METHOD AND SYSTEM FOR REGENERATION OF A MEMBRANE USED TO SEPARATE FLUIDS IN A WELLBORE

Inventor: David R. Underdown, Conroe, TX (US)

Correspondence Address:
Richard J. Schulte
Chevron Texaco Corporation
P.O. Box 6006
San Ramon, CA 94583-0806 (US)

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ABSTRACT

A system is provided which has a downhole membrane separator, including a membrane, which separates hydrocarbons, such as methane and oil, from other contaminants, such as CO₂ and water. After the membrane becomes fouled with contaminants after separating a sufficient quantity of a feedstock, the membrane is backflushed or chemically treated, in place to assist in the removal of contaminants from the membrane. An explosive may be used to create the a pressure wave which backflushes the membrane. Or else, the pressure differential across the membrane may be reversed to create the backflushing action. Chemicals may be used to assist in removing foulants. Or else, a spray or bubbler system may be used to create turbulence to assist in the removal of a foulant. Methods of unfoiling the membrane are also taught including backflushing and chemical treatment of the membranes to removed unwanted contaminants from the membrane.
FIG. 4A

FIG. 4B
METHOD AND SYSTEM FOR REGENERATION OF A MEMBRANE USED TO SEPARATE FLUIDS IN A WELLBORE

TECHNICAL FIELD

[0001] The present invention relates to methods and systems of separating fluids in a wellbore using membranes, and more particularly, to those methods and systems used in oil and gas producing wells.

BACKGROUND OF THE INVENTION

[0002] It is sometimes desirable to separate fluid components of a fluid mixture in a wellbore. Fluid components which are desirable may be produced to the surface of a well. Meanwhile, undesirable components or contaminants are ideally disposed of into a subterranean formation without ever coming to the surface of the well. This greatly reduces environmental concerns associated with disposal of the undesirable components through surface disposal or reinjection into an associated disposal well. Consequently, cost savings can be realized from reduced disposal expenditures. Further, because only the desired fluid components are produced to the well surface, pumping or lifting costs can often be reduced. Also, these unwanted fluid components can sometimes be re-injected adjacent the producing formation to maintain pressure on the producing formation.

[0003] An example of a fluid mixture which is sometimes separated downhole is an oil and water mixture. This mixture is received into a wellbore through perforations in the wellbore’s casing and surrounding production tubing. The oil is ideally separated from the water with the concentrated oil being produced to the well surface. The separated water is then either disposed of into a formation adjacent the wellbore or conveyed to the surface for further processing and disposal.

[0004] Another example of a fluid mixture which may be separated downhole includes a gas mixture comprising hydrocarbons, such as methane, ethane or propane, and carbon dioxide, hydrogen sulfide, and other gases. Ideally, the separated hydrocarbons are produced to the surface of a well while the contaminants, i.e., CO₂, H₂S, etc., are injected into an available subterranean formation.

[0005] Presently, a preferred method of separation is the use of cyclonic separators. A fluid mixture is spun with heavier fluid components moving to the radially outer portion of the separator while lighter portions tend to remain nearer the axis of spinning. Thus heavier water can be separated from light oil. Likewise, lighter gas can be separated from heavier liquids. Further, lighter gases such as CO₂ can be separated from heavier gases like methane, ethane or propane.

[0006] A less common separation technique employs a selectively permeable membrane. These membranes let a particular fluid component pass more rapidly than through another fluid component. Accordingly, the first fluid component passes through the membrane more rapidly than does the second component. This first fluid component, or permeate, thus becomes enriched in the first fluid component. Likewise, the portion of the fluid mixture which does not pass through the membrane, the retentate, becomes increasingly concentrated in the second fluid component. Ideally, the selective permeability and the permselectivity is sufficiently high that this separation technique is economical for separating desired fluid components.

[0007] The concentrated permeate and retentate fluid mixtures are then routed as desired. For example, if water or CO₂ is the fluid component which is of increased concentration in the permeate fluid mixture, then the permeate fluid may be delivered to a subterranean disposal formation. Or else, this permeate fluid may be conveyed to the well surface for further processing and disposal. The retentate, which may now contain highly undesirable hydrocarbons, such as oil or natural gas, will be collected and passed to the well surface for further production. Of course, it is also possible through the selection of other membranes that the concentrated components of the permeate and retentate fluid mixtures will be reversed. That is, the hydrocarbons may be permeated through a membrane while contaminants are retained within the membrane.

