

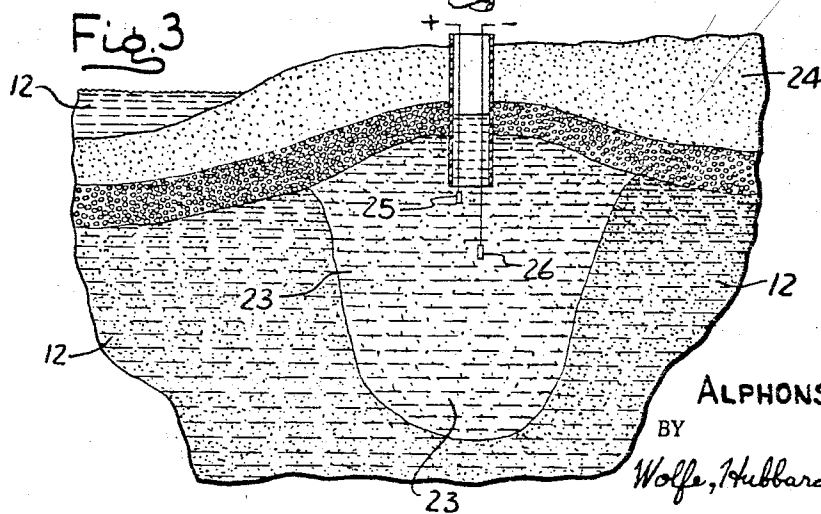
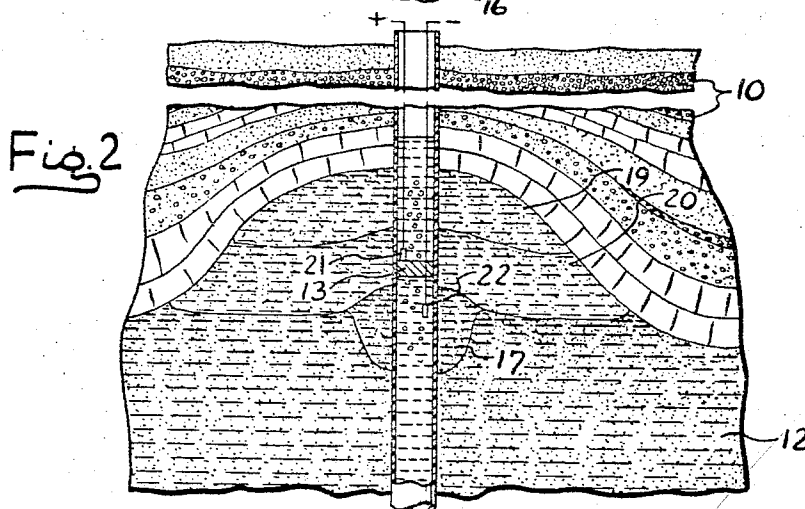
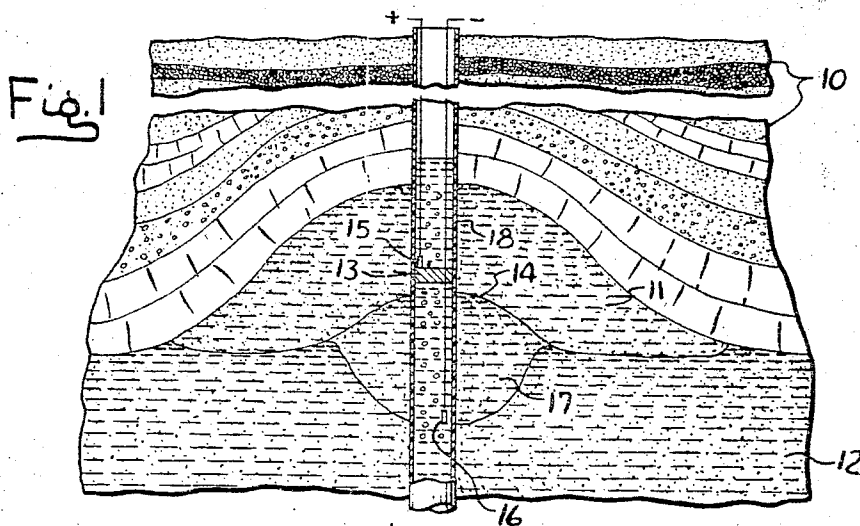
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METHOD OF CONTROLLING FLUID FLOW

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METHOD OF CONTROLLING FLUID FLOW
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This invention is directed to a method of preventing salt water breakthrough in wells.

Although this invention may be applied to wells for fresh water in coastal regions and islands, it finds particular application in natural oil wells where the oil reservoir is in contact with a salt water table under pressure.

