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(54) **DOWNHOLE SYSTEM FOR REMEDIAL TREATMENT**

(57) The present invention relates to a downhole system for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity and thereby accumulating water in the toe of the well. The downhole system comprises a production metal casing having a first inner diameter and a first production zone, and a velocity metal string having a second inner diameter smaller than the first inner diameter and being arranged inside the production metal casing to reduce the flow area and increase the flow velocity of the fluid flowing in the well. The velocity metal string comprises a first annular barrier comprising a tubular metal part for mounting as part of the velocity metal string, the tubular metal part having an outer face, an expandable metal sleeve surrounding the tubular metal part and having an inner face facing the tubular metal part and an outer face facing the production metal casing, each end of the expandable metal sleeve being connected with the tubular metal part, and an annular space between the inner face of the expandable metal sleeve and the tubular metal part, the expandable metal sleeve being configured to expand by expanding the annular space. The first annular barrier is expanded so that the expandable metal sleeve abuts the production metal casing, dividing an annulus between the production metal casing and the velocity metal string into a first annulus section and a second annulus section, the first annulus section being arranged closer to a top of the well than the second annulus section. Furthermore, the invention relates to a downhole gas lift method for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity.

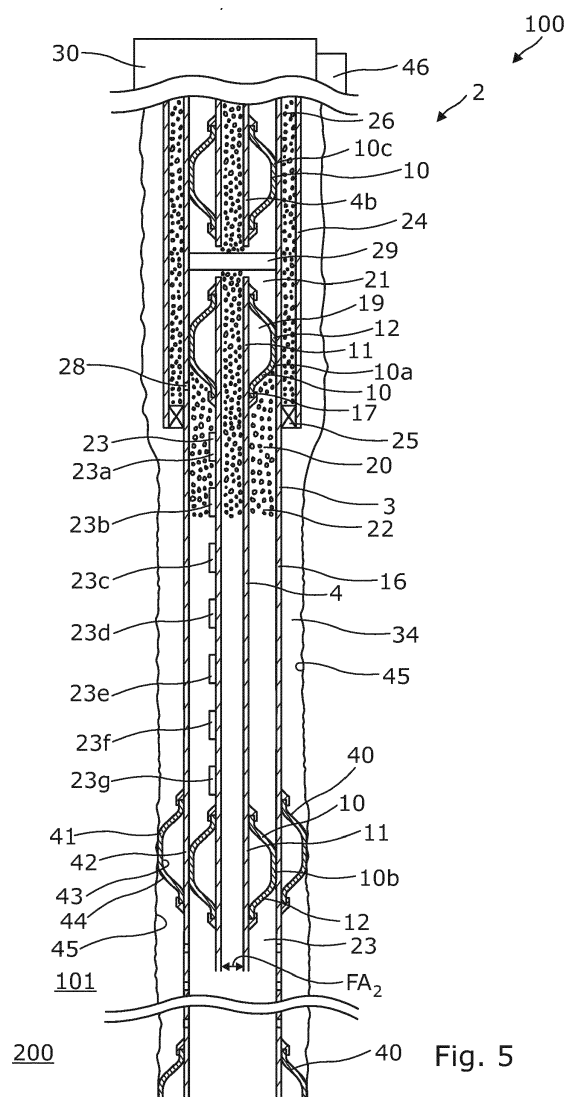


Fig. 5

Description

Field of the invention

[0001] The present invention relates to a downhole system for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity, thereby accumulating water in the toe of the well. Furthermore, the invention relates to a downhole gas lift method for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity.

Background art

[0002] Some hydro-carbon producing wells have the problem that the flow velocity of the produced fluid is not high enough, which allows the fluid to undergo phase transformation and form water droplets which are disposed on the inner face of the production metal casing and run along the inner face and accumulate in the bottom or the toe of the well, slowly destroying the well until it stops producing.

Summary of the invention

[0003] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved downhole system increasing the flow velocity of the produced fluid.

[0004] The above objects, together with numerous other objects, advantages and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a downhole system for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity, thereby accumulating water in the toe of the well, the downhole system comprising:

- a production metal casing having a first inner diameter and a first production zone, and
- a velocity metal string having a second inner diameter smaller than the first inner diameter and being arranged inside the production metal casing to reduce the flow area and increase the flow velocity of the fluid flowing in the well, wherein the velocity metal string comprises a first annular barrier comprising:
 - a tubular metal part for mounting as part of the velocity metal string, the tubular metal part having an outer face,
 - an expandable metal sleeve surrounding the tubular metal part and having an inner face facing the tubular metal part and an outer face facing the production metal casing, each end of the expandable metal sleeve being connected with the tubular metal part, and

- an annular space between the inner face of the expandable metal sleeve and the tubular metal part, the expandable metal sleeve being configured to expand by expanding the annular space, and

wherein the first annular barrier is expanded so that the expandable metal sleeve abuts the production metal casing, dividing an annulus between the production metal casing and the velocity metal string into a first annulus section and a second annulus section, the first annulus section being arranged closer to a top of the well than the second annulus section.

[0005] The velocity metal string may comprise gas lift valves arranged opposite the first annulus section or the second annulus section.

[0006] Furthermore, the gas lift valves may be arranged above the first annular barrier.

[0007] Also, the velocity metal string may extend into the well from the top of the well.

[0008] Moreover, the velocity metal string may be coiled tubing.

