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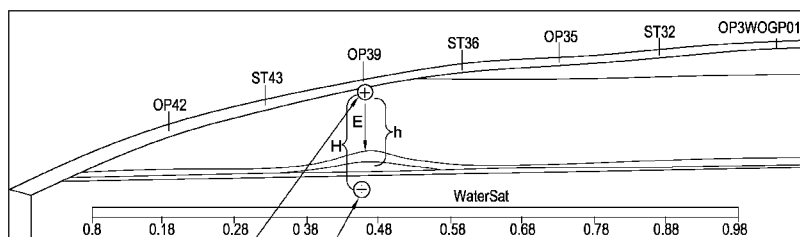


Figure 2a

(57) **Abstract:** The invention relates to a method and system for extracting oil from a reservoir using the electro-osmotic effect. The system comprises at least one pair of electrodes in the reservoir, wherein the or each pair of electrodes comprises a positive electrode (10) and a negative electrode (22) which are set a distance H apart within the reservoir and which are either side of an interface between a layer of oil and a layer of water in the reservoir. The system further comprises means for applying an electric field to the or each pair of electrodes and a controller to control the applied electric field whereby a distance h between the interface and one of the electrodes is controllable.



Oil and Water Separation in an Oil Reservoir

Technical field

- 5 The invention relates to the field of oil reservoirs and wells for extracting oil from such reservoirs.

Background

- 10 Figure 1a is a schematic illustration showing some of the features of a typical oil production well. A plurality of production wells 10 extend down through the ground from the well head 18 on the surface. The production well 10 extends into a porous reservoir or formation containing an oil layer 12 from which oil is extracted and drawn through the walls of the production well along the well to the well head. The formation
15 also typically contains layers of gas 14 and water 16. Figure 1b shows an example of the water saturation levels in the various layers. As shown, there is initially little water within the oil layer. However, over time as oil is drawn into the well, water may enter into the oil layer to replace the oil which has been extracted. Once the tip of the water cone or finger reaches the well, water will be drawn into the well with the oil.

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It would be desirable to produce oil from formations leaving the water behind. If the water content of the produced oil could be reduced (or even totally prevented), this would reduce the need for fluid processing, e.g. separation at the well head.

25 Summary of the invention

According to a first aspect of the invention, there is provided an oil extraction system for extracting oil from a reservoir; the system comprising

- 30 at least one pair of electrodes in the reservoir, wherein the or each pair of electrodes comprises a positive electrode and a negative electrode which are set a distance H apart within the reservoir and which are either side of a fluid (or oil/water) interface between a layer of oil and a layer of water in the reservoir;

means for applying an electric field to the or each pair of electrodes and

- 35 a controller to control the applied electric voltage whereby a distance h between the fluid (or oil/water) interface and one of the electrodes is controllable.

According to a second aspect of the invention, there is provided a method for controlling flow of water in a reservoir from which oil is to be extracted, the method comprising

- 5 providing at least one pair of electrodes in the reservoir, wherein the or each pair of electrodes comprises a positive electrode and a negative electrode which are set a distance H apart within the reservoir and which are either side of a fluid interface between a layer of oil and a layer of water in the reservoir;
- applying a voltage to the at least one pair of electrodes to generate an electric
- 10 field within to the reservoir and
- controlling the applied electric field to control a distance h between the fluid interface and one of the electrodes in the or each pair of electrodes.

By within the reservoir, it is meant that the electrodes may be directly in the reservoir

15 itself or within well pipes or other equipment within the reservoir or at different locations on the well construction.

The following features apply to both aspects of the invention and show how an electro-osmotic effect can be used within the oil recovery process. Water is an electrolyte but

20 oil is not. Hence, applying an electric field E within a system containing both oil and water will cause the water but not the oil to move using electro-osmotic flow. The flow can be controlled at a macro-level, in other words, throughout the entire reservoir with the rock comprising the reservoir forming a porous material between the electrodes.

25 The strength of the applied voltage may be adjustable to control the electric field between the electrodes. For example, the electric field may be calculated from:

$$E = \frac{U}{h}$$

where h is the distance between the electrodes and U is the applied voltage. However,

30 where the electrodes are separated by two or more fluids e.g. oil and water separated by an oil interface, the applied voltage is the sum of the applied voltage over each fluid, i.e. $U = U_1 + U_2$. The corresponding electric fields E_1 and E_2 are calculated from

$$E_1 = \frac{U_1}{h_1}; E_2 = \frac{U_2}{h_2}$$

where $h = h_1 + h_2$ is the distance between the electrodes with h_1 being the thickness of the first liquid (e.g. oil) and h_2 being the thickness of the second liquid (e.g. water) and U_1 is the applied voltage over the first fluid and U_2 is the applied voltage over the second fluid. It will be appreciated that where there are more than two fluids, the electric field in each may be calculated from the applied voltage over each fluid and the thickness of the fluid.

The controller may be configured to calculate the distance h between the fluid interface and one electrode in the pair of electrodes; determine whether said calculated distance is within an expected range and output an adjustment to the applied electric field when it is determined that said calculated distance falls outside said expected range. The system may comprise at least one current sensor for measuring the current within the between the or each pair of electrodes. The system may measure the current at the power supply which provides the means for applying the electric field. The system may comprise at least one resistivity sensor for measuring the resistivity of the rock, oil and/or water within the reservoir. For example, the resistivity may be measured from fluid or core samples taken from the reservoir. Alternatively, the resistivity may be calculated, e.g. by measuring properties related to resistivity in the fluid or core samples.

The distance h between the interface and the electrode may be calculated from the voltage and current of the applied electric field together with the resistivity of oil, water and rock within the reservoir.

Distance h may be calculated using:

$$h(U, I) = \frac{U - I \cdot r_{\text{water}} \cdot H}{I \cdot (\min(r_{\text{oil}}; r_{\text{formation}}) - r_{\text{water}})}.$$

Where

R_{Tot} is the total electric resistance

r_{Water} is the specific electrical resistance for water

r_{Oil} is the specific electrical resistance for oil

$r_{Formation}$ is the specific electrical resistance for rock

H is the distance between each electrode in the pair of electrodes

5 The calculating, determining and adjusting steps may be repeated at periodic intervals. In this way, the correct interface level may be maintained over time. The expected range may also be altered, e.g. by a user or automatically by the system. When an alteration is input into the system, the calculating, determining and adjusting steps may be repeated again. In this way, any changes to the electric field which are necessitated
10 by the change to the expected range may be calculated. The expected range may be changed so that the direction of the electric field is reversed at the adjusting step. In this way, water may be drawn towards the negative electrode to assist with oil extraction, i.e. to force oil into the production well.

15 The expected range is greater than zero, typically greater than 1m to prevent water from intruding into the well. However, the expected range will depend on the pressure gradient at the well and other physical parameters.

There may be a plurality of pairs of electrodes, which for example are spread
20 throughout the reservoir. A plurality of separate electric fields may be applied using separate pairs of electrodes and the calculating, determining and adjusting steps may be performed separately for each pair of electrodes. Thus, the controller may be configured to separately control the applied electric voltage to each of the plurality of pairs of electrodes whereby the distance h between the fluid interface and one of the
25 electrodes in each of the plurality of pairs of electrodes is individually adjustable. Each pair of electrodes may have an associated expected range which is separately adjustable. This may enable a water sweep through the reservoir to assist in oil recovery. Alternatively, the applied voltage may be altered for other design patterns, such as pulsing. Pulsing could be beneficial for "shaking" the oil from the reservoir.

30 The system may further comprise a production well for extracting oil from the reservoir, the production well comprising the positive electrode. Similarly, the system may comprise an injection well for injecting fluid into the reservoir, the injection well comprising the negative electrode. By comprising, it is meant that the electrode may
35 be housed within the well or may be formed integrally therewith. It may not be

necessary for the system to comprise an injection well in which case the negative electrode may be otherwise provided in the reservoir, for example within a transportation pipe.

5 Where the system does comprise an injection well for injecting fluid into the reservoir; and a production well for extracting oil from the reservoir, at least one of the electrodes may extend along at least part of the production well or along at least part of the injection well.

10 For example, wherein the injected fluid is water (including water with other components such as polymers), the production well may comprise the or each positive electrode and the injection well may comprise the or each negative electrode. Alternatively, the injected fluid may be steam which creates a steam chamber within which the oil is heated. In this arrangement, the injection well may comprise the or each said positive
15 electrode and the production well may comprise the or each negative electrode. Alternatively, the fluid may be any suitable polar fluid, including dipolar fluids.

For macro-control, the negative electrode is at a significant distance, i.e. a distance much greater than the width of the production well, from the production well. However,
20 it is also possible to control the water flow over smaller distances. For example, the at least one pair of electrodes may be provided within a pipe, e.g. injection well, extraction well or transportation pipe within the well. In this case, the electrodes are set apart by a distance which is comparable with the width of the pipe, e.g. H is approximately 100 to 200mm. In this case, the expected range may be between 0 and H, more preferably
25 between 100mm and H.

The flow may also be controlled at a micro-level by providing fluid flow controllers which may act as barriers, valves or channels along parts of the water and/or oil pipes (e.g. the injection and/or production wells). These micro level fluid flow controllers may
30 be used separately or in conjunction with the electrodes described above for providing large scale control. The fluid flow controllers may be used on one or both of the production and/or injection wells and/or another transportation pipe within the system.

The micro level fluid flow controller may comprise a positive electrode, a negative
35 electrode and a porous material between the positive and negative electrodes. In use,

a voltage is applied to the positive and negative electrodes to generate an electric field between the electrodes to control the flow of fluid within the porous material. The strength of the applied voltage may be adjustable to control the electric field between the electrodes and hence to control the fluid flow. For example, the electric field may be calculated between the electrodes at the micro-level using the same equation above, e.g. from:

$$E = \frac{U}{h}$$

where h is the distance between the electrodes and U is the applied voltage.

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At a macro-level, the porous material is that which is within the reservoir and thus cannot be controlled. However, at a micro-level, the properties and design of the porous material within the fluid flow controller may be selected and/or adjusted to suit the purpose of the fluid flow controller. For example, the porous material may be a nano-material, e.g. graphene. An important property of nano materials is that the surface area to volume ratio is extremely large and thus the properties of the material can be maintained even when the material is subject to a large pressure drop (e.g. as oil passes through into the well). Graphene has good mechanical, electrical and thermal properties which is useful to combine the electro-osmotic effect with the nano material. The porous material may specially designed for a particular purpose, for example the porous material may be designed to work effectively in straight channels with small diameter.