In the operation of a natural oil well, the pressure of the salt water table in contact with the oil-containing reservoir is employed to force the oil upward through the sand of the reservoir to the surface. According to standard procedures, the oil well is plugged or blocked off within the oil-producing sand. In the absence of such a plug, the salt water would have a direct path to the surface and could readily break through the oil reservoir, resulting in a salt water or brine producing well. Although the provision of such a plug alleviates the situation to some extent by blocking the direct path between the salt water and the surface, the danger of salt water breakthrough is not completely avoided. The danger of salt water breakthrough still exists where the pressure of the salt water table on the oil-containing reservoir is at a high level. This danger also exists where a high production rate is employed as such a rate will result in a corresponding reduction in the pressure which opposes the salt water table pressure. Furthermore, if the crude is a highly viscous oil, the possibility of salt water breakthrough is increased and may even occur under very low production rates.

A further difficulty is encountered where it is desired to obtain the oil contained in the oil-water transition zone of a natural oil well reservoir. As the transition zone contains both oil and salt water, the difference in the specific gravity of the transition zone and the salt water table is less than that between the oil zone and the salt water table thereby not only increasing the possibility of salt water breakthrough but also presenting the problem of entrainment of salt water from the salt water table.

Similar conditions exist in fresh water wells which are located in coastal regions and on islands where the fresh ground water is in contact with salt-containing sea water. Although the fresh water and the salt water are in contact, they stay remarkably separate with the fresh water floating upon the more dense salt-containing sea water just as oil floats upon water. Such fresh water, which is formed by collection of rainfall, forms reservoirs or lenses having a major part thereof below sea level. If the specific gravity of fresh water is taken as 1 and that of sea water as 1.025, the depth (h) below sea level to which the fresh water lens extends may be expressed according to the Herzburg formula as follows: $h=40t$, where t is the elevation of the fresh water table above sea level. As seen from this equation, the lowermost point of contact between the fresh water lens and the sea water will be elevated 40 feet for every foot of drawdown in the fresh water elevation above sea level. It will thus be seen that such a fresh water well is subject to salt water breakthrough and may produce salt water or brine if pumped at a high rate or if the salt water table is at a high pressure level.

An object of this invention is to provide a method of increasing the production rate of oil wells and fresh water wells without incurring salt water breakthrough.

A further object of this invention is to provide a method

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of obtaining a satisfactory production rate from high viscosity oil wells while preventing salt water breakthrough.

Another object of this invention is to provide a method of including the oil-water transition zone of the oil reservoir in the production from an oil well without also including salt water from the salt water table.

An additional object of this invention is to provide a novel method of achieving the above-described objectives in an oil well field having two or more wells.

Other objects of this invention will become apparent from the following description, taken in connection with the accompanying drawings, wherein:

FIGURE 1 is a cross sectional view of an oil well illustrating the application of this invention;

FIG. 2 is a cross sectional view of an oil well illustrating the recovery of the oil-water transition zone as well as the oil zone of the oil reservoir by means of this invention; and

FIG. 3 is a cross sectional view illustrating the application of this invention to a fresh water well in a coastal area.

Briefly, the above-described salt water breakthrough is prevented according to the method of this invention by having a control fluid lens, preferably fresh water, in contact with the salt water table, the fluid having an electrical conductivity and a specific gravity less than that of salt water, inserting a positive electrode to a point above the salt water table and inserting a negative electrode a substantial distance below the positive electrode with the electrodes being connected to a voltage source.

With reference to FIG. 1, a producing natural oil well is illustrated as having been driven through low permeability rock 10, the oil reservoir 11 and thence into the salt water table 12. A plug 13 is inserted to block the well off within the oil-sand reservoir 11. As the well is producing, the resulting pressure reduction allows the lowermost portion of the oil reservoir 11 to cone up as illustrated at 14. As the plug blocks the direct path between the salt water table and the surface, the pressure of the salt water drive forces the oil through the sand and to the surface.