[0009] The downhole system may further comprise an intermediate casing arranged at the top of the well, surrounding the production metal casing, and a main barrier arranged between the intermediate casing and the production metal casing, defining an intermediate annulus, the velocity metal string comprising a second annular barrier, the first annular barrier being arranged below the main barrier and the second annular barrier being arranged above the main barrier, enclosing the first annulus section, and the production metal casing having an aperture providing fluid communication between the intermediate annulus and the first annulus section.

[0010] In addition, the downhole system may further comprise a pump device configured to suck well fluid up through the velocity metal string.

[0011] Also, the downhole system may further comprise a downhole safety valve arranged in the production metal casing above the first annular barrier

[0012] Moreover, the downhole system may further comprise a second velocity metal string arranged above the downhole safety valve.

[0013] The second velocity metal string may comprise at least one annular barrier.

[0014] Furthermore, the velocity metal string may comprise gas lift valves arranged opposite the first annulus section being closest to the top of well.

[0015] Additionally, the velocity metal string may have a first end and a second end, the second end being arranged opposite the first production zone.

[0016] Also, the velocity metal string may reduce the flow area by more than 50% of the flow area of the production metal casing.

[0017] Moreover, the velocity metal string may be configured to be temporarily positioned in the well.

[0018] Further, the velocity metal string may comprise a plurality of annular barriers.

[0019] In addition, the annular barrier(s) may be configured to suspend the velocity metal string in the production metal casing.

[0020] Furthermore, a first expansion opening may be arranged in the annular barrier, providing access to the annular space so that the expandable metal sleeve is configured to expand when pressurised fluid is injected into the annular space through the first expansion opening.

[0021] Also, the tubular metal part may have the first expansion opening.

[0022] Additionally, a flow line may be connected to the first expansion opening of the annular barrier, the flow line being arranged outside the velocity metal string.

[0023] Moreover, the flow line may extend from the top of the well along the first annulus section to the first expansion opening.

[0024] Furthermore, the annular space may comprise at least one thermally decomposable compound, which compound is thermally decomposable below a temperature of 400°C and is adapted to generate gas or supercritical fluid upon decomposition.

[0025] Also, the compound may comprise nitrogen.

[0026] The compound may be selected from a group consisting of: ammonium dichromate, ammonium nitrate, ammonium nitrite, barium azide, sodium nitrate or a combination thereof.

[0027] Further, the compound may decompose at temperatures above 100°C, preferably above 180°C.

[0028] In addition, the annular space may be pre-pressurised to a pressure above 5 bar, preferably above 50 bar, more preferably above 100 bar, and even more preferably above 250 bar.

[0029] Moreover, the compound may be present in the form of a powder, a powder dispersed in a liquid or a powder dissolved in a liquid.

[0030] Furthermore, the production metal casing may comprise one or more casing annular barriers each having an expandable metal sleeve surrounding the tubular metal part and being mounted as part of production metal casing and having an inner face facing the tubular metal part and an outer face facing a wall of a borehole.

[0031] The downhole system may further comprise a gas lift pump configured to pressurise the first annulus section to provide gas lift.

[0032] Moreover, the well may have a liquid level.

[0033] Additionally, the second end of the velocity metal string may be arranged below the liquid level.

[0034] The present invention furthermore relates to a downhole gas lift method for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity, thereby accumulating water in the toe of the well, the method comprising:

- inserting a velocity metal string of the downhole system according to any of the proceeding claims, and
- expanding the annular barrier so that the expandable metal sleeve abuts the production metal casing, di-

viding an annulus between the production metal casing and the velocity metal string into a first annulus section and a second annulus section, the first annulus section being arranged closer to the top of the well than the second annulus section.

[0035] The method may further comprise the step of pressurising the first annulus section with gas.

[0036] Finally, the method may further comprise the step of allowing the gas to flow into the velocity metal string through the gas lift valves.

Brief description of the drawings

[0037] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which

Fig. 1 shows a partially cross-sectional view of a downhole system in a well accumulating water,

Fig. 2 shows a partially cross-sectional view of another downhole system having gas lift valves,

Fig. 3 shows a partially cross-sectional view of another downhole system having a velocity metal string with two annular barriers,

Fig. 4 shows a partially cross-sectional view of yet another downhole system using gas lift, and

Fig. 5 shows a partially cross-sectional view of yet another downhole system having two velocity metal strings.

[0038] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

Detailed description of the invention

[0039] Fig. 1 shows a downhole system 100 for remedial treatment of a well 2 having insufficient flow velocity and thereby accumulating water, illustrated by a liquid level 47, in a toe or bottom of the well 2 in a hydro-carbon reservoir 200. The downhole system 100 comprises a production metal casing 3 having a first inner diameter ID_1 and a first production zone 101. The downhole system 100 further comprises a velocity metal string 4 having a second inner diameter ID_2 smaller than the first inner diameter and arranged inside the production metal casing 3 to reduce the flow area FA from the flow area FA_1 of the production metal casing 3 having no velocity metal string to the flow area FA_2 of the well 2 having the velocity metal string 4 inside the production metal casing 3.

Thereby, the velocity metal string 4 increases the flow velocity of the fluid flowing in the well 2, which prevents the fluid from undergoing phase transformation, meaning that water droplets are no longer able to generate and deposit on the inner face of the production metal casing 3 and accumulate in the bottom or toe of the well 2.

