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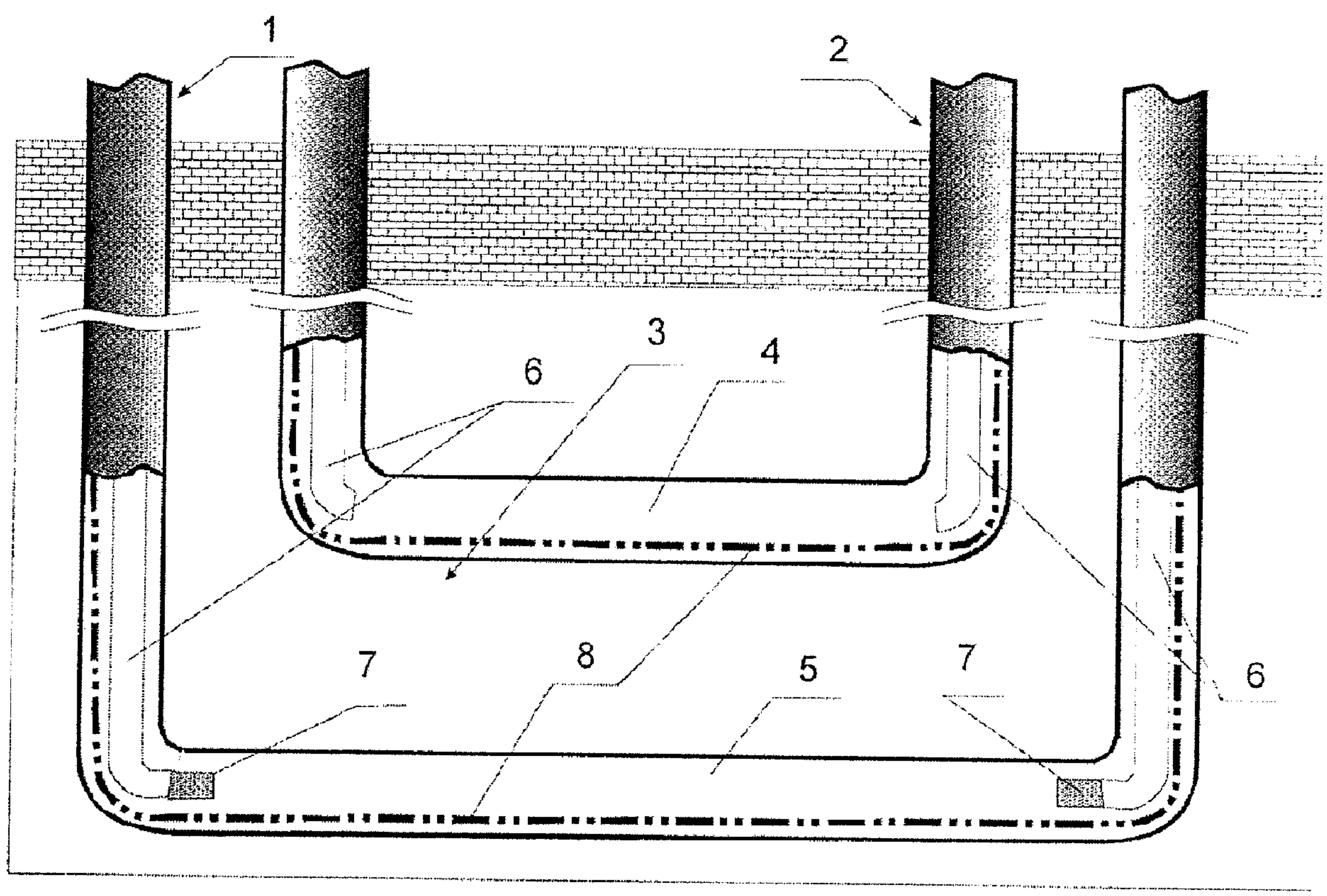
(54) **Titre :** METHODE DE PRODUCTION DE PETROLE LOURD
(54) **Title:** METHOD OF HEAVY OIL PRODUCTION



(57) **Abrégé/Abstract:**
The present invention relates to the oil production industry, and more particularly to heavy oil production methods using horizontal wells with steam stimulation of formations. The objective of the claimed method of heavy oil production is to increase heavy oil recovery through the enhanced reservoir sweep efficiency and more precise control of uniform steam chamber heating by controlling steam injection and product recovery conditions. To attain this objective, a pair of horizontal injection and production wells is used, with their parallel horizontal wellbores being spaced one above the other in the vertical plane of the productive

(57) Abrégé(suite)/Abstract(continued):
formation. The wells are completed with tubing strings for simultaneous heat carrier injection and product recovery. The method comprises steam injection, formation heating with steam chamber creation, product recovery through the tubing string of the production well and control of formation and well technological parameters. The novelty of the method is that the ends of the tubing strings are placed at the opposite end portions of the horizontal sections of the wellbores, and heating of the reservoir is started with the injection of steam into both wells. The interwell zone of the productive formation is heated thereby reducing heavy oil viscosity. A steam chamber is formed as the result of steam injection, the steam collecting at the top of the productive formation as the steam chamber grows. The produced water salinity is measured 2-3 times a week and the relation between the produced water salinity salinity and the uniformity of steam chamber heating is analyzed. The results of the salinity measurements are used for maintaining uniformity of steam chamber heating by controlling the heat carrier injection or the product recovery until a stable value of the produced water salinity is obtained.

Abstract

The present invention relates to the oil production industry, and more particularly to heavy oil production methods using horizontal wells with steam stimulation of formations. The objective of the claimed method of heavy oil production is to increase heavy oil recovery through the enhanced reservoir sweep efficiency and more precise control of uniform steam chamber heating by controlling steam injection and product recovery conditions. To attain this objective, a pair of horizontal injection and production wells is used, with their parallel horizontal wellbores being spaced one above the other in the vertical plane of the productive formation. The wells are completed with tubing strings for simultaneous heat carrier injection and product recovery. The method comprises steam injection, formation heating with steam chamber creation, product recovery through the tubing string of the production well and control of formation and well technological parameters. The novelty of the method is that the ends of the tubing strings are placed at the opposite end portions of the horizontal sections of the wellbores, and heating of the reservoir is started with the injection of steam into both wells. The interwell zone of the productive formation is heated thereby reducing heavy oil viscosity. A steam chamber is formed as the result of steam injection, the steam collecting at the top of the productive formation as the steam chamber grows. The produced water salinity is measured 2-3 times a week and the relation between the produced water salinity salinity and the uniformity of steam chamber heating is analyzed. The results of the salinity measurements are used for maintaining uniformity of steam chamber heating by controlling the heat carrier injection or the product recovery until a stable value of the produced water salinity is obtained.

