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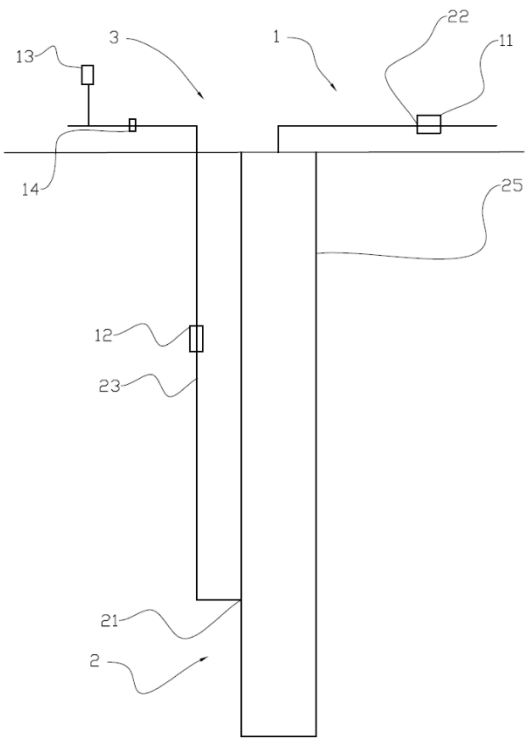
(54) Title **A method of determining a rate of injection of gas-lift gas into a well**

(56) References Cited: WO 2015191026 A1, US 5031697 A, WO 0165056 A1, WO 0165053 A1

(57) Abstract

The invention relates to a method of determining a rate of injection of a gas-lift gas into a well (3), the well (3) comprising a production flow line (2) and an injection line (23), the injection line (23) being connected to the production flow line (2), the method comprising the following steps:
- injecting a tracer substance at a known rate of injection into the injection line (23) at a first position in the injection line (23);
- using a device (12) for determining a concentration of the tracer substance in the injection line (23) at a second position in the injection line (23), wherein the second position is downstream of the first position in the injection line (23).
Further, the invention relates to a well (3) comprising:
- a production flow line (2);
- an injection line (23) for injecting a gas-lift gas into the production flowline (2);
- a device (12) for determining a concentration of a tracer substance in the injection line (23); and
- a tracer-supplying device (13) for supplying tracer into the injection line (23), wherein the tracer-supplying device (13) is connected to the injection line in a first position and the device (12) for determining the concentration of the tracer substance in the injection line is connected to the injection line (23) in a second position, wherein the second position is downstream of the first position.



A METHOD OF DETERMINING A RATE OF INJECTION OF GAS-LIFT GAS INTO A WELL

Field of invention

The present invention relates to a method of determining a rate of injection of gas-lift gas into a well, and to a well having an injection line connected to a production flow line. Further, the invention may relate to determining an effect of changing a rate of injection of a gas-lift gas into the production flow line on a rate of produced fluid from the well.

Background

In a wide range of contexts, it can be important to determine a parameter of a flow of a produced fluid in a well, e.g. to quantify a production rate from the well. For example, it can be important to quantify a flow rate in a well to investigate if the well is producing as expected, and to investigate effects of how changing a setting of a control unit may affect the production rate.

There exist flow meters that may be used to obtain a measurement of a flow rate of a fluid from a well. However, the flow meters are expensive, and the accuracy of the flow meters can often be poor. The flow meters may also require frequent replacement and/or maintenance to provide acceptable accuracy. Because of the disadvantages, many wells do not have a flow meter to quantify production rate.

Alternatively, to obtain a measurement of production rate from a well, the production line of the well can be connected to a test separator. This can be challenging: Some wells do not have test separators easily accessible. For some installations, it is necessary to acquire the services of a truck or a ship having a test separator and to connect said test separator to the well to be tested. Even when test separators are available on an installation site, and the test separator can easily be connected to the production line of a well, it may be inefficient to use the test separator. For example, if an operator wants to test the effect of a change of rate of injection of gas-lift gas into a well, it may take several days for the resulting rate of production to stabilize and to be obtainable from measurements by use of the test separator. In such cases, the production line of said well may occupy the test separator for a long time. This may be very problematic as test separator capacity can often be a limited resource. Furthermore, production from a well may be lost when the well is connected to the test separator.

An object of the invention is to remedy or to reduce at least one of the drawbacks of prior art.