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The properties and design of the porous material may be selected to optimise oil flow through the fluid flow controller. As an example of the properties and design, the porous material may be a hydrophobic material, e.g. hydrophobic sand, to prevent water flow through the fluid flow controller. It will be appreciated that a hydrophobic material may be used on its own without the electro-osmotic effect of applying an electric field. Alternatively, the properties and design of the porous material may be selected to optimise water flow through the fluid flow controller. For example, the porous material may be an oil-phobic material.

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A micro-level fluid flow controller on a production well may be designed so that the application of the electric field assists in minimising or reducing water flow and

maximising or increasing oil flow into the production well. A fluid flow controller on the production well may also be designed so that the application of the electric field assists in removing water from the production well through the fluid flow controller. By contrast, a fluid flow controller on the injection well may be designed so that the application of the electric field draws fluid (e.g. water) into the injection well and/or
5 ejects fluid (e.g. water or steam) from the injection well at a different location.

The micro-level fluid flow controller may have a generally annular shape. This is particularly useful where the injection and/or production well comprise at least one fluid
10 flow controller. An annular fluid flow controller may sit around the outer surface of at least part of the wall of the injection and/or production well or form part of the wall.

The positive electrode may be on an inner surface of the fluid flow controller and the negative electrode may be on an outer surface of the fluid flow controller. When such a
15 micro-level fluid flow controller is used on an injection well, the application of an electric field may draw water from within the injection well to be injected into the reservoir through the fluid flow controller. When such a micro-level fluid flow controller is used on a production well, the application of an electric field may prevent or reduce water flow into the production well. Thus, in this case, the fluid flow controller acts as a water
20 barrier.

Alternatively, the fluid flow controller may have the positive electrode on an outer surface and the negative electrode on an inner surface. When such a fluid flow controller is used on an injection well, the application of an electric field may draw
25 water into the injection well.

In any of the micro-level arrangements described above or below, the polarity of the electrodes may be interchanged, i.e. the positive electrode becomes the negative electrode and vice versa. At the micro-level, one use is to avoid clogging pores in the
30 porous membrane. The polarity may be changed at regular or irregular intervals which may span nano seconds or days depending on what is most effective in a particular situation. Such interchanging of polarity may be termed pulsing and may be beneficial for transport and chemical reactions.

The injection well, transportation pipes and/or the production well may comprise a plurality of micro-level fluid flow controllers as described above. The fluid flow controllers may be spaced apart along at least part, possible the whole, length of the injection well, transportation pipes and/or the production well. There may be a combination of different fluid flow controllers on the well, for example some which allow water to be drawn into the injection well from the production well and some which inject water. This is an efficient arrangement which reduces the need for water to be drawn from an alternative source and hence pumped into the reservoir.

The electric field applied to each micro-level fluid flow controller may be independently adjustable giving greater control. Furthermore, by measuring the electric current for each electrode pair along the well or pipe, the water volume flow may be calculated. The water volume flow is a function of the measured electric current and the parameters of the device itself such as pulse intervals, pressure difference across the membrane, applied voltage across the membrane, pore diameter of the membrane, thickness of membrane, type of material (electrodes and membrane), porosity of the membrane and physical properties of the fluids. If the measured electric current is reduced it indicates there may be clogging within the device. To prevent clogging pulsing can be used or the applied voltage can be changed. This can be done at regular intervals or if the electric current has reached a limit. Thus the water flow volume at a micro-level may be used for minimising the power consumption and for minimising clogging (e.g. using pulsing as described above) within the porous material. At a macro-level, as explained above, the water interface can be changed.

As an alternative (or in addition) to using a plurality of micro-level fluid flow controllers, each fluid flow controller may be divided into a plurality of sections each of which can be controlled separately. For an annular fluid flow controller, the sections may be radial sections. Alternatively, in other arrangements the sections may be axial. This provides additional flexibility and control in the system.

The injection well may be positioned within the production well along at least part of its length. In this arrangement, when an electric field is applied water may be drawn through the fluid flow controller from the production well into the injection well. This may be achieved, for example by a fluid flow controller having the positive electrode on an inner surface and the negative electrode on an outer surface wherein water is drawn

in the opposite direction to the applied electric field. It may be possible, because of fluid levels within the production well, for the fluid flow controller to comprise porous material in its lower section only and be non porous elsewhere. This may reduce the use of an expensive porous material.

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The injection well and the production well may be adjacent one another along at least part of their length. In this arrangement, at least one micro-level fluid flow controller may be used to connect the injection well and the production well where the wells are adjacent one another. The at least one fluid flow controller forms a channel between the production well and the injection well whereby when an electric field is applied to the at least one fluid flow controller, water is drawn through the channel from the production well into the injection well. In this arrangement, the porous material may be housed within a housing to define the channel between the two wells, e.g. a channel having a generally rectangular cross-section.

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A combined production and injection well may also be used. The combined well may comprise a production chamber which forms the production well and an injection chamber which forms the injection well, wherein the fluid flow controller extends along the length of the combined well to separate the chambers. The positive electrode may be adjacent the production chamber and the negative electrode adjacent the injection chamber so that when an electric field is applied between the positive and negative electrodes, water flows through the fluid flow controller from the production chamber into the injection chamber. Again this means that water need not be pumped from a separate source and also improves the quality of the fluid from the production well. In this arrangement, the fluid flow controller is acting as a wall or barrier between the two chambers. The fluid flow controller may be planar or non-planar.

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In each of the embodiments above, the full system is described. However, it will be appreciated that the fluid flow controller, the injection well and/or the production well may be separately formed. Thus, according to another aspect of the invention, there is provided a fluid flow controller for use in any of the systems described above, the fluid flow controller comprising a positive electrode, a negative electrode and a porous material between the positive and negative electrodes wherein when an electric field is applied between the positive and negative electrodes flow of fluid through the porous material is controlled. Similarly, according to another aspect of the invention, there is

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provided an injection well comprising at least one fluid flow controller as described above. Similarly, according to another aspect of the invention, there is provided a production well comprising at least one fluid flow controller as described above.

5 Both macro and micro control of a fluid using electro-osmotic effect is described above. Thus, in a very general sense, there is provided, according to an aspect of the invention, an oil extraction system for extracting oil from a reservoir, the system comprising at least one pair of electrodes in the reservoir with a porous material between the electrodes, wherein the pair of electrodes comprises a positive electrode
10 and a negative electrode and means for applying an electric field to the electrodes to control fluid flow within the porous material whereby fluid flow within the reservoir is controlled. For macro control, the porous material may be the reservoir material itself. For micro control, the porous material may be designed for optimum use. The features of the various aspects of the invention described above may be used in this general
15 aspect.

Brief description of the drawings

These and other aspects of the invention will now be further described, by way of
20 example only, with reference to the accompanying figures in which:

Figure 1a is a schematic illustration of a standard well head with a plurality of production wells extending into formations containing oil;

25 Figure 1b is a schematic cross-section of a formation from which oil is being extracted in a conventional manner;

Figure 2a is a schematic cross-section of a formation from which oil is being extracted according to the present invention;
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Figure 2b is a flowchart showing how the voltage to be applied is determined;

Figure 2c is a schematic block diagram of the system for implementing the steps of the flowchart of Figure 2b;
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Figure 2d is a schematic close-up of a section of a formation from which oil is being extracted according to the present invention;

5 Figures 3a to 3c show the formation of Figure 2a with an alternative arrangement for extracting oil according to the present invention;

Figure 4 is a schematic illustration of a steam assisted gravity drilling (SAGD) arrangement for extracting oil according to the present invention;

10 Figures 5a and 5b are cross-sections across a production well such as that used in Figure 2a;

Figure 5c is a cross-section along the length of the production well of Figure 5a;

15 Figure 6 is a cross-section through adjacent production and injection wells according to another aspect of the present invention;

Figure 7a is a cross-section through a pair of production and injection wells according to another aspect of the present invention;

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Figure 7b is a cross-section through an injection well which may be used in the arrangement of Figure 7a; and

25 Figure 7c is a cross-section through a pair of production and injection wells according to another aspect of the present invention.

Detailed description of the drawings

30 Figure 2a shows the formation of Figure 1a in which there are two wells; a first well 10 which is the production well and a second well 22. Each of the wells comprises an electrode or is itself an electrode to which a voltage is applied. The second well 22 may be an injection well, e.g. to inject water back into the formation to replace the withdrawn oil so that pressure levels within the formation are maintained. Alternatively, the second well may just be a dummy well for the insertion of an electrode at a suitable

location. It may also be possible to place the electrode on the sea bed without needing a separate well.

Water is an electrolyte but oil is not. Hence, applying an electric field E within a formation containing both oil and water will cause the water but not the oil to move using electro-osmotic flow. The direction of the flow is in the direction of the applied electric field, namely from the positive electrode (anode) to the negative electrode (cathode). Accordingly, as shown in Figure 2a, the production well 10 comprises a positive electrode and the second well 22 comprises the negative electrode so that water flows away from the production well.

This water flow is schematically illustrated in Figure 2d which shows a production well 10 positioned at the top of the oil layer 12. The production well 10 has an electric field applied to it from the generator 24 to be a positive electrode. There are two electrodes 22 in the water layer 16 both of which are connected to the generator 24 so that they are negative electrodes. These electrodes 22 may be within second wells or may be positioned without a well if possible. The direction of the water flow is indicated by arrows A.

In both the arrangements of Figures 2a and 2d, the positive and negative electrodes are set at a height H from one another. One consequence of applying the electric field is that the height of the water cone shown in Figure 1a is reduced as shown in Figure 2a. Water and oil do not mix and there is thus an interface or surface at which the two layers meet. The distance from the positive electrode to the water-oil interface is indicated as height h. The electric field E may be applied to maximise h so that the water-oil interface is significantly below the production well and thus water cannot flow into the production well.

