Receive a production fluid

Add salt to the production fluid

Separate the production fluid to produce an oil product and a water product

Fig. 1

Abstract: A method is disclosed for enhancing the separation of oil-water micellar emulsion, such as those found in production fluid. Specifically, an embodiment of the invention is separating oil and water phases in recovered production fluid by adding an ionic salt such as sodium chloride, calcium chloride, sodium carbonate, sodium bicarbonate, and/or a high-molecular weight alcohol, such as 2-ethyl hexanol or decanol, to the production fluid. The production fluid may include fluids produced from an enhanced oil recovery method.
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A METHOD OF BREAKING OIL-WATER MICELLAR EMULSIONS

TECHNICAL FIELD

The present disclosure generally relates to a method for separating production fluids into oil and water phases. In particular cases, the present disclosure concerns a method of using a chemical compound, such as an ionic salt (e.g., sodium chloride, calcium chloride, sodium carbonate, sodium bicarbonate) and/or a high-molecular weight alcohol (e.g., 2-ethyl hexanol, decanol), to separate the tight micellar oil-water emulsions in produced fluids, such as those produced from chemically enhanced oil recovery methods.

BACKGROUND

Reservoir systems, such as petroleum reservoirs, typically contain fluids such as water and a mixture of hydrocarbons such as oil and gas. To produce the hydrocarbons from the reservoir, different mechanisms can be utilized such as primary, secondary or tertiary recovery processes.

In a primary recovery process, hydrocarbons are displaced from a reservoir due to the high natural differential pressure between the reservoir and the bottomhole pressure within a wellbore. The reservoir’s energy and natural forces drive the hydrocarbons contained in the reservoir into the production well and up to the surface. Artificial lift systems, such as sucker rod pumps, electrical submersible pumps or gas-lift systems, are often implemented in the primary production stage to reduce the bottomhole pressure within the well. Such systems increase the differential pressure between the reservoir and the wellbore intake; thus, increasing hydrocarbon production. However, even with use of such artificial lift systems only a small fraction of the original-oil-in-place (OOIP) is typically recovered using primary recovery processes as the reservoir pressure, and the differential pressure between the reservoir and the wellbore intake declines overtime due to production. For example, typically only about 10-20% of the OOIP can be produced before primary recovery reaches its limit, either when the reservoir pressure is so low that the production rates are not economical, or when the proportions of gas or water in the production stream are too high.

In order to increase the production life of the reservoir, secondary or tertiary recovery processes can be used. Secondary recovery processes include water or gas well injection, while tertiary methods are based on injecting additional chemical compounds into the well. Typically in these processes, fluids are injected into the reservoir to maintain reservoir
pressure and drive the hydrocarbons to producing wells. An additional 10-50% of OOIP can be produced in addition to that produced during primary recovery. While secondary and tertiary methods of oil recovery can further enhance oil production from a reservoir, care must be taken in choosing the right processes and injection fluid for each reservoir, as some methods may cause formation damage or plugging.

A well-known tertiary recovery process is surfactant-polymer (SP) flooding. Polymers are used to increase the viscosity of a fluid, thereby leading to a reduced mobility ratio and to improved sweep efficiency. The most commonly used polymer for surfactant-polymer flooding is polyacrylamide (PAM) in its anionic form, hydrolyzed polyacrylamide (HPAM). Surfactants are used to lower the interfacial properties of the reservoir, thereby reducing capillary forces and increasing the efficiency of the displacement of oil. A wide variety of surfactants exist, but the most widely used are petroleum sulfonates. The compositions of chemicals used in enhanced oil recovery (EOR) processes may vary depending on the type, environment, and composition of the reservoir formation.

In the enhanced oil recovery process, the addition of surfactants, polymers, co-solvents and electrolytes improves oil recovery significantly. However, since surfactants can produce tight micellar oil-water micro-emulsions and these emulsions are further stabilized with polymer, it is difficult to separate EOR produced fluids into oil and water phases. Traditional demulsifying chemicals, generally provided from specialty chemical companies, do not effectively break such micro-emulsions unless they are used in very high concentrations; 1000 to 2000 ppm, for example, compared with the normal concentrations of 25-100 ppm in non-EOR separation applications.