[0040] The velocity metal string 4 comprises a first annular barrier 10 having a tubular metal part 11 mounted as part of the velocity metal string. The first annular barrier 10 comprises an expandable metal sleeve 12 surrounding the tubular metal part 11 and having an inner face 14 facing the tubular metal part and an outer face 15 facing a wall 16 of the production metal casing 3. Each end 17 of the expandable metal sleeve 12 is connected with the tubular metal part 11, defining an annular space 19 between the inner face 14 of the expandable metal sleeve and the tubular metal part. The expandable metal sleeve 12 is expanded to abut the production metal casing 3, dividing an annulus 20 between the production metal casing and the velocity metal string 4 into a first annulus section 21 and a second annulus section 22. The first annulus section 21 is arranged closer to a top 30 of the well 2 than the second annulus section 22. As the flow velocity of the fluid increases, the water accumulated at the bottom will to some extent be mixed with well fluid and water droplets will be carried with the high flow fluid, meaning that some of the accumulated water will be removed from the bottom of the well.

[0041] The velocity metal string 4 extends into the well 2 from the top 30 of the well, and the velocity metal string is in Fig. 1 shown as coiled tubing around which the first annular barrier 10, 10a is provided. The velocity metal string 4 is mounted from a plurality of tubing sections to form the string and is suspended from the production metal casing 3 by means of the first annular barrier 10 so that the velocity metal string 4 does not have to be hung-off in larger equipment at the top 30 of the well 2.

[0042] In Fig. 2, the velocity metal string 4 comprises gas lift valves 23, 23a-h arranged opposite the first annulus section 21 above the annular barrier 10. The first annulus section 21 may then be pressurised with gas flowing first in through a first gas lift valve 23a, then a second gas lift valve 23b, and subsequently, the first gas lift valve 23a closes. The pressurisation continues and the gas also flows into a third gas lift valve 23c, and as the gas continues downwards and displaces the fluid in the first annulus section 21, the second gas lift valve 23b closes. The pressurisation continues until gas in turn has also entered a fourth gas lift valve 23d, a fifth gas lift valve 23e, a sixth gas lift valve 23f, a seventh gas lift valve 23g and an eighth gas lift valve 23h, thereby lifting the column of well fluid in the velocity metal string 4 and increasing the flow velocity even further. As can be seen, the velocity metal string 4 has a first end 41 and a second end 42, and the second end is arranged opposite the first production zone 101.

[0043] In Fig. 3, the velocity metal string 4 comprises the first annular barrier 10, 10a and a second annular

barrier 10, 10b which together enclose the first annulus section 21. The second annular barrier 10, 10b thus divides the annulus 20 into the second annulus section 22 and a third annulus section 33. The velocity metal string comprises gas lift valves 23 arranged opposite the first annulus section 21 which, when pressurised with gas, flow into the fluid in the velocity metal string 4 and increase the flow velocity of the fluid.

[0044] In Fig. 4, the downhole system 100 further comprises an intermediate casing 24 arranged at the top of the well and surrounding the production metal casing 3. The downhole system 100 further comprises a main barrier 25 arranged between the intermediate casing 24 and the production metal casing 3, defining an intermediate annulus 26. The velocity metal string 4 comprises a second annular barrier 10, 10b, and the first annular barrier 10, 10a is arranged above the main barrier 25 when seen along the longitudinal axis 27 of the production metal casing 3, and the second annular barrier is arranged below the main barrier 25, enclosing the first annulus section 21. The production metal casing 3 has an aperture 28 providing fluid communication between the intermediate annulus 26 and the first annulus section 21. The velocity metal string 4 comprises gas lift valves 23, 23a-g arranged opposite the first annulus section 21 which, when pressurised with gas, flow into the fluid in the velocity metal string 4 and increase the flow velocity of the fluid. In this way, the gas lift is provided further down the well 2 than just by the gas lift valves 23, 23a-g shown in Fig. 3, and the flow velocity of the fluid is further increased when needed.

[0045] As shown in Fig. 5, the downhole system 100 further comprises a downhole safety valve 29 arranged in the production metal casing 3 above the first annular barrier 10a. A downhole safety valve 29 can only be removed by pulling the production metal casing 3 out of the well 2, which is not desired as such an operation is very expensive, and furthermore, the production metal casing without the valve needs to be inserted again before the velocity metal string 4 is inserted. Therefore, the downhole system 100 comprises a second velocity metal string 4b arranged above the downhole safety valve 29. The second velocity metal string 4b comprises an annular barrier 10c for connecting the second velocity metal string 4b to the production metal casing 3.

[0046] Furthermore, the downhole system 100 comprises a pump device configured to suck well fluid up through the velocity metal string.

[0047] Also, the velocity metal string reduces the flow area by more than 50% of the flow area of the production metal casing.