The resistivity of oil and formation water are significantly different and are both typically much higher than the electric resistance of the formation. The overall resistivity from the formation can be determined from:

$$R_{Tot} = r_{Water} \cdot (H - h) + \min(r_{Oil}, r_{Formation}) \cdot h$$

Where

R_{Tot} is the total electric resistance [Ω]

r_{Water} is the specific electrical resistance for water (compensated for porosity) [Ω/m]

r_{Oil} is the specific electrical resistance for oil (compensated for porosity) [Ω/m]

$r_{Formation}$ is the specific electrical resistance for rock (compensated for porosity) [Ω/m]

5 H is the distance between the electrodes [m]

h is the distance between the well (positive electrode) and the water front [m]

10 Provided the water resistance is approximately known and is different (normally much lower than) the oil and formation resistances, it is possible to determine the position of the oil-water contact when a known voltage U is applied and the electric current I is measured:

$$I = \frac{U}{R_{Tot}} = \frac{U}{r_{Water} \cdot (H - h) + \min(r_{Oil}, r_{Formation}) \cdot h}$$

$$\Downarrow$$

$$r_{Water} \cdot (H - h) + \min(r_{Oil}, r_{Formation}) \cdot h = \frac{U}{I}$$

$$\Downarrow$$

$$h(U, I) = \frac{U - I \cdot r_{Water} \cdot H}{I \cdot (\min(r_{Oil}, r_{Formation}) - r_{Water})}$$

15

Accordingly, the strength of the applied voltage may also be varied to influence the height h for example as illustrated in the flowchart of Figure 2b.

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The first step is to determine the resistivity of the formation within which the oil is located (S100). The resistivity of the rock may be measured before the production well is inserted or may be measured when the oil is being produced. The resistivity may be measured using known methods, e.g. for core samples taken when the well was drilled. The resistivity of the oil and water are next measured (S102). It will be appreciated that these can be measured together with the resistivity of the formation. However, the resistivity of the oil and water are more likely to be changing with time and thus may need to be more frequently measured. These may be measured from the water and oil which is drawn out of the well, i.e. at the well head or at the power supply, or may be measured by sensors located within the well. The repetition of the measurement can be at regular intervals which may be between 10 minutes and an hour apart.

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The next stage is to apply a known voltage U (S104) to generate the electro-osmotic flow (according to known principles). The current I is then measured (S106). The simplest method may be to measure the voltage and current at the power supply. However, it is possible that the current within the electric field may be measured using sensors located within the formation. The height h , i.e. the distance from the well containing the positive electrode to the oil-water interface, is then determined using the equation above (S108). The determined height is compared with a threshold value to determine whether or not the determined height is within the acceptable range for production. The maximum range is $0 \leq h \leq H$, perhaps $1m \leq h \leq H$. If the height is acceptable, the system loops back to measuring the current I and recalculating the height to make sure that the production continues to remain within the acceptable parameters. The repetition of the measurement can be at regular intervals which may be between 10 minutes and an hour apart. The measurements can be timed to take place at the same time as the resistivity measurements above.

If the height h is not acceptable, the system determines a correction to the applied voltage U , e.g. increases the voltage if the height is too low or reduces the applied voltage if the height is too great (S112). The system then loops back to apply the corrected voltage (S104) and to repeat the measuring and determining steps to make sure that the applied correction has had the desired effect.

Figure 2c is a schematic block diagram of the components of the system. The system comprises a controller 100 which comprises a processor 106 (e.g. a microprocessor), memory 108 and program code 110. The functionality of the controller 100 is shown within a single device (e.g. a server) but as is well known in the art may be distributed across multiple devices. The processor and memory of the controller are standard well known component and are not described in detail. The controller is a hardware device which is programmed and controlled by program code 110 in a standard known manner.

The controller 100 receives data from a current sensor 102 and one or more resistivity sensors 104. The controller may use the data to determine whether or not any changes to the applied voltage U are to be made as described above. If a change is to be made, the controller may directly notify the generator 112 which applies a different

voltage to the electrodes 114 within the formation. In this way, automatic control of the production well is achieved. However, the controller 100 may also output suggested changes to a display of a user computer 116. The user may be to input changes to the generator 112 or may send the changes via the controller 100. The user computer 116
5 also has a user interface by which the user can input control information to the controller 100 or the generator 112.

Figure 3a shows a schematic illustration in which the production well 10 extends along the upper surface of the formation and the injection well 22 along the lower surface of
10 the formation. A plurality of positive and negative electrodes 30,32 are distributed along each well. The electrodes may be equidistantly distributed along each well as shown or may be distributed according to another pattern (e.g. more closely at the far end of the wells). Each of the electrodes is preferably separately driven so that a different electric field can be achieved between each pair of electrodes.

15 As shown in Figure 3b, there are four water cones 20 between four different pairs of electrodes. There is also an area 34 of the formation from which oil production is slowing down. Accordingly, it is desired to force water into this area to accelerate the drawing of oil from this area. The height of the water cone, and thus the height of the
20 water-oil interface, may be controlled as described above. By decreasing the electric field, the height of the water cone may be increased. In more extreme cases, it may be necessary to reverse the direction of the electric field between the electrodes either side of area 34, to attract water towards the production well and further increase the height of the water cone 20 in this area. Thus, as shown there are more (seven) water
25 cones shown in Figure 3c. Reversing the electric field, changes the water flow direction and the additional flow of water forces more oil into the production well to increase the drainage and oil recovery. Accordingly, another use of the electro-osmotic flow is to improve the water sweep within the formation to increase the oil recovery from the oil reservoir within the formation.

30 Figure 4 shows another use of the electro-osmotic flow. Figure 4 shows a reservoir 210 of oil sand beneath other layers of rock, soil etc. A known method of extracting the bitumen from the reservoir is to drill two well lines 212, 214 into the reservoir forming a wellpair. The first well line 212 is for inputting steam into the reservoir to heat the
35 bitumen. The arrows along the well line indicate the direction of steam flow. The

second well line 214 is for extracting the bitumen from the reservoir. As shown, the two well lines are not connected to each other and are spaced apart, perhaps generally parallel to one another into the reservoir.

5 Initially, the steam injected into the reservoir creates a small steam chamber. The steam expands in both the longitudinal and axial direction as indicated by arrows A and flows to the interface between the steam chamber and the reservoir. The steam expansion gradually expands the steam chamber 218. The steam heats the bitumen which flows under gravity to the lower portion of the steam chamber as indicated by
10 arrows B. The bitumen (and any other condensate) is drawn off through the second well line using a pump. The arrows along the well line indicate the direction of output fluid flow. Uniform steam chamber development is critical to ensure a productive well.

The well lines 212,214 comprise electrodes as described above and an electric field is
15 applied to control the electro-osmotic flow of the steam which is input into the reservoir. The applied electric field will also generate heat in the reservoir which will aid in the recovery of the bitumen. Using the electro-osmotic effect with steam is the same as with water although the efficiency may be reduced because the molecules are further apart in steam when compared with water.

20 In the above examples, electro-osmotic flow is used on a large scale to control the water flow within the entire reservoir/formation. Figures 5a to 5c show how electro-osmotic flow can be used at a smaller scale to help prevent water flowing into the production well. Figures 5a and 5b are schematic cross-sections across a production
25 well. A fluid flow controller which in this arrangement acts as a barrier 40 as explained in more detail below surrounds at least part of the well. The barrier 40 comprises an outer layer 42 and an inner layer 44 and is generally annular in cross-section. The inner layer 44 is adjacent the outer wall of the production well. As shown in Figure 5a, the barrier 40 is divided into four sections 41a, 41b, 41c and 41d which may be
30 independently controllable.

As shown more clearly in Figure 5b, the inner layer 44 forms a positive electrode and the outer layer 42 forms a negative electrode so that an electric field illustrated by the
35 arrows is generated within the layer. The electric field is radially directed from the inner layer towards the outer layer. The strength of the electric field may be adjusted

as required by the controller 100 of Figure 2c and may be same through the entire barrier or different in the different sections 41a-d. As explained above, water but not oil is affected by an electric field. Accordingly, the application of the electric field will prevent (or at least reduce) water flow through the barrier into the production well whilst still allowing oil to flow into the well. It will also be appreciated that by reversing the electric field, any water within the well will be forced out through the barrier. Thus the barrier could also be applied to an injection well to promote the flow of water from the injection well into the reservoir.

A porous medium is contained between the inner and outer layers 42, 44. The porosity of the medium may also be selected to optimise transmission of the oil through the barrier. The porosity of the medium may be selected to prevent clogging of the oil or other unwanted effects. Other properties such as tortuosity may also be optimised. The porous medium may also be a hydrophobic material to prevent water flowing through the barrier into the production well. Furthermore, a hydrophobic material will also reduce water flow through the barrier parallel to the well. It will be appreciated that a hydrophobic material may be used on its own without the electro-osmotic effect but that the combination of the two effects is likely to produce better results.

The hydrophobic material may for example be hydrophobic sand which can be applied as gravel pack around the outer wall of the production well. The hydrophobic material may also be a conductive material which enhances the electro-osmotic effect. The material of the barrier may be a porous nano material such as those which may be designed to be hydrophobic or hydrophilic. An important property of nano materials is that the surface area to volume ratio is extremely large and thus the properties of the material can be maintained even when the material is subject to a large pressure drop (e.g. as oil passes through into the well). An example of a suitable nano material is graphene which has good mechanical, electrical and thermal properties which is useful to combine the electro-osmotic effect with the nano material.

The barrier can be used along the whole or parts of the well. Figure 5c is a schematic cross-section along the length of a production well and shows that the barrier 40 is formed in separate, discrete sections rather than along the full length of the production well. As shown, each section of the barrier is equally spaced from the next section but it will be appreciated that the placement of each section can be varied as necessary,

e.g. to have more barriers in parts of the reservoir having more water or where more water needs to be injected. The outer wall of the well may be non-porous to both oil and water in the regions between the barriers and thus as indicated by the arrows, flow into the well may only occur in the barrier regions which in effect form channels into (or out of) the well. If the barrier is using electro-osmotic effect, the strength of the electric field applied to each region of the barrier may be independently adjustable to control the water flow in each region. This may be particularly useful where the barrier is used on an injection well because it enables the injection of water into localised areas within the reservoir. The electric field E may be calculated from:

$$E = \frac{U}{h}$$

Where h is the distance between the electrodes and U is the voltage. Thus, the voltage U may be adjusted to give a desired electric field E . The direction as well as the strength may be controlled (e.g. by the controller of Figure 2c). The direction of the electric field may be interchanged, e.g. pulsed.