An anode or positive electrode 15 is inserted into the well to a point above the salt water table within the oil-containing reservoir 11. For the sake of convenience, the anode terminates at the top of the plug 13. A cathode or negative electrode 16 is also inserted within the well to a point a substantial distance below the positive electrode 15. It will be understood that the electrodes are connected to any suitable source of voltage. A control fluid 17 is provided around the negative electrode, as by pumping the same down through the well. The well may have a casing 18, which in the embodiment illustrated in FIGURE 1 is composed of a non-conductive material, such as plastic, to avoid the possibility of a short circuit. As an alternative, the casing may be dispensed with entirely or a metal casing may be employed provided the portion of the casing extending from above the positive electrode to below the negative electrode is removed. It will be understood that if a casing is employed, it will be perforated both above and below the plug 13. Although water is the preferred control fluid, any relatively inert fluid may be employed provided the fluid has an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water. The control fluid 17 assumes the shape of a lens between the oil-containing reservoir 11 and the salt water table 12. It is preferred to have the cathode 16 extend a distance below the anode at least equal to the vertical thickness or height of the control fluid lens 17. With such an arrangement, the fluid of the lens 17 as well

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as the salt water from the table 12 will be prevented from breaking through the oil reservoir.

The oil well in FIG. 1 is depicted as being in normal operation with the salt water forcing the oil into the well without salt water breakthrough. In other words, the three layers of oil, control fluid and salt water are in their normal position as distinct layers. As the exposed part of the anode 15 is in the oil-containing reservoir 11 and as oil is an insulator, there is no conduction of electric current or fluid flow between the two electrodes. However, when the possibility of a salt water breakthrough becomes imminent due to one of the aforementioned causes, both the control fluid and the salt water table will rise or cone up in the area of the well. As soon as the fresh water touches the anode, an electric current will commence to flow from the anode through the fresh water to the cathode. In terms of electron flow, the flow is from the negative electrode to the positive electrode. As an electric current will take the path of least resistance, a large percent of the current will pass through the fresh water to the lower resistance salt water to the cathode. Also, as the electrical resistance of salt water is relatively low and the electrical resistance of fresh water is relatively high, most of the voltage drop will be across the fresh water portion of the electrical circuit. The resulting voltage gradient produces an electrostatic pressure in the fresh water lens in direct opposition to the upward movement of the salt water. An electroosmotic flow of control fluid also occurs in a direction away from the anode towards the cathode. This electrokinetic fluid flow moves against the pressure of the salt water drive to prevent the threatened salt water breakthrough. In essence, the method of this invention provides a self-sealing mechanism for preventing salt water breakthrough.

FIG. 2 represents an illustration of a natural oil well operating to recover both the oil zone 19 and the oil-water transition zone 20 of the reservoir. The plug 13 is located so as to block off the well in the oil-water transition zone. The anode 21 is inserted in the well to a point within this transition zone. The cathode 22 is inserted into the well to a point a substantial distance below the anode. However, with this arrangement, it is not necessary to have the cathode extend a distance below the anode at least equal to the height or vertical thickness of the control fluid lens 17, although in some cases it may be desirable. This arrangement is permissible as the self-sealing fluid flow between electrodes will function when the negative electrode is covered with the control fluid. The negative electrode 22 need not even extend into the control fluid lens during normal operation. As soon as the control fluid lens covers the negative electrode, an electric current is turned on and will pass from the anode 21 through the salt water in the oil-water transition zone 20 and thence through the control fluid 17 to the cathode 22. As the electrical resistance of the oil-water in the transition zone is lower than the resistance of the control fluid, most of the voltage drop will be across the control fluid. The resulting voltage gradient functions in a manner similar to that described in FIG. 1 to develop an electrostatic pressure in the control fluid lens and an electroosmotic fluid flow from the anode towards the cathode to prevent any threatened salt water breakthrough. It should be noted that if this electrokinetic pressure is not sufficient to counteract the threatened salt water breakthrough, the anode will become immersed in the control fluid and as soon as the salt water in the salt water table contacts the cathode, an application of electrokinetic pressure identical to that described in FIG. 1 will result. As the difference between the electrical resistances in the fresh water and salt water circuit is greater than the difference in electrical resistance of the oil-water and fresh water circuit, the former will exert a greater electrokinetic pressure and more effectively prevent salt water breakthrough.

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In the systems of both FIG. 1 and FIG. 2, the electrostatic pressure always develops in the control fluid where the voltage drop is the greatest, the control fluid in turn always being adjacent to and in direct opposition to the salt water drive. Likewise, the electrokinetic fluid flow is downward from the anode to the cathode in both systems.

Although the above-described method of preventing salt water breakthrough may be applied to each individual well in a field, it is often desirable to place the anodes in some wells and the cathodes in other wells. The control fluid should be pumped into the wells that will be the most effective in controlling the flow of oil, which are those in the area of highest salt water table pressure. The exact location of the electrodes and control fluid will depend on whether the oil field is an edge salt water drive or a bottom salt water drive. If the field is an edge salt water drive field, the anode and control fluid would be located in the outermost wells; whereas, if the field is a bottom salt water drive field, the anode and control fluid would be located in the centermost wells. Where only one electrode is inserted in a given well, that well may be provided with a metal casing; in fact, the metal casing may serve as the electrode.

