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(54) **System for downhole separation**

(57) System for the subsurface separation of well fluid into a gas-containing fluid and a liquid and for transportation of at least the gas-containing fluid to the surface, which system comprises at least two riser wells (3a/b/c) each extending upwardly from a production interval (6a/b/c) to the surface (7), wherein the production interval (6a/b/c) of each riser well (3a/b/c) penetrates an underground production formation (8a/b/c) and is arranged to receive well fluid therefrom, and wherein in or

above each production interval (6a/b/c) an underground main separator (12a/b/c) is arranged for separation of the well fluid into a gas-containing fluid and a liquid, which main separator (12a/b/c) is connected to means (18a/b/c) for transporting the gas-containing fluid to the surface, and to means (24a/b/c) for transporting the liquid to a collection well section (20), which collection well section (20) is arranged below the lowest production interval (6a/b/c) and has an outlet for liquid (28).

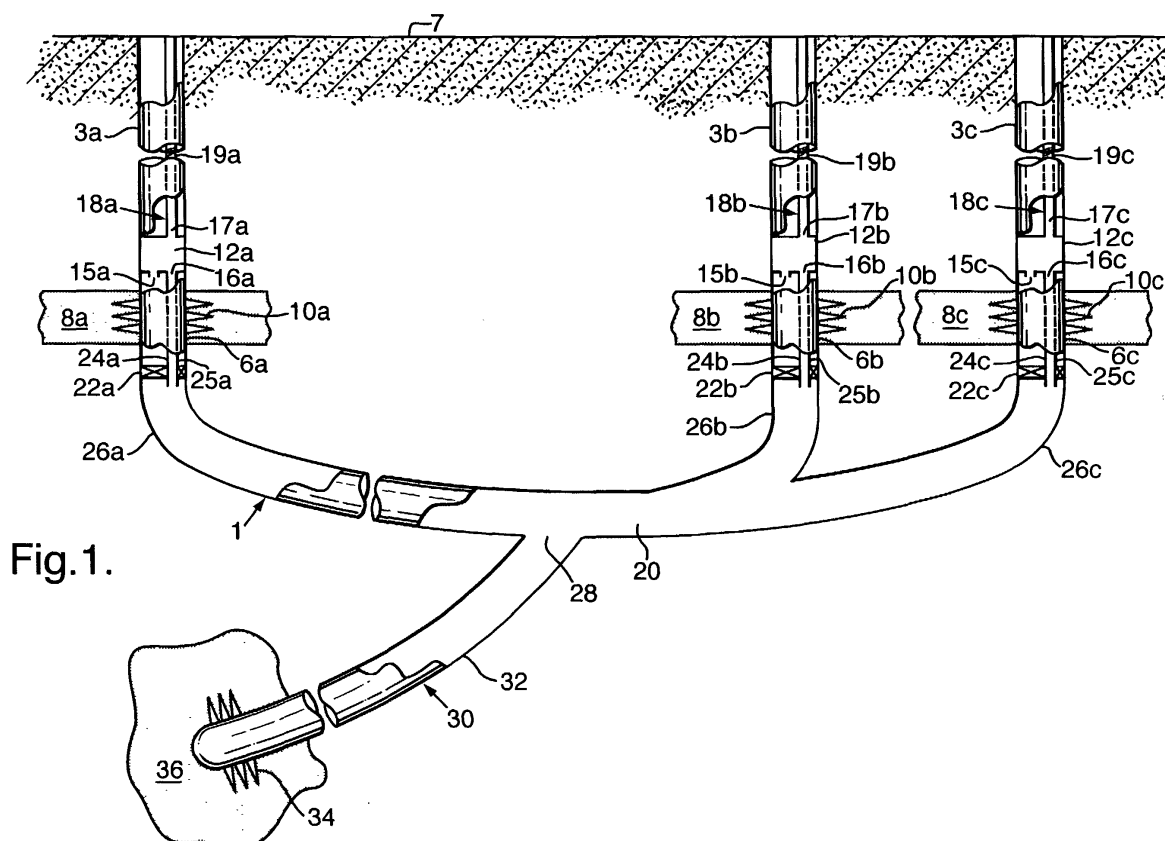


Fig. 1.

Description

[0001] The present invention relates to a system for subsurface separation of a well fluid into a liquid and a gas-containing fluid and for transportation of at least the gas-containing fluid to the earth's surface. It will be understood, that the earth's surface may also be the bottom of the sea.