Figure 6 shows another example of how electro-osmotic effect can be used to promote water flow through a fluid flow controller which in this arrangement acts as a channel whose porosity is controllable. As shown in Figure 2a, there may be two wells within a reservoir (or formation). One well is the production well for drawing oil from the reservoir and the second well may be an injection well through which water (or steam) is injected into the reservoir, for example to maintain the pressure within the reservoir. In Figure 2a, the two wells are shown spaced apart, at least within the reservoir itself. Figure 6 shows an alternative arrangement in which the two wells 310, 312 are adjacent one another; at least along part of their length.

In Figure 6, the production well 310 is located above the injection well 312, although clearly the positions could be reversed. A channel 314 is connected between the production and injection wells and allows fluid to flow between the two wells 310, 312. The production well 310 typically contains a mix of oil (and possibly gas) with water and the injection well 312 contains water. As shown in Figure 6, two electrodes are placed in the channel, one adjacent each well. A positive electrode is placed adjacent the production well 310 and a negative electrode adjacent the injection well 312. An electric field is applied to the channel 314 to promote the flow of water from the

production well 310 into the injection well 312, i.e. from the anode to the cathode. Oil, which is not an electrolyte, is unaffected by the electric field and remains within the well. In this way, the electro-osmotic effect is creating a pump so that waste water is removed from the production well into the injection well where it can be recirculated into the reservoir as needed.

The channel 314 comprises a porous material, which may be as described in relation to Figures 5a to 5c. Thus, the porosity and other properties such as tortuosity may be selected to optimise the flow within the channel. The porous material may be a nano-material and may also be conductive to improve the electro-osmotic effect. A suitable material is graphene. It is also possible to use a nano-material without an electric field. However, it is then necessary to pump the water from the production well to the injection well by creating a pressure difference between the two wells. Pumping the water may also lead to oil leakage. This may be minimised by using a hydrophilic porous material to promote the flow of water in preference to the flow of oil. Alternatively, the properties of the porous material may be adjusted to allow only water and not oil to flow.

As explained above, it is beneficial to reduce the amount of water within the production well to avoid separation processing at the well head. The arrangement of Figure 6 allows the water to be removed from the production well 310 within or at least close to the reservoir, thus reducing the length of the flow path for the water and reducing the lift required to get the fluid from the reservoir. This reduces or alleviates the need to transport water from or to the processing unit because of the local separation. Furthermore, water is added to the injection well which is beneficial for rehydrating the reservoir. Moreover, the conditions (e.g. pressure, temperature and/or flow) for separation of the oil and water may be more favourable in or near the reservoir.

The barrier of Figure 5a and the electrode arrangements of Figure 2a and 2d are designed to prevent water entering the production well but nevertheless some water may enter the production well. Thus, the arrangement of Figure 6 could be used in conjunction with these arrangements to further improve the reduction of water in the injection well. For example, the barrier and channel could be used at different locations within the reservoir with the barrier being used when the injection well and the

production well are spaced apart and the channel being used when they are close together.

5 As an alternative to providing a channel between two separate wells, the arrangements of Figures 7a to 7c can be used (either alone or in conjunction with the arrangements of Figures 2a, 2d and 5a). Figure 7a shows the injection well 322 is housed within the production well 320 (at least along part of its length). The injection well 322 is surrounded by a fluid flow controller which forms a channel 324 which is similar to the barrier of Figures 5a to 5c and thus uses the same materials. Thus the channel 324
10 comprises an outer layer and an inner layer between which there is a porous material. In the arrangements shown in Figures 5a and 5b, the electric field is applied so that it radiates outwards from the inner layer to the outer layer to prevent water entering. However, in this arrangement, the electric field is radiating inwards to draw water from the production well 320 into the injection well 322. The oil is unaffected by the electric field and will thus remain within the production well 320 provided that there is not a significant pressure drop between the two wells. If the pressure is lower in the injection well, it may be necessary to apply an oil phobic material (e.g. graphene) to the inner surface of the barrier (or the outer surface of the inner wall).

20 Figure 7b shows a variation of the barrier 324 which may be used in Figure 7a. Oil is lighter than water and the two fluids are immiscible. Accordingly, the highest concentrations of water will be found at the lowest points of the production well. Thus, depending on the fluid levels within the production well 320, it may only be necessary to use a channel around the lower portion 326 of the injection well 322. The remaining
25 portion 328 around the injection well is simply an impervious closed sleeve. Alternatively, the well pipe could be formed with the channel only in the lower part of the pipe wall.

Figure 7c shows another variation in which there is a single well 330. In this
30 arrangement, the well 330 is divided into two sections 334, 336 by a wall 332 which extends along the length of the well 330. The wall 332 comprises two outer electrode layers between which is a porous material such as those used in previous embodiments. One electrode is positive (marked +) and the other is negative (marked -). When an electric field is applied, electro-osmotic effect will draw water through the
35 wall from section 334 to section 336 and thus the wall acts as a fluid flow controller. In

this way, section 334 can be used as the production well and section 336 can be used as an injection well or sections 334 and 336 can be used as transport pipes or processing equipment.

5 Although the wall in Figure 7c is shown as a vertical, planar wall which bisects the well; it will be appreciated that this is just one arrangement. The wall may be designed to suit the requirements of the well. For example, the wall may be planar or non-planar (e.g. curved). Furthermore, the wall may be at any angle within the well, e.g. horizontal, vertical or an angle between the two extremes. The wall may divide the well
10 into equal sized portions for oil and water. Alternatively, if a greater volume of oil is expected, the wall may divide the well so that there is a greater section available for oil than water (or vice versa). The wall may also be flexible. Such a flexible wall may locally alter the volume of each of the production and/or injection chambers depending on the local pressure difference between the fluids at various positions.

15 The pressure in the injection chamber (i.e. on the water side) is preferably higher than the pressure in the production chamber (i.e. on the oil side) otherwise oil may be forced through the fluid flow controller. However, if the pressure difference is too great, the electric field will need to be very strong to overcome the pressure difference.
20 Accordingly, the pressure difference is preferably minimised to minimise power consumption. The pressure difference may be measured and at least one outlet valve 338 may be provided on one or both sides of the fluid flow controller. The outlet valve(s) may be activated when the pressure difference is too great. The activation may be automatically controlled.

25 In each of the examples of Figures 5a to 7c, the porous material between two electrodes effectively acts as a one-way valve which promotes water flow through the material from the positive to the negative electrode and prevents water flow through the material from the negative to the positive electrode.

30 The above embodiments are examples of the use of the electro-osmotic effect within the oil recovery process. Accordingly, the above examples use oil (hydrocarbon) and water as the fluids subject to electro-osmotic effect. However, the principle is more general and can be applied to any dipole or polar fluid (other than water) mixed with a
35 non-dipole fluid (other than oil) provided the fluids are separable. The electro-osmotic

effect may be useful for separating fluids having small differences in fluid densities. By contrast, gravitational force alone is not typically suitable for separating fluids having small differences in fluid densities (e.g. heavy oil and water).

- 5 Similarly, the above embodiments describe flow of oil and water within wells which are pipes. However, oil and water are transported in other types of pipes such as from the wells to the processing units, between processing units and from processing units to receivers or customers. Accordingly, the principles described above can be used when oil and water are flowing through all types of pipes.

10

Further modifications and alterations will be apparent to the skilled man. It will be understood that the invention is not limited to the described embodiments and encompasses modifications apparent to those skilled in the art lying within the spirit and scope of the claims appended hereto.

15

CLAIMS

1. An oil extraction system for extracting oil from a reservoir; the system comprising

5 at least one pair of electrodes within the reservoir, wherein the or each pair of electrodes comprises a positive electrode and a negative electrode which are set a distance H apart within the reservoir and which are either side of a fluid interface between a layer of oil and a layer of water in the reservoir;

means for applying a voltage to the or each pair of electrodes to generate an electric field between the electrodes and

10 a controller to control the applied electric voltage whereby a distance h between the fluid interface and one of the electrodes is controllable.

2. The system of claim 1 wherein the controller is configured to calculate the distance h between the fluid interface and one electrode in the pair of electrodes;

determine whether said calculated distance is within an expected range and output an adjustment to the applied electric voltage when it is determined that said calculated distance falls outside said expected range.

20 3. The system of claim 1 or claim 2, comprising calculating the distance h using:

$$h(U, I) = \frac{U - I \cdot r_{\text{water}} \cdot H}{I \cdot (\min(r_{\text{oil}}; r_{\text{formation}}) - r_{\text{water}})}.$$

Where

25 R_{Tot} is the total electric resistance

r_{Water} is the specific electrical resistance for water

r_{Oil} is the specific electrical resistance for oil

$r_{\text{Formation}}$ is the specific electrical resistance for rock

H is the distance between each electrode in the pair of electrodes and

30 h is the distance between the fluid interface and one electrode in the pair of electrodes.

4. The system of claim 2 or claim 3, wherein the expected range is between 0 and H, more preferably between 1m and H.

5. The system of claim 2 or claim 3, the at least one pair of electrodes are within a pipe and wherein the expected range is between 0 and H, more preferably between 1m and H.

5

6. The system of any one of claims 1 to 45, comprising a plurality of pairs of electrodes.

10

7. The system of claim 6, wherein the controller is configured to separately control the applied electric voltage to each of the plurality of pairs of electrodes whereby the distance h between the fluid interface and one of the electrodes in each of the plurality of pairs of electrodes is individually adjustable.

15

8. The system of any one of claims 1 to 7, comprising at least one current sensor for measuring the electric current between the electrodes.

9. The system of any one of claims 1 to 8, comprising at least one resistivity sensor for measuring the resistivity of the rock, oil and/or water within the reservoir

20

10. The system of any one of claims 1 to 9, comprising a production well for extracting oil from the reservoir, wherein the or each positive electrode extends along at least part of the production well.

25

11. The system of claim 10, comprising an injection well for injecting fluid into the reservoir, wherein the or each negative electrode extends along at least part of the injection well.

30

12. The system of claim 11, wherein the injected fluid is water, steam or another suitable polar fluid.

35

13. The system of any one of claims 1 to 12, comprising a production well for extracting oil from the reservoir and at least one fluid flow controller on the production well, the fluid flow controller comprising
a positive electrode,
a negative electrode and

a porous material between the positive and negative electrodes
wherein a voltage is applied to the positive and negative electrodes to generate
an electric field between the electrodes to control the flow of fluid within the
porous material.

5

14. The system of claim 13, wherein the properties and design of the porous
material are selected to optimise oil transport and minimise electric power consumption
through the fluid flow controller.