Patent document WO2015/191026A1 discloses methods and computer program products for evaluating the performance of a gas lift well. The method includes measuring key gas lift well parameter data and concentration of tracer present in a substance retrieved from the gas lift well which was injected into the annulus formed between a well casing and a production tubing of the gas lift well.

Patent document US5,031,697 discloses a method provided for troubleshooting gas-lift wells, to identify whether gas-lift valves on the production tubing are open or closed, without the use of wireline tools.

Patent document WO01/65056 discloses a method for optimising the production of a petroleum well. The petroleum well includes a borehole, a piping structure positioned within the borehole, and a tubing string positioned within the borehole for conveying a production fluid.

Summary of the invention

The invention is defined by the independent patent claims. The dependent claims define advantageous embodiments of the invention.

Description and drawings

In the following is described examples of preferred embodiments illustrated in the accompanying drawings, wherein:

Fig. 1 shows a schematic representation of a first embodiment of an apparatus for determining a parameter of a flow of a produced fluid from a well;

Fig. 2 shows a schematic representation of a second embodiment of the apparatus; and

Fig. 3 shows a schematic representation of a third embodiment of the apparatus.

Figure 1 shows an apparatus 1 for determining a parameter of a flow of a produced fluid from a well 3. The well has a production flow line 2 comprising a production bore 25 and an injection line 23 connected to the production flow line 2 in a first location 21 of the production flow line 2. In a second location 22 of the production flow line 2, a spectrometer 11 for obtaining a measurement of a tracer substance is arranged to obtain a measurement of the tracer substance in a flow of fluid. The flow of fluid is a mixture of a reservoir fluid from a reservoir (not shown) and a fluid injected from the injection line into the production flow line in the first location 21. The direction of flow is from the reservoir, through the first location 21, towards and through the second location 22. Thus, the second location 22 can be said to be downstream of the first location 21.

A method for determining a parameter of a flow of a produced fluid in the well 3, using the apparatus 1, is performed as follows:

A tracer substance is injected into the production flow line 2 at the first location 21, the tracer substance being injected at a known rate of injection. The spectrometer 11 obtains a measurement of the tracer substance at the second location 22. More precisely, the spectrometer 11 obtains a measurement of a concentration of the tracer substance in the flow of fluid in the second location 22 of the production flow line 2. Then, the measurement of concentration of tracer substance is used to determine the parameter of the flow of the produced fluid. More precisely, the flow rate of produced fluid is determined.

When the flow rate of injected tracer substance in the first location 21, Q_{ti1}, is known, and the concentration of tracer substance in the second location 22, c_{t2}, is determined, the flow rate in the second location 22, Q_{f2} , can be determined by using the following formula: $Q_{f2} = {Q_{ti2}}/{c_{t2}}$.

The produced fluid measurement of concentration of tracer substance in this embodiment is a concentration of tracer substance of a flow of gas in the flow of fluid. Q_{f2}, therefore, is a flow rate of the gas. The total produced fluid in the second location comprises both gas and oil, and the GOR is known. As the GOR is known and is substantially constant (for a period of time), the flow of oil can be determined by using the following formula: $Q_O = {Q_{f2}}/{GOR}$.

The above-mentioned calculation can be used if the tracer substance is not present in the reservoir fluid. If the tracer substance is present in the reservoir fluid as one of a plurality of substances that makes out the fluid, it must be determined a concentration of the tracer substance in the reservoir fluid without the injected tracer substance, c_1, a concentration of the tracer substance in the produced fluid with injected tracer substance, c_2, and an increase in concentration, Δc, where $\Delta c = c_2 - c_1$.

The flow rate of gas in the second location 22 in the production flow line 2 may be determined using the following formula: $Q_{f2} = {Q_{ti2}}/{\Delta c}$. The flow rate of oil may thereafter be determined as above.

Figure 2 shows the apparatus in a second embodiment, wherein the apparatus has all the same parts as in Figure 1 and additionally a device 13 for supplying tracer substance into the injection line connected to the injection line in a first position in the injection line and a spectrometer 12 connected to the injection line in a second position in the injection line. The second position is downstream of the first position in the injection line.

By use of the device 13, tracer substance is added to the fluid stream in the injection line at a known rate. The spectrometer 12 is used to determine a concentration of the tracer substance in the second position in the injection line.