Method of Heavy Oil Production

Field of the Invention

The present invention relates to oil producing industry, particularly to heavy oil production methods using horizontal wells and heat treatment of formations.

Background of the Invention

A method for developing a non-uniform oil-bearing formation comprising periods of pumping water through an injection well with simultaneous formation fluid recovery through producing wells when water pumping stops is know from the prior art (patent RU No. 2095549, IPC E21B43/22, published on 11.05.1994). Salinity of the produced water is periodically, once in 2-3 days, analyzed, and injecting water with simultaneous formation fluids recovery is carried out until stable salinity of the produced water is achieved. The method provides for more accurate determination of duration for the water injection and recovery of the formation fluid cycles.

The disadvantage of this method is low effectiveness when developing heavy oil formations using a method of thermal-steam formation treatment through horizontal wells.

A method of continuous viscous hydrocarbons recovery in a gravitation mode with heated liquid injection is known from the prior art (US patent No. 4344485, IPC E21B 43/26, published on 26.06.1980). In the method of developing heavy oil fields a pair of parallel producing well and injection well located one above the other in a vertical plane and completed with tubing strings are used. The method comprises injection of a heat carrier, heating the productive formation, forming a steam chamber, recovering products and controlling technological parameters of the formation and well.

The method is targeted on providing mobility to usually motionless heavy oil and withdrawing it from a tar sand reservoir with a producing well and injection well. Initially a heat carrier is injected through the injection well at a high speed so that a heat connection is formed between the wells, and a heated penetrable (steam) chamber is created.

At the chamber border steam is condensed, and heat is transferred to cooler surrounding areas. Oil temperature near the chamber increases, and oil flows down together with the hot steam condensate. Oil is continuously recovered at a place that is lower than the steam chamber.

The heat carrier expands the heated penetrable chamber while oil flows continuously in the producing well.

The movable heavy oil is recovered through the producing well.

Steam is used as the heat carrier.

Oil production is controlled so that separate flows of oil and water are adjusted and excess steam breakthrough is eliminated.

Various configurations of wells are used in the invention. The following factors are common for all configurations: (a) a producing well is "extended" through the tar sand formation as a horizontal wellbore or by creating ruptures (or combination of both); (b) a "heat connection" between the producing well and injection well is created before starting oil production.

Double concentric strings are arranged inside the casing string. Inner string is inside the surrounding outer string of bigger diameter.

The water and heavy oil recovery are thoroughly controlled to provide optimum oil production without excess steam breakthrough.

Low effectiveness of the method in developing heavy oil fields due to lack of adjustment of uniform steam chamber heating is the main disadvantage of the method.

The closest reference in terms of technology is a method of heavy oil production disclosed in RU patent No. 2305762, IPC E21B 43/24, published on 10.09.07. In the method a pair of horizontal producing well and injection well is used, horizontal wellbores of the wells are parallel one above the other in a vertical plane of the production formation. The wells are provided with tubing strings for simultaneous injection of a heat carrier and product recovery, heating the production formation, creating a steam chamber, recovering products through the producing well tubing string and controlling technological parameters of the formation and wells. The trajectory of the horizontal wellbore passes not lower than the minimum distance to the subface of the heavy oil or bitumen or water-bitumen contact increasing water-free period of well operation.

Casing strings with a filter in the production interval are installed, annular space is cemented, and tubing strings with centralizers are arranged. The heat carrier is injected through the upper horizontal injection well, and simultaneously product is withdrawn through the lower horizontal well.

The mode of injection is selected depending on in-place permeability, pay thickness of the formation, oil or bitumen viscosity. The injected heat carrier moves to the formation top forming a steam chamber. Heavy oil is displaced by the heat carrier over the entire surface.

Volumes of injected steam and recovered heavy oil, an amount of water in oil and pressure at both well heads are periodically checked. All above parameters characterize the formation and the well operation, and they are technological parameters of the formation and the well respectively. The modes of steam injection are changed if required, and optimum modes of heavy oil recovery are selected.

However a breakthrough of condensate or formation water to the producing well can happen in producing heavy oil. It is accompanied by an increase or decrease in temperature near the producing well and by a decrease in uniformity of formation heating and water-free period of the producing well operation. Selection of water injection mode according to this method does not allow controlling uniformity of formation heating accurately enough. What is more, said position of the producing wellbore results in lesser heat coverage of the formation.

The disadvantage of the method is significant energy consumption, low effectiveness of heavy oil recovery due to insufficient control of uniform steam chamber heating.

The technical objective of the present method of heavy oil production is to increase heavy oil recovery through increase in coverage of the formation with thermal action, providing more accurate control of steam chamber heating uniformity by adjusting modes of heat carrier injection and product recovery. The method is an addition to the scope of technology methods of heavy oil production.

The technical result is achieved using the claimed method of heavy oil production. The method comprises providing a pair of horizontal injection and producing wells having horizontal wellbores arranged parallel one above the other in the vertical plane of the productive formation. The wells are provided with tubing strings for simultaneous injection of a heat carrier, production of oil, heating the production formation through creation of a steam chamber, and recovery of product through the tubing string of the producing well, at the same time controlling technological parameters of the formation and well. The method is novel because the ends of the tubing strings are located at the opposite sides of the parallel horizontal wellbores. The heating of the productive formation starts with steam injection through both wells for heating the interwell zone and lowering viscosity of heavy oil. A steam chamber is created by injection of the heat carrier spreading at the top of the productive formation. The size of the chamber increases with product recovery. Salinity of produced water is checked regularly (2-3 times a week), and the relation between the salinity of the produced water and the uniformity of steam chamber heating is evaluated. Taking into account the change in produced water salinity, uniform heating of the steam chamber is adjusted by controlling the heat carrier injection or product recovery until stable level of produced water salinity is achieved.

Brief Description of the Drawings

Figs. 1a, b show positions of the wells.

Figs. 2, 3, 4 and 5 show examples of particular embodiments (graphs of relation between recovery of heavy oil and produced water salinity).

Description of the Invention

At present heat treatment for increasing amount of recoverable oil from heavy oil and natural bitumen deposits has no alternative. The most common methods of such heat treatment are the method based of using steam or a mixture of steam and gas.

Oil extraction increases when steam is injected. It is due to a decrease in viscosity of oil under heating, its thermal expansion, distillation of residual oil by steam, beneficial effect of oil and water movement and phase penetrability of oil and water, and effect of gas drive.

A pair of horizontal injection and producing wells having their horizontal wellbores arranged parallel in a vertical plane of the formation one above the other, the wells being provided with tubing strings.