[0048] A first expansion opening 51 of the annular barrier 10 shown in Fig. 2 provides access to the annular space 19 so that the expandable metal sleeve is configured to expand when pressurised fluid is injected into the annular space through the first expansion opening. The fluid for expanding the annular barrier 10 is provided by means of a flow line 52 from surface which is arranged

outside the velocity metal string 4. In another embodiment, the tubular metal part 11 of the annular barrier 10 comprises the first expansion opening 51 so that the velocity metal string 4 is pressurised to expand the expandable metal sleeve 12. Another way of expanding the expandable metal sleeve is by way of a compound arranged in the annular space 19, which compound is thermally decomposable below a temperature of 400°C and is adapted to generate gas or super-critical fluid upon decomposition and thereby expand the expandable metal sleeve 12. The compound comprises nitrogen and is selected from a group consisting of: ammonium dichromate, ammonium nitrate, ammonium nitrite, barium azide, sodium nitrate or a combination thereof. The compound is present in the form of a powder, a powder dispersed in a liquid or a powder dissolved in a liquid, and the compound decomposes at temperatures above 100°C, preferably above 180°C. The annular barriers 10 may also be expanded by inserting a tool isolating a zone opposite the expansion opening and pressurising the isolated zone and expanding the expandable metal sleeve 12.

[0049] In order to expand the expandable metal sleeve 12, the annular space 19 is pre-pressurised to a pressure above 5 bar, preferably above 50 bar, more preferably above 100 bar, and even more preferably above 250 bar.

[0050] In Fig. 5, the production metal casing 3 comprises two casing annular barriers 40, each having an expandable metal sleeve 12 surrounding the tubular metal part 42 being mounted as part of production metal casing 3 and having an inner face 43 facing the tubular metal part and an outer face 44 facing a wall 45 of the borehole 34. The downhole system 100 further comprises a gas lift pump 46 configured to pressurise the first annulus section 21 to provide gas lift.

[0051] Downhole gas lift is provided for remedial treatment of a well 2 in a hydro-carbon reservoir 200 having insufficient flow velocity and thereby accumulating water in the toe of the well. The gas lift is provided by inserting a velocity metal string 4 of the downhole system 100 and then expanding the annular barrier 10 so that the expandable metal sleeve 12 abuts the production metal casing 3, dividing an annulus 20 between the production metal casing and the velocity metal string into a first annulus section 21 and a second annulus section 22, the first annulus section being arranged closer to the top 30 of the well 2 than the second annulus section. Subsequently, gas can be provided down the first annulus section 21, allowing the gas to flow into the velocity metal string 4 through gas lift valves 23, 23a-h, as shown in Fig. 2.

[0052] By fluid or well fluid is meant any kind of fluid that may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By gas is meant any kind of gas composition present in a well, completion, or open hole, and by oil is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil, and water fluids may thus all comprise other elements or substances than gas, oil, and/or water, re-

spectively.

[0053] By a casing or production metal casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0054] In the event that the tool is not submergible all the way into the casing, a downhole tractor can be used to push the tool all the way into position in the well. The downhole tractor may have projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0055] Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

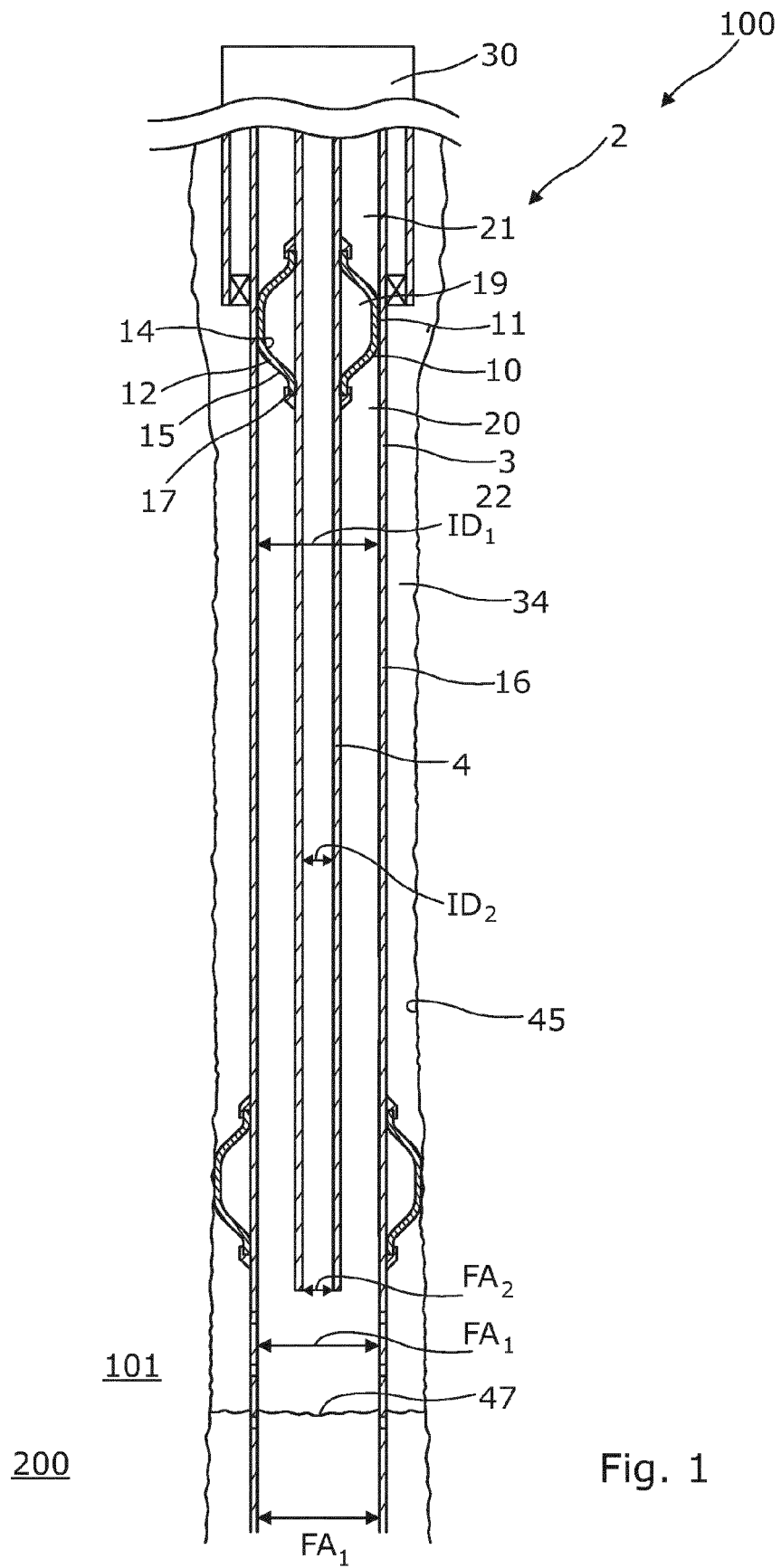
1. A downhole system (100) for remedial treatment of a well (2) in a hydro-carbon reservoir (200) having insufficient flow velocity and thereby accumulating water in the toe of the well, the downhole system comprising:

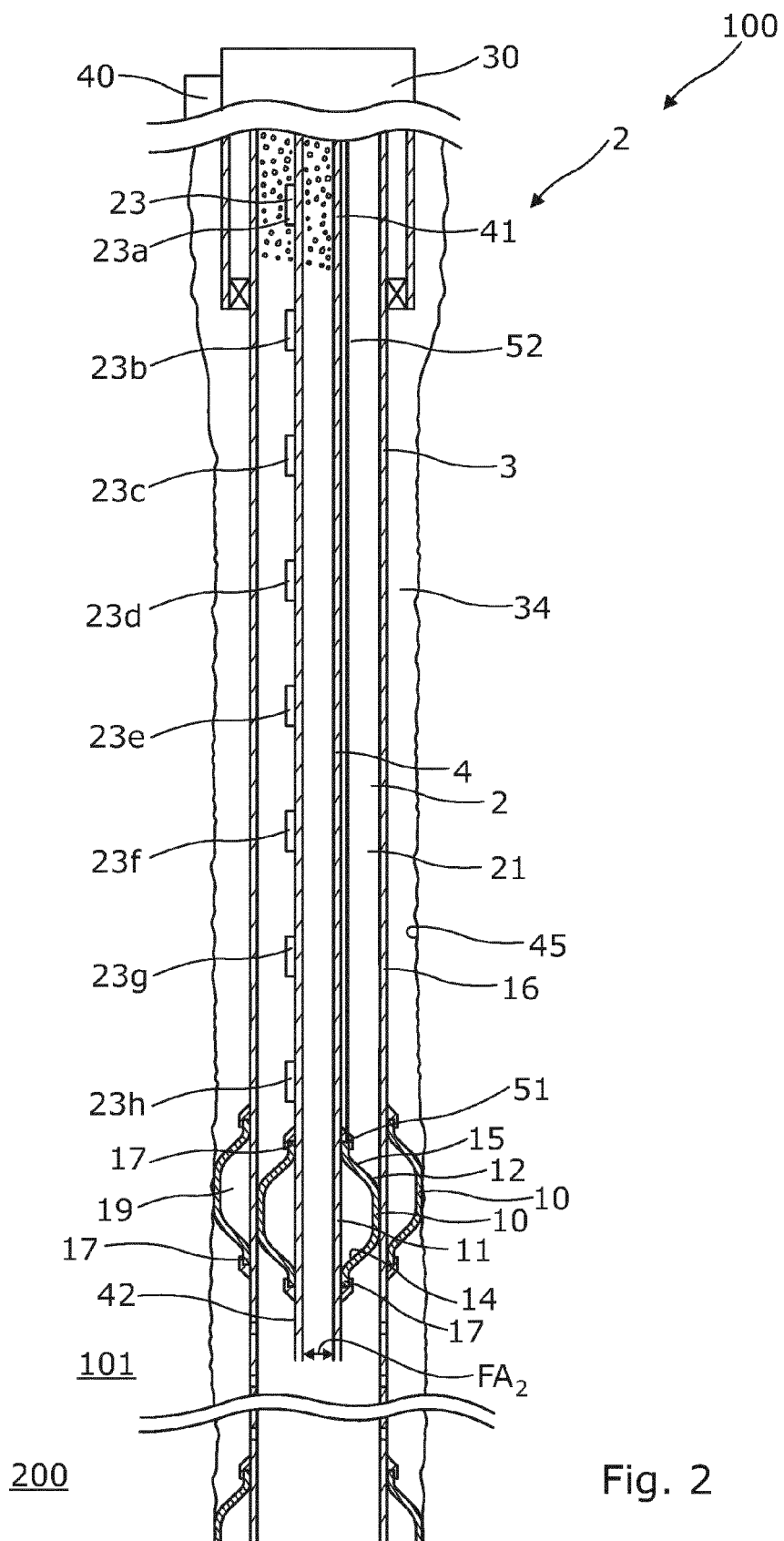
- a production metal casing (3) having a first inner diameter (ID_1) and a first production zone (101), and
 - a velocity metal string (4) having a second inner diameter (ID_2) smaller than the first inner diameter and being arranged inside the production metal casing to reduce the flow area (FA) and increase the flow velocity of the fluid flowing in the well,
- wherein the velocity metal string comprises a first annular barrier (10, 10a) comprising:

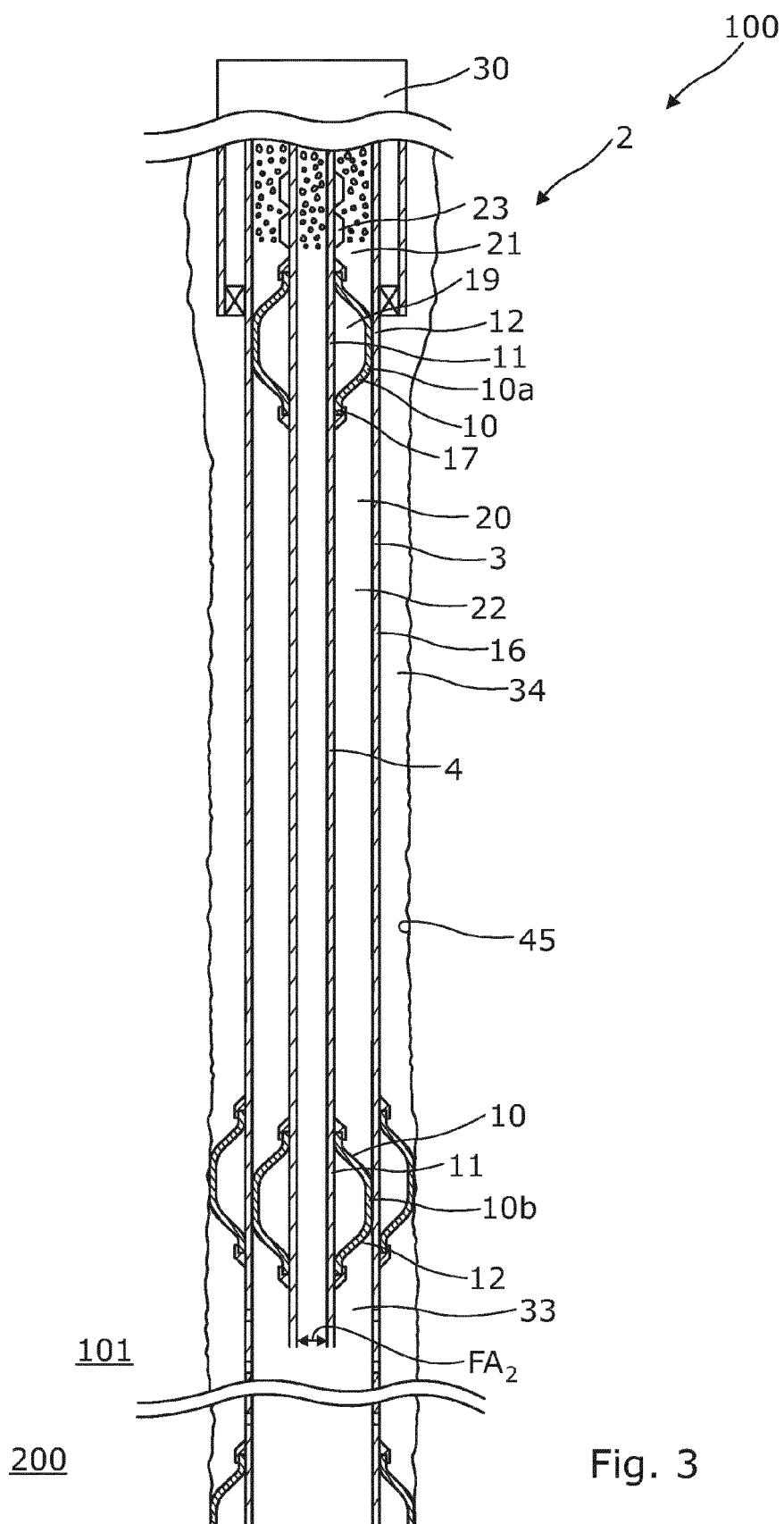
- a tubular metal part (11) for mounting as part of the velocity metal string,
- an expandable metal sleeve (12) surrounding the tubular metal part and having an inner face (14) facing the tubular metal part and an outer face (15) facing the production metal casing, each end of the expandable metal sleeve being connected with the tubular metal part, and
- an annular space (19) between the inner face of the expandable metal sleeve and the tubular metal part, the expandable metal sleeve being configured to expand by expanding the annular space, and