**SUMMARY**

Aspects of the invention include a method of separating fluids produced from chemically enhanced oil recovery methods. A general embodiment of the disclosure is a method of separating fluids produced from a chemical enhanced oil recovery flooding process, comprising: receiving a production fluid from a chemical enhanced oil recovery flooding processes comprising an oil-water micellar emulsion, b) adding a chemical compound to the production fluid, the chemical compound being selected from the group consisting of an ionic inorganic salt, a C₄₋C₁₀ alcohol, or a combination thereof, and c) separating the production fluid to produce an oil product and a water product. In embodiments of the disclosure, the oil product has a basic sediment and water content of less than 1%. The water product may have an oil content of less than 1000 ppm, less than 500
ppm, or less than 300 ppm. Additionally, embodiments of the disclosure further include mixing the production fluid and the one or more chemical compounds prior to separating the production fluid. An additional demulsifying agent may also be added to the production fluid. Steps a-c may be performed off-shore or on-shore. In embodiments of the invention, the chemical compound is a solid or is in solution. The method may further comprise heating the production fluid to 100°F, at least about 125°F, at least about 150°F, at least about 175°F, at least about 200°F, at least about 225°F, or at least about 250°F, or at least 275°F. The added chemical compound may comprise at least about 0.25%, 0.5%, about 1.0%, about 1.5%, about 2.0%, at least about 3.0%, at least about 4.0%, or at least about 5.0% by weight of the production fluid. The production fluid may be processed to remove a gas product. In embodiments of the disclosure, the production fluid further comprises at least one of a surfactant and a polymer.

In embodiments of the disclosure, the chemical compound is an ionic inorganic salt. The ionic inorganic salt may be sodium chloride, calcium chloride, sodium carbonate, sodium bicarbonate, or a mixture thereof. The chemical compound may be sodium chloride provided in the form of seawater or waste brine. In embodiments of the disclosure, the waste brine is water brine from water treatment, waste brine from a boiler blow down, or waste brine from a water softener. In some embodiments, the seawater comprises at least 0.5%, at least 0.75%, at least 1.0%, at least 1.25%, at least 1.5%, at least 1.75%, at least 2.0%, at least 2.25%, at least 2.5%, at least 2.75%, at least 3.0%, or at least 3.5% sodium chloride. In embodiments of the disclosure, the chemical compound is a C_4^- Cio alcohol. The C_4^- Cio alcohol may be 2-ethyl hexane, decanol, or a mixture thereof.

In specific embodiments of the disclosure, the production fluid is separated in a wash tank. The production fluid may reside in the wash tank for at least 20 minutes, at least 30 minutes, at least 1 hour, at least 2 hours, at least 3 hours, at least 4 hours, at least 5 hours, at least 6 hours, at least 7 hours, or at least 8 hours. In other embodiments of the disclosure, the production fluid is separated in a pressure vessel.

Another general embodiment of the disclosure is a method of separating an oil-water micellar emulsion, the method comprising: a) receiving a production fluid comprising an oil-water micellar emulsion, b) adding waste brine or sea water to the production fluid, and c) separating the production fluid to produce an oil product and a water product. The waste brine may be waste brine from a water treatment process, from a boiler blow down, from a water softening process, or combinations thereof.
The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

- Fig. 1 is a flow diagram of an embodiment of the invention;
- Fig. 2 is an example of a tank based separation system;
- Fig. 3 illustrates a functioning free water knockout tank; and
- Fig. 4 illustrates a functioning wash tank;
- Fig. 5 is an example of a pressure vessel based separation system.

**DETAILED DESCRIPTION**

Aspects of the present invention describe a method for enhancing the separation of oil and water phases from produced fluids. Specifically, an embodiment of the invention is separating an oil-water micellar emulsion into separate or distinct oil and water phases. The oil-water micellar emulsion may be in production fluid recovered from an enhanced oil recovery processes. An embodiment of the method includes adding a chemical compound, such as an ionic salt and/or a high-molecular weight alcohol, to the production fluid. Examples of ionic salts include, but are not limited to, inorganic ionic salts such as sodium chloride, calcium chloride, sodium carbonate, and sodium bicarbonate. The addition of the ionic salt may be in the form of seawater. High-molecular weight alcohols include C4-C10
alcohols, for example 2-ethyl hexanol and decanol. Another aspect of the disclosure is separating oil and water phases in recovered production fluid by adding sea water or waste brine to the recovered production fluid.