A heat carrier is injected in the heavy oil deposit heating the productive formation by creating a steam chamber, the product is recovered though the tubing string of the producing well, and technology parameters of the formation and the well being controlled.

The method of heavy oil production is effective when at least one pair of one-wellhead or two-wellhead horizontal wells is used.

When two-head horizontal wells are used, a tubing string is lowered through each head, and their ends are positioned at the beginning and at the end of the parallel horizontal wellbores (Fig. 1a).

When a one-head horizontal well is used, two parallel tubing strings are lowered, and their ends are also positioned at the beginning and at the end of the conditionally horizontal portion of the well (Fig. 1b). When it is difficult to arrange a pair of parallel tubing strings, the wells can be provided with continuous (flexible) tube.

The diagram of string positions shown in Figs. 1a and 1b include a producing well 1 and an injection well 2 in productive formation 3 with or without rising to the day surface. The wells are drilled so that the horizontal wellbore 4 of the well 2 is above the horizontal wellbore 5 of the well 1 in one vertical plane at a distance from each other. The well 2 is used for injecting a heat carrier in the formation, and the well 1 is used for recovering heavy oil. The wells are provided with tubing strings 6 lowered from different heads of the two-head well (Fig. 1a) and lowered parallel in a one-head well (Fig. 1b). Ends of tubing strings are positioned at a beginning and at an end of the horizontal wellbore to allow injecting a heat carrier and withdrawing production simultaneously at two points. Such positioning of the tubing strings provides for wider heat action on the formation. The well 2 is equipped with pumps 7 for lifting heavy oil to the surface. The upper horizontal wellbore is used for injection of the heat carrier (steam) into the formation and creation of a steam chamber. The process of the thermal-steam formation treatment starts with the step of preliminary heating when steam is circulated in both wells. The interwell zone (the zone between the producing and injection wells) is heated wherein the viscosity of heavy oil decreases, it expands, and its mobility rises. Then in the process of the heavy oil recovery steam is pumped in the injection well, the steam moves to the top of the production formation due to difference in the densities creating an expanding steam chamber. At the surface of the interface between the steam chamber and the cold oil-saturated mass there is continuous heat exchange. As a result, steam is condensed into water that flows under gravity to the producing well together with the heated heavy oil.

Product is withdrawn at two opposite ends of the horizontal wellbore of the producing well. The product comprises produced formation water of high salinity besides heavy oil and condensed water. The formation water salinity decreases when it mixes with the condensate, and the produced water salinity has an intermediate value. Steam salinity and correspondingly condensate salinity are equal to zero, i.e. C_s<1 g/l, while the salinity of the formation water can be $C_{s \cdot w}$ = 100 g/l. The salinity of produced water can vary in the range from 1 to 100 g/l depending on the heavy oil deposit development stage.

In the mode of continuous injection and withdrawal a balance is established between the amount of extracted oil and the salinity of the produced water. This value of water salinity is called an equilibrium value of salinity. Change in the equilibrium is indicated by a change in salinity of the produced water. In the process of product withdrawal the salinity of the produced water is periodically, 2 or 3 times a week, is determined, and changes are reviewed and a graph of interrelation of the heavy oil extraction and the salinity of the produced water is plot.

An increase in the salinity of the produced water by more than 10% to the equilibrium salinity value indicates that the withdrawal of the formation water having a temperature in the range of 5 to 15°C grows. As a result, the temperature near the producing well and in the interwell zone drops leading to uneven heating of the steam chamber and decreasing of the formation portion under thermal-steam treatment. Temperature decrease near the producing well and in the interwell zone results in a recovered heavy oil viscosity increase in its turn leading to a decrease in the amount of extracted heavy oil and to a decrease in the effectiveness of the thermal-steam treatment.

For decreasing the salinity of the produced water and increasing the temperature near the producing well and in the interwell zone thereby increasing steam chamber heating uniformity, it is required either to increase the volume of injected steam or to decrease the product withdrawal and consequently the volume of produced water. When the volume of injected steam is increased, the whole volume of the steam chamber is more evenly heated, and the decrease in the temperature near the producing well and in the interwell zone is stopped. At the same time the formation water is diluted by the condensate, and the salinity of the produced water decreases. After steady heating of the steam chamber is restored, the balance between the amount of extracted oil and the salinity of the produced water is restored too but not necessarily at the same level as before, as indicated by the graph of relation between the extraction of heavy oil and the salinity of the produced water.

When the salinity of the produced water falls below 10% of the balance level, it also indicates that the steam chamber is not heated uniformly. In this case a steam breakthrough to the producing well can occur. It results in steam drain increasing energy consumption. The steam breakthrough can also lead to some damage to the technology equipment because of high temperature. That is why it is important to decrease the volume of injected steam or increase the withdrawal of the product when the salinity of the produced water falls. When the product recovery increases, the volume of the cold formation water with high level of salinity increases too, therefore the salinity of the produced water also increases. As mentioned above, the temperature of the formation water is in the range of 5-15°C, and when its recovery increases, the temperature near the producing well and in the interwell zone decreases. The increasing recovery continues until the balance between the amount of extracted oil and the salinity of the produced water is restored. The graph of the relation between the extraction of heavy oil and the salinity of the produced water shows when the balance is restored.

A method of controlling uniform heating of the steam chamber using temperature detectors is known in the prior art but it is not effective because of frequent failures of the detectors.

It follows from aforesaid that the method of heavy oil production allowing to control injection of heat carrier and product recovery based on the analysis of produced water salinity is a very simple and effective method for controlling uniformity of steam chamber heating and enhancing effectiveness of oil extraction from heavy oil fields.

Method Embodiment Examples

Example 1

At the experimental site of the Ashalchinsky heavy oil field at a depth of 90 having non-uniform formations with a thickness of 20-30 m, a temperature of 8°C, a pressure of 0.5 MPa, oil saturation of 0.70 units, a porosity of 30%, a permeability of 2.65 μm^2, and oil with a density of 960 kg/m^3 and a viscosity of 22000 mPa·s, a pair of horizontal two-head wells (Fig. 1a) was drilled.

