upstream of the production formation; and

FIG. 3C is a partially cross-sectional view of the system described in FIG. 3A except that production of gas and oil from multiple zones is accomplished using multiple isolation packers in the horizontal portion of the wellbore for multiple sections of the horizontal wellbore and in which multiple open-close port valves are selectively operated. The gas/oil/water separation takes place in the separation chamber defined in the vertical section of the wellbore running to surface.

In each of the views depicted in FIGS. 3A, 3B and 3C, the horizontal portion of the wellbore is shown as an “openhole” completion. It will be recognized by those skilled in well drilling technology that in openhole completions one or more liners may be run into the wellbore where for example, unstable rock or sands require additional support.

Detailed Description of the Invention

FIG. 1 depicts a partially cross-sectional view of the first embodiment of the system in a vertical oil or oil with gas wellbore **1**. A casing **2**, normally cemented in situ in the wellbore **1** in a conventional manner, defines at its interior a borehole cylinder **4**. Positioned concentrically within the borehole cylinder **4** is a production tubing **5** which defines an annulus **6** with the casing **2**. Each of the production tubing **5** and the casing **2** extend to ground surface, not depicted, of the borehole **1**; the depth of the well, drilled to penetrate an identified oil or oil and gas-bearing formation (not depicted) is normally several thousand feet in length and so defines an extended annulus **6**. The top of the borehole **1** at ground surface is normally capped except for the tubing **5**, which is coupled by surface equipment to production tankage or pipeline.

The bottom of the casing **2** unless in openhole completion, is normally terminated with a cement plug, thus completing the borehole cylinder **4**.

Positioned normally several feet above the production zone **22**, a bottomhole pump **7** operates within the tubing **5**. The drawing FIG. 1 depicts a reciprocal piston pump **9** in which the piston reciprocates axially relative to the tubing **5**. Differing types of downhole pump designs may be used. The downhole pump **7**, shown, operates under engagement with a coupled pump rod **8**, and is normally driven at ground surface by an electrically operated pump drive. The pump piston **9** operates between a piston seat **10** and an upper piston location **11** positionally controlled from surface, depending on downhole conditions such as the characteristics of the oil/gas/water production for the well. The pump piston **9** defines a chamber **12** by its stroke within the tubing **5**. The pump piston **9** discharges the oil/gas/water volume within the chamber **12** through the slip-type check valve **13** and engages the lower pump check valve **14** located adjacent the piston seat **10**. In this embodiment the drawing in FIG. 1 depicts the slip-type check valve assembly **13**, involving an outerlying sealing element which expands and disengages from the underlying tubing **5** to permit outward flow of the hydrocarbon/water mixture, and reseals against the underlying tubing **5** on the release of the pump expansion pressure. An upper check valve **15** in the chamber **12** seals the chamber **12** against discharge into the lower end of the tubing **5**.

The annulus **6** is open to upward oil and gas flow to surface and downward water flow to the water injection horizon **16** through the by-pass water flow conduit **17**

discharging into the water injection horizon **16** of the geological horizon identified at the bottom of the casing **2**. Casing perforations **18** and tubing perforations **19** in the casing **2** and the adjacent tubing **5** admit production fluids into the tubing string **5**; the isolation packers **20** seal the annulus **6**, both above and below the production zone **22**, and the concentric tubing **5** from downward discharge into the bottom of the borehole **1**.

In the embodiment shown in FIG. 2 the water reinjection horizon **16** is identified lying above the production zone **22**, with the perforations **18** in the casing **2** discharging the reinjection water directly into the water reinjection horizon **16**.

In the embodiment shown in FIG. 3A, 3B and 3C the vertical borehole **1** (as shown in FIG. 1 or 2) are deviated horizontally to access a production formation which are capable of more economic development with horizontal openhole or liner **3** and tubing **5**.

The well completion shown in FIG. 3A is similar to that shown in FIG. 1 excepting for the orientation of the downstream portion of the wellbore **1**, which lies generally horizontally.