As used herein, the term "equal" refers to equal values or values within the standard of error of measuring such values. The term "substantially equal," or "about" as used herein, refers to an amount that is within 3% of the value recited.

As used herein, "a" or "an" means "at least one" or "one or more" unless otherwise indicated.

As used herein, "high-molecular weight alcohol" refers to a C4-C10 alcohol. For example, 2-ethyl hexanol and decanol are both considered high-molecular weight alcohols for the purposes of this disclosure.

"Ionic salt," as used herein, refers to a neutrally charged ionic compound that comprises a cation and an anion. "Salt" and "sodium chloride," are used interchangeably and refer to NaCl.

As used herein "production fluid" or "produced fluid" refers to fluid directly recovered from a production well, or to production fluid that has already undergone some sort of processing. For example, production fluid that has been previously processed to remove gas is still considered "production fluid" for the purposes of this disclosure.

Production fluids recovered from reservoirs contain a mixture of both hydrocarbons (gas and oil) and water. It is necessary to separate this mixture into parts. During enhanced oil recovery, the addition of surfactants and polymers to the production fluids complicates the separation process, as they produce tight micellar microemulsions. An embodiment of the disclosure is a method for breaking the microemulsions of produced liquids recovered after a Surfactant Polymer (SP) flood by adding in an additional chemical compound, such as an ionic salt or a high molecular weight alcohol. Not to be limited by theory, the salinity of produced fluids is built up with the addition of chemical compounds, such as the ionic salt and/or high molecular weight alcohol, thereby promoting the change of phase behavior of the microemulsions from Winsor type I (oil in water microemulsions) to Winsor type II (water in oil microemulsions). Such behavior change induces the partitioning of the surfactant micelles from water phase into the crude oil phase, thereby breaking the microemulsions. In additional to enhancing the separation of the oil from the water, these methods have also been found to improve the quality of the water.

The methods of the disclosure may be performed on-shore or off-shore, and may be adjusted to make the most efficient use of the location. As an example, seawater may be used
to provide sodium chloride (the chemical compound) during off-shore oil production, since
off-shore production facilities tend to have an abundance of seawater available, limited
storage space, and transportation costs to and from off-shore site are typically high. The
seawater can be processed prior to addition to the production fluids, such as through water
softening, in order to reduce any scale formation that could occur after the separation steps.
Additionally, the ionic salt or high molecular weight alcohol may be added to the production
fluid as a solid form or in a solution. For example, solid sodium chloride may be used at an
on-shore site to reduce the shipping costs associated with shipping a liquid. Solid forms of
the chemical compound, such as solid sodium chloride, calcium carbonate, and calcium bicarbonate may be used in on-shore or off-shore applications. The solid forms may be put
into solution prior to addition to the production fluid, or the solid form may be directly added
to the production fluid.

In one or more embodiments, waste brine from drilling operations, water treatment,
water softening processes, or boiler blowouts may be used as the chemical compound. This
waste brine generally contains sodium chloride, as well as magnesium chloride, strontium
chloride, and calcium chloride. For example, the waste stream from a reverse osmosis water
treatment process or a boiler blow down may be piped into the production fluid to facilitate
breaking the microemulsions. The waste brine or waste salt may be processed prior to
addition to the produced fluid.

In embodiments of the invention, the chemical compound is mixed into the
production fluid. The mixing may occur by an active process, such as stirring or vortex, or
the mixing may occur passively, such as by the addition of the chemical compound into
flowing production fluid.

The addition of the chemical compounds described throughout may also be used in
conjunction with other demulsifying chemicals, such as a polyamine or phenol-formaldehyde
resins. For example, salt may be added to the water or oil phases that have previously been
separated using a chemical demulsifying agent.

Separation equipment, such as a wash tank or a pressurized vessel, is used to separate
the gas, oil, and water phases of the production fluid. Known separation processing systems
include atmospheric tank systems, pressurized vessel systems, and combinations thereof.
Tanks are mainly used in on-shore processes, while pressurized vessels are used mainly off-
shore. An example of a tank based dehydration process is shown in Fig. 2. Production fluid
from the production well enters a gas boot, which separates gas and vapor from the water and
oil. The water and oil production fluid is then passed through a free water knockout (FWKO)
tank which removes the low lying water. The oil and remaining water are then passed to the wash tank, which further separates out water from the oil. Further illustrations of examples of a FWKO and a wash tank are found in Figs. 3 and 4, respectively. An example of a pressurized vessel separation system is illustrated in Fig. 5. The separation system of Fig. 5 comprises two stages of pressurized separators, followed by an electrostatic treater.