By knowing the rate of supply of tracer substance in the first position in the injection line, Q_t, and determining the concentration of the tracer substance in the second position in the injection line, c_t, a rate of injection of gas from the injection line into the production flow line, Q_{ig}, can be determined:

$$Q_{ig} = {Q_t}/{c_t}.$$

It can be important to know the injection rate to accurately determine the production rate from a reservoir. When the production flow rate, Q_{f2}, is determined, and the injection rate, Q_{ig}, is determined, the production rate from the reservoir, Q_r, can be determined by subtracting the injection rate from the production flow rate:

$$Q_r = Q_{f2} - Q_{ig}.$$

Figure 3 shows an embodiment having a control unit 14 in the form of a choke valve 14 in the injection line 23 to adjust an injection rate of a gas-lift gas. The injection line 23 further has a spectrometer 12 for determining a concentration of an injected tracer substance placed downstream of a device 13 for supplying tracer substance into the injection line 23.

Furthermore, the embodiment in Figure 3 has a spectrometer 11 in a second location 22 in the production flow line 2 downstream of a first location 21, where the injection line 23 connects to the production flow line 2. The first location 21 is downhole, whereas the second location is topside.

By use of the choke valve 14, it is possible to change the rate of injection of gas-lift gas into the well, and thus to affect a production flow rate in the production flow line 2. By use of the spectrometer 12 in the injection line 23, it is possible to accurately quantify the injection rate, and by use of the spectrometer 11 in the production flow line 2 it is possible to accurately quantify the production flow rate.

With the apparatus shown in Figure 3 it is possible to change an injection rate, determine the injection rate, affect the production flow rate, determine the production flow rate, and, through determining the injection rate and the resulting production flow rate for a plurality of different injection rates, to determine an injection rate that leads to a better production flow rate than other injection rates.

The embodiment shown in Figure 3 is highly advantageous compared to prior art, as to find a resulting flow rate from a change of injection rate with no need for connecting the production flow line to a separator.

The embodiment and method are particularly advantageous for an installation site having multiple wells sharing a limited, same source of gas-lift gas, to find a gas-lift gas distribution to the wells for good and/or improved and/or optimal total production from the wells.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. For example, in place of a spectrometer 11, 12, another device may be used to obtain the measurement or measurements, e.g. a chromatograph. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. A method of determining a rate of injection of a gas-lift gas into a well (3), the well (3) comprising a production flow line (2), and an injection line (23) from which the gas-lift gas exits and then enters into the well, downhole, the injection line (23) being connected to the production flow line (2), characterised in that the method comprises the steps of:

injecting a tracer substance at a known rate into the injection line (23) at a first injection line position;

using a device (12) for determining a concentration of the tracer substance in the injection line (23) at a second injection line position which is downstream of the first injection line position; and

using the concentration of the tracer substance in the injection line (23) at the second injection line position to determine the rate of injection of the gas-lift gas.

2. The method according to claim 1, wherein the device (12) is a spectrometer (12).

3. The method according to claim 1 or 2, wherein the step of using the concentration of the tracer substance in the injection line (23) at the second injection line position to determine the rate of injection of the gas-lift gas comprises dividing the known rate of injection of the tracer substance into the injection line (23) by the concentration of the tracer substance to obtain the rate of injection of the gas-lift gas.

4. A method to determine a flow rate of produced fluid in a production flow line of a well, the well (3) comprising a production flow line (2), and an injection line (23) from which the gas-lift gas downhole exits to the well, the injection line (23) being downhole connected to the production flow line (2), characterised in that the method comprises the steps of:

determining a rate of injection of a gas-lift gas into the well (3), comprising: injecting a tracer substance at a known rate into the injection line (23) at a first injection line position; using a device (12) for determining a concentration of the tracer substance in the injection line (23) at a second injection line position which is downstream of the first injection line position; and using the concentration of the tracer substance in the injection line (23) at the second injection line position to determine the rate of injection of the gas-lift gas;

providing means (11) for obtaining a measurement of the tracer in the production flow line at a second production flow line position (22), which is downstream of a first production line position (21), the first production line position being located downhole and where the injection line (23) is connected to the production flow line (2);

using said means (11) to determine a concentration of the tracer in a flow of produced fluid in the production flow line (2) at the second production line position (22), in the production flow line (2); and

determining a flow rate of produced fluid in the production flow line (2) based on the determined concentration of the tracer in the flow of fluid in the production flow line (2).