The pair included an injection well and a producing well with horizontal wellbores being parallel and located one above the other in the vertical plane of the productive formation and provided with tubing strings for simultaneous injection of a heat carrier and product recovery. Before putting the producing well in operation, a zone between the wells was heated by simultaneous circulation of steam through each of said wells. In the process of heavy oil recovery, steam is pumped through the injection well. Steam rises and forms a steam chamber growing in size. In the process of recovery salinity of the produced water is regularly (2-3 times a week) determined, and a graph of relation between the extraction of heavy oil and the salinity of the produced water is plotted (Fig. 2). At the beginning stage of the heavy oil formation development there is a balance between the amount of extracted oil and the salinity of the produced water during the period from 15.03.07 and 20.03.07 indicating uniform heating of the steam chamber. The well production of heavy oil is 12 m^3/day, and the salinity of the produced water is 2.15-2.3 g/l. The balance (average) salinity is 2.2 g/l. The analysis carried out on 25.03.07 indicates that salinity is growing from 2.3 g/l (on 20.03.07) to 3.1 g/l, or by 34.8% while the well production drops from 12 m^3/day to 6 m^3/day. It is an indication that the inflow of cold formation water increased bringing the temperature and mobility of heavy oil down and causing disruption in uniform steam chamber heating. The volume of steam injection was 44 m^3/day at that moment. On the ground of the analysis result, it was decided to increase the volume of injected steam. It was increased to 60 m^3/day (Fig. 2) from 25.03.07 to 30.03.07.

After that the salinity of the produced water began to decrease and was 2.28 g/l on 30.03.07; the well production increased to 11.3 m^3/day. The well production of heavy oil stabilized at 11.3 m^3/day, and later the salinity changed insignificantly in the range from 2.28 g/l to 2.4 g/l.

Fig. 4 represents the time graph of relation between the extraction of heavy oil and the salinity of the produced water. In the period from 24.08.07 to 04.09.07 the salinity of the produced water increased from 3.7 g/l to 4.5 g/l, or by 22%. The daily production of heavy oil decreased from 12.7 m^3/day to 10.5 m^3/day indicating cooling down of the steam chamber. For improving the uniformity of steam chamber heating, the withdrawal of the produced water was decreased from 99 m^3/day to 86 m^3/day. After that the salinity of the produced water began to gradually decrease and reached the value of 3.8 g/l, and the heavy oil production began to grow and stabilized at 12.9 m^3/day.

Example 2

At the experimental site of a heavy oil field at a depth of 90 m having non-uniform formations with a thickness of 20-30 m, a temperature of 8°C, a pressure of 0.5 MPa, oil saturation of 0.70 units, a porosity of 30%, a permeability of 2.65 μm^2, and oil with a density of 960 kg/m^3 and a viscosity of 22000 mPa·s, a pair of horizontal one-head wells (Fig. 1b) was drilled.

There was a balance relation between the amount of recovered heavy oil (12-12.8 m^3/day) and the salinity of the produced water (3.58-3.45 g/l) during the period from 07.06.07 to 22.06.07. The balance (average) salinity value was 3.52 g/l. Analysis of the next sample revealed that by 27.06.07 the salinity of the produced water sharply dropped to 2.2 g/l, the change by 37% of the balance value. It shows that a steam breakthrough to the producing well occurred resulting in decrease of action on the formation, decrease of the uniformity of steam chamber heating and drain of heat carrier. For normalizing the salinity and correspondingly temperature near the producing well, the extraction of liquid was increased from 86.1 m^3/day to 99 m^3/day. The salinity was normalized by 07.07.07 to 3.45 g/l. The oil recovery dropped at first moment after the steam breakthrough but then after the extraction increase it stabilized at the level of 13.5 m^3/day (Fig. 3).

Example 3

The graph of changing salinity of the produced water and heavy oil extraction in time is shown in Fig. 5. There was a stable relation between the heavy oil extraction and the salinity of the produced water up to 26.06.08. As a result of a steam breakthrough the salinity of the produced water and the heavy oil recovery decreased. For restoring the balance, the volume of steam injection was decreased from 80 m^3/day to 65 m^3/day. The salinity increased to 3.1 g/l on 07.07.07 and further it was stable at this level. The oil recovery gradually increased up to 9.2 m^3/day.

The claimed method of heavy oil production allow increasing heavy oil recovery through the enhanced reservoir sweep efficiency and more precise control of uniform steam chamber heating by changing heat carrier injection and production conditions.

WHAT IS CLAIMED:

1. A method of heavy oil production using a pair of horizontal injection and production wells with their parallel horizontal wellbores spaced one above the other in a vertical plane of a productive formation, said wells being completed with tubing strings for simultaneous steam injection and product extraction, said method comprising injecting a heat carrier, heating the productive formation and creating a steam chamber, recovering product through the tubing string of the production well and controlling technological parameters of the formation and the well,

characterized in that:

placing the ends of the tubing strings at the opposite end portions of the horizontal sections of the wellbores;

heating the productive formation starting with injection of steam into both wells;

heating the interwell zone of the productive formation thereby reducing heavy oil viscosity;

forming a steam chamber by injecting steam as it fills the top of the productive formation and expands in the process of product recovery;

measuring the produced water salinity 2-3 times a week;

analyzing relation between the produced water salinity and the uniformity of steam chamber heating;

using results of the salinity measurements for maintaining uniformity of steam chamber heating by controlling the heat carrier injection or the product recovery until a stable value of the produced water salinity is obtained.