Additionally, as shown in Fig. 5, the oil-water mixture, such as production fluid, may be heated (e.g., using a heating element or heat exchanger) to further enhance the effect of the added chemical compound. For example, the oil-water mixture may be heated to at least about 100°F (about 37.8 degrees Celsius), at least about 125°F (about 51.7 degrees Celsius), at least about 150°F (about 65.6 degrees Celsius), at least about 175°F (about 79.4 degrees Celsius), at least about 200°F (about 93.3 degrees Celsius), at least about 225°F (about 107.2 degrees Celsius), or at least about 250°F (about 121.1 degrees Celsius), or at least 275°F (about 135 degrees Celsius). The heating element of Fig. 5 could also be used in the tank system of Fig. 2. The oil-water mixture to be separated may also stay for a period of time in the separation equipment. For example, the production fluid may have a residence time in the wash tank or pressurized vessel of at least about 20 minutes, at least about 30 minutes, at least about 1 hours, at least about 2 hours, at least about 3 hours, at least about 4 hours, at least about 5 hours, at least about 6 hours, at least about 7 hours, at least about 8 hours, at least about 9 hours, at least about 10 hours, or at least about 15 hours, or at least about 24 hours.

In embodiments, the ionic salt or high molecular weight alcohols described herein may be added to the production fluid at anytime. For example, salt may be added to the production fluid downhole, at the wellhead, at manifold, prior to passing through the gas boot, after passing through the gas boot but before passing through the free water knockout tank, and after passing through the free water knockout tank but before passing through the wash tank, or in the recycled fluids. Additionally, the salt may be added directly to the downhole location, wellhead, manifold, gas boot, directly to the free water knockout tank, or directly to the wash tank. Salt may also be added multiple times to the process at different points. In other embodiments of the invention, the ionic salts and high molecular weight alcohols described here, salt for example, may be added prior to each separation step in a pressurized separation process, or may be added directly to each of the pressure vessels. Further, the ionic salt or high molecular weight alcohol may be added to the water or oil phases that have been previously separated using a demulsifying agent or separation
technique. For example, the chemical compounds herein could be added to the water phase recovered from the separation of an emulsion using a known demulsifying agent.

One example of a method of the current disclosure is found in Fig. 1. Production fluid is received from a production well, for example. A chemical compound, such as salt as shown, is added to the production fluid. The production fluid is then separated to produce an oil product and a water product. The oil product may have less than 1% by volume basic sediment and water (BS&W).

**Crude Dehydration**

The acceptable shipping oil quality is less than 1% by volume BS&W. Examples of produced crude from surfactant-polymer flooding may only reach approximately 15-40% water-cut after settling for 6 hours at a producing temperature of about 185°F (about 85 degrees Celsius). However, the addition of a inorganic ionic salt such as sodium chloride, calcium chloride, sodium carbonate, sodium bicarbonate, or a high-molecular weight alcohol is able to dehydrate the crude to meet the shipping oil quality of < 1% BS&W. Examples 1-7 illustrate that crude dehydration using the chemical compounds described here can achieve < 1% BS&W and also show that the addition of such chemical compounds compete positively with commercially sold chemical demulsifying agents. Examples of commercially available demulsifying agents are amphoteric acrylic acid copolymers, branched polyoxyalkylene copolyesters, and vinyl phenol polymer.

1. **Crude Dehydration using Salt**

An embodiment of the present disclosure is the addition of sodium chloride to production fluids recovered from enhanced oil recovery processes. Conventionally, sodium chloride has been removed from the production fluid, not added. Sodium chloride has been traditionally held to be a detriment to the process of oil recovery, as salt is well known to cause corrosion issues in refining and shipping processes. As will be described, the addition of sodium chloride not only reduces the BS&W of the oil phase, but it can also increase the quality of the water phase. For example, Example 1 shows an oil-in-water content of 214 ppm at 1.0% salt content.