[0008] One drawback to the use of membranes for wellbore separation is that the membranes can become fouled. Producing fluid mixtures often contain contaminants such as mineral particles, asphaltenes, paraffins and others, which over time have a tendency to collect on a membrane. The collection of these contaminants can clog pores which can inhibit the passage of desired fluid components through the membrane. Consequently, the separation efficiency of the membrane drops. The membranes must then be periodically replaced when they become sufficiently fouled with contaminants. With a hydrocarbon well, this often requires the expensive procedure of working over the well to replace the membrane.

[0009] Accordingly, there is a need to remove, in situ, the contaminants collecting on downhole membranes, thereby regenerating the membranes. If this need can be met, expenditure associated with working over a well can be avoided. The present invention provides such a solution to removing membrane contaminants in a wellbore.

SUMMARY OF THE INVENTION

[0010] It is an object of this invention to provide a method and system for removing foulants from a membrane used downhole to separate contaminants from hydrocarbon fluids.

[0011] It is yet another object to provide a system wherein a pressure reversal is created downhole to backflush a membrane to remove foulants from a membrane.

[0012] It is yet another object to provide a system where dispersants and other chemicals may be introduced to a membrane to assist in the removal of foulants which otherwise would reduce the performance of the downhole membrane separation system.

[0013] A system is provided which has a downhole membrane separator, including a membrane, which separates hydrocarbons, such as methane and oil, from other contaminants, such as CO₂ and water. After the membrane becomes fouled with contaminants after separate a sufficient quantity of a feedstock, the membrane is backflushed or chemically treated, in place to assist in the removal of contaminants. An explosive may be used to create the pressure wave which backflushes the membrane. Or else, the pressure differential across the membrane may be reversed to create the backflushing action. Chemicals may be used to assist in removing
foulants. Or else, a spray or bubbler system may be used to create turbulence to assist in the removal of a foulant.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a regenerative membrane system in a wellbore used to separate fluid components of a fluid mixture received from a subterranean hydrocarbon producing formation;

FIG. 2 is an enlarged schematic view of a membrane used in FIG. 1 having an adjacent pressure impulse producing device such as a detonating cord;

FIG. 3 is an enlarged fragmentary view illustrating the detonating cord exploding and creating an impulse wave which dislodges a portion of contaminants formed on the inside of the membrane;

FIGS. 4A and 4B illustrate that pressure pulses used to dislodge contaminants from a membrane can be of either a slow pressure build up or else be one or more impulses;

FIG. 5 illustrates a suction device used to seal with and decrease the pressure within a membrane separator to induce backflow and removal of contaminants from a membrane; and

FIG. 6 illustrates a regeneration system which utilizes a coiled tubing to introduce dispersants to the membrane; and

FIG. 7 illustrates a regeneration system which utilizes a spray head to spray dispersants upon a membrane.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

The present invention is directed to backflushing or otherwise removing contaminants from one or more membranes utilized in a membrane separator located downhole in a hydrocarbon producing well. By substantially removing contaminants which build up on membranes, membrane separators containing the membranes are “regenerated” such that its efficiency in separating fluid components from a fluid mixture is ideally returned near or to the level of when the membrane separator was first installed in the wellbore.

FIG. 1 illustrates a well system 20 for separating fluid components in a fluid mixture in a wellbore 22. Wellbore 22 is lined with a casing 24. A string of tubing 26 having an inlet opening 28 therein is located within casing 24. A membrane separator 30 is interposed in tubing string 26. Located beneath membrane separator 30 is a packer 32 which seals an annulus 34 formed between casing 24 and tubing 26. Perforations 36 in casing 24 allow a fluid mixture, i.e. production fluids including hydrocarbons, to flow into wellbore 22 from a producing zone 38. Well system 20 further includes a well surface 40. A well head 42 and a fluid handling apparatus injection apparatus 44 are mounted on well surface 40.

As shown in FIG. 1, annulus 34 surrounding the string of tubing 26 may include a fluid pump 62. Fluid pump 62 is used pump to undesirable fluid components, such as water or CO₂, from annulus 34 into an adjacent subterranean disposal zone 59. Alternatively, if fluid pump 62 is not used, the fluid including contaminants can be delivered up annulus 34 to well surface 40 for treatment and/or disposal. Apparatus 44 includes a pump 46 and valves 48 and 49 for injecting fluid into or removing from wellbore 22.