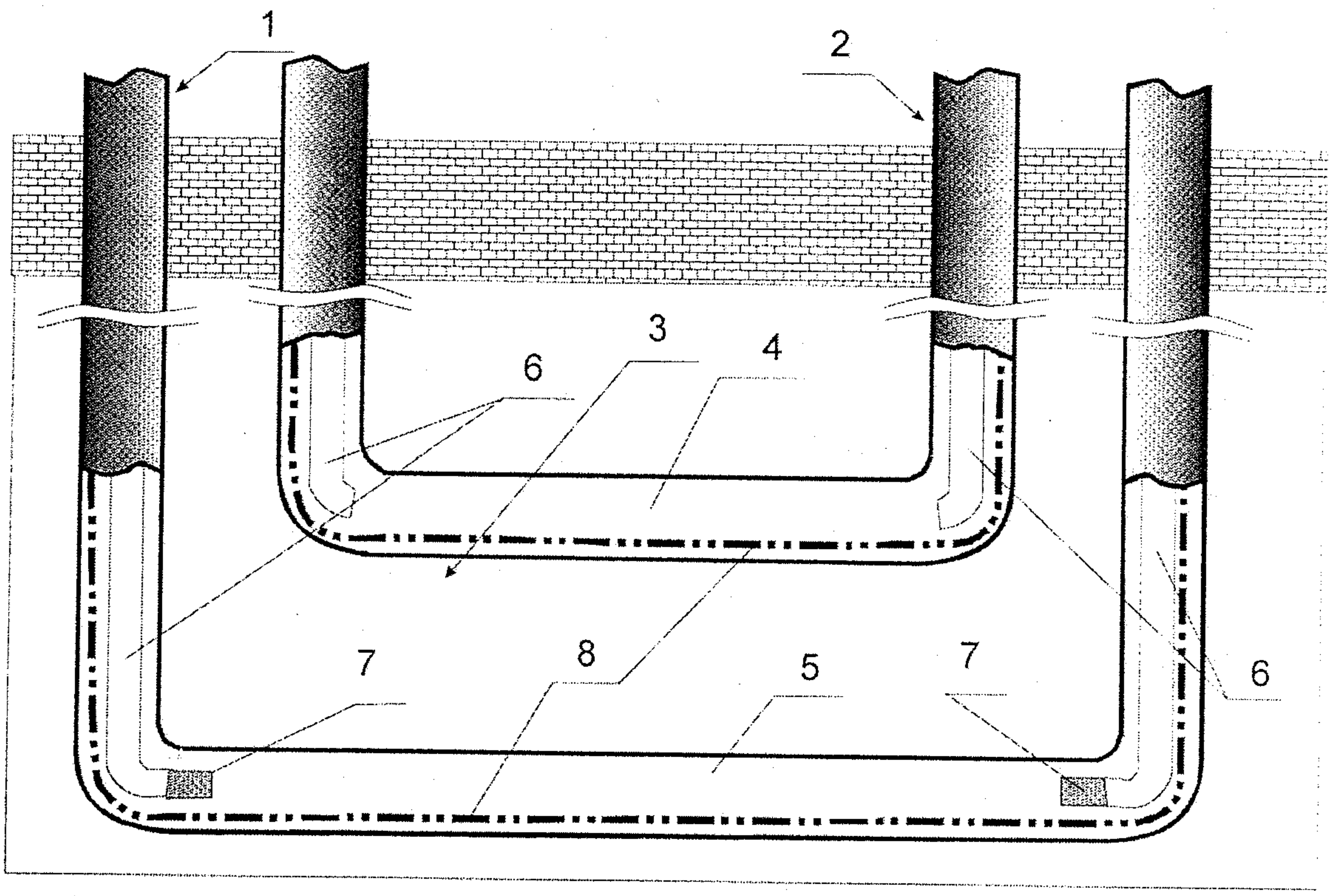


Fig. 1a

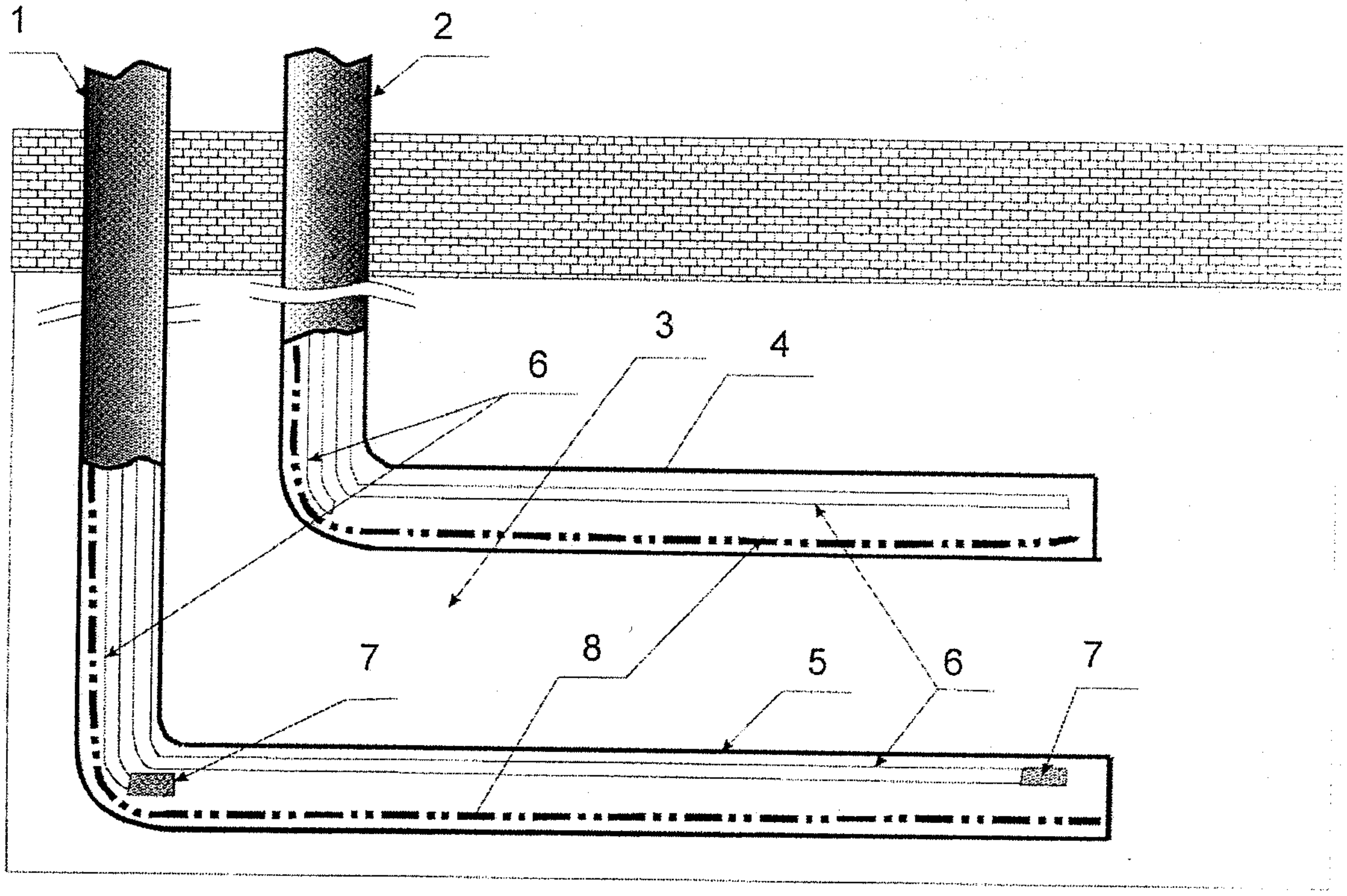


Fig. 1 b

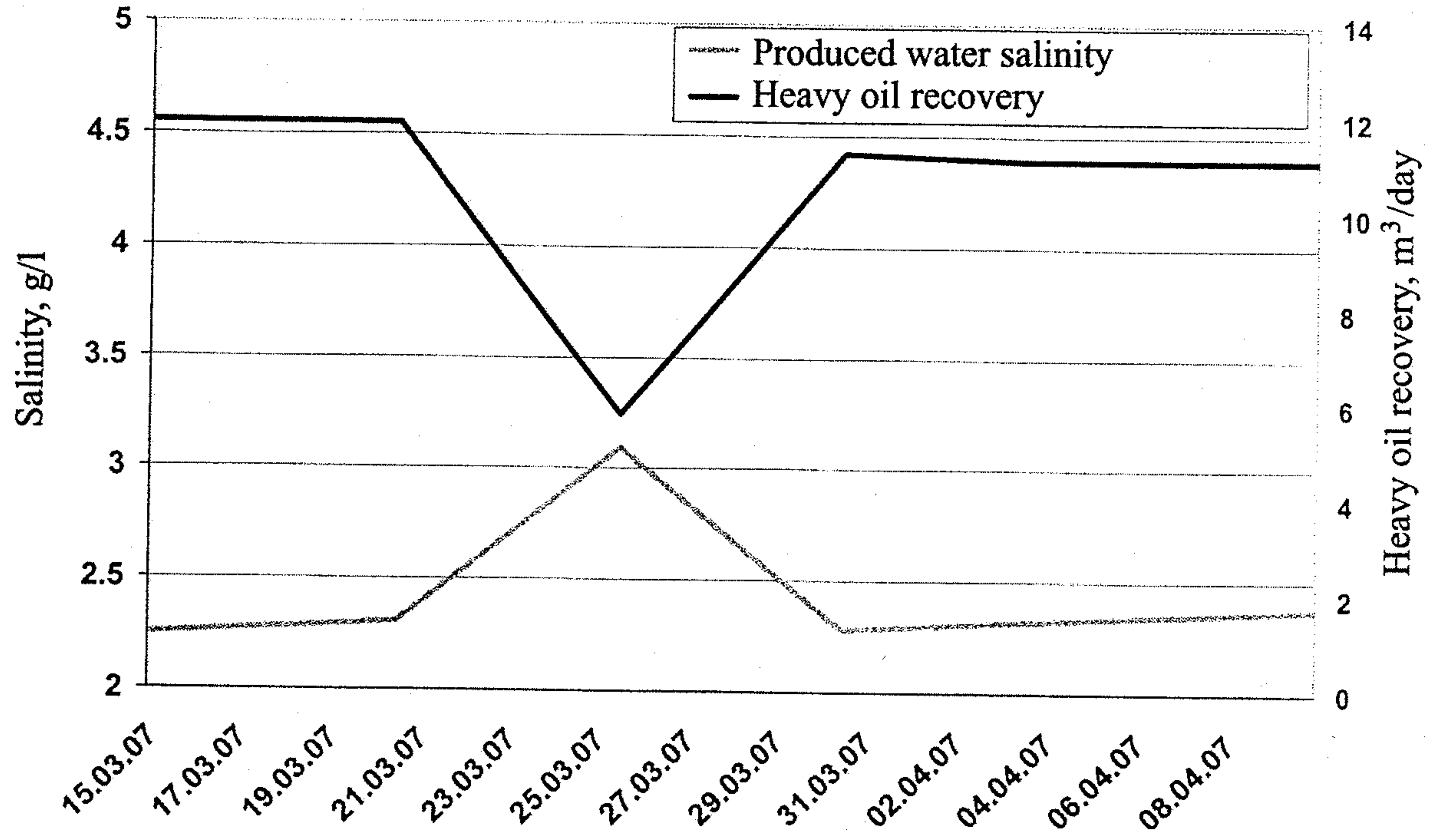

5
4.5
4
3.5
3
2.5
2
Salinity, g/l
14
12
10
8
6
4
2
0
Heavy oil recovery, m3/day
Produced water salinity
Heavy oil recovery
15.03.07
17.03.07
19.03.07
21.03.07
23.03.07
25.03.07
27.03.07
29.03.07
31.03.07
02.04.07
04.04.07
06.04.07
08.04.07