2. **Crude Dehydration using other chemical compounds**

In some embodiments, chemical compounds other than sodium chloride may be used for crude oil and water treatment. For example, the chemical compounds includes other ionic salts such as calcium chloride, sodium bicarbonate, and sodium carbonate. Additionally, the chemical compounds include high molecular weight alcohols such as 2-Ethyl Hexanol, and Decanol. Examples 2 and 3 relate to the testing of these specific compounds.
It was found that the addition of inorganic compounds, such as salt, calcium chloride, sodium carbonate, or sodium bicarbonate, breaks the micellar emulsions found in enhanced oil recovery methods, and produces an oil phase with reasonable BS&W and oil content in water. The control (without any salt or the disclosed chemical compounds) had very high BS&W in the crude oil and high oil content in water. Similarly, the addition of organic compounds, such as 2-ethyl hexanol or decanol, broke the micellar emulsions, and produced oil with reasonable BS&W and oil content in water.

**EXAMPLES**

The following examples are included to demonstrate specific embodiments of the disclosure. It should be appreciated by those of skill in the art that the techniques disclosed in the examples that follow represent techniques discovered by the inventors to function well in the practice of the invention, and thus, can be considered to constitute modes for its practice. However, those skilled in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

**EXAMPLE 1**

**Use of Sodium Chloride**

A microemulsion was made by mixing a light crude oil with equal amount of synthetic water solution containing 0.5% (by weight) of sulfonates surfactants and solvent such as ethylene glycol butyl ether (EGBE), 0.1% of polyacrylamide polymer, and 0.5% sodium carbonate. The amount of these chemicals simulates the expected breakthrough (production) fluids from a surfactant-polymer flood. The microemulsion was made by simulating downhole electric pump production in the oilfields.

Laboratory tests were conducted at the temperature of about 185°F (about 85 degrees Celsius) with 35 API crude (to simulate an example production temperature). The following testing results demonstrate that these tight micellar oil-water emulsions were broken into an oil phase and a relatively low oil-in-water phase.

The testing procedure is summarized as follows:

1. A reagent grade salt (sodium chloride) was dissolved into deionized water to make a 10% (by weight) brine solution.
2. An ASP solution was prepared which contained 0.5% (by weight) of surfactants, 0.1% polymer, and 0.5% sodium carbonate, simulating the produced fluid from the ASP flooding.

3. Synthetic water was prepared according to the chemical composition of the produced water.

4. 250 ml (15.26 cubic inches) of the ASP solution and 250 ml (15.26 cubic inches) of the synthetic water were measured in a 1000 ml (61.02 cubic inches) beaker, and heated in an oven to reach 185°F (85 degrees Celsius) (simulating a produced fluid temperature).

5. The above fluid was mixed at a shearing rate that simulates downhole electric submersible pump shearing action during production and produced a tight micellar oil-water emulsion.

6. Steps 4 and 5 were repeated with 1,000 ml (61.0 cubic inches) total oil-water emulsions for the following tests.

7. 100 ml (6.1 cubic inches) each of the above emulsion were put into bottles.

8. The salt solution (step 1) was added into the bottles to make the following concentrations: 0 (no salt), 0.1, 0.2, 0.25, 0.35, 0.5, 0.75, 1.0 and 2.0% by weight based upon the total fluid.

9. The bottles were shaken and placed into a constant temperature water bath at 185 °F (85 degrees Celsius).

10. After 2 hours, 20 ml (1.22 cubic inches) of water was removed from each bottle, and the oil content in this water was measured.

11. After 4 hours, all free-water was removed from the bottom of each bottle.

12. The percent BS&W of the oil of each bottle was measured.

Results for the above tests are shown below. As the salt concentration increased the water content in oil and oil content in water decreased. This trend showed that the addition of salt improves both oil (oil dehydration) and water qualities.

<table>
<thead>
<tr>
<th>Salt Content %</th>
<th>0.0</th>
<th>0.10</th>
<th>0.20</th>
<th>0.25</th>
<th>0.35</th>
<th>0.50</th>
<th>0.75</th>
<th>1.0</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content in Oil, %</td>
<td>16.0</td>
<td>6.0</td>
<td>3.2</td>
<td>6.4</td>
<td>4.0</td>
<td>4.8</td>
<td>2.4</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Oil Content in Water, ppm</td>
<td>7010</td>
<td>3537</td>
<td>496</td>
<td>389</td>
<td>375</td>
<td>299</td>
<td>677</td>
<td>214</td>
<td>130</td>
</tr>
</tbody>
</table>
EXAMPLE 2

Use of Calcium Chloride, Sodium Carbonate and Sodium Bicarbonate

The same procedure as given in Example 1 was followed, but the salt was replaced with calcium chloride (Table 2), sodium carbonate (Table 3), and sodium bicarbonate (Table 4). As the chemical concentration increased, the water contents in oil and oil content in water generally decreased. This trend shows that the addition of these chemical compounds improve both oil and water qualities.