5. The method according to claim 4, which further comprises:

providing the well with a control unit (14) for adjusting the rate of injection of gas-lift gas into the production flow line (2);

using the control unit (14) to adjust the rate of injection of gas-lift gas into the production flow line (2);

determining the rate of injection of gas-lift gas into the production flow line (2) following the adjustment of the rate of injection of gas-lift gas; and

determining the flow rate of produced fluid in the production flow line (2) following the adjustment of the rate of injection of gas-lift gas.

6. A method of improving the flow rate of produced fluid from a well, characterised in that the method comprises the steps of:

performing the method according to claim 5 to obtain the flow rate of produced fluid in the production flow line following the adjustment of the rate of injection of gas-lift gas;

comparing the flow rate of the produced fluid prior to the adjustment of the rate of injection of the gas-lift gas and the flow rate of the produced fluid following the adjustment of the rate of injection of gas-lift gas;

repeating the adjustment of the rate of injection of gas-lift gas into the production flow line using the control unit (14), and determining the rate of injection of gas-lift gas and the flow rate of produced fluid after the adjustment of the control unit for a plurality of different settings of the control unit (14); and

comparing the flow rates of the produced fluid for the different settings of the control unit (14) to determine a best setting of the control unit (14) for improving the flow rate of the produced fluid from the well.

7. The method according to claim 6, wherein the control unit (14) comprises a choke valve (14).

8. An apparatus (1) for determining the injection rate of a gas-lift gas into a production flow line, characterised in that the apparatus comprises:

a production flow line (2);

an injection line (23);

a tracer-supplying device (13) for supplying a tracer substance at a known rate into the injection line (23) at a first injection line position;

a device (12) for determining a concentration of the tracer substance in the injection line (23) at a second injection line position which is downstream of the first injection line position; and

means to determine an injection rate of the gas-lift gas using the concentration of the tracer substance in the injection line at the second injection line position.

9. The apparatus according to claim 8, wherein the injection line (23) further comprises a control unit (14) for adjusting an injection rate of gas-lift gas.

10. The apparatus according to claim 8 or 9, wherein the production flow line (2) further comprises means (11) for obtaining a measurement of the tracer substance in the production flow line (2) upon the gas-lift gas having been injected into the production flow line, said means (11) for obtaining the measurement of the tracer substance in the production flow line being connected to the production flow line (2) in a second production flow line position, which is downstream of a first production flow line position.

11. The apparatus according to any of claims 8 to 10, wherein the device (12) for determining the concentration of the tracer substance comprises a spectrometer (12).

12. The apparatus according to claim 10 or 11, wherein the means (11) for obtaining the measurement of the tracer substance in the production flow line (2) comprises a spectrometer (11).

PATENTKRAV

1. Fremgangsmåte for å fastslå en injeksjonshastighet til en gassløft-gass inn i en brønn (3), idet brønnen (3) omfatter en produksjonsstrømledning (2), og en injeksjonsledning (23) fra hvilken gassløft-gassen kommer ut og så går inn i brønnen, nedihulls, idet injeksjonsledningen (23) er koblet til produksjonsstrømledningen (2), k a r a k t e r i s e r t v e d at fremgangsmåten omfatter trinnene:

å injisere et tracerstoff i en kjent hastighet inn i injeksjonsledningen (23) ved en første posisjon på injeksjonsledningen;

å anvende en anordning (12) for å fastslå en konsentrasjon av tracerstoffet i injeksjonsledningen (23) ved en andre posisjon på injeksjonsledningen som er nedstrøms for den første posisjonen på injeksjonsledningen; og

å anvende konsentrasjonen av tracerstoffet i injeksjonsledningen (23) ved den andre posisjonen på injeksjonsledningen til å fastslå injeksjonshastigheten til gassløft-gassen.

2. Fremgangsmåte ifølge krav 1, hvor anordningen (12) er et spektrometer (12).

3. Fremgangsmåte ifølge krav 1 eller 2, hvor trinnet å anvende konsentrasjonen av tracerstoffet i injeksjonsledningen (23) ved den andre posisjonen på injeksjonsledningen til å fastslå injeksjonshastigheten til gassløft-gassen, omfatter å dividere den kjente injeksjonshastigheten til tracerstoffet inn i injeksjonsledningen (23) med konsentrasjonen av tracerstoffet for å oppnå injeksjonshastigheten til gassløft-gassen.