FIG. 3 illustrates the application of the method of this invention to a fresh water well located in a coastal region or on an island. The salt-containing sea water is indicated at 12, while the fresh water lens formed by the natural accumulation of rainfall is indicated at 23. In this instance, the naturally occurring fresh water serves as the control-fluid. The well is drilled down through the high permeability soil 24 until the fresh water lens 23 is reached. At this point, a positive electrode 25 and a negative electrode 26 are inserted into the well with the negative electrode 26 extending a substantial distance below the positive electrode 25. As fresh water has a relatively low electrical conductivity, very little if any current passes between the electrodes during normal operation. In the event of a threatened salt water breakthrough caused by a high pumping rate or by relatively high salt water pressure, an additional electrokinetic pressure will be developed in a manner similar to that previously described as soon as the salt water makes contact with the negative electrode 26.

With a given arrangement, both the negative and positive electrodes may be in the same fluid during normal operation, e.g., the oil-salt water of the transition zone. In this event, the voltage may be reduced for economy to a level just sufficient to obtain a current indication. When a threatened salt water breakthrough commences, the control fluid would move up to cover the cathode and cause a reduction in the current indication. At this point, the voltage would be increased to a level such that the resulting electrostatic pressure and electrokinetic fluid flow would resist the threatened breakthrough.

Although a source of direct current is usually employed for wells down to about 1500 feet, it is preferred to employ a source of alternating current at high voltage for wells of greater depth. In the latter instance, the alternating current is converted to direct current at operating voltage levels at the bottom of the well by a rectifier. This avoids the necessity of using very large and heavy conductors required for long runs of direct current.

While the invention has been described in the usual environment where the natural electrical charge of the earth is positive, it is to be understood that if an earth having a natural negative charge is encountered the potential of the electrodes would be reversed for proper operation. This can readily be accomplished in the field by reversing the negative and positive electrode lead wires. Thus, the anode or positive electrode would be lower than the negative electrode, whereby the developed electrostatic pressure and the electrokinetic fluid flow, in this case from the cathode towards the anode, will act downwardly towards the salt water table.

While the preferred forms of this invention have been described herein, it will be understood that changes in the details thereof may be made without departing from the spirit of this invention, and it is intended to cover all those changes which come within the scope of the appended claims.

I claim as my invention:

1. A method of preventing salt water breakthrough in a well contacting a fluid to be produced having a control fluid lens in contact with a salt water table and where the natural electrical charge of the earth is positive, said control fluid having an electrical conductivity and a specific gravity less than that of salt water, comprising the steps of inserting a positive electrode within said well to a point below the uppermost level of the fluid to be produced and above said salt water table, and inserting a negative electrode within said well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a voltage source.

2. A method of preventing salt water breakthrough in a well contacting a fluid to be produced having a fresh water lens in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of inserting a positive electrode within said well to a point below the uppermost level of the fluid to be produced and above said salt water table and inserting a negative electrode within said well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a voltage source.

3. A method of preventing salt water breakthrough in a well contacting a fluid to be produced having a fresh water lens in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of inserting a positive electrode within said well to a point below the uppermost level of the fluid to be produced and above said salt water table, and inserting a negative electrode within said well to a point within said fresh water lens and at a substantial distance below said positive electrode, said positive and negative electrodes being connected to a source of voltage.

4. A method of preventing salt water breakthrough in fresh water wells having a fresh water lens in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of inserting an anode within a well into said lens and inserting a cathode within a well into said lens to a point a substantial distance below said anode but above said salt water table, said anode and cathode being connected to a source of voltage.

5. A method of preventing salt water breakthrough in an oil well having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting a control fluid within the well below said reservoir thereby providing a control fluid lens above said salt water table and in fluid communication with said reservoir, said fluid having an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water, inserting a positive electrode within the well into said oil-containing reservoir and inserting a negative electrode within the well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a voltage source, and producing oil from said reservoir through said well.

6. A method of preventing salt water breakthrough in an oil well having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting a control fluid within the well below said reservoir thereby providing a fresh water lens above said salt water table, and in fluid communication with said reservoir, inserting a positive electrode within the well into said oil-containing reservoir and inserting a negative elec-

trode within the well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a source of voltage.

7. A method of preventing salt water breakthrough in oil wells having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting a control fluid within a well below said reservoir thereby providing a control fluid lens above said salt water table, and in fluid communication with said reservoir, said fluid having an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water, inserting a positive electrode within a well into said oil-containing reservoir, and inserting a negative electrode within a well into said control fluid lens, said positive and negative electrodes being connected to a voltage source.