10

15. The system of claim 13 or claim 14, wherein the positive electrode is on an
inner surface of the fluid flow controller and the negative electrode on an outer surface
and wherein when an electric voltage is applied between the positive and negative
electrodes, water flow through the fluid flow controller into the production well is
reduced.

15

16. The system of any one of claims 1 to 15, comprising an injection well for
injecting fluid into the reservoir and at least one fluid flow controller on the injection
well, the fluid flow controller comprising

a positive electrode,

20

a negative electrode and

a porous material between the positive and negative electrodes

wherein a voltage is applied to the positive and negative electrodes to generate
an electric field between the electrodes to control the flow of fluid within the
porous material.

25

17. The system of claim 16, wherein the positive electrode is on an inner surface of
the fluid flow controller and the negative electrode on an outer surface of the fluid flow
controller and wherein when an electric voltage is applied between the positive and
negative electrodes, water is drawn into the injection well through the fluid flow
controller.

30

18. The system of claim 16, wherein the fluid flow controller has the positive
electrode on an outer surface and the negative electrode on an inner surface and
wherein when an electric voltage is applied between the positive and negative
electrodes, water is injected from the injection well through the fluid flow controller.

35

19. The system of any one of claim 1 to 9 comprising
an injection well for injecting fluid into the reservoir;
a production well for extracting oil from the reservoir which is adjacent the
injection well along at least part of their length, and
at least one channel between the injection well and the production well, the or
each channel being located where the injection well and production well are adjacent
one another;
the or each channel comprising a porous material between a pair of electrodes
wherein when a voltage is applied to the electrodes, water is drawn through the
channel from the production well into the injection well.
20. The system of any one of claims 13 to 19, wherein the properties of the porous
material are selected to optimise water transmission through the fluid flow controller.
21. The system of any one of claims 13 to 19, wherein the porous material is a
nano-material.
22. A method for controlling flow of water in a reservoir from which oil is to be
extracted, the method comprising
providing at least one pair of electrodes in the reservoir, wherein the or each
pair of electrodes comprises a positive electrode and a negative electrode which are
set a distance H apart within the reservoir and which are either side of a fluid interface
between a layer of oil and a layer of water in the reservoir;
applying a voltage to the or each pair of electrodes to generate an electric field
between the electrodes and
controlling the applied electric voltage to control a distance h between the fluid
interface and one of the electrodes in the or each pair of electrodes.
23. The method according to claim 22, wherein controlling the applied electric field
comprises
calculating the distance h between the fluid interface and one electrode in the
pair of electrodes;
determining whether said calculated distance is within an expected range and

adjusting the applied electric voltage when it is determined that said calculated distance falls outside said expected range.

24. The method of claim 23, comprising calculating the distance h between the fluid interface and the electrode from the voltage and current of the applied electric voltage together with the resistivity of oil, water and rock within the reservoir.

25. The method of claim 24, comprising calculating the distance h using:

$$h(U, I) = \frac{U - I \cdot r_{\text{water}} \cdot H}{I \cdot (\min(r_{\text{oil}}; r_{\text{formation}}) - r_{\text{water}})}.$$

Where

R_{Tot} is the total electric resistance

r_{Water} is the specific electrical resistance for water

15 r_{Oil} is the specific electrical resistance for oil

$r_{\text{Formation}}$ is the specific electrical resistance for rock

H is the distance between each electrode in the pair of electrodes

26. The method of any one of claims 23 to 25, comprising repeating the calculating, determining and adjusting steps at periodic intervals.

27. The method of any one of claims 23 to 26, comprising calculating the distance h between the fluid interface and the positive electrode and wherein the expected range is greater than zero to prevent water contacting the positive electrode.

25

28. The method of any one of claims 23 to 27, comprising altering the expected range and repeating the calculating, determining and adjusting steps.

29. The method of claim 28, comprising altering the expected range so that the direction of the electric field is reversed at the adjusting step.

30

30. The method of any one of claims 22 to 29, comprising providing a plurality of pairs of electrodes and applying a plurality of separate electric fields using separate pairs of electrodes.

31. The method of claim 30, comprising controlling the applied electric voltage to each of the pairs of electrodes to separately control the distance h between the fluid interface and one of the electrodes in each pair of electrodes.