TABLE 2

<table>
<thead>
<tr>
<th>Calcium Chloride, %</th>
<th>0.0</th>
<th>0.10</th>
<th>0.20</th>
<th>0.25</th>
<th>0.35</th>
<th>0.5</th>
<th>0.75</th>
<th>1.0</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content in Oil, %</td>
<td>30.0</td>
<td>3.2</td>
<td>3.2</td>
<td>3.0</td>
<td>3.1</td>
<td>2.8</td>
<td>2.4</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Oil Content in Water, ppm</td>
<td>6210</td>
<td>5981</td>
<td>888</td>
<td>427</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*No test was conducted because the quality of water appeared equal or better than oil content of 427 ppm as determined at the 0.25% calcium chloride concentration.

TABLE 3

<table>
<thead>
<tr>
<th>Sodium Carbonate, %</th>
<th>0.0</th>
<th>0.10</th>
<th>0.20</th>
<th>0.25</th>
<th>0.35</th>
<th>0.5</th>
<th>0.75</th>
<th>1.0</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content in Oil, %</td>
<td>15.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.6</td>
<td>5.2</td>
<td>4.2</td>
<td>3.5</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Oil Content in Water, ppm</td>
<td>3237</td>
<td>5015</td>
<td>302</td>
<td>103</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

** No test was conducted because the quality of water appeared equal or better than oil content of 103 ppm as determined at the 0.25% sodium carbonate concentration.
No test was conducted because the quality of water appeared equal or better than oil content of 86 ppm as determined at the 0.25% sodium bicarbonate concentration.

**EXAMPLE 3**

Use of high-molecular weight alcohols

The same procedure as given in Example 1 was followed, but the salt was replaced with 2-ethyl hexane (Table 5) and decanol (Table 6). As the chemical concentration increased the water content in oil and oil content in water generally decreased. This trend shows that the addition of these chemical compounds improve both oil and water qualities.
EXAMPLE 4

Large scale pilot testing using sodium chloride as a demulsifier

Example 1 previously illustrated that sodium chloride can be used as a demulsifying chemical for treating produced emulsions. A larger scale pilot test was conducted with a 75% water-cut crude emulsion at a continuous flow rate of 9.6-12 gpm in a 6-inch diameter and 20 feet high steel column. The crude emulsion entered the column at the 3 feet level, and exited at the 16 feet level. A 20% brine solution was used and injected at a concentration of 3 to 4% by weight into the crude emulsion before entering the column continuously at 185°F (85 degrees Celsius). At the 6th hour, oil samples were collected at various levels of the 16 foot (4.88 meters) column. Results of the BS&W measurements at 6 hours residence time are shown as follows:

<table>
<thead>
<tr>
<th>Level</th>
<th>BS&amp;W</th>
</tr>
</thead>
<tbody>
<tr>
<td>14'</td>
<td>1.6%</td>
</tr>
<tr>
<td>12'</td>
<td>1.6%</td>
</tr>
<tr>
<td>10'</td>
<td>1.6%</td>
</tr>
<tr>
<td>8'</td>
<td>2.0%</td>
</tr>
<tr>
<td>6'</td>
<td>3.2%</td>
</tr>
<tr>
<td>4'</td>
<td>Water Phase</td>
</tr>
</tbody>
</table>

After 6 hours residence time in the column, oil was allowed to flow out continuously at the level of 16' and %BS&W were measured for the produced oil.

Results are as follows:

<table>
<thead>
<tr>
<th>Residence Time</th>
<th>BS&amp;W</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 hours 30 minutes</td>
<td>1.6%</td>
</tr>
<tr>
<td>7 hours</td>
<td>1.6%</td>
</tr>
<tr>
<td>7 hours 30 minutes</td>
<td>1.6%</td>
</tr>
<tr>
<td>8 hours</td>
<td>1.2%</td>
</tr>
<tr>
<td>8 hours 20 minutes</td>
<td>0.8%</td>
</tr>
</tbody>
</table>
The above results indicate that with 8 hours 20 minutes residence time in the column (simulating wash tank), the BS&W of oil would meet the pipeline standard of 1.0%. The separated water had an oil content of 378 ppm.