8. A method as defined in claim 7 wherein said negative electrode extends a distance below said positive electrode at least equal to the height of said control fluid lens.

9. The method of preventing salt water breakthrough in an oil well having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting fresh water within said well below said reservoir thereby providing a fresh water lens above said salt water table, and in fluid communication with said well, inserting a positive electrode within said well into said oil-containing reservoir, and inserting a negative electrode within said well into said lens, said positive and negative electrodes being connected to a voltage source and producing oil from said reservoir through said well.

10. A method as defined in claim 9 wherein the negative electrode extends a distance below said positive electrode at least equal to the height of said lens.

11. A method of preventing salt water breakthrough in an oil well having a reservoir containing an oil zone and an oil-salt water zone in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting a control fluid within the well below said reservoir thereby providing a control fluid lens between said oil-salt water zone and said salt water table, and in fluid communication with said reservoir, said fluid having an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water, inserting a positive electrode within the well into said oil-salt water zone of said reservoir, and inserting a negative electrode within the well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a voltage source.

12. A method of preventing salt water breakthrough in an oil well having a reservoir containing an oil zone and an oil-salt water zone in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting fresh water within said well below said reservoir thereby providing a fresh water lens above said salt water table and beneath said oil-salt water zone of the reservoir and in fluid communication with said reservoir, inserting a positive electrode within said well into said oil-salt water zone of the reservoir, and inserting a negative electrode within said well to a point a substantial distance below said positive electrode, said positive and negative electrodes being connected to a source of voltage.

13. A method as defined in claim 12 wherein the negative electrode terminates in the oil-salt water zone of the reservoir.

14. A method as defined in claim 12 wherein the negative electrode terminates in the fresh water lens.

15. A method of preventing salt water breakthrough in an oil well field having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps

of injecting a control fluid below said reservoir thereby providing a control fluid lens above the salt water table in the wells located in the area of highest salt water table pressure, said control fluid having an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water, inserting positive electrodes into the wells containing said control fluid lens, said positive electrodes extending into and terminating within the oil-containing reservoir, and inserting negative electrodes into the other wells, said negative electrodes extending into said salt water table, and connecting said positive and negative electrodes to a source of voltage and producing oil from said reservoir through said wells.

16. A method of preventing salt water breakthrough in an oil well field having an oil-containing reservoir in contact with a salt water table and where the natural electrical charge of the earth is positive comprising the steps of injecting fresh water below said reservoir thereby providing a fresh water lens above said salt water table in the wells located in the area of highest salt water table pressure, inserting positive electrodes into the wells containing said lens, said positive electrodes extending into and terminating within said oil-containing reservoir, and inserting negative electrodes into the other wells, said negative electrodes extending into said salt water table, and connecting said positive and negative electrodes to a voltage source.

17. A method of preventing salt water breakthrough in a well contacting a fluid to be produced driven in earth having a natural electrical charge and having a control fluid lens in contact with a salt water table and in fluid communication with said well, said control fluid having an electrical conductivity and a specific gravity less than that of salt water, comprising the steps of inserting within the well a first electrode having the same polarity as said natural charge to a point below the uppermost level of the fluid to be produced and above said salt water table, and inserting within the well a second electrode having a polarity opposite to said first electrode to a point a substantial distance below said first electrode,

said first and second electrodes being connected to a voltage source.

18. A method of preventing salt water breakthrough in a well contacting a fluid to be produced driven in earth having a natural electrical charge and having a fresh water lens in contact with a salt water table and in fluid communication with said well comprising the steps of inserting within the well a first electrode having the same polarity as said natural charge to a point below the uppermost level of the fluid to be produced and above said salt water table and inserting within the well a second electrode having a polarity opposite to said first electrode to a point a substantial distance below said first electrode, said first and second electrodes being connected to a voltage source.

19. A method of preventing salt water breakthrough in an oil well field and where the natural electrical charge of the earth is positive having an oil-containing reservoir in contact with a zone of salt water comprising the steps of injecting a control fluid between said reservoir and said salt water zone thereby providing a control fluid lens between said reservoir and said salt water zone and in fluid communication with a producing well, said control fluid having an electrical conductivity less than that of salt water and a specific gravity between that of oil and salt water, inserting a positive electrode within the producing well and below the uppermost level of said reservoir, inserting a negative electrode within another well, said negative electrode extending into said salt water zone, connecting said positive and negative electrodes to a source of voltage, and producing oil from said reservoir through said producing well.

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