4. Fremgangsmåte for å fastslå en strømningshastighet av produsert fluid i en produksjonsstrømledning av en brønn, idet brønnen (3) omfatter en produksjonsstrømledning (2), og en injeksjonsledning (23) fra hvilken gassløft-gassen nedihulls går ut til brønnen, idet injeksjonsledningen (23) er nedihulls koblet til produksjonsstrømledningen (2), k a r a k t e r i s e r t v e d at fremgangsmåten omfatter trinnene:

å fastslå en injeksjonshastighet til en gassløft-gass inn i brønnen (3), omfattende: å injisere et tracerstoff i en kjent hastighet inn i injeksjonsledningen (23) ved en første posisjon på injeksjonsledningen; å anvende en anordning (12) for å fastslå en konsentrasjon av tracerstoffet i injeksjonsledningen (23) ved en andre posisjon av injeksjonsledningen som er nedstrøms for den første posisjonen på injeksjonsledningen; og å anvende konsentrasjonen av tracerstoffet i injeksjonsledningen (23) ved den andre posisjonen på injeksjonsledningen til å fastslå injeksjonshastigheten til gassløft-gassen;

å tilveiebringe middel (11) for å oppnå en måling av traceren i produksjonsstrømledningen ved en andre posisjon (22) på produksjonsstrømledningen, som er nedstrøms for en første posisjon (21) på produksjonsledningen, idet den første posisjonen på produksjonsledningen befinner seg nedihulls og hvor injeksjonsledningen (23) er koblet til

produksjonsstrømledningen (2);

å anvende nevnte middel (11) til å fastslå en konsentrasjon av traceren i en strøm av produsert fluid i produksjonsstrømledningen (2) ved den andre posisjonen (22) på produksjonsledningen, i produksjonsstrømledningen (2); og

å fastslå en strømningshastighet av produsert fluid i produksjonsstrømledningen (2) basert på den fastslåtte konsentrasjonen av traceren i strømmen av fluid i produksjonsstrømledningen (2).

5. Fremgangsmåte ifølge krav 4, som videre omfatter:

å forsyne brønnen med en kontrollenhet (14) for å justere injeksjonshastigheten til gassløft-gass inn i produksjonsstrømledningen (2);

å anvende kontrollenheten (14) til å justere injeksjonshastigheten til gassløft-gass inn i produksjonsstrømledningen (2);

å fastslå injeksjonshastigheten til gassløft-gass inn i produksjonsstrømledningen (2) etter justeringen av injeksjonshastigheten til gassløft-gass; og

å fastslå strømningshastigheten til produsert fluid i produksjonsstrømledningen (2) etter justeringen av injeksjonshastigheten til gassløft-gass.

6. Fremgangsmåte for å forbedre strømningshastigheten til produsert fluid fra en brønn, k a r a k t e r i s e r t v e d at fremgangsmåten omfatter trinnene:

å utføre fremgangsmåten ifølge krav 5 for å oppnå strømningshastigheten til produsert fluid i produksjonsstrømledningen etter justeringen av injeksjonshastigheten til gassløft-gass;

å sammenligne strømningshastigheten til det produserte fluidet før justeringen av injeksjonshastigheten til gassløft-gassen og strømningshastigheten til det produserte fluidet etter justeringen av injeksjonshastigheten til gassløft-gass;

å gjenta justeringen av injeksjonshastigheten til gassløft-gass inn i produksjonsstrømledningen ved anvendelse av kontrollenheten (14), og fastslå injeksjonshastigheten til gassløft-gass og strømningshastigheten til produsert fluid etter justeringen av kontrollenheten for en flerhet av forskjellige innstillinger av kontrollenheten (14); og

å sammenligne strømningshastighetene til det produserte fluidet for de forskjellige innstillingene til kontrollenheten (14) for å fastslå en beste innstilling for kontrollenheten (14) for å forbedre strømningshastigheten til det produserte fluidet fra brønnen.

7. Fremgangsmåte ifølge krav 6, hvor kontrollenheten (14) omfatter en strupeventil (14).

8. Apparat (1) for å fastslå injeksjonshastigheten til en gassløft-gass inn i en produksjonsstrømledning, k a r a k t e r i s e r t v e d at apparatet omfatter:

en produksjonsstrømledning (2);

en injeksjonsledning (23);

en anordning (13) for tilførsel av tracer for å tilføre et tracerstoff i en kjent has-

tighet inn i injeksjonsledningen (23) ved en første posisjon på injeksjonsledningen;

en anordning (12) for å fastslå en konsentrasjon av tracerstoffet i injeksjonsledningen (23) ved en andre posisjon på injeksjonsledningen som er nedstrøms for den første posisjonen på injeksjonsledningen; og

middel for å fastslå en injeksjonshastighet til gassløft-gassen ved anvendelse av konsentrasjonen av tracerstoffet i injeksjonsledningen ved den andre posisjonen på injeksjonsledningen.