[0002] In the specification and in the claims, the expression 'well fluid' will be used to refer to a fluid comprising gas and liquid, wherein the liquid can comprise hydrocarbon oil, water, or both. Hydrocarbon oil will be referred to as oil. A gas-containing fluid can be a liquid-free gas or a mixture of gas and liquid.

[0003] In many well systems for the production of oil or gas, the well fluid comprises both gas and liquid components. The gas can be dissolved in or physically mixed with the liquid, or both. Producing such a well fluid in practice presents a number of problems.

[0004] Problems occur for example in case the liquid comprises water (or brine). It is generally undesirable to produce the water together with gas or oil to the surface. Not only does the water limit the production capacity through a production well, it also bears the risk that ice plugs or gas hydrate plugs are formed at low temperatures. These plugs can cause enormous problems in downstream equipment.

[0005] Another problem is encountered in wells wherein the well fluid comprises large amounts of gas, and wherein one is mainly interested in the production of gas to the surface. There, liquid which is present in the production well above the production zone exerts a hydrostatic pressure and thereby impedes fluid flowing into the well from the underground production formation. Further, liquid hampers the application of special techniques for producing gas to the surface, e.g. gas compression techniques.

[0006] Yet another problem is encountered in wells wherein the well fluid comprises next to oil a significant amount of gas, and wherein one is mainly interested in the production of oil to the surface. If the reservoir pressure is insufficient for producing the oil, often additional pumping is applied. It is well known, however, that a significant amount of gas in the fluid severely decreases the pumping efficiency.

[0007] Wells provided with means for the subsurface separation of a well fluid are known in the art. However, a common problem of the known wells is that after separation the components have to be dealt with individually in the well. Transporting all components to the surface through the well is often not efficient, particularly in the event that one is only interested in the production of one of the separated components. It is sometimes an alternative to provide the well with means for discharging one of the separated components, e.g. water, into an underground formation. However, in a production field wherein a number of wells are arranged it is very expensive to provide each well with such discharge

means.

[0008] It is therefore an object of the present invention to provide an efficient system for subsurface separation of liquid from a well fluid.

[0009] To this end the present invention provides a system for the subsurface separation of well fluid into a gas-containing fluid and a liquid and for transportation of at least the gas-containing fluid to the surface, which system comprises at least two riser wells each extending upwardly from a production interval to the surface, wherein the production interval of each riser well penetrates an underground production formation and is arranged to receive well fluid therefrom, and wherein in or above each production interval an underground main separator is arranged to separate the well fluid into a gas-containing fluid and a liquid, which main separator is connected to means for transporting the gas-containing fluid to the surface, and to means for transporting the liquid to a collection well section which collection well section is arranged below the lowest production interval and has an outlet for liquid.

[0010] Applicant has found, that collecting the separated liquids in a collection well section below the lowest production interval allows an efficient further handling of the collected liquid. If the collected liquid is water of sufficient purity, it can for example be discharged via a central discharge system comprising a liquid discharge well for injection into an underground formation. If the liquid comprises oil, it can be produced to the surface via a central production well. If the liquid comprises oil and water, it can also be subjected to a further liquid separation step. In the latter case, relatively dry oil can be produced to the surface and sufficiently pure water can be discharged into an underground formation.

[0011] The invention will now be described by way of example in more detail with reference to the accompanying drawings, wherein

Figure 1 shows schematically a first embodiment of the present invention;

Figure 2 shows schematically a second embodiment of the present invention;

Figure 3 shows schematically detail III of Figure 2 drawn to a larger scale; and

Figure 4 shows schematically a third embodiment of the present invention.

[0012] Reference is made to Figure 1, showing a first embodiment of a system 1 according to the present invention, which embodiment is particularly well suited for the event that the well fluid mainly comprises gas and water. The system 1 for the subsurface separation of well fluid comprises three riser wells 3a, 3b, 3c each extending upwardly from a production interval 6a/b/c to the surface 7. Each production interval 6a/b/c penetrates an underground production formation 8a/8b/8c. The underground production formations 8a/8b/8c can all be part of the same formation. Each production interval 6a/b/c

is provided with inlet means 10a/b/c for receiving well fluid from the underground production formation 8a/b/c. Above each production interval 6a/b/c a main separator 12a/b/c is arranged. Each main separator has an inlet 15a/b/c for well fluid at its lower end, a first outlet 16a/b/c for separated liquid at its lower end, and a second outlet 17a/b/c for gas-containing fluid. The main separators 12a/b/c sealingly fit into the riser wells 3a/b/c in order to prevent fluid from bypassing the main separators. At the second outlet 17a/b/c the main separator 12a/b/c is connected to means 18a/b/c for transporting the gas-containing fluid to the surface 7 in the form of production tubing 19a/b/c.