EXAMPLE 5

Water treatment

Salt treatment was conducted in laboratory simulated tests for water separated from oil in a wash tank using commercially available demulsifying chemicals, Demulsifiers A, B, C, D, E, F and G. This water had relatively high oil content due to the inefficiency of the chemicals used during the crude dehydration treatment. When this water was tested with salt addition, it showed that, in most cases, it would require approximately 0.50-0.75% by weight salt to reduce the oil content to a level below 300 ppm in the production fluid recovered from the same production run at two different time periods.

Table 7: First production period

<table>
<thead>
<tr>
<th>Salt Concentration</th>
<th>Demulsifier A</th>
<th>Demulsifier B</th>
<th>Demulsifier C</th>
<th>Demulsifier D</th>
<th>Demulsifier E</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75%</td>
<td>120</td>
<td>290</td>
<td>250</td>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>0.50%</td>
<td>210</td>
<td>680</td>
<td>680</td>
<td>194, 1060</td>
<td>1200</td>
</tr>
<tr>
<td>0.25%</td>
<td>2820</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Second time production period

<table>
<thead>
<tr>
<th>Chemical Concentration ppm</th>
<th>Demulsifier A</th>
<th>Demulsifier F</th>
<th>Demulsifier G</th>
<th>Demulsifier C</th>
<th>Control</th>
</tr>
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<tbody>
<tr>
<td>Salt 0.75%</td>
<td>100</td>
<td>80</td>
<td>466</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Salt 0.50%</td>
<td>60</td>
<td>140</td>
<td>480</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Salt 0.00%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>390</td>
</tr>
</tbody>
</table>
EXAMPLE 6

Additional testing with salt

Formulation Changes of Surfactants and Solvent

With formulation change of surfactant, the performance of salt was still consistent whereas some commercially available demulsifying agents could not tolerate the formula changes. Even doubling the surfactant concentration had minimal impact on salt performance, but it did impact performance of commercial demulsifying compounds. Additionally, changing the surfactant solvent did not affect the salt performance.

Use of Salt Solution or Solid Salt

Laboratory tests were conducted using a salt solution and solid salt, which showed that both functioned well.

Temperature Effect

When the operating temperature was increased from 185°F to 200°F (from 85.0 to 93.3 degrees Celsius), the performance of salt was slightly better, however, both functioned well.

EXAMPLE 7

Production fluid with salt

Laboratory tests were conducted using salt to break produced fluid emulsions. 100mL of oil from a production line off plot was used as the starting sample. The addition of salt was compared to using three emulsion breaking chemicals that were purchased from an outside vendor. The amount of each chemical or salt added is summarized in Table 9 below
As shown in below, the samples which were treated with just salt (sample numbers 8 and 9) resulted in the lowest BS&W in both the top cut and the mix cut (Table 10) and the highest percent of water recovery (Table 11).
### Table 10: Oil water interface quality and top and mix cut BS&W.

<table>
<thead>
<tr>
<th>No.</th>
<th>Oil-Water Interface Quality</th>
<th>Top Cut</th>
<th>Mix Cut</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>W/O F 46</td>
<td>BS&amp;W %</td>
</tr>
<tr>
<td>1</td>
<td>TR</td>
<td>6.00</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>TR</td>
<td>4.60</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>TR</td>
<td>4.00</td>
<td>0.05</td>
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<tr>
<td>4</td>
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<td>5</td>
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<td>6.00</td>
<td>0.05</td>
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<tr>
<td>6</td>
<td>W</td>
<td>5.60</td>
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</tr>
<tr>
<td>7</td>
<td>W</td>
<td>5.20</td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>TR</td>
<td>0.40</td>
<td>0.05</td>
</tr>
<tr>
<td>9</td>
<td>TR</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>10</td>
<td>W</td>
<td>5.20</td>
<td>0.05</td>
</tr>
<tr>
<td>11</td>
<td>LR</td>
<td>2.80</td>
<td>0.05</td>
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The abbreviations are as follows: TR= tight rag; W = webby; and LR = loose rag.