9. Apparat ifølge krav 8, hvor injeksjonsledningen (23) videre omfatter en kontrollenhet (14) for å justere en injeksjonshastighet til gassløft-gass.

10. Apparat ifølge krav 8 eller 9, hvor produksjonsstrømledningen (2) videre omfatter middel (11) for å oppnå en måling av tracerstoffet i produksjonsstrømledningen (2) idet gassløft-gassen er blitt injisert inn i produksjonsstrømledningen, idet nevnte middel (11) for å oppnå målingen av tracerstoffet i produksjonsstrømledningen er koblet til produksjonsstrømledningen (2) i en andre posisjon på produksjonsstrømledningen, som er nedstrøms for en første posisjon på produksjonsstrømledningen.

11. Apparat ifølge et hvilket som helst av kravene 8 til 10, hvor anordningen (12) for å fastslå konsentrasjonen av tracerstoffet omfatter et spektrometer (12).

12. Apparat ifølge krav 10 eller 11, hvor middelet (11) for å oppnå målingen av tracerstoffet i produksjonsstrømledningen (2) omfatter et spektrometer (11).

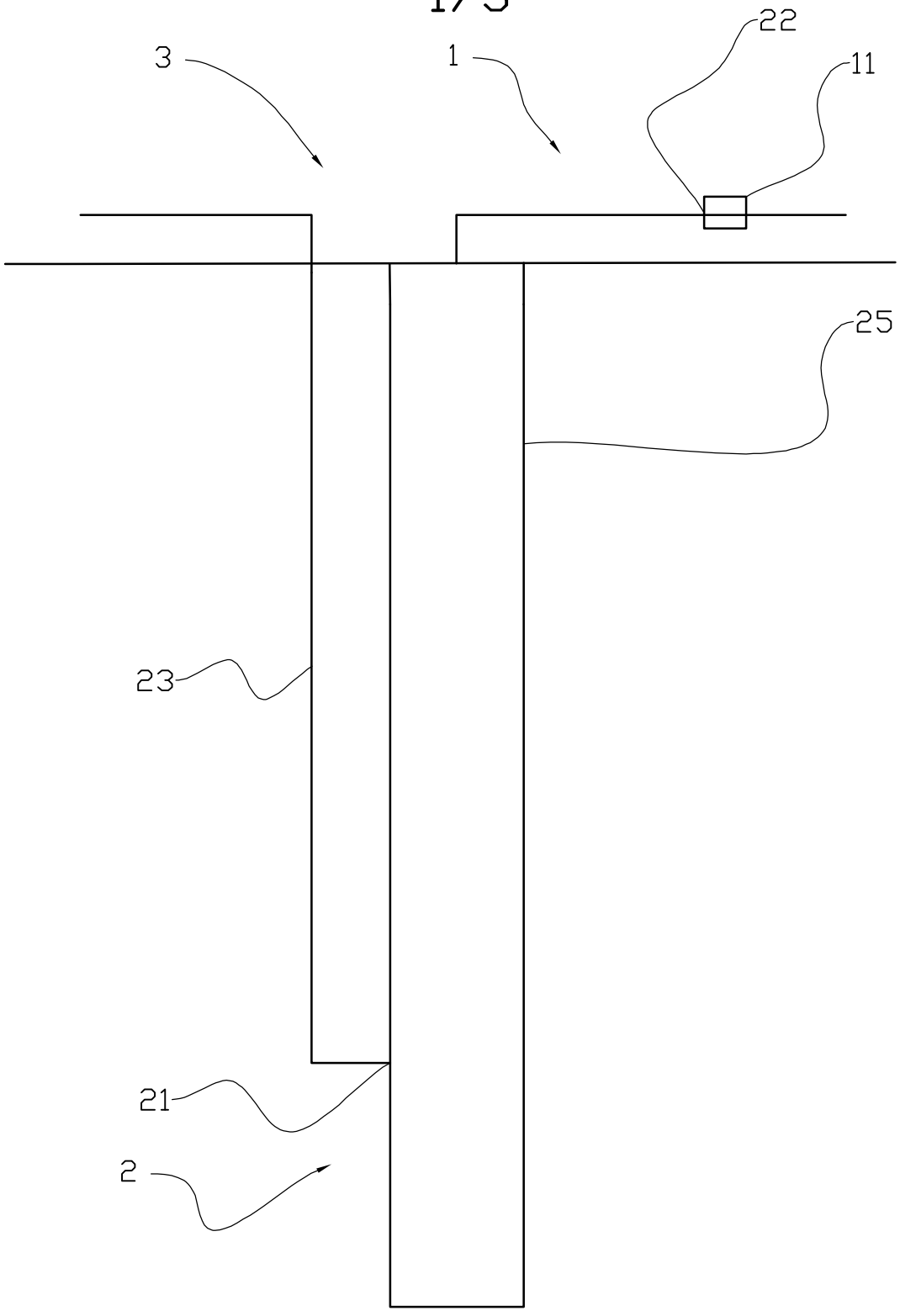


Fig. 1

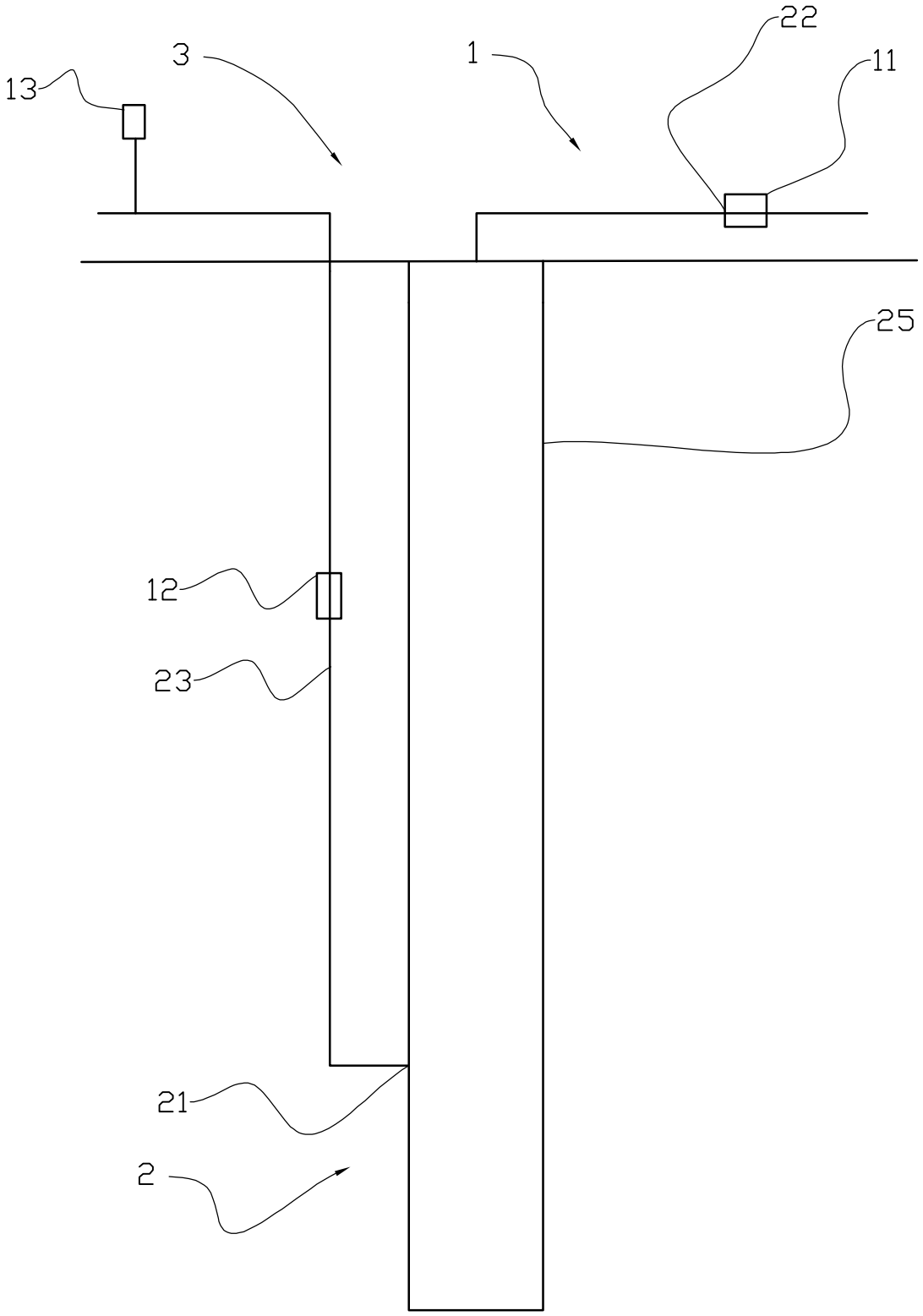


Fig. 2

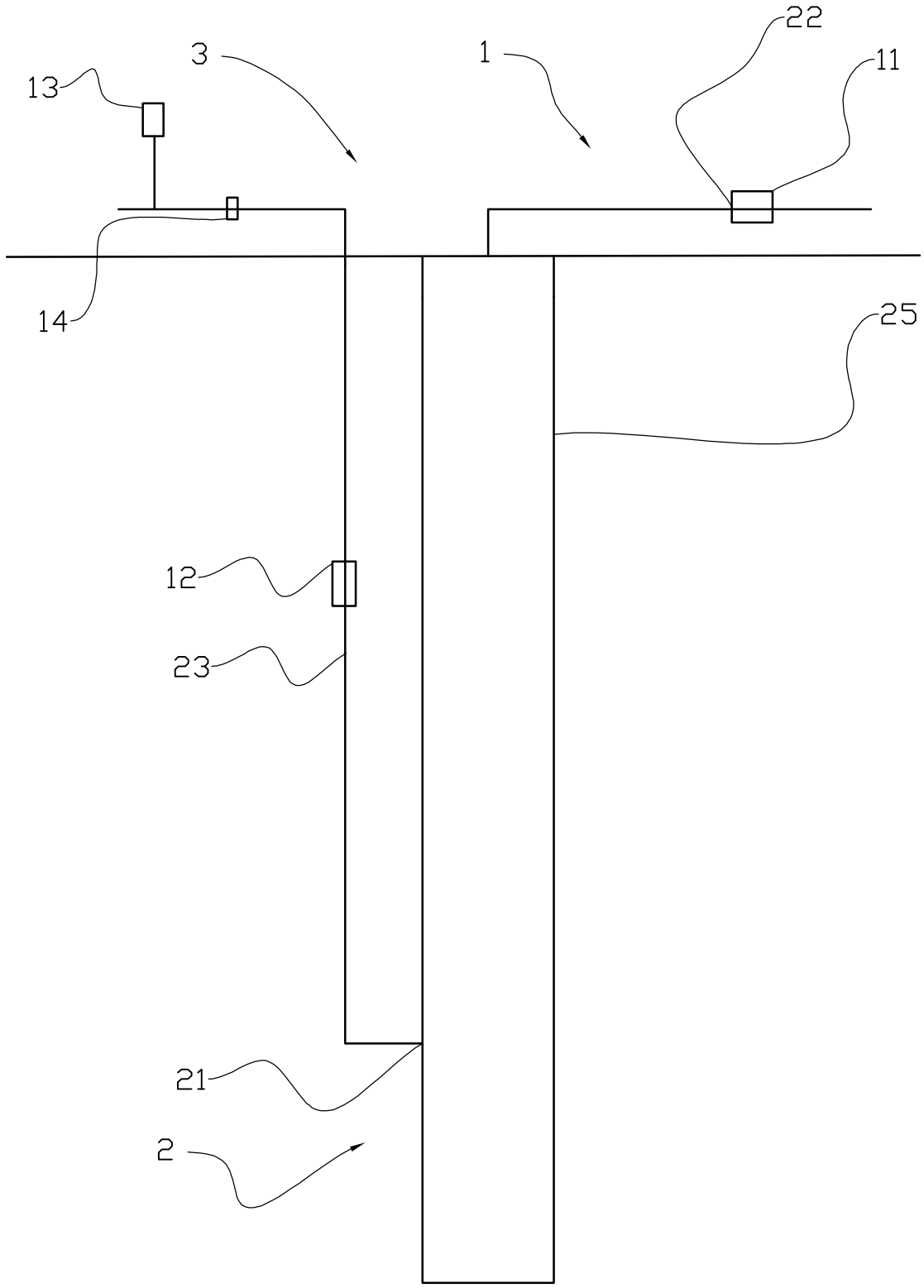


Fig. 3