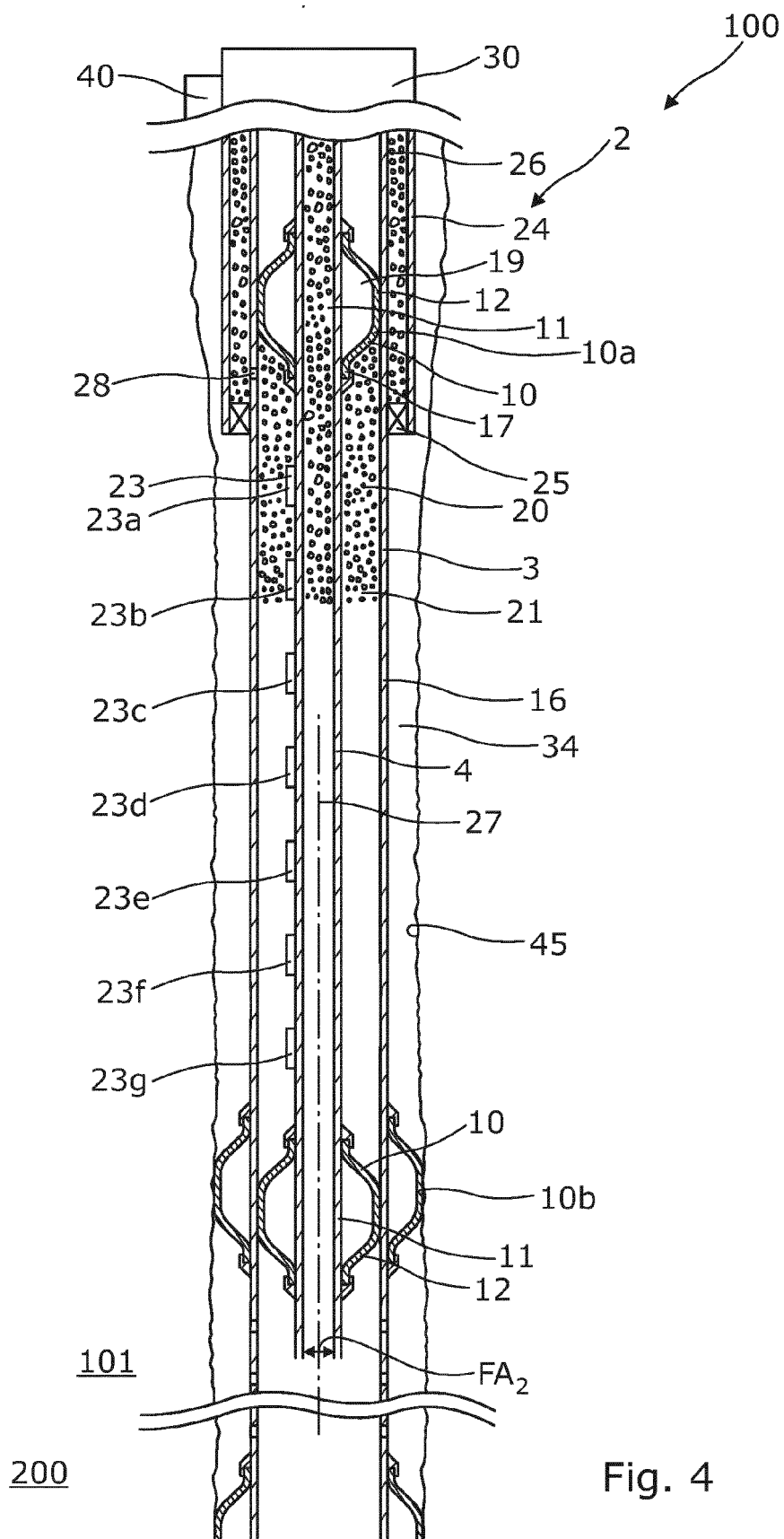
wherein the first annular barrier is expanded so that the expandable metal sleeve abuts the production