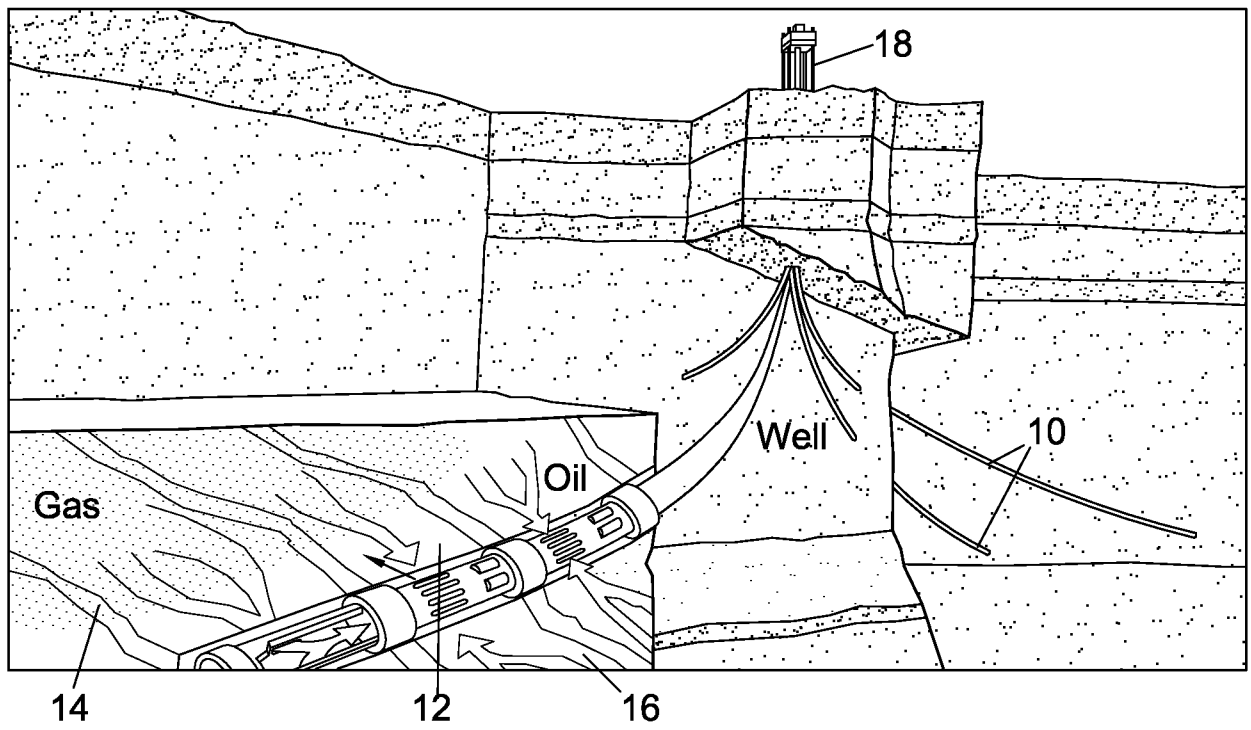


Figure 1a
Prior Art

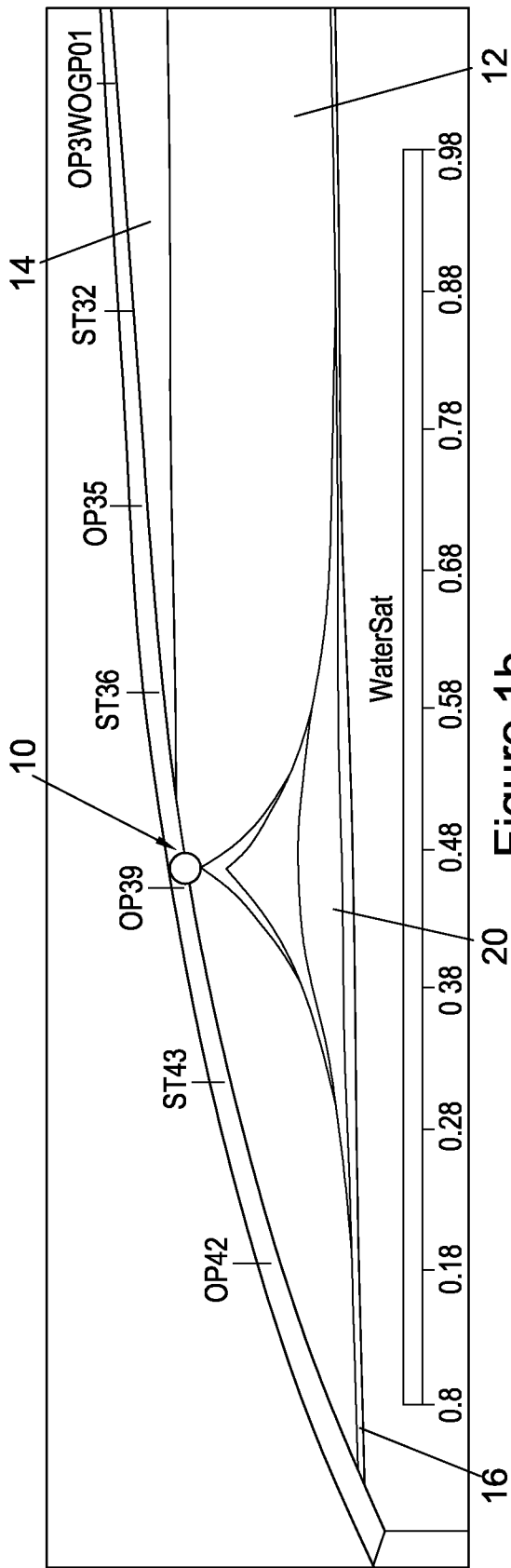


Figure 1b
Prior Art

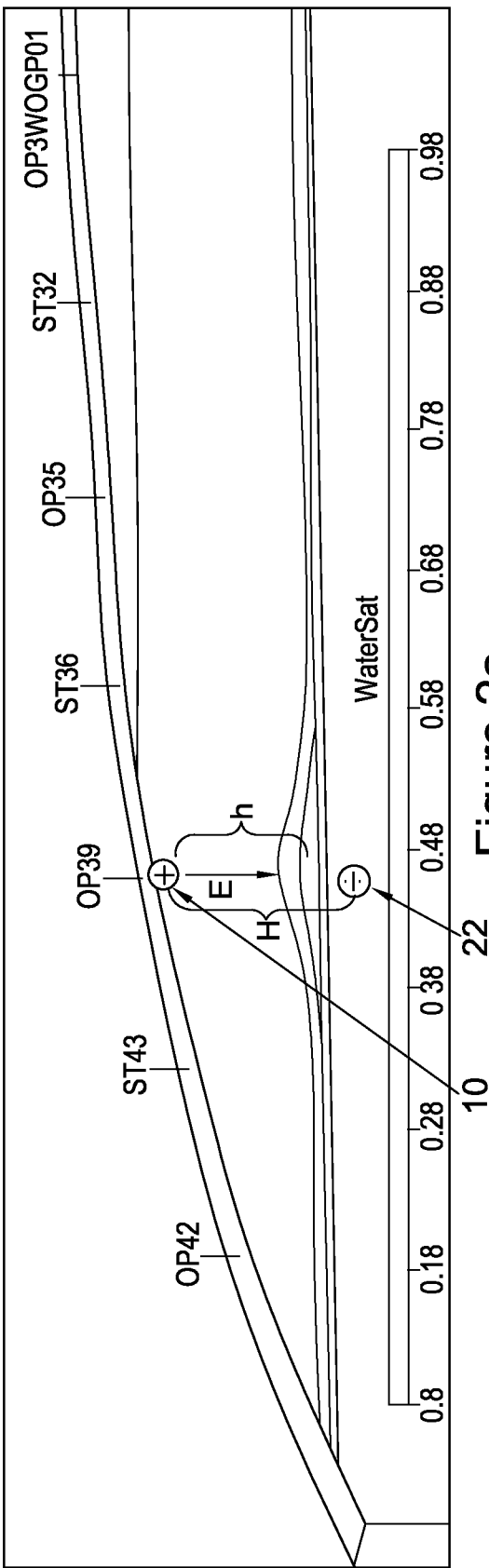


Figure 2a

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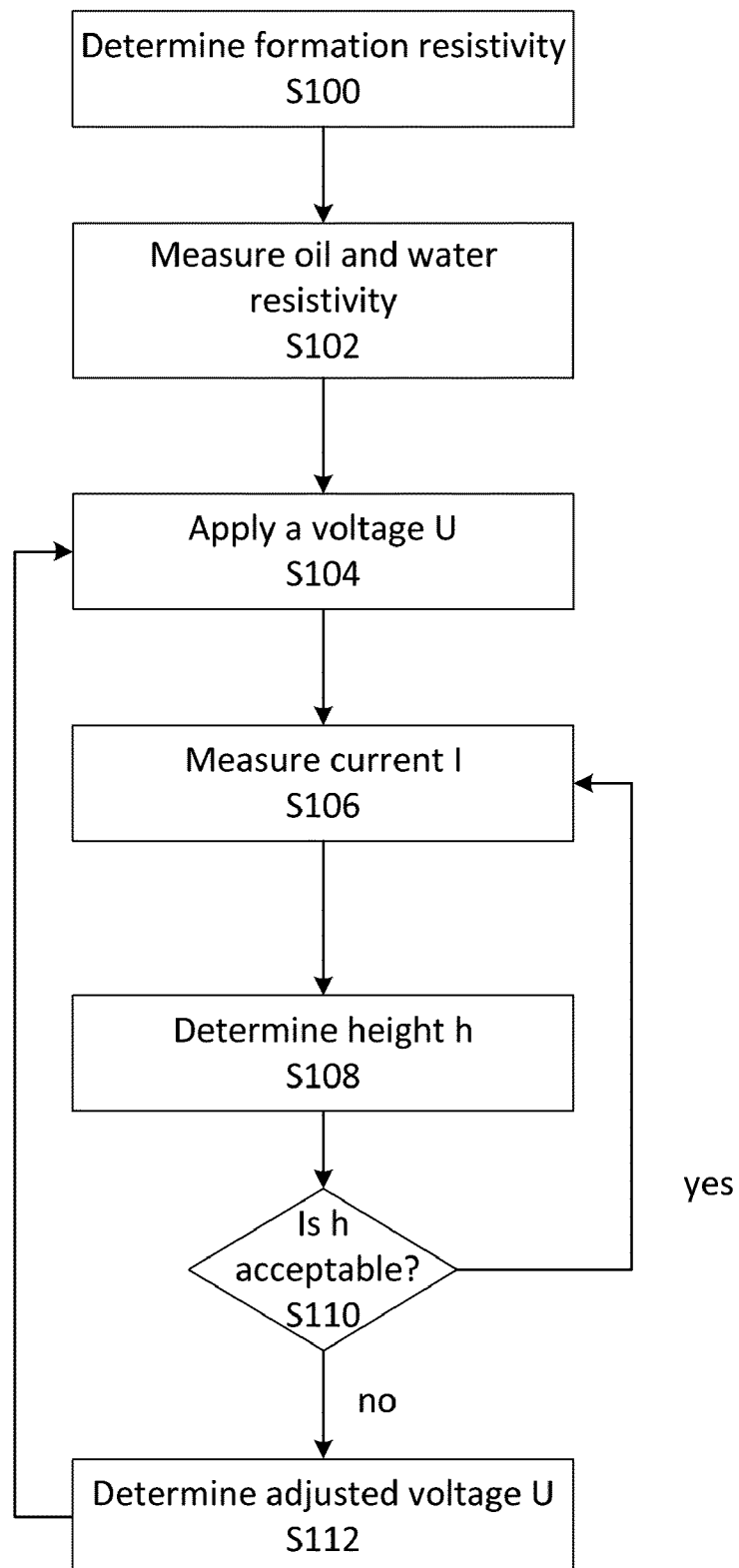


Figure 2b

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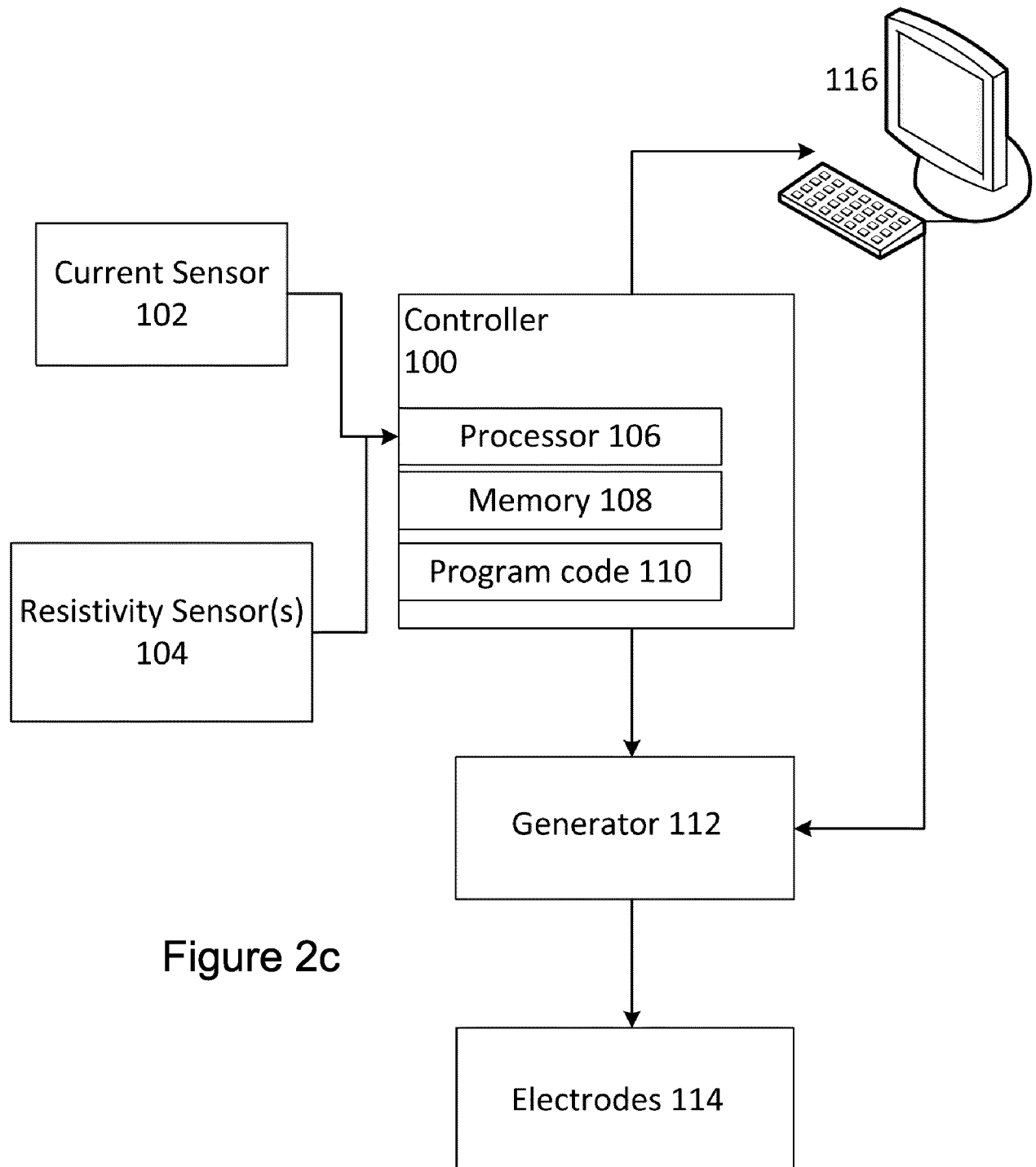