[0013] Further, the system 1 comprises a collection well section 20 below the lowest production interval. In each riser well 3a/b/c a packer 22a/b/c is arranged below the production interval 6a/b/c. At the first outlet 16a/b/c the main separator 12a/b/c is connected to means 24a/b/c for transporting the liquid to the collection well section in the form of conduit 25a/b/c. The conduit 25a/b/c extends from the first outlet 16a/b/c through the packer 22a/b/c and opens into lower well section 26a/b/c below the packer 22a/b/c. The lower well sections 26a/b/c of the system 1 directly communicate with the collection well section 20.

[0014] The collection well section 20 has an outlet for liquid 28 which is connected to a liquid discharge system in the form of a water discharge system 30. The water discharge system 30 comprises a liquid discharge well 32, outlet means 34 for the injection of water into the underground formation 36, a pump (not shown) and means to prevent water from flowing back (not shown).

[0015] During normal operation of the system 1, well fluid comprising water and gas is received through the inlet means 10a/b/c. The packers 22a/b/c seal the passage of the well fluid to the well sections 26a/b/c, and therefore the well fluid is forced to enter the main separators 12a/b/c through the inlets 15a/b/c. The liquid separated from the well fluid comprises mainly water, and the separated water is passed through the outlets 16a/b/c via the conduits 25a/b/c and the well sections 26a/b/c to the collection well section 20. The collected water is discharged from the collection well section through the outlet 28 and the water discharge system 30 into the formation 36.

[0016] The gas-containing fluid remaining after separation of the water from the well fluid in the main separators 12a/b/c is passed through the second outlets 17a/b/c and via the production tubing 19a/b/c further on to the surface 7 from where it is discharged at the wellhead (not shown).

[0017] Reference is now made to Figure 2, showing schematically an alternative embodiment of the invention. Parts that are similar to parts discussed with reference to Figure 1 have been referred to with the same reference numerals. The system 2 of Figure 2 is particularly well suited for the situation that the well fluid received from the underground production formations 8a/

b comprises both oil and gas in significant quantities, and it provides for the separate production of gas and oil to the surface. The system 2 differs from the system 1 shown in Figure 1 in that it comprises only two riser wells 3a/b, and in that it comprises instead of a liquid discharge system a production well 50. The production well 50 extends downwardly from the surface 7, and it has an underground inlet 52 which is connected to the outlet 28 of the collection well section. The production well 50 can be provided with means for pumping liquid to the surface (not shown). A further difference between the system 2 and the system 1 is in the separation of the oil from the gas-containing fluid, which will be described in more detail with reference to Figure 3.

[0018] Reference is made to Figure 3, showing schematically detail III of Figure 2 drawn to a larger scale. Like numerals are used to refer to the same parts as in Figure 2. The well 3a is provided with a casing 70a. Within the production interval 6a, perforations 72a are arranged in the casing 70a to serve as inlet means 10a for well fluid from the underground production formation 8a. An upper packer 75a and a lower packer 22a are arranged above and below the production interval 6a. The upper packer 75a is provided with an opening 76a through which a conduit 78a is fitted. The conduit 78a has an inlet 79a arranged in the upper region 80a of the space 82a defined between the packers 75a and 22a. The outlet 85a of the conduit 78a is connected to the inlet 87a of the main separator 88a, which main separator is arranged above the production interval 6a. The main separator 88a further has a first outlet 90a for separated oil and a second outlet 91a for gas-containing fluid. The outlet 91a is connected to means for transporting gas-containing fluid to the surface in the form of production tubing 92a, and the outlet 90a opens into the space 93a above the upper packer 75a. Further, a conduit 94a is arranged having an inlet 95a in the lower part of the space 93a and an outlet 96a opening into the well section 26a below the lower packer 22a. The conduit 94a is fitted through an opening 97a in the upper packer and an opening 98a in the lower packer.

[0019] Reference is made to both Figures 2 and 3. During normal operation of the system 2, well fluid enters the space 82a through the perforations 72a. Well fluid can leave the space 82a only through the conduit 78a to enter the main separator 88a where it is separated into oil and a gas-containing fluid. The gas-containing fluid leaves the main separator through outlet 91a and flows on to the surface 7 through production tubing 92a. The oil leaves the main separator through outlet 90a, fills the space 93a above the upper packer 75a, and is conducted from the space 93a via the conduit 94a to the well section 26a. The riser well 3b is constructed and operated analogously, and separated oil from the main separator 88b is received by the well section 26b. The collection well 20 connects the well sections 26a and 26b and receives separated oil from both well sections. From the collection well oil is pumped to the surface 7

through the production well 50.