### Table 11: Water quality and separation

<table>
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<tr>
<th>No.</th>
<th>0-1 hours</th>
<th>2 hours</th>
<th>3 hours</th>
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<tr>
<td></td>
<td>% separation</td>
<td>Water quality</td>
<td>% separation</td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>MT</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>4.0</td>
<td>ST</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>ST</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>ST</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1.5</td>
<td>ST</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>MT</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1.0</td>
<td>MT</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>18.0</td>
<td>ST</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>22.0</td>
<td>C</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>1.5</td>
<td>ST</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>5.0</td>
<td>C</td>
<td>5</td>
</tr>
</tbody>
</table>
The abbreviations are as follows: C = clear; ST = slightly turbid; MT = moderately turbid; VT = very turbid; and ND = not detectable. The percent water separation is listed after the amount of hours in each column had passed.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present disclosure is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.
WHAT IS CLAIMED IS:

1. A method of separating fluids produced from a chemical enhanced oil recovery flooding process, comprising:
   a) receiving a production fluid from a chemical enhanced oil recovery flooding processes comprising an oil-water micellar emulsion;
   b) adding a chemical compound to the production fluid, the chemical compound being selected from the group consisting of an ionic inorganic salt and a C₄₋C₁₀ alcohol; and
   c) separating the production fluid to produce an oil product and a water product.

2. The method of claim 1, wherein the oil product has a basic sediment and water content of less than 1%.

3. The method of claim 1, wherein the water product has an oil content of less than 1000 ppm, less than 500 ppm, or less than 300 ppm.

4. The method of claim 1, wherein the ionic organic salt is sodium chloride, calcium chloride, sodium carbonate, sodium bicarbonate, or a mixture thereof.

5. The method of claim 1, wherein the C₄₋C₁₀ alcohol is 2-ethyl hexane, decanol, or a mixture thereof.

6. The method of claim 1, further comprising mixing the production fluid and the one or more chemical compounds prior to separating the production fluid.

7. The method of claim 1, further comprising adding a demulsifying agent to the production fluid.

8. The method of claim 1, wherein the production fluid is separated in a wash tank.

9. The method of claim 1, wherein the production fluid is separated in a pressure vessel.

10. The method of claim 1, wherein the production fluid is separated in a pressure vessel.
11. The method of claim 1, further comprising heating the production fluid to 100°F, at least about 125°F, at least about 150°F, at least about 175°F, at least about 200°F, at least about 225°F, or at least about 250°F, or at least 275°F.

12. The method of claim 1, wherein the added chemical compound comprises at least about 0.25%, 0.5%, about 1.0%, about 1.5%, or about 2.0% by weight of the production fluid.

13. The method of claim 1, wherein steps a-c are performed off-shore.

14. The method of claim 1, wherein the chemical compound is in solution.

15. The method of claim 1, wherein the chemical compound is sodium chloride provided in the form of seawater.

16. The method of claim 15, wherein the seawater comprises at least 0.5%, at least 0.75%, at least 1.0%, at least 1.25%, at least 1.5%, at least 1.75%, at least 2.0%, at least 2.25%, at least 2.5%, at least 2.75%, at least 3.0%, or at least 3.5% sodium chloride.

17. The method of claim 1, wherein the chemical compound is sodium chloride provided in the form of waste brine.

18. The method of claim 17, wherein the waste brine is waste brine from water treatment, waste brine from a boiler blow down, or waste brine from a water softener.

19. The method of claim 1, further comprising processing the production fluid to remove a gas product.

20. The method of claim 1, wherein the production fluid further comprises at least one of a surfactant and a polymer.
Receive a production fluid

Add salt to the production fluid

Separate the production fluid to produce an oil product and a water product

Fig. 1
A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D17/04 C10G33/04

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US 4 216 079 A (NEWCOMBE JACK [US]) 5 August 1980 (1980-08-05) claims 1,6; examples 4-12</td>
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<td>US 4 226 702 A (VINATIERI JAMES [E]) 7 October 1980 (1980-10-07) claims 1,5; example 1</td>
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See patent family annex.

* Special categories of cited documents:

- **A** document defining the general state of the art which is not considered to be of particular relevance
- **E** earlier application or patent but published on or after the international filing date
- **L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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- **&** document member of the same patent family

Date of the actual completion of the international search 11 June 2014

Date of mailing of the international search report 01/07/2014

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Authorized officer Gilliquet, J
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