Figure 2c

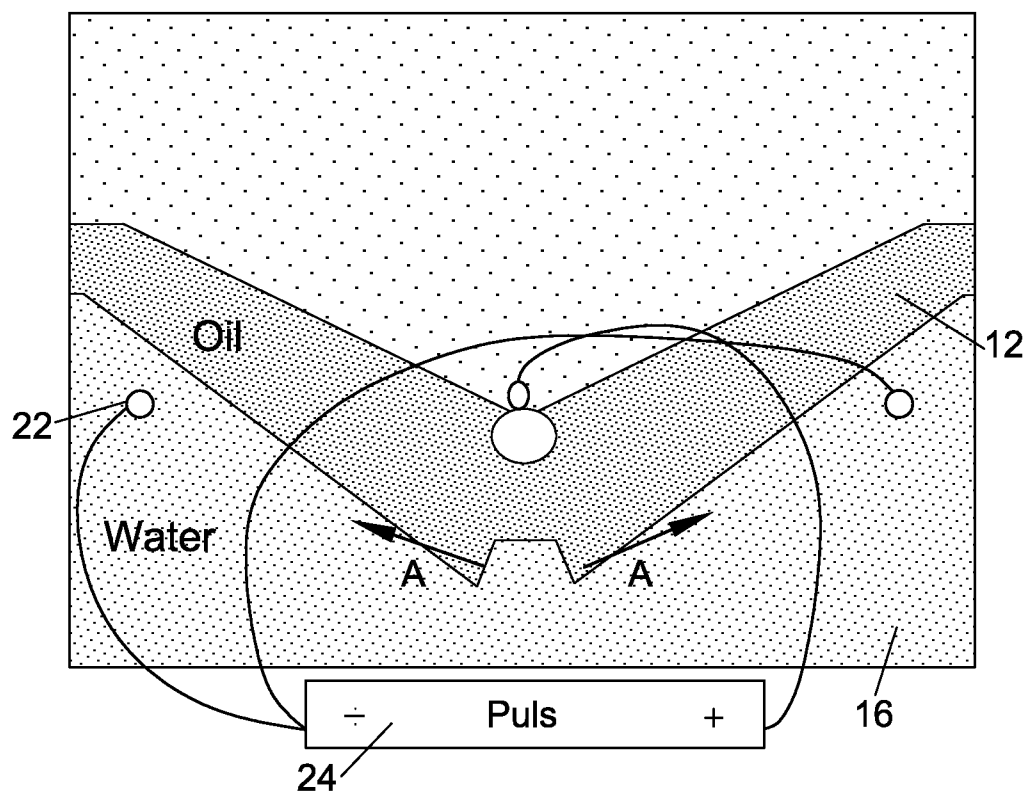


Figure 2d

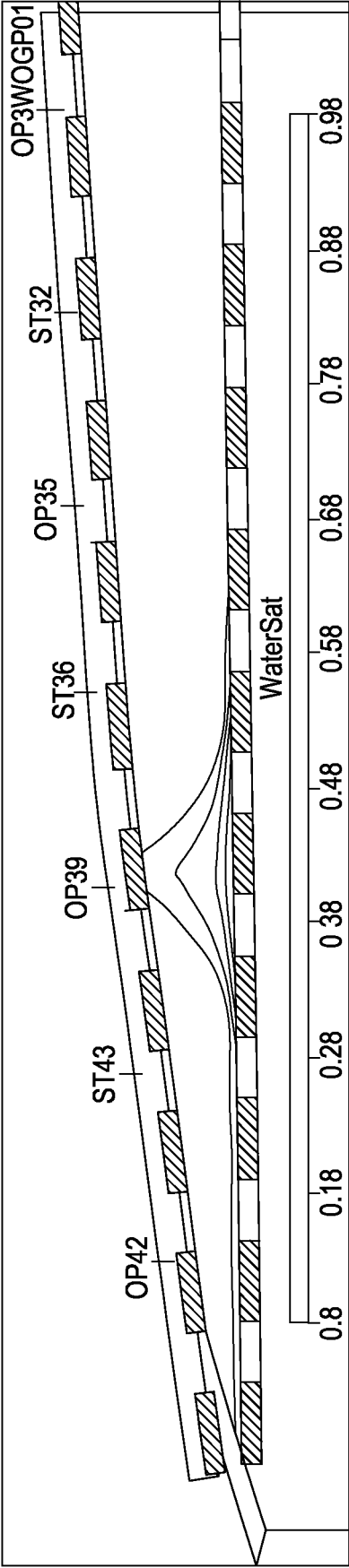


Figure 3a

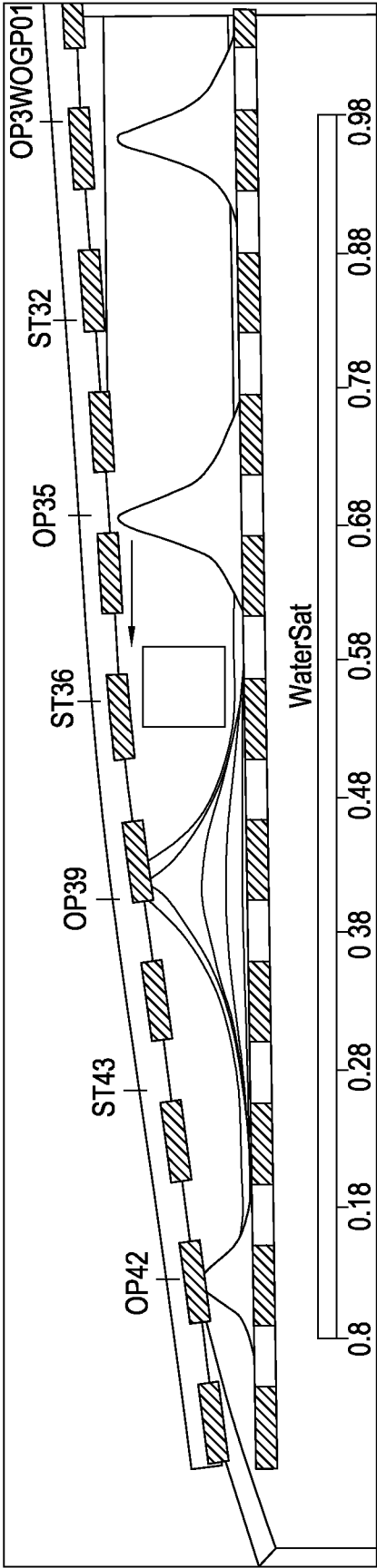


Figure 3b

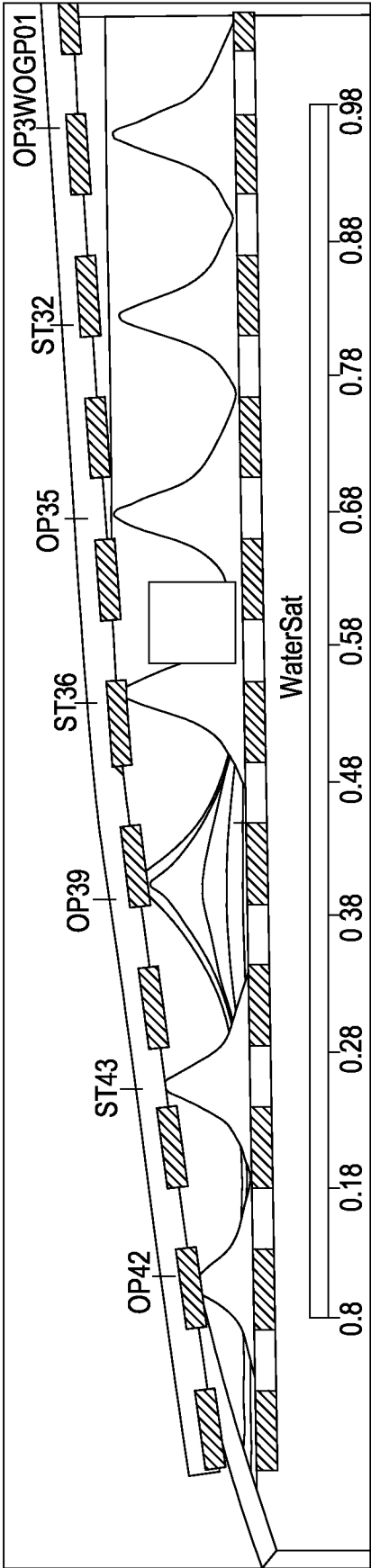


Figure3c

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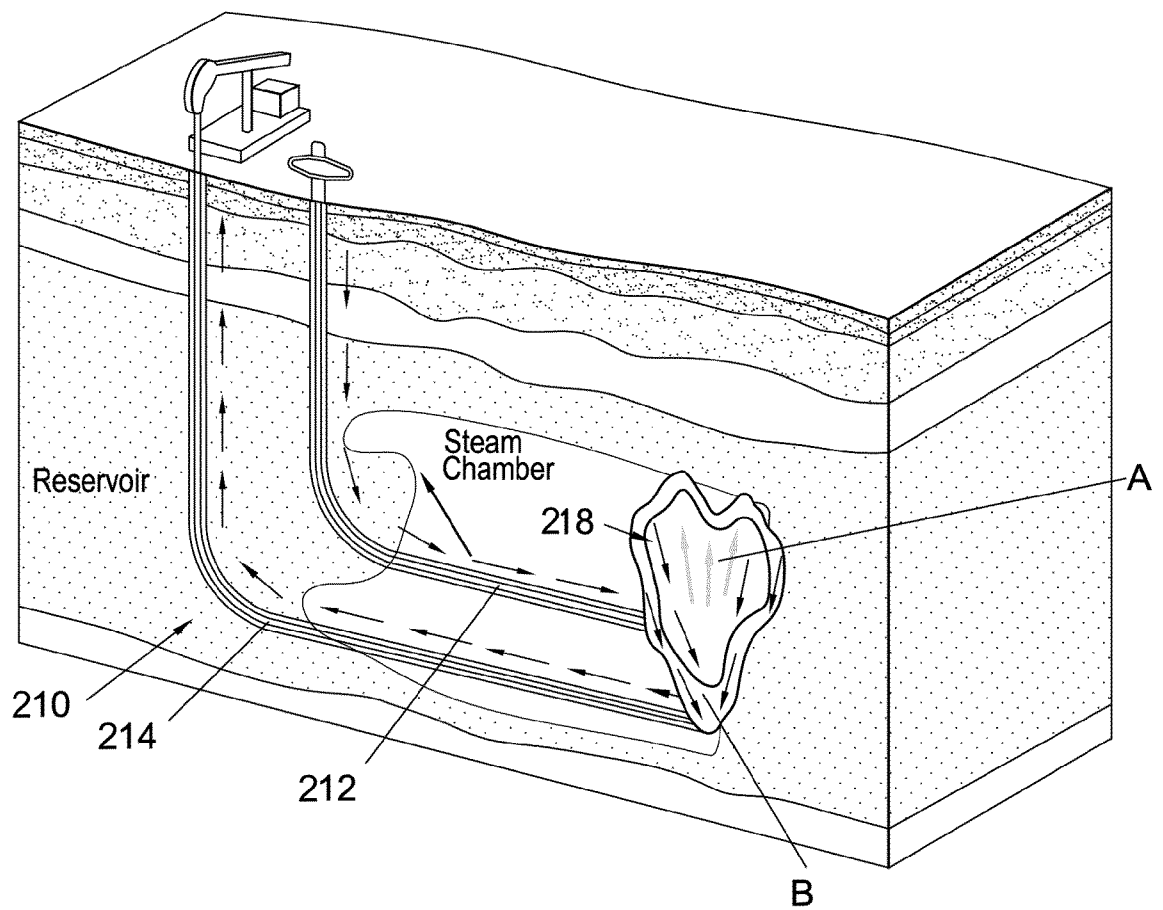