[0020] Reference is now made to Figure 4, showing schematically a third embodiment of the invention. Parts that are similar to parts discussed with reference to any one of Figures 1-3 have been referred to with the same reference numerals. The system 4 of Figure 4 is particularly well suited for the situation that the well fluid received from the underground production formations comprises the three components gas, oil, and water, and wherein one is interested to produce gas and oil separately to the surface 7. To this end the system 4 of this embodiment comprises an auxiliary underground liquid/liquid separator for further separation of the liquid which is separated from the well fluid by the main separators 8a/b, and collected in the collection well section 20. In this embodiment the main separators 12a/b/c are operated such that liquid collected in the collection well section 20 comprises hydrocarbon oil and water, so the liquid/liquid separator has the form of an oil/water separator 100.

[0021] The oil/water separator 100 has an inlet 102 which is arranged to receive the collected liquid from the collection well section 20 through the outlet 28. The separator 100 further has an outlet for a first liquid 104 and an outlet for a second liquid 106. The outlet 104 is connected to production tubing 108 extending to the surface 7 through the production well 50. A packer 109 seals the space between the tubing 108 and the wall (e.g. formed by casing) of the production well 50. Attached to the tubing 108 there can further be arranged a pump (not shown). The outlet for the second liquid 106 communicates with a liquid-discharge system in the form of the water-discharge system 30.

[0022] During normal operation of the system 4, well fluid comprising gas, oil and water is received from the production formations 8a/b/c through the inlet means 10a/b/c. The well fluid is forced to enter the main separators 12a/b/c through the inlets 15a/b/c. The liquid separated from the well fluid comprises water and oil, and this liquid is passed through the outlets 16a/b/c via the conduits 25a/b/c and the well sections 26a/b/c to the collection well section 20. The liquid thus collected from the three main separators flows via the outlet 28 and the inlet 102 into the oil/water separator 100, where it is separated into a first liquid, i.e. relatively pure oil for production to the surface, and a second liquid, i.e. water of sufficient purity to allow discharge into the underground discharge formation 36. The water is discharged from the oil/water separator 100 via the outlet 106, which is in fluid communication with the water discharge system 30. The oil leaves the oil/water separator 100 through the outlet 104 and is produced (e.g. pumped) via the production tubing 108 to the surface from where it is discharged at the wellhead (not shown).

[0023] In the embodiment of system 4 the liquid/liquid separator is arranged to receive liquid from the outlet for liquid 28 of the collection well section 20. It will be clear, that in a different embodiment the separator can also be

arranged in the collection well section, and in this case the outlet for liquid of the collection well section can comprise separate outlets for the first and the second liquid, e.g. oil and water. In this case a production well or a liquid discharge well can be arranged in the system to receive the first of the second liquid. The collection well itself, of parts thereof such as a sufficiently long horizontal or inclined section, can serve as oil/water separator.

[0024] An additional advantageous feature of the present invention is that the subsurface separation of well fluid can obviate the need for further separation on the surface before gas and/or liquid are transported away from a wellhead. This is for example particularly advantageous for offshore installations where the cost for surface separation (on the seafloor, or on a platform) is relatively high.

[0025] It will be clear that the collection well section can comprise a number of interconnected wells or well sections.

[0026] It will further be clear that in a different embodiment any separated water can also be transported to the surface.

[0027] The terms liquid and gas are used in the specification and in the claims to refer to the state of a fluid under the local environmental conditions (e.g. temperature, pressure) in the well system. It will be understood that the state of a fluid can change when the environmental conditions change, for example from underground conditions to normal conditions at the surface. For example, at underground conditions a liquid (oil) can also comprise an amount of dissolved components which are gaseous under normal conditions. Also, a gas can carry components that condense to a liquid under normal conditions.

[0028] Many types of separators are suitable for use with the present invention. The main separator, or the liquid/liquid separator, can for example comprise separation devices like a centrifugal separation device, a gravity separation chamber, or a plate pack. Also, the main separator can be arranged such that gravity separation simply takes place in the casing above an upper packer above the production interval. A separator can also comprise more than one separation device, which can be of the same type or of different types. For example, by arranging several centrifugal separation devices in series in the main separator it can be achieved that the gas-containing fluid contains mainly gas. The main separator can be arranged above, or entirely or partly within a production interval.