Fig. 2

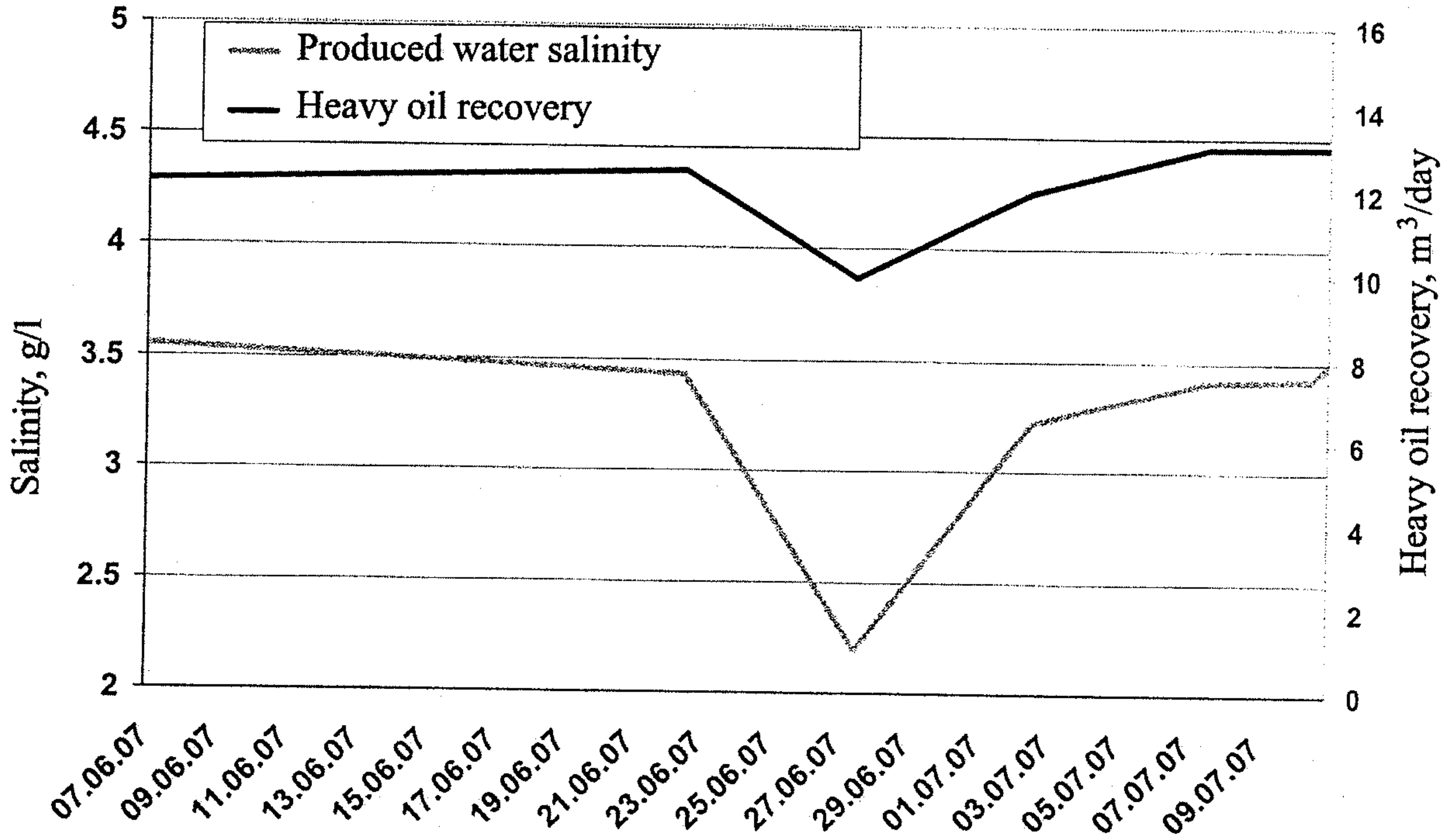

5
4.5
4
3.5
3
2.5
2
Salinity, g/l
16
14
12
10
8
6
4
2
0
Heavy oil recovery, m3/day
Produced water salinity
Heavy oil recovery
07.06.07
09.06.07
11.06.07
13.06.07
15.06.07
17.06.07
19.06.07
21.06.07
23.06.07
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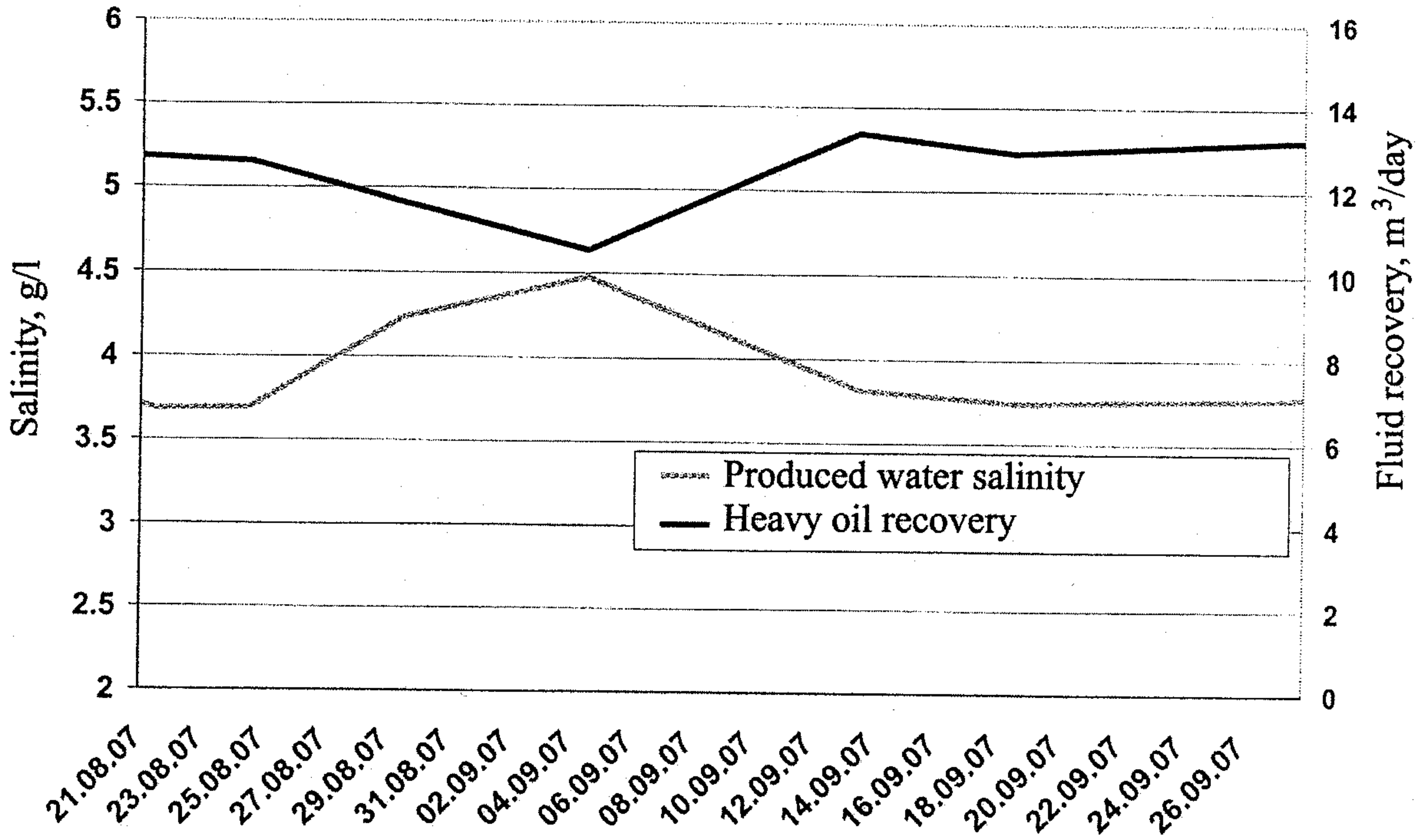
Fig. 3