Figure 4

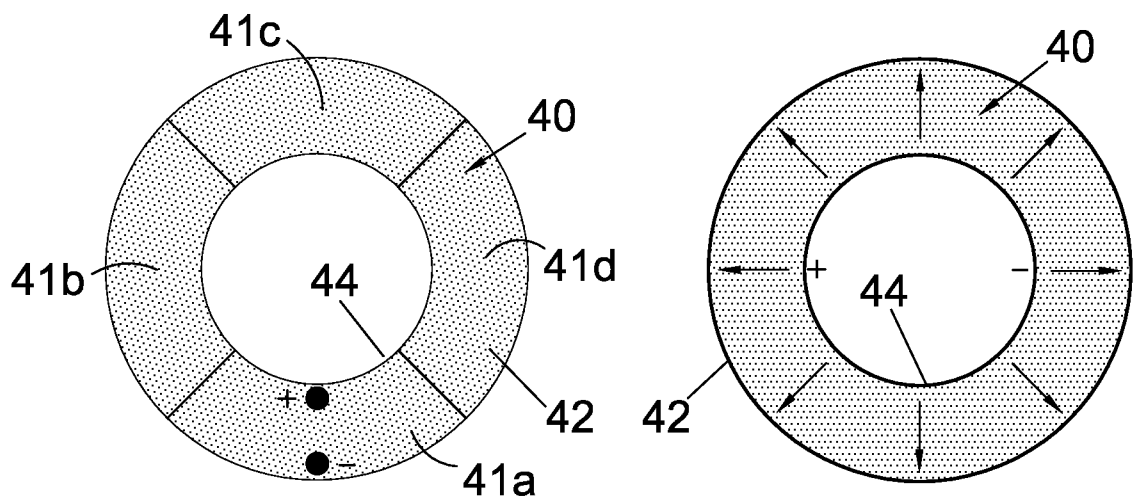


Figure 5a

Figure 5b

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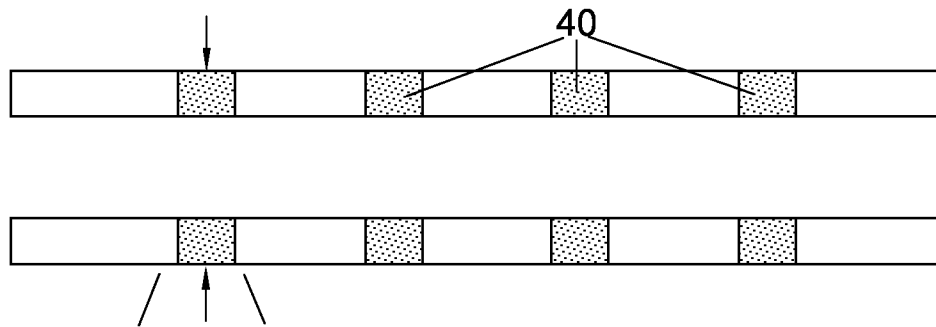


Figure 5c

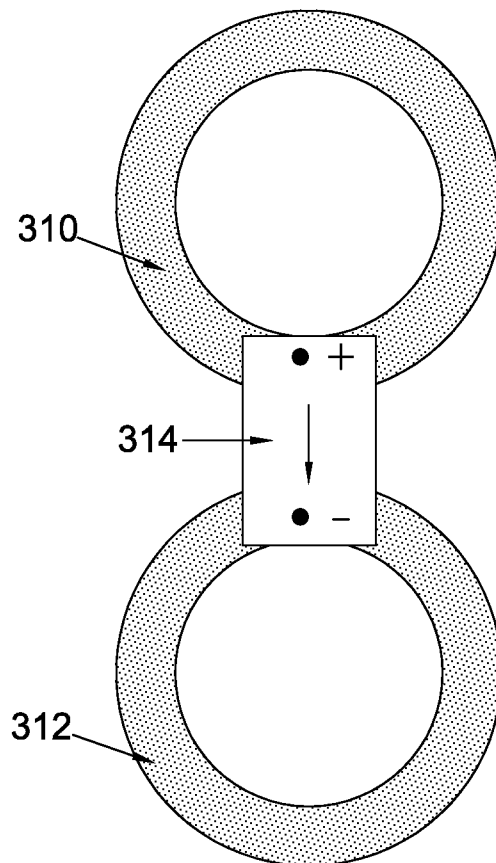


Figure 6

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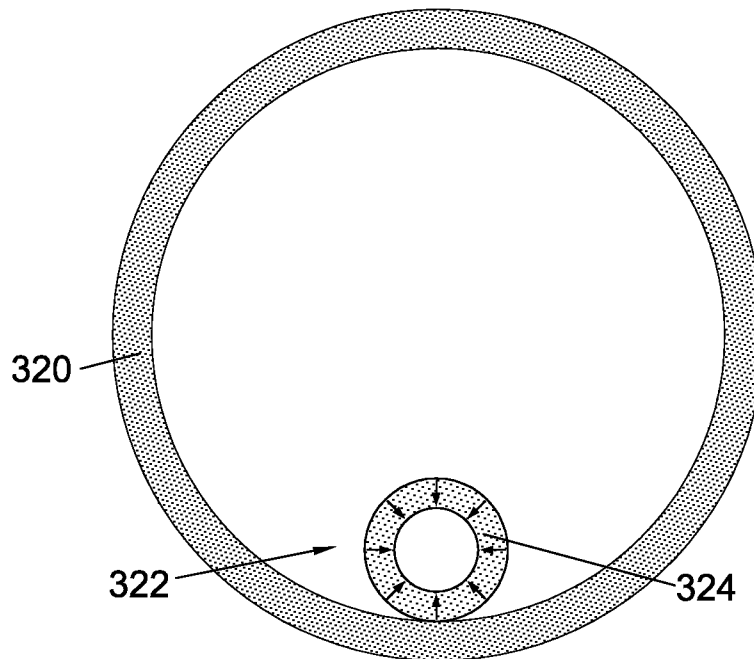


Figure 7a

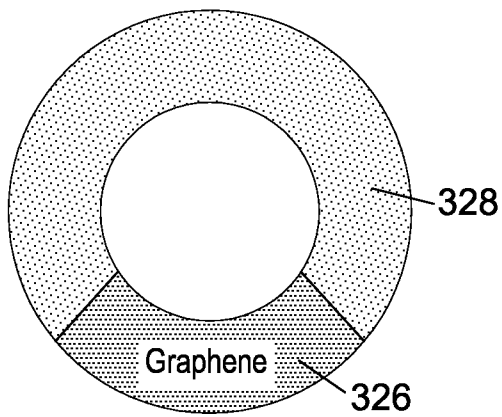


Figure 7b

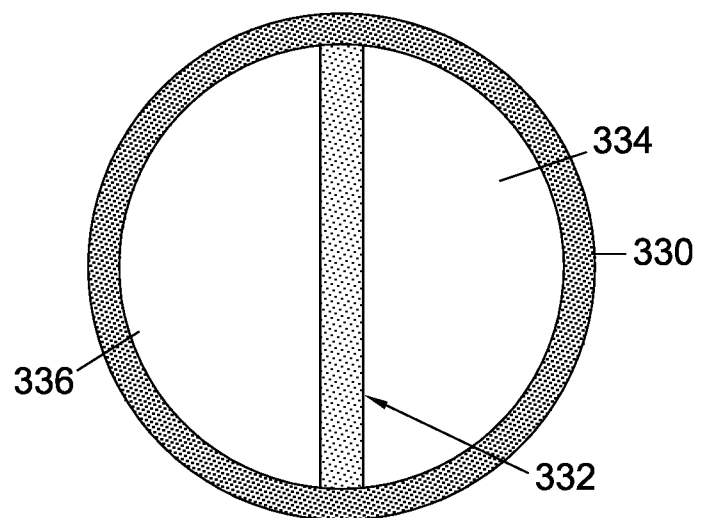


Figure 7c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/060741

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/32 E21B47/10
ADD.

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)
E21B H05B G01V

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 202 215 A (STANONIS ALPHONSO F) 24 August 1965 (1965-08-24) figure 1 column 2, line 4 - column 3, line 36 -----	1-31
A	EP 2 677 116 A1 (SCHLUMBERGER SERVICES PETROL [FR]; SCHLUMBERGER TECHNOLOGY BV [NL]; SC) 25 December 2013 (2013-12-25) figures 1-4 paragraphs [0028], [0032], [0038], [0041] - [0042] -----	1-31
A	US 2002/088618 A1 (RAMAKRISHNAN TERIZHANDUR S [US] ET AL) 11 July 2002 (2002-07-11) figures 1-8B paragraph [0038] ----- -/--	1-31



Further documents are listed in the continuation of Box C.



See patent family annex.

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 January 2015

Date of mailing of the international search report

26/01/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Brassart, P

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/060741

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/074510 A1 (ELECTRO PETROLEUM [US]; HAROUN MOHAMMED [AE]; WITTLE J KENNETH [US]; C) 7 June 2012 (2012-06-07) the whole document -----	1-31

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/060741

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3202215	A	24-08-1965	NONE	

EP 2677116	A1	25-12-2013	EP 2677116 A1	25-12-2013
			WO 2013178765 A2	05-12-2013

US 2002088618	A1	11-07-2002	BR 0105266 A	08-10-2002
			CA 2361026 A1	30-05-2002
			GB 2369631 A	05-06-2002
			NO 20015829 A	31-05-2002
			US 2002088618 A1	11-07-2002

WO 2012074510	A1	07-06-2012	CA 2818991 A1	07-06-2012
			US 2013277046 A1	24-10-2013
			WO 2012074510 A1	07-06-2012