Claims

1. System for the subsurface separation of well fluid into a gas-containing fluid and a liquid and for transportation of at least the gas-containing fluid to the surface, which system comprises at least two riser wells each extending upwardly from a production

interval to the surface, wherein the production interval of each riser well penetrates an underground production formation and is arranged to receive well fluid therefrom, and wherein in or above each production interval an underground main separator is arranged to separate the well fluid into a gas-containing fluid and a liquid, which main separator is connected to means for transporting the gas-containing fluid to the surface, and to means for transporting the liquid to a collection well section which collection well section is arranged below the lowest production interval and has an outlet for liquid.

2. System according to claim 1, wherein the system further comprises an underground liquid/liquid separator arranged to receive liquid from the collection well section, and having an outlet for a first liquid and an outlet for a second liquid.
3. System according to claim 1, further comprising a production well extending downwardly from the surface, which production well is arranged to receive liquid from the outlet for liquid and to produce this liquid to the surface.
4. System according to claim 2, further comprising a production well extending downwardly from the surface, which production well is arranged to receive liquid from the outlet for the first liquid or the outlet for the second liquid and to produce this liquid to the surface.
5. System according to claim 1, further comprising a liquid discharge well penetrating an underground discharge formation, which liquid discharge well is arranged to receive liquid from the outlet for liquid and to inject this liquid into the discharge formation.
6. System according to claim 2, further comprising a liquid discharge well penetrating an underground discharge formation, which liquid discharge well is arranged to receive liquid from the outlet for the first liquid or the outlet for the second liquid, and to inject this liquid into the discharge formation.
7. System according to any one of claims 1-6, wherein in at least one of the riser wells the underground main separator is arranged above the production interval, which riser well further comprises an upper packer arranged above the production interval and a lower packer arranged below the production interval, which upper packer is provided with an opening to allow well fluid to flow from the production interval to the well section above the upper packer, and which upper and lower packers are provided with openings for a conduit to allow liquid to flow from the well section above the upper packer to the well section below the lower packer.