Salinity, g/l
Fluid recovery, m3/day
Produced water salinity
Heavy oil recovery
6
5.5
5
4.5
4
3.5
3
2.5
2
16
14
12
10
8
6
4
2
0
21.08.07
23.08.07
25.08.07
27.08.07
29.08.07
31.08.07
02.09.07
04.09.07
06.09.07
08.09.07
10.09.07
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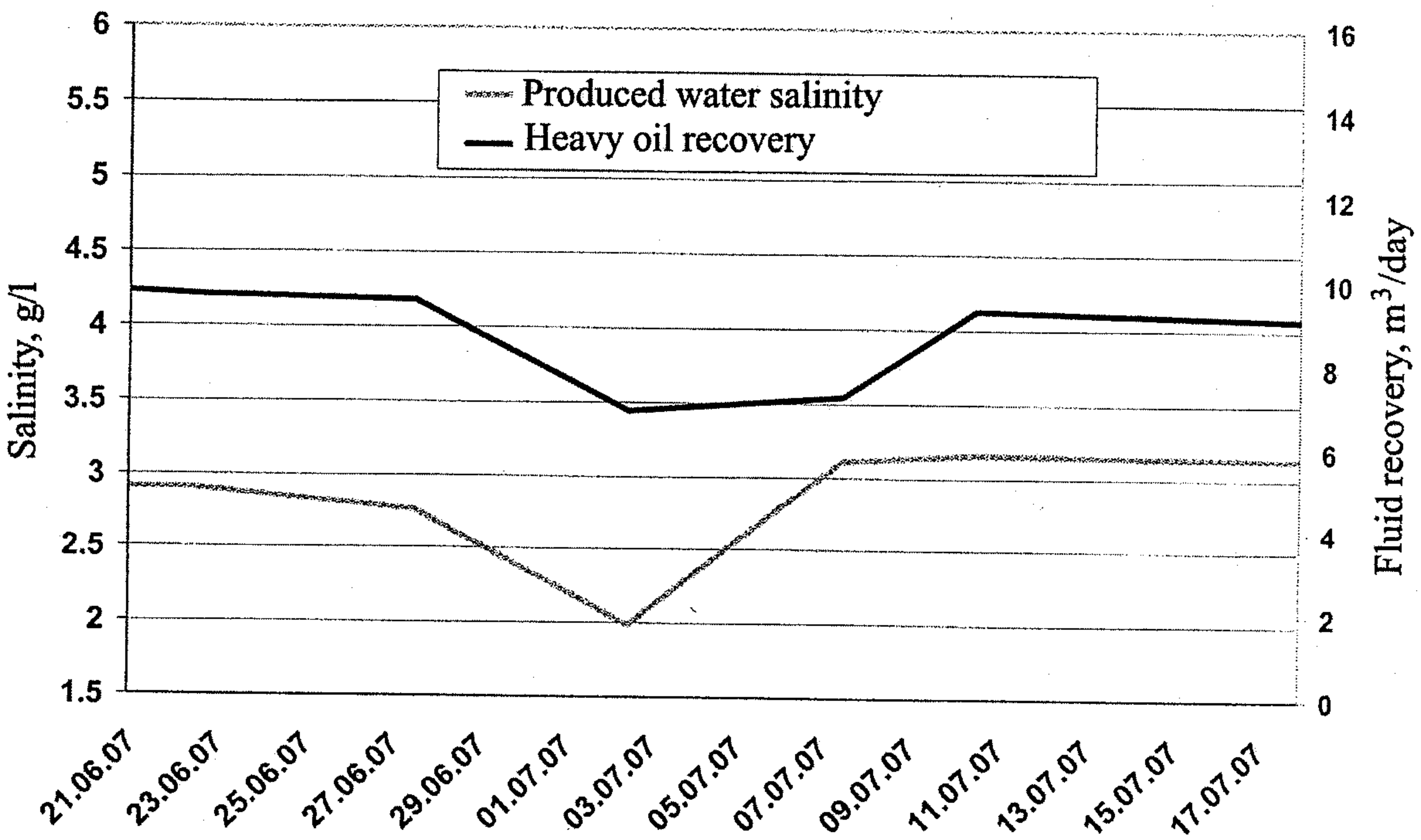
26.09.07

Fig. 4



Salinity, g/l
Fluid recovery, m3/day
Produced water salinity
Heavy oil recovery
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
16
14
12
10
8
6
4
2
0
21.06.07
23.06.07
25.06.07
27.06.07
29.06.07
01.07.07
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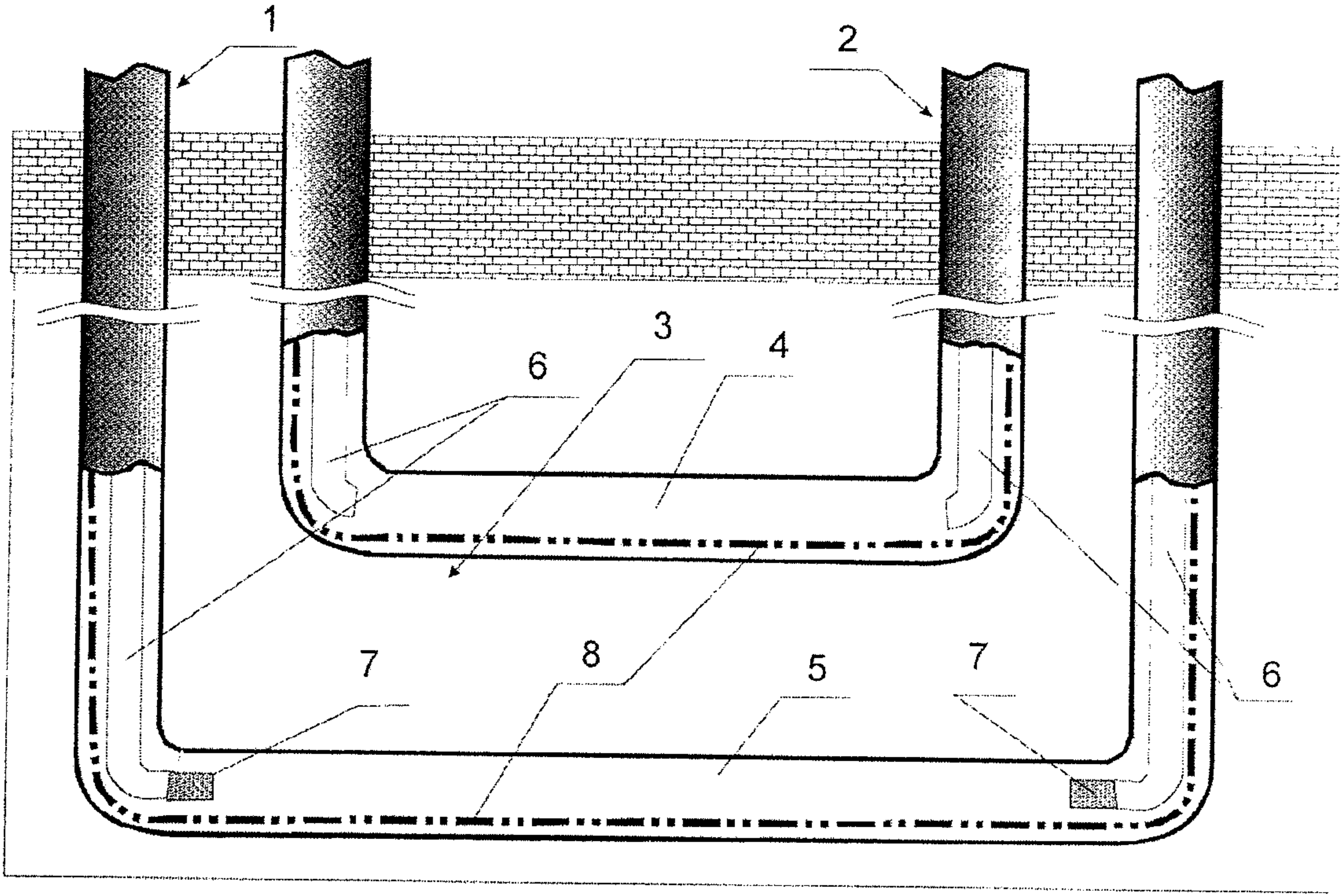
Fig. 5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