



(51) International Patent Classification:

E21B 23/06 (2006.01) *E21B 43/12* (2006.01)
E21B 33/127 (2006.01) *E21B 43/14* (2006.01)
E21B 43/24 (2006.01)

(21) International Application Number:

PCT/EP2011/055414

(22) International Filing Date:

7 April 2011 (07.04.2011)

(25) Filing Language:

English

(26) Publication Language:

English

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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
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KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG,
SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ,
UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG,
ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: TEMPERATURE RESPONSIVE PACKER AND ASSOCIATED HYDROCARBON PRODUCTION SYSTEM

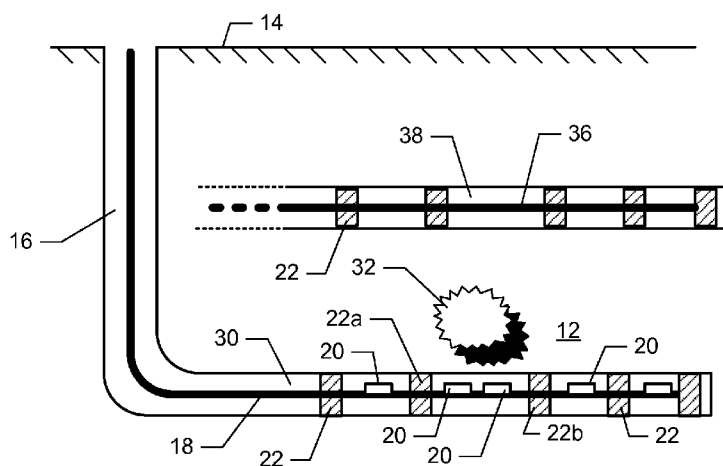


Fig. 1b

(57) Abstract: The present invention relates to a hydrocarbon production system (10). The hydrocarbon production system comprises: a pipe (18) placeable in a hole or wellbore (16), wherein an annulus (30) is defined between the pipe and the hole or wellbore; and at least one ring-shaped packer (22) provided around the pipe, wherein the packer comprises at least one fluid-filled bellows or pocket (24) which is adapted to reversibly expand when externally subjected to increased temperature, such that the annulus (30) is restricted. The present invention also relates to a packer (22), and a method of restricting the annulus (30) between a production or injector pipe (18) and a hole or wellbore (16).

TEMPERATURE RESPONSIVE PACKER AND ASSOCIATED HYDROCARBON PRODUCTION SYSTEM

The present invention relates to a hydrocarbon production system, a packer for a hydrocarbon production system, and a method of restricting the annulus between a production or injection pipe and a hole/wellbore.

A packer is a device that may be used to seal the annulus between a production tubing and a wellbore or casing in a hydrocarbon production system. The packer can have a smaller initial outer diameter allowing it to be smoothly run into the wellbore, whereafter the packer is expanded to create the seal.

Prior art packers include swellable packers. Swellable packers may comprise elastomers that expand and form an annular seal when immersed in certain wellbore fluids. However, the temperature in particular applications can be higher than the elastomers can manage. Further, known swellable packers are irreversible, meaning that it is impossible to run the production tubing out of the wellbore. Also, swellable packers give high friction when running in the wellbore, thereby limiting the number of packers that can be used.

Prior art packers also include inflatable packers, which can be expanded by pumping fluid into the packer. However, inflatable packers require equipment for pumping fluid into the packer, resulting in a more expensive and complicated solution.

Further, US 2003/0075341 (Kurlenya et al.) discloses a packer and a method for fixation thereof in a well. The packer comprises a chamber, which in turn may include a liquid and a thermoheater. By means of the thermoheater, the liquid in the chamber may be converted into a gas, causing the packer to expand and seal the well. Supposedly, the temperature in the well at the level of mounting the packer will promote the heating. However, the packer in US 2003/0075341 is not for restricting the annulus between a production tubing and wellbore, but for completely sealing the well, like a plug.

Further, US 2010/0038086 (Bunnell et al.) discloses a method, apparatus, and production well system that utilize stimulus-responsive materials for "conformance control" and profile control along the fluid flow path in a well as part of a gravel pack or a coating on a well tool. The stimulus-responsive materials are typically polymeric materials that reversibly or irreversibly swell or collapse in the presence of stimulus such as changes in concentration of a fluid media in contact with the stimulus-responsive material, pH or polarity of the media the stimulus-responsive material is in contact with, salinity, current, or temperature. The stimulus-responsive materials may swell upon contact with a rust stimulus and shrink or collapse upon contact with a

second stimulus or vice-versa. The changes between production and injection profiles may supposedly be automatic with the application of the stimulus-responsive materials and may occur without user intervention. FIG. 3B in US 2010/0038086 discloses that an intelligent polymer has an expanded configuration for low temperatures, and the volume
5 of the polymer decreases with increased temperature.