Production fluids enter the openhole or liner **3** and tubing **5** at perforations **19** to admit produced fluids into the lower end of the tubing string **5**, with isolation packers **20** sealing the annulus **6** and the concentric tubing **5** from downstream discharge into the water injection horizon **16** and directing the produced fluids upstream for discharge into the annulus **6** through the check valve ports as at **13**. Thus, the isolation packers **20** segregate the production zone **22** from all other pressure sources including hydrostatic and formation pressure.

The well completion shown in FIG. 3B is similar to that shown in FIG. 3A excepting that the water reinjection horizon **16** lies upstream of the production zone **22** and is charged with reinjection water on the downstream flow from the check valve ports as at **13**. Oil, gas and water from the production zone **22** are directed upwardly into the vertical section of the system where separation of the oil, gas and water occurs.

A further modification of the vertical-to-horizontal production system is shown in FIG. 3C wherein production is taken from multiple zones using multiple isolation packers **20** in the horizontal portion of the wellbore at **1**, in FIG. 3C; selectively open/close port valves **21** operated from surface controls (not shown) whose construction and operation are well established and known to those skilled in the art to which this invention relates, allow production to be taken selectively from differing sections of the production zone **22**.

In certain cases, the origin of the produced fluids may be in multilateral locations drilled from the main wellbore **1**, using offsetting whipstock or horizontal drilling techniques familiar to those knowledgeable in the art.

It will be recognized that in either vertical or horizontal completions the bottomhole pump **7** as shown in FIG. 1, may be used to increase pressure in the annular separation system **6** in order to reinject the produced water back into the water injection horizon **16** and to deliver the hydrocarbon production to surface if the pressure within the hydrocarbon formation is insufficient.

It will be recognized under certain conditions, in either vertical or horizontal completions, where exceptionally high water volumes are present, a bottomhole pump means, as shown in FIG. 1, may be required with its only dedication being the reinjection of the water into the water reinjection horizon **16** through the by-pass water flow conduit **17**.

Volumes of gas may be produced along with oil. The gas may be separated from the oil at surface in conventional oil/gas separation systems. Large gas volumes produced with the oil may require larger scaled oil/gas separators at surface.

CLAIMS:

1. An apparatus for separating hydrocarbons and water produced from an underground formation comprising:
 - a casing for lining a borehole in the formation;
 - a tubing string in said casing defining an annulus with said casing;
 - first perforations in said casing at a production zone of said borehole for introducing production fluid into the casing;
 - second perforations in said tubing string for admitting production fluid from the casing into said tubing string;
 - third perforations in said casing for discharging separated water from the annulus into the formation at an injection zone;
 - a first packer in said annulus separating said first perforations from said third perforations;
 - a first check valve in said tubing string above said packer for admitting production fluid under pressure from said tubing string into said annulus where the water separates by gravity from the hydrocarbons for discharge through said third perforations; and
 - a second check valve in said tubing string above said first check valve for admitting separated hydrocarbons from said annulus into said tubing string for passage to the top of the borehole.
2. The apparatus of claim 1, including a flow diverter in said tubing string between said first packer and said first check valve for directing production fluid upwardly in the

tubing string to said first check valve and directing separated water from the annulus downwardly; and a bypass conduit connected to said flow diverter in said tubing string for conveying separated water to a water discharge zone in the formation.

3. The apparatus of claim 2 including a downhole pump in said tubing string between said flow diverter and said first check valve for pumping production fluid upwardly to said first check valve.

4. The apparatus of claim 1, including a second packer spaced apart from said first packer in said annulus, the casing between the first and second packers containing said first perforations and the casing beneath the packers containing the third perforations.

5. The apparatus of claim 1, wherein the first packer is located above said first and second perforations and below said third perforations for a formation in which the production zone is above the packer and the injection zone is beneath the packer.