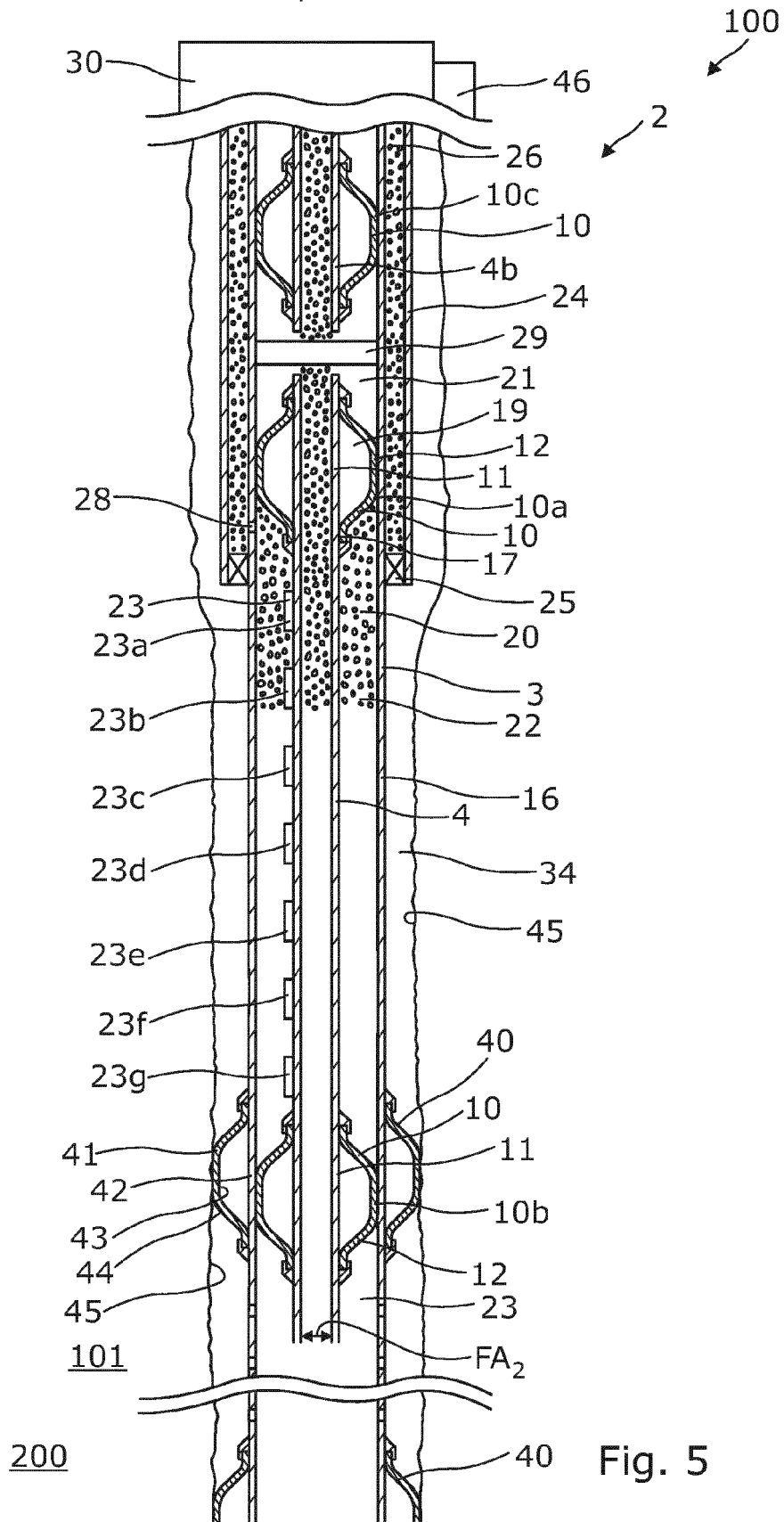
- metal casing, dividing an annulus (20) between the production metal casing and the velocity metal string into a first annulus section (21) and a second annulus section (22), the first annulus section being arranged closer to a top (30) of the well than the second annulus section.
2. A downhole system according to claim 1, wherein the velocity metal string comprises gas lift valves (23, 23a-h) arranged opposite the first annulus section.
 3. A downhole system according to any of the preceding claims, wherein the velocity metal string is coiled tubing.
 4. A downhole system according to any of the preceding claims, further comprising an intermediate casing (24) arranged at the top of the well, surrounding the production metal casing, and a main barrier (25) arranged between the intermediate casing and the production metal casing, defining an intermediate annulus (26), the velocity metal string comprising a second annular barrier (10, 10b), the first annular barrier being arranged below the main barrier and the second annular barrier being arranged above the main barrier, enclosing the first annulus section, and the production metal casing having an aperture (28) providing fluid communication between the intermediate annulus and the first annulus section.
 5. A downhole system according to any of the preceding claims, further comprising a downhole safety valve (29) arranged in the production metal casing above the first annular barrier.
 6. A downhole system according to claim 5, further comprising a second velocity metal string (4b) arranged above the downhole safety valve.
 7. A downhole system according to claim 6, wherein the second velocity metal string comprises at least one annular barrier.
 8. A downhole system according to any of the preceding claims, wherein the velocity metal string has a first end (41) and a second end (42), the second end being arranged opposite the first production zone.
 9. A downhole system according to any of the preceding claims, wherein the velocity metal string reduces the flow area by more than 50% of the flow area of the production metal casing.
 10. A downhole system according to any of the preceding claims, wherein the annular barrier(s) is/are configured to suspend the velocity metal string in the production metal casing.
 11. A downhole system according to any of the preceding claims, wherein a first expansion opening (51) is arranged in the annular barrier, providing access to the annular space so that the expandable metal sleeve is configured to expand when pressurised fluid is injected into the annular space through the first expansion opening.
 12. A downhole system according to claim 11, wherein a flow line (52) is connected to the first expansion opening of the annular barrier, the flow line being arranged outside the velocity metal string.
 13. A downhole system according to any of the preceding claims, wherein the production metal casing comprises one or more casing annular barriers (40) each having an expandable metal sleeve surrounding the tubular metal part and being mounted as part of production metal casing and having an inner face (43) facing the tubular metal part and an outer face (44) facing a wall (45) of a borehole (34).
 14. A downhole system according to any of the preceding claims, further comprising a gas lift pump (46) configured to pressurise the first annulus section to provide gas lift.
 15. A downhole gas lift method for remedial treatment of a well in a hydro-carbon reservoir having insufficient flow velocity, thereby accumulating water in the toe of the well, the method comprising:
 - inserting a velocity metal string of the downhole system according to any of the preceding claims, and
 - expanding the annular barrier so that the expandable metal sleeve abuts the production metal casing, dividing an annulus between the production metal casing and the velocity metal string into a first annulus section and a second annulus section, the first annulus section being arranged closer to the top of the well than the second annulus section.













EUROPEAN SEARCH REPORT

Application Number
EP 16 17 1716

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1 A	EP 2 728 111 A1 (WELLTEC AS [DK]) 7 May 2014 (2014-05-07)	4	
1 A	US 2013/199794 A1 (LANE WILLIAM C [US] ET AL) 8 August 2013 (2013-08-08) -/--	3	
3	The present search report has been drawn up for all claims		
Place of search Munich		Date of completion of the search 19 January 2017	Examiner Beran, Jiri
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	



EUROPEAN SEARCH REPORT

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Munich		19 January 2017	Beran, Jiri
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			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 17 1716

5 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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