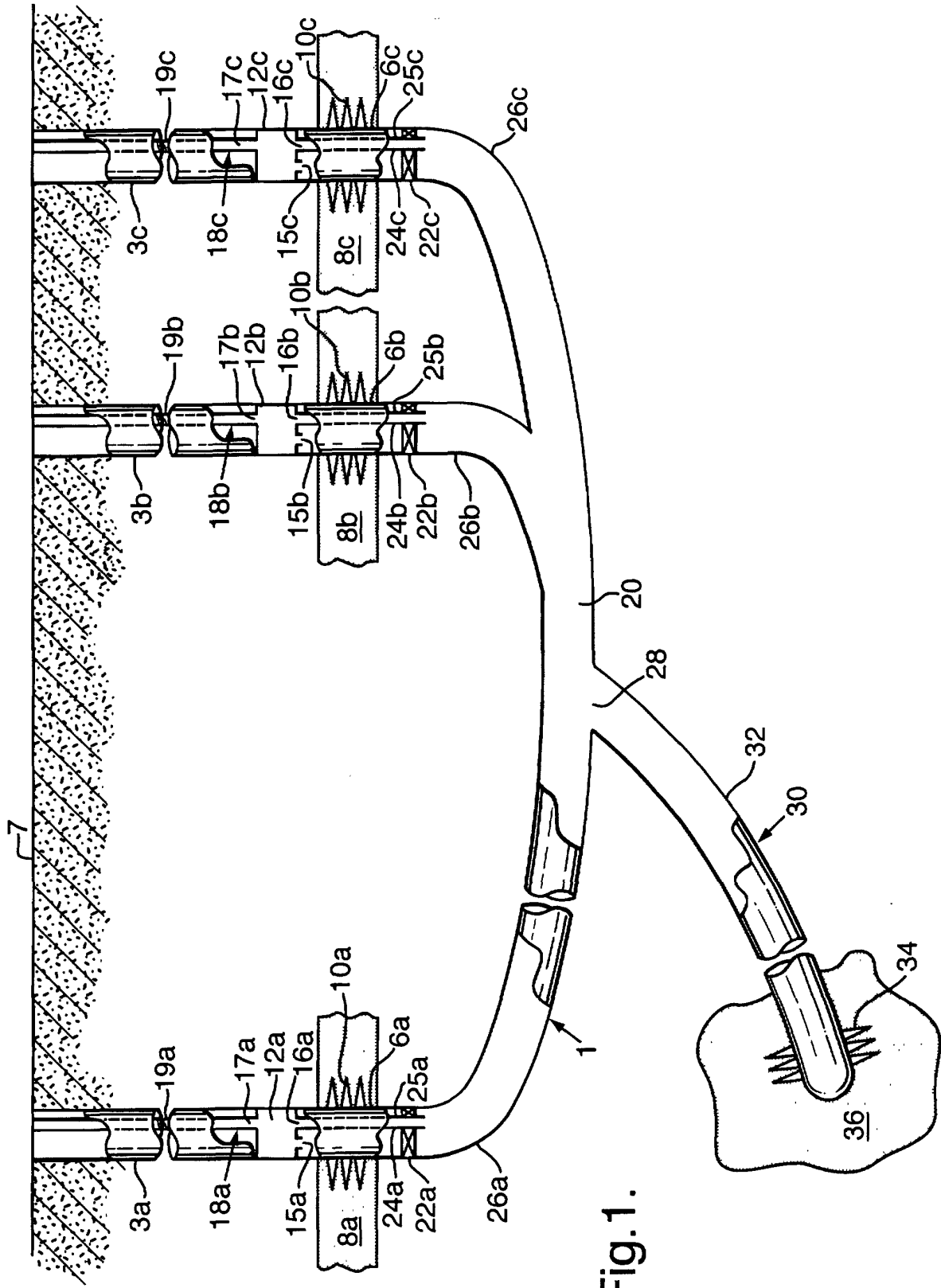


Fig. 1.

Fig.2.