It is an object of the present invention to at least partly overcome the above problem(s), and to provide an improved hydrocarbon production system and packer.

This object, and other objects that will be apparent from the following
10 description, is achieved by a hydrocarbon production system, packer, and a method of restricting the annulus between a production or injection pipe and a hole/wellbore according to the appended independent claims. Embodiments are set forth in the appended dependent claims.

According to an aspect of the invention, there is provided a hydrocarbon
15 production system, comprising: a pipe placeable in a hole or wellbore, wherein an annulus is defined between the pipe and the hole or wellbore wall; and at least one ring-shaped packer provided around the pipe, wherein the packer comprises at least one fluid-filled bellows or pocket which is adapted to reversibly expand when externally subjected to increased temperature, such that the annulus is restricted.

20 By having at least one fluid-filled bellows or pocket that expands when externally subjected to increased temperature, the packer may automatically be expanded or “activated” due to changes in the environment surrounding the packer. The packer may for instance be activated as or when a production temperature is reached. No dedicated internal heater is necessary to expand the packer. Also, no external
25 equipment is necessary to activate the packer. Further, when the temperature decreases (e.g. because the hydrocarbon production is shut off), the reversibly expandable fluid-filled bellows or pocket contracts, which facilitates or enables removal of the pipe from the hole or wellbore.

The at least one packer may be adapted to completely seal the annulus when the
30 at least one packer is externally subjected to (sufficiently) increased temperature. Alternatively, the at least one packer may be adapted to expand so as to restrict the annulus at least about 80 percent.

Further, the fluid in the bellows or pocket may be a liquid, and the at least one packer may be adapted to expand by means of boiling of said liquid. Hence, the phase
35 transition of liquid to gas is used to expand the packer. The liquid may have a boiling temperature that is lower than that of water for a particular or typical reservoir pressure. Hence, if the packer is subjected to water vapour or steam, the liquid in the bellows or

pocket will be converted into gas and thus expand the packer to create the seal. Suitable liquids include difference alcohols, alcohol-water mixtures, acetone, ammonia, etcetera.

Further, the system may comprise a plurality of ring-shaped packers of the type mentioned above, wherein the pipe is a production pipe that includes a plurality of inflow devices or valves arranged along a length of the production pipe for allowing matter into the production pipe, and wherein one or more of said inflow devices or valves are provided between two (or every two) of said ring-shaped packers. This allows a hotspot or steam breakthrough to be isolated, and the hydrocarbon (e.g. oil) recovery may be increased.

Further, the packer may comprise a plurality of fluid-filled bellows or pockets. Having several smaller fluid-filled bellows or pockets makes the packer less prone to puncturing, compared to an embodiment wherein the packer comprises one larger fluid-filled bellows or pocket. The latter embodiment is nevertheless within the scope of the present invention.

Further, the hole or wellbore may be open (i.e. without a casing or the like) or at least partly cased or provided with a slotted liner.

Further, said pipe may be a production pipe, wherein the system also comprises a steam injector placeable in another hole or wellbore, and at least one packer is provided around the steam injector. Hence, packers of the present invention may be used to seal around both a production pipe and a steam injector (pipe) in a Steam Assisted Gravity Drainage (SAGD) arrangement. The packer(s) around the injector allows steam to be injected in particular zones or directions.

According to another aspect of the invention, there is provided a packer for a hydrocarbon production system, wherein the packer is ring-shaped and comprises at least one fluid-filled bellows or pocket which is adapted to reversibly expand when subjected to heat from an external source such that the outer diameter of the packer is increased (or decreased when cooled). This aspect may exhibit the same or similar features and technical effects as the previously described aspect of the invention, and vice versa.

According to yet another aspect of the invention, there is provided a method of sealing the annulus between a production or injector pipe and a hole or wellbore, which method comprises: providing at least one ring-shaped packer on the pipe, wherein the packer comprises at least one fluid-filled bellows or pocket which is adapted to reversibly expand when externally subjected to increased temperature such that the outer diameter of the packer is increased (or decreased when cooled); and placing the pipe (with the at least one packer) in the hole or wellbore. This aspect may exhibit the

same or similar features and technical effects as the previously described aspects of the invention, and vice versa.

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing currently preferred
5 embodiments of the invention.

Figs. 1a-1b schematically illustrate a hydrocarbon production system comprising a plurality of packers according to an embodiment of the present invention.

Figs. 2a-2e are cross-sectional side views showing packers according to
10 embodiments of the present invention.

Figs. 1a-1b illustrate a hydrocarbon production system 10. The system 10 may for instance be used to produce at least one of oil (e.g. heavy crude oil), (natural) gas, and bitumen from a formation or reservoir 12 under the earth surface or sea floor 14. A
15 hole or wellbore 16 goes from the earth surface/sea floor 14 to the reservoir 12. The wellbore 16 may be open or at least partly cased.

The hydrocarbon production system 10 comprises a production pipe 18. The production pipe 18 is placed in the wellbore 16 for providing a flow path for hydrocarbons and other fluids through the wellbore 16. The production pipe 18 may be
20 placed concentric or substantially concentric with the wellbore 16. Between the production pipe 18 and the wellbore 16 (or the wellbore wall), there is an annulus (or annular space) 30. In case of an open wellbore 16, the annulus 30 may be defined as the space between the production pipe 18 and the reservoir 12 (e.g. rock). In case of a cased wellbore 16, the annulus 30 may be the space between the production pipe 18 and the
25 casing (not shown).

The production pipe 18 extends into the reservoir 12, and may have an at least partly horizontal orientation. The production pipe 18 includes a plurality of inflow devices or valves 20 arranged along a length of the production pipe 18, as illustrated. The valves 20 are generally adapted to allow matter, in particular hydrocarbons, into the
30 production pipe 18. The inflow devices or valves 20 may for instance be autonomous valves of the type disclosed in WO 2008004875 A1, the contents of which herein is incorporated by reference.

The hydrocarbon production system 10 further comprises a plurality of packers 22. The packers 22 are generally ring-shaped or doughnut-shaped, and provided or
35 wrapped around the production pipe 18, as illustrated in particular in the enlarged perspective view in fig. 1a. The packers 22 may for instance be welded onto the production pipe 18 before the production pipe 18 with the packers 22 are inserted into

the hole or wellbore 16. The packers 22 are distributed along the length of the production pipe 18, next to the valves 20, such that at least one valve 20 preferably is situated between every two packers 22.

Each packer 22 comprises at least one fluid-filled bellows or pocket 24, as illustrated more in detail in figs. 2a-2e. The pocket, or rather the fluid inside the pocket, is adapted to reversibly expand when subjected to increased temperature. In this way, the outer diameter D of the packer may be increased when the packer is subjected to heat from an external source. Contrary, the outer diameter of the packer may decrease when the packer is cooled.

In more detail, each packer 22 comprises two holder rings 26a and 26b attached to the production pipe 18. The two holder rings 26a and 26b are for instance attached to the production pipe 18 by means of welding, as mentioned above. Between the holder rings 26a and 26b, an outer flexible or elastic tube-shaped element 28 is fastened. In the embodiment of figs. 2a-2b, the space between the element 28 and the outer surface of the production pipe 18 between the holder rings 26a and 26b is filled with a fluid, thus is a fluid-filled bellows or pocket 24 formed. The fluid inside the pocket 24 may be a liquid having a boiling temperature that is lower than that of water for a particular or typical reservoir pressure. Suitable liquids include difference alcohols, alcohol-water mixtures, acetone, etcetera. Hence, at lower temperatures, the fluid may be in liquid phase occupying lesser space as indicated in fig. 2a (outer packer diameter D_1). In fig. 2b, the packer 22 is subjected to heat sufficient for the liquid to start to boil, whereby the packer 22 is expanded and the annulus 30 is sealed (outer packer diameter $D_2 > D_1$). Fig. 2c illustrates an embodiment of the present packer with one closed volume, i.e. a single fluid-filled pocket 24, whereas fig. 2d illustrates an embodiment with multiple closed volumes, i.e. several fluid-filled pockets 24a, b, etcetera. The fluid filled pockets in fig. 2d may for instance be ring-shaped. However, several longitudinal pockets could also be used. Fig. 2e illustrates an embodiment with smaller expanding elements 34 compared to fig. 2d. The expanding elements 34 may for instance be fluid-filled balls.

Returning to figs. 1a-1b, the system 10 may further comprise a steam injector 36. The steam injector 36 is placed in another hole/wellbore 38 which may be arranged above and substantially parallel to the hole/wellbore 16 for the production pipe 18. At least one packer of the type mentioned above may be provided also around the steam injector 36, as illustrated.

Directly following installation, the packers 22 are initially in a non-expanded state (fig. 1a).

Typically, the packers 22 will then be gradually and automatically expanded as the temperature is increased. The temperature may be increased due to steam injection

from the steam injector 36. When a production temperature is reached, at which temperature the hydrocarbon in question may have become sufficiently mobile for production, the packers 22 can be so expanded that the annulus 30 is substantially or completely restricted (fig. 1b). In this way, material is prevented to travel un-restricted along the pipe 18. In particular, if a steam breakthrough 32 occurs along the production pipe 18 as illustrated in fig. 1b, the nearby packers 22a and 22b will restrict or completely seal the annulus 30 on both sides to the steam breakthrough 32, whereby the steam breakthrough 32 is "isolated" and steam is prevented from travelling along the production pipe 18 and reach other inflow valves 20. Alternatively, if the packers are not expanded at the time of regular operation of the system, they can be automatically expanded when a steam breakthrough occurs. Hence, the packers 22 may also in this situation isolate the breakthrough, though packers more remote from the breakthrough are possible not expanded. Overall, by creating isolated zones along the production pipe 18, the hydrocarbon (e.g. oil) recovery may be increased. Further, by creating isolated zones along the injector 36, the injection of steam may be better controlled

It should be noted that if the valves 20 are autonomous valves of the type disclosed for example in WO 2008004875 A1, the inflow through the valve or valves near the steam breakthrough will automatically be reduced. But without the packers 22, the steam from the breakthrough would just continue in the annulus 30 along the production pipe 18 and instead enter through nearby valves.

As the temperature subsequently decreases, for instance because the hydrocarbon production is shut off, the packers 22 contract. This facilitates or enables removal of the production pipe 18 from the wellbore 16.

In a typical application of the present invention, the reservoir pressure is about 20-30 bar, the boiling temperature for water is about 212-234°C, and the boiling temperature for a water-ethanol mixture contained in the packers 22 is about 180°C. Hence, if such a packer is subjected to water steam at this pressure, the water-ethanol mixture transits into gaseous phase, and the packer is expanded. Further, it should be "cold" during installation, so that the packers do not expand before the production pipe is in place.

The person skilled in the art will realize that the present invention by no means is limited to the embodiment described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

For instance, instead of the packers being triggered or activated by a steam breakthrough, the packers may be (purposely) expanded by means of in-situ combustion. Also, the present invention may be used also in a non-SAGD applications.

C l a i m s

1. A hydrocarbon production system (10), comprising:
a pipe (18; 36) placeable in a hole or wellbore (16), wherein an annulus (30) is
5 defined between the pipe and the hole or wellbore; and
at least one ring-shaped packer (22) provided around the pipe,
wherein the packer comprises at least one fluid-filled bellows or pocket (24)
which is adapted to reversibly expand when externally subjected to increased
temperature, such that the annulus (30) is restricted.
10
2. A system according to claim 1, wherein the at least one packer is adapted to
completely seal the annulus when the at least one packer is externally subjected to
increased temperature.
- 15 3. A system according to claim 1 or 2, wherein the fluid in the bellows or pocket is
a liquid, and wherein the at least one packer is adapted to expand by means of boiling of
said liquid.
4. A system according to claim 3, wherein the liquid has a boiling temperature that
20 is lower than that of water for a particular or typical reservoir pressure.
5. A system according to any preceding claim, comprising a plurality of ring-
shaped packers (22), wherein the pipe is a production pipe (18) that includes a plurality
of inflow devices or valves (20) arranged along a length of the production pipe for
25 allowing matter into the production pipe, and wherein one or more of said inflow
devices or valves are provided between two or every two of said ring-shaped packers.
6. A system according to any preceding claim, wherein the packer comprises a
plurality of fluid-filled bellows or pockets (24).
30
7. A system according to any preceding claim, wherein the hole or wellbore is one
of: open, at least partly cased, and provided with a slotted liner.
8. A system according to any preceding claim, wherein said pipe is a production
35 pipe (18), the system further comprises a steam injector (36) placeable in another hole
or wellbore (38), and at least one packer is provided around the steam injector.

9. A packer (22) for a hydrocarbon production system, wherein the packer is ring-shaped and comprises at least one fluid-filled bellows or pocket (24) which is adapted to reversibly expand when subjected to heat from an external source such that the outer
5 diameter (D) of the packer is increased.

10. A method of restricting the annulus (30) between a production or injection pipe (18; 36) and a hole or wellbore (16; 38), which method comprises:
providing at least one ring-shaped packer (22) on the pipe, wherein the packer
10 comprises at least one fluid-filled bellows or pocket (24) which is adapted to reversibly expand when externally subjected to increased temperature such that the outer diameter (D) of the packer is increased; and
placing the pipe in the hole or wellbore.

11. A method according to claim 10, further comprising:
completely sealing the annulus between the pipe and the hole or wellbore by
15 means of at least one of said packer(s).

12. A method according to claim 10 or 11, wherein the fluid in the bellows or pocket
20 is a liquid at a lower temperature, and wherein the at least one packer is adapted to expand by means of boiling of said liquid when subjected to a higher temperature.

13. A method according to claim 12, wherein the liquid has a boiling temperature that is lower than that of water for a particular or typical reservoir pressure.

25 14. A method according to any one of the claims 10 – 13, wherein the pipe is a production pipe that includes a plurality of inflow devices or valves arranged along a length of the production pipe for allowing matter into the production pipe, and wherein the method comprises providing a plurality of ring-shaped packers (22) on the
30 production pipe, such that one or more of said inflow devices or valves are situated between two or every two of said ring-shaped packers.

15. A method according to any one of the claims 9 – 14, wherein the packer
35 comprises a plurality of fluid-filled bellows or pockets.

16. A method according to any one of the claims 9 – 15, wherein the hole or wellbore is open or cased or provided with a slotted liner.

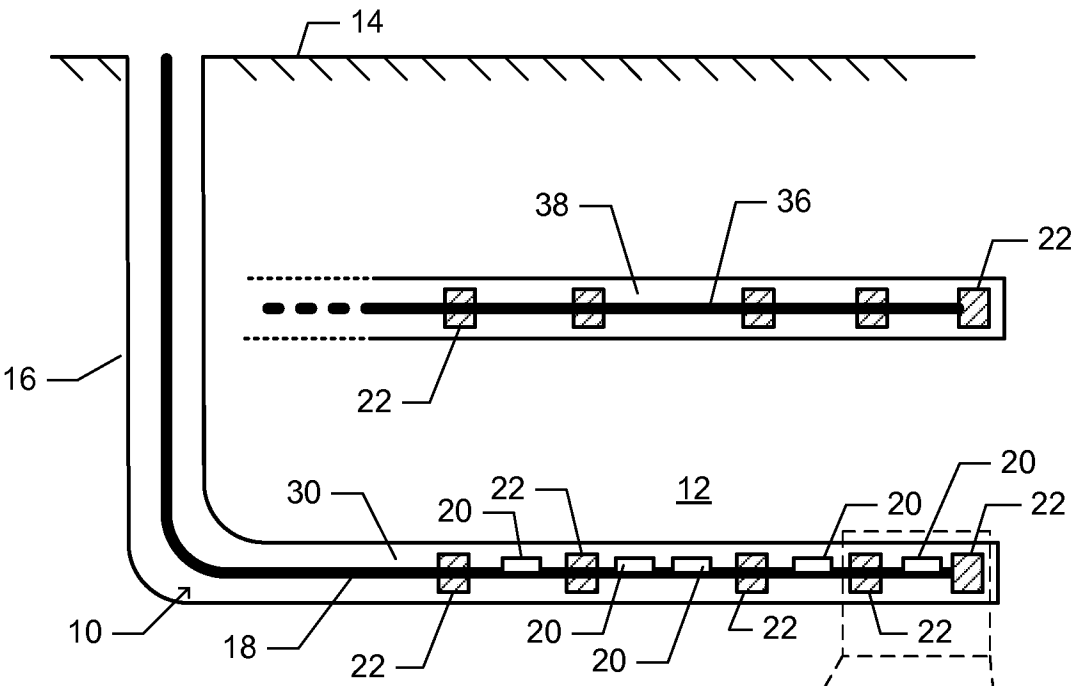
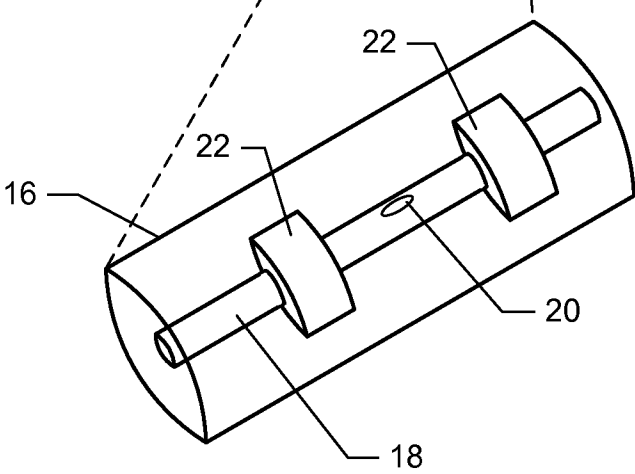


Fig. 1a



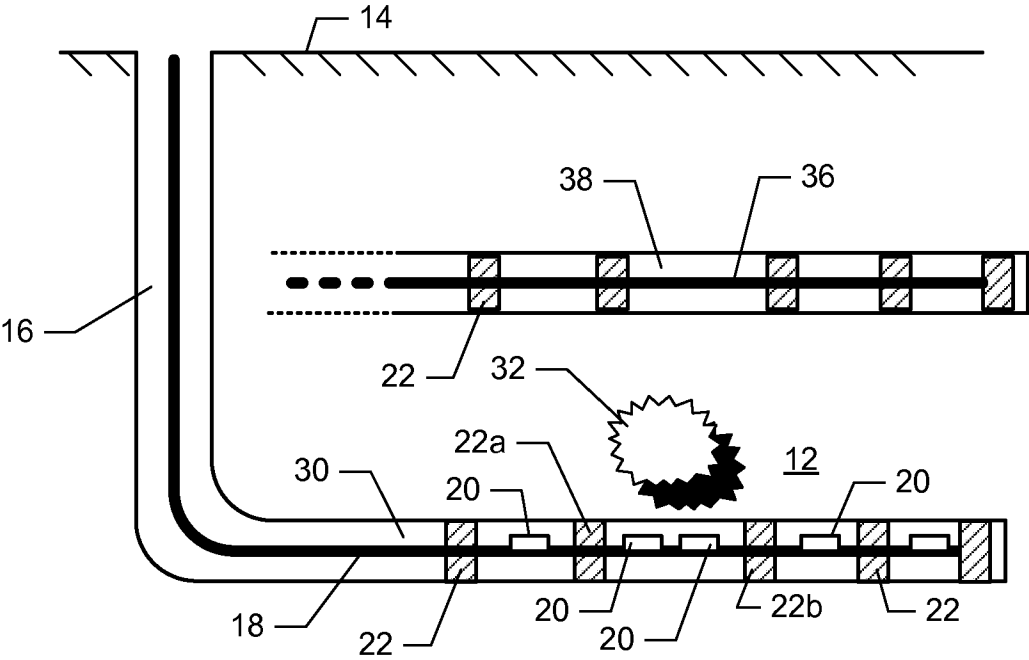


Fig. 1b

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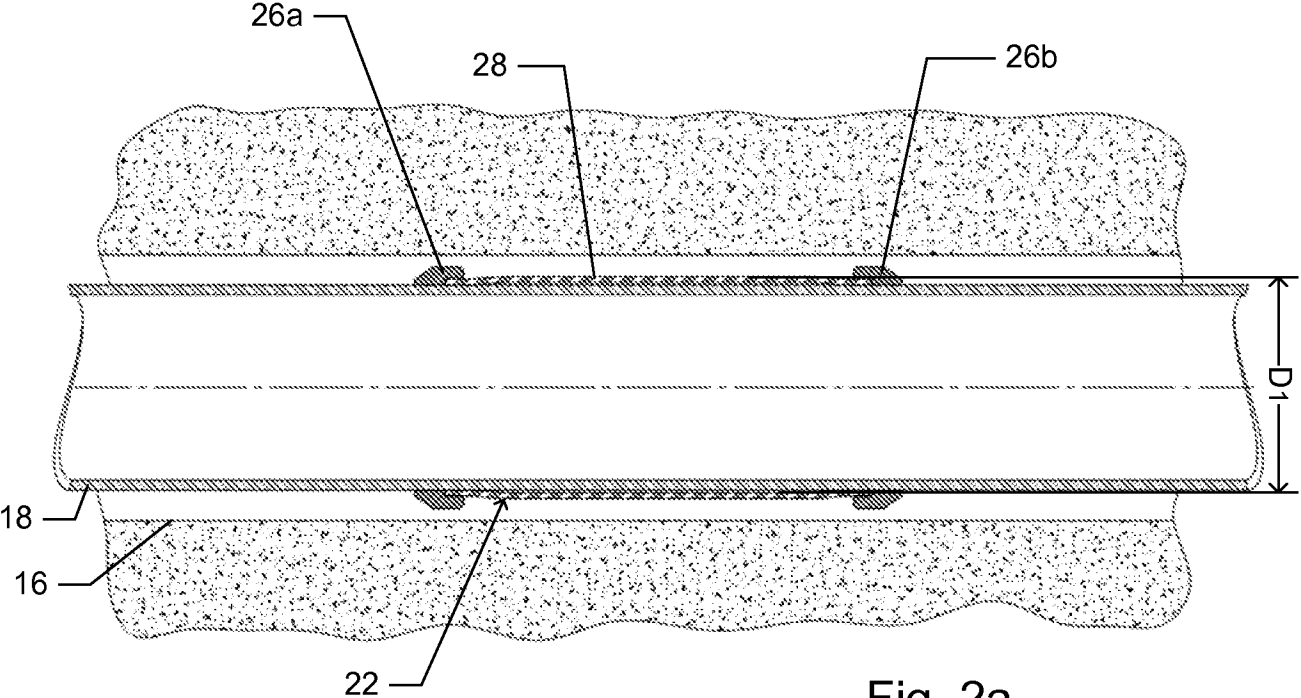


Fig. 2a

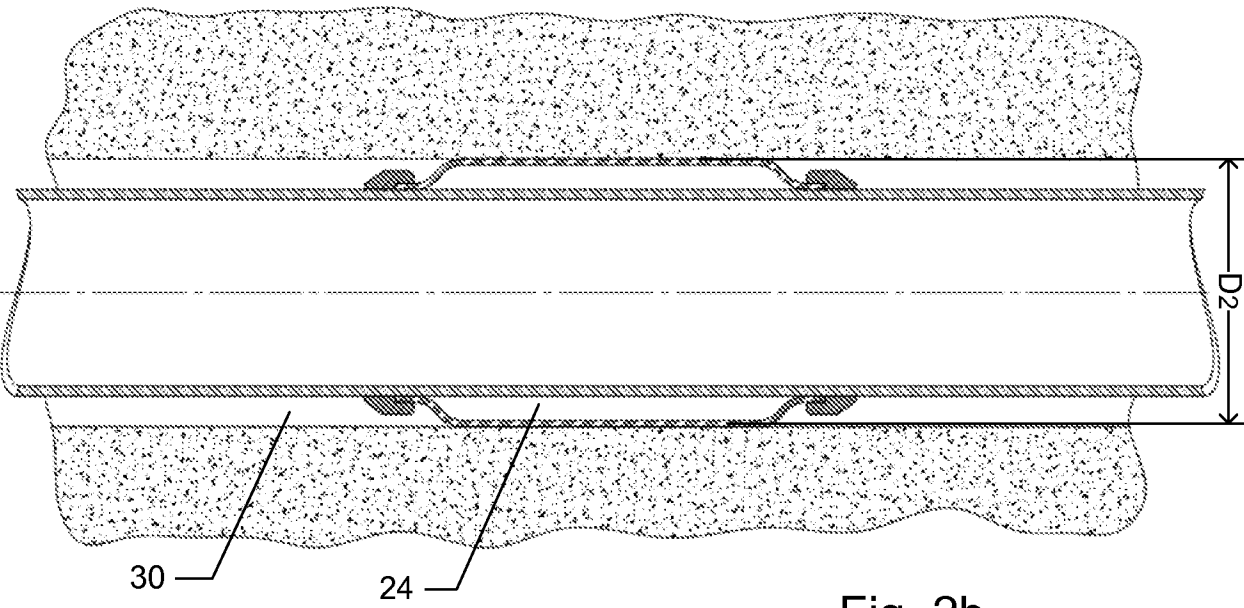