Membrane separator 30 includes inner and outer perforated cylinders 50 and 52 and bottom and top end caps 54 and 56. Captured between inner and outer cylinders 50, 52 and end caps 54 and 56 is a membrane 60. The geometry of membrane 60 may take any one of several forms such pleated, spiral winding, tubules, etc. In the exemplary embodiment shown in FIG. 1, membrane 60 is pleated. However, the principles of this invention apply to the removal of contaminants from membranes of any configuration.

The composition of membrane 60 is dependent upon the desired components to be separated. By way of example and not limitation, when hydrocarbons gases, such as natural gas, are to be separated from other gases including CO₂, membranes may be made from polyimidies or other suitable gas separating materials. For the separation of liquids such as oil and water, suitable membranes include modified polycrylonitriles, modified polyethersulphones, alpha alumina and others.

Ideally, membrane 60 has a high degree of selectivity and permittivity. Membrane 60 has a retentate side 62 and a permeate side 64. Retentate side 62 is the side to which the fluid mixture or feedstock is introduced. Permeate side 64 is the side of membrane 60 from which fluids permeate or exit. Also, those skilled in the art will appreciate that a series of longitudinally arranged membrane separators having different membranes may be used. For example, suitable membranes for first separating water and oil may be used and then upstream therefrom membrane separators for separating gases, i.e. CO₂ and natural gas may be used. Often it is preferably to remove liquids so that gas membranes are exposed only to gases which are to be separated.

In normal operation, a fluid mixture from producing zone 38 enters wellbore 22 through perforations 36. The fluid mixture enters tubing 26 by way of opening 28. The fluid mixture passes up tubing 26 until reaching membrane separator 30. The pressure in tubing 26 and on the retentate side 62 is substantially higher than in annulus 34 and on the permeate side 64. Inner cylinder 50 is perforated and allows the fluid mixture to reach permeate side 62 of membrane 60. As membrane 60 is ideally highly selective to the passage of one fluid component relative to another, the fluid which permeates through membrane 60 is enriched in concentration relative to the original fluid mixture received from producing zone 38. This first fluid component is ideally a contaminant to be disposed of such as CO₂, H₂S or water. Similarly, the more restricted second fluid component, i.e. a hydrocarbon such as natural gas or oil, which is ideally retained in tubing 26, continues to pass by membrane 60 without substantially passing through. The now more concentrated first fluid component, or hydrocarbon such as gas or oil, continues to pass up tubing 26 and out well head 42 for further processing and storage.

Meanwhile, the undesired first fluid component, such as CO₂ or water, passes through perforations in outer
cylinder 52 and into annulus 34. If so desired, disposal pump 62 pumps this first fluid component into disposal formation 39. Or else, the first fluid component can be withdrawn by fluid handling apparatus 40 from annulus 34 and passed and/or disposed of.

[0031] After membrane 60 has filtered a sufficient quantity of fluids, contaminants collect on the retenate side 62 and in the pores of membrane 60. This may lead to the creation of foulants 70 on the inside of inner cylinder 50 and on the retentate side of membrane 60. Regeneration device 100 is used to create a higher pressure on the permeate side 64 than on the retentate side 62 and thus a backflushing of membrane 60. Foulants 70 restrict the flow of the fluid mixture through inner cylinder 50 and membrane 60. Consequently, rather than the fluid mixture from producing zone 38 being separated by membrane 60 into the desired first and second fluid components, the fluid mixture continues to pass up tubing 26 with the fluid mixture being only slightly enriched in the desired fluid component, i.e., hydrocarbons.

[0032] FIG. 2 illustrates an enlarged view from FIG. 1. A regeneration device 100 is used to dislodge or remove foulants 70 from membrane separator 30, and more specifically, membrane 60. Regeneration device 100 is used to create a higher pressure on the permeate side 64 than on the retentate side and thus a backflushing of membrane 60. In this exemplary embodiment, regeneration device 100 includes a length of detonation cord 110 aligned adjacent membrane separator 30. Detonation cord 110 is suspended and actuated from the well surface 40. Other alternatives for regeneration device 100 include a conventional charge strips containing spaced apart charges. Or else, mechanical devices, such as water hammers (not shown), may be used to create a sudden pressure spike or impulse to cause backflushing of membrane 60.

[0033] FIG. 3 is an enlarged fragmentary view from FIG. 2 illustrating the detonation of a detonation cord 110. When a detonation cord 110 is set off, pressure waves 116 in the fluid in annulus 34 are created. These pressure waves 116 pass through perforations in outer cylinder 52 and cause backflushing of fluid from permeate side 64 through membrane 60 and out retentate side 62. In this manner, foulants 70 are dislodged from membrane 60 and inner cylinder 50 of membrane separator 30. The flow of the fluid mixture in production tubing 26 will then carry away the foulants 70 to the well's surface 40. Above ground separators or filters can remove the contaminants or else the contaminants may be chemically treated.

[0034] Another alternative is to gradually increase the pressure in annulus 34 above that inside membrane separator 30 and production tubing 26 to initiate backflushing. The pressure reversal across membrane 60 will cause the reversal of flow through separator membrane 30. This backflushing will dislodge the contaminants from membrane separator 30, and more particularly, from membrane 60. Also, during this backflushing process, chemicals may be added to the annulus 34 which help dissolve or remove contaminants from membrane separator 30. The type of chemical used will depend upon the particular characteristics of the well and the particular contaminants causing the fouling membrane 60. For instance chemicals such as dispersants, surfactants, alcohol surfactants or derivatives thereof, or demulsifiers may be used to assist in removing the contaminants from membrane 60. Coiled tubing may replace electric line 102 to deliver the dispersants in FIG. 1. Fluid handling apparatus 44 employing pump 46 can be used to pressurize annulus 34.

[0035] FIG. 4A illustrates the soft pressure up of fluid contained within annulus 34 adjacent membrane separator 30. In the example shown in FIG. 4A, a line 120 is shown gradually increasing in pressure over time. This pressure must overcome the pressure in tubing 26, as shown by line 122. Thus the pressure is gradually increased until the pressure on permeate side 64 of membrane 60 is greater than the pressure on retentate side 62. In contrast, with the use of the detonating cords or charges or a water hammer, i.e., a hard pressure up, as shown by spikes 122, is created which utilizes one or more impulse or shock waves to loosen and dislodge the contaminants clogging membrane 60. Dispersants are preferred to be used with the soft pressure up while the sharp pressure spikes may be sufficient to dislodge contaminants based upon fluid forces alone.

[0036] FIG. 5 illustrates another embodiment of a regeneration system 150. Regeneration system 150 includes a membrane separator 152 having inner and outer cylinders 154, 156 and bottom and top end caps 160, 162. A membrane 164 is contained within the walls 154, 156, 160, 162. A string of tubing 166 carries fluid to a well surface. A casing 170 surrounds membrane separator 152 and tubing 166 with an annulus 168 formed between tubing 166 and casing 170. A removal device 172 includes a disk 174 which is expandable to press an annular seal 176 against inner wall 154. A coiled tubing 176 is suspended from the well surface and supports disk 174. Orifices 180 are formed in coiled tubing 176.

[0037] In operation, a vacuum can be applied across coiled tubing 176 with fluid being drawn into coiled tubing 176. Disk 174 and seal 176 cooperate to seal with the bottom of membrane separator 152. Eventually, the pressure within tubing 166 and membrane separator 152 drops below that of annulus causing a backflushing of membrane 164 and removal of contaminants therefrom. Contaminant fragments 182 are shown being removed from the retentate side of membrane separator 152.

[0038] FIG. 6 illustrates an additional embodiment of a regeneration system 200. A membrane separator 202 is interposed in a string of tubing 204 which is disposed within a casing 206. Membrane separator 202 includes a membrane 210. Coiled tubing 212 is disposed within tubing 204 from a well surface down to below membrane separator 202. A gas, preferably nitrogen, is pumped down coiled tubing 212. Gas bubbles 214 are formed as the gas is forced from coiled tubing 212. The expanding gas bubbles 214 engage the retentate side of membrane 210 causing contaminants formed therein to be dislodged. The gas may contain a dispersant as well to assist in the removal of contaminants from membrane 210.

[0039] FIG. 7 shows yet another embodiment. A membrane separator 230 is interposed in a string of tubing 232 which is disposed within a casing 234. Membrane separator 230 includes a membrane 236. A coiled tubing 244 supports a spray head 246 which sprays a dispersant 250 upon membrane 242 to dislodge contaminants from membrane 236. Alternatively an aerator could be used to create bubbles. The bubbles of gas are introduced to the retentate side of the membrane to reduce fluid pressure thereon thereby causing fluid to backflush membrane 236.
While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purposes of illustration, it will be apparent to those skilled in the art that the invention is susceptible to alteration and that certain other details described herein can vary considerably without departing from the basic principles of the invention.

What is claimed:

1. A method of regenerating a membrane in a wellbore which is used to separate contaminants from a fluid mixture, comprising the steps of:
   - backflushing the membrane with a fluid passing from a permeate side to a retentate side to dislodge contaminants from the membrane thereby regenerating the membrane.
2. The method of claim 1 wherein:
   - the step of backflushing includes increasing the fluid pressure on the permeate side over that on the retentate side to induce fluid to flow from permeate side to the retentate side with contaminants being removed from the membrane.
3. The method of claim 1 wherein:
   - the step of backflushing includes detonating an explosive to create a relative high pressure wave which causes fluid to backflush through the membrane.
4. The method of claim 1 wherein:
   - a mechanical device is actuated to create a high pressure wave which causes fluid to backflush through the membrane.
5. The method of claim 1 wherein: fluid pressure on the permeate side of the membrane is gradually increased over the fluid pressure on the retentate side to cause fluid to backflush through the membrane.
6. The method of claim 1 further including:
   - adding a chemical to a fluid in the wellbore which contacts the membrane to at least partially release the contaminants on the membrane.
7. The method of claim 1 wherein:
   - bubbles of gas are introduced to the retentate side of the membrane to reduce fluid pressure thereon thereby causing fluid to backflush through the membrane.
8. The method of claim 1 wherein:
   - the wellbore includes a fluid tubing passing a fluid there down to introduce fluid into the wellbore at or below the location of the membrane.
9. The method of claim 8 wherein:
   - a nozzle is attached outside a production string.
10. The method of claim 8 wherein:
    - gas bubbles are created by an aerator which is in communication with the fluid tubing.
11. A method for regenerating a membrane which separates first and second fluid components from a fluid mixture in a wellbore, the method comprising the steps of:
    - positioning a membrane having a first retentate side and a second permeate side in a wellbore, the membrane being selectively permeable to more readily allow a first fluid component to pass there through than a second fluid component;
    - introducing a fluid mixture, comprising the first and second fluid components and contaminants therein, to the permeate side of the membrane with the fluid pressure on the retentate side being at a higher pressure than on the permeate side;
    - allowing the first fluid component to partially pass through the membrane and the permeate side of the membrane being enriched in the first fluid component and the retentate side becoming enriched in the second fluid component and with a contaminants from the fluid mixture forming on the retentate side of the membrane;
    - increasing the pressure on permeate side of the membrane to dislodge the contaminants from the membrane thereby regenerating the membrane.
12. A regenerative membrane system for separating fluid components and contaminants of a fluid mixture in a wellbore to produce a desired fluid component to the surface of a well, the system comprising:
    - a wellbore which receives a fluid mixture from a subterranean formation, the fluid mixture including a first fluid component and a second fluid component;
    - a membrane separator positioned within the wellbore to receive the fluid mixture; the membrane separator including a membrane having a first retentate side and a second permeate side and the membrane being selectively permeable to more readily allow the first fluid component to pass there through than the second fluid component;
    - a tubing located within the wellbore and in fluid communication with one of the retentate side and the permeate side of the membrane and in fluid communication with the surface of the well;
    - a casing located within the wellbore and in fluid communication with the other of the retentate side and permeate side of the membrane;
    - at least one of the casing and the tubing being in fluid communication with the surface of the well to deliver one of the first and the second fluid components to the surface of the well;
    - a pressure actuation device which may be actuated to increase the fluid pressure on the permeate side of the membrane to be greater than the retentate side of the membrane;
    - wherein under normal operating conditions the fluid mixture may be introduced to the retentate side with the first fluid component becoming enriched in one of the tubing and the casing and the permeate side being enriched in the second fluid component and the other of the tubing and the casing with contaminants being formed on the permeate side of the membrane; and
    - wherein the pressure actuation device may be actuated to increase the fluid pressure on the permeate side to be greater than on the retentate side such that the contaminants are not at least partially dislodged from the membrane thereby regenerating the membrane.