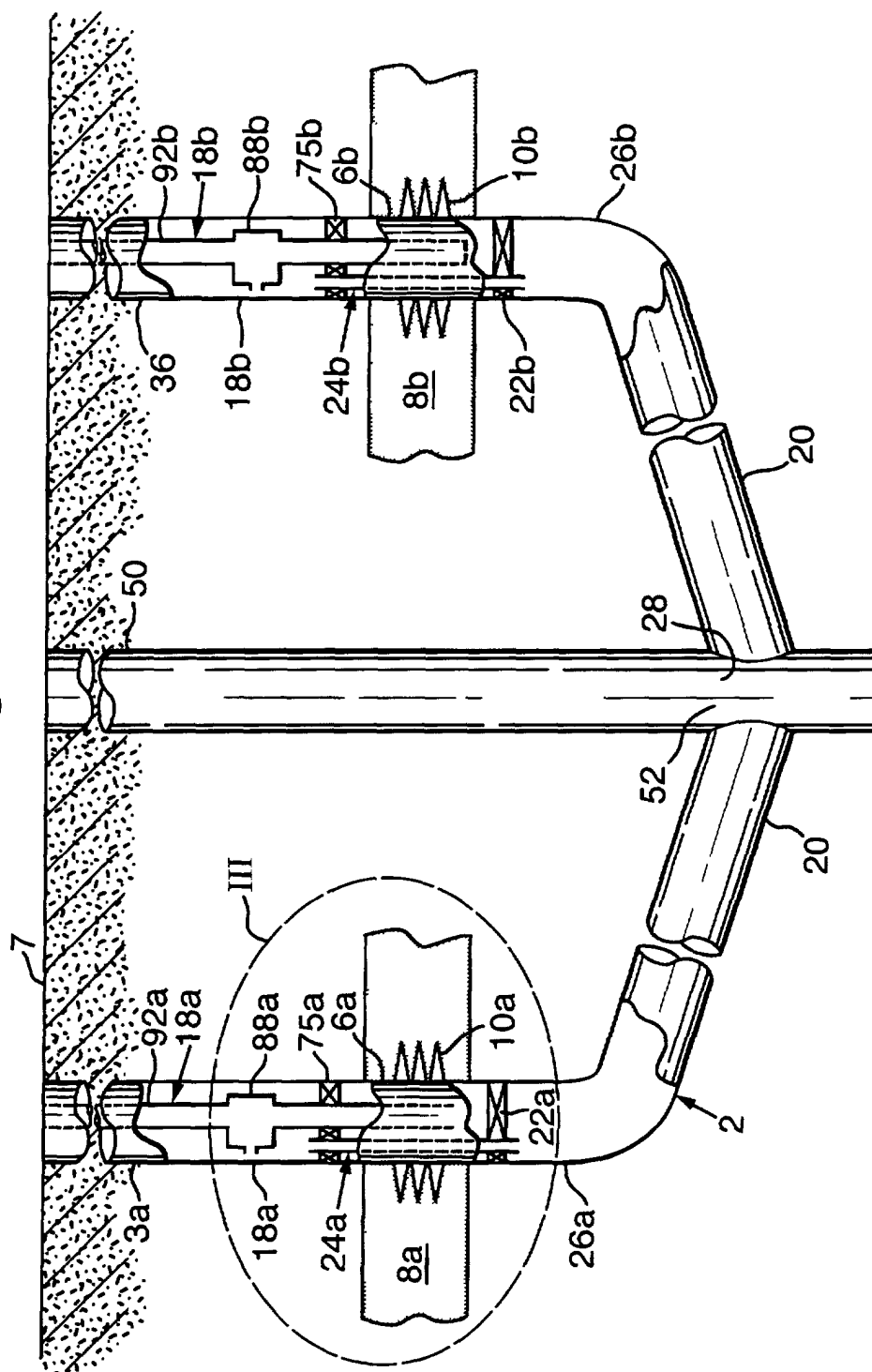
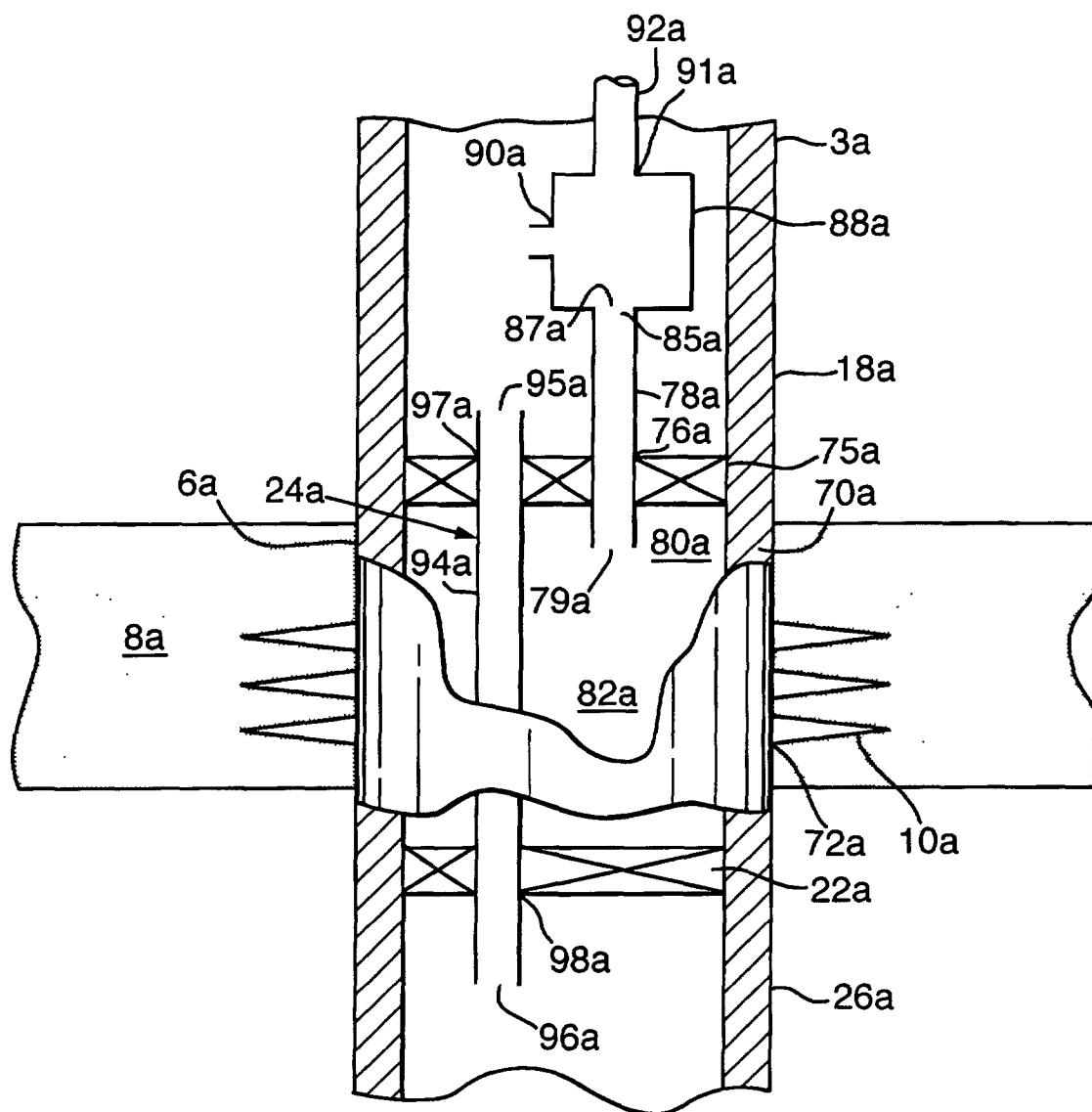
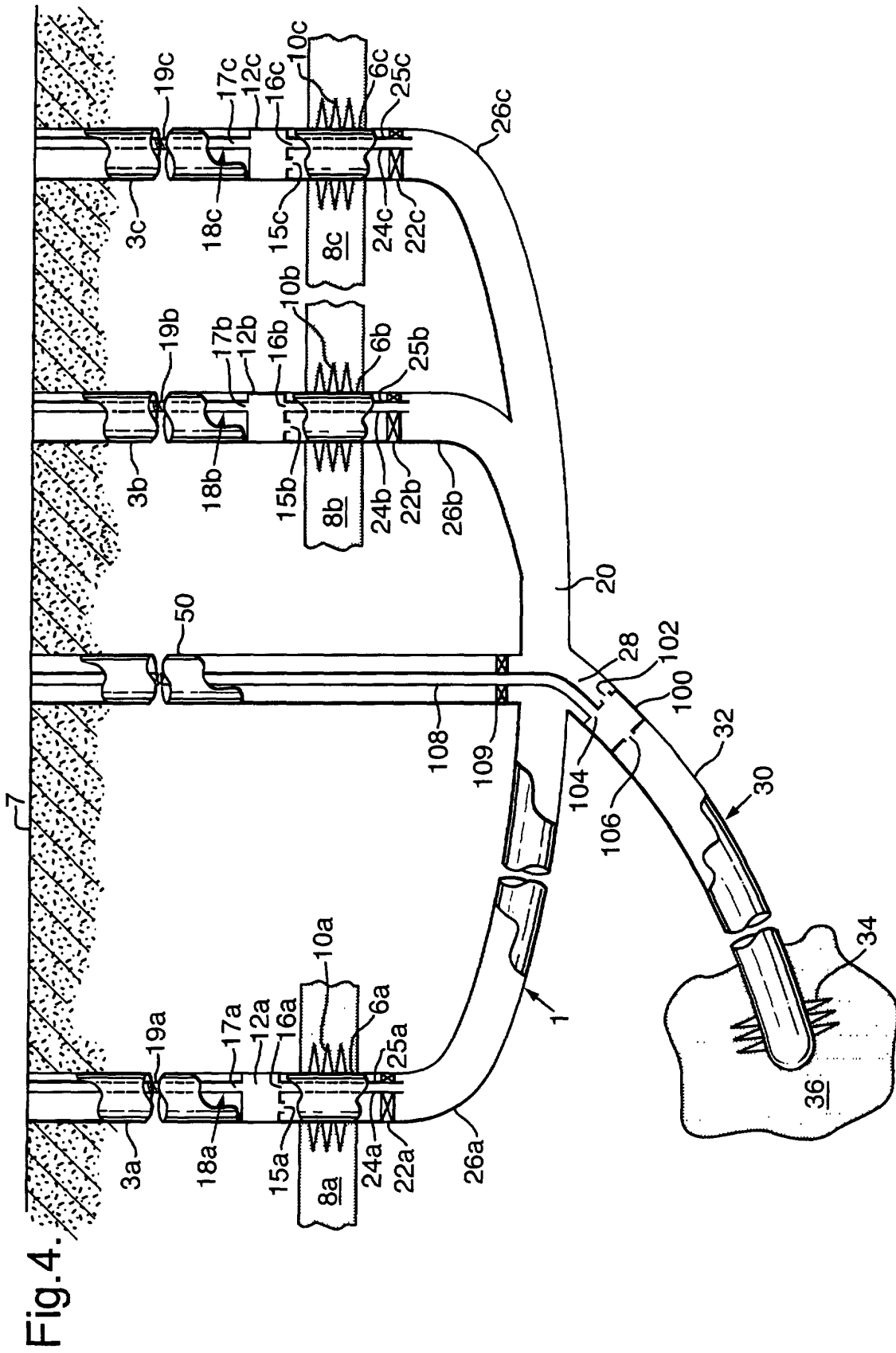


Fig.3.







European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 7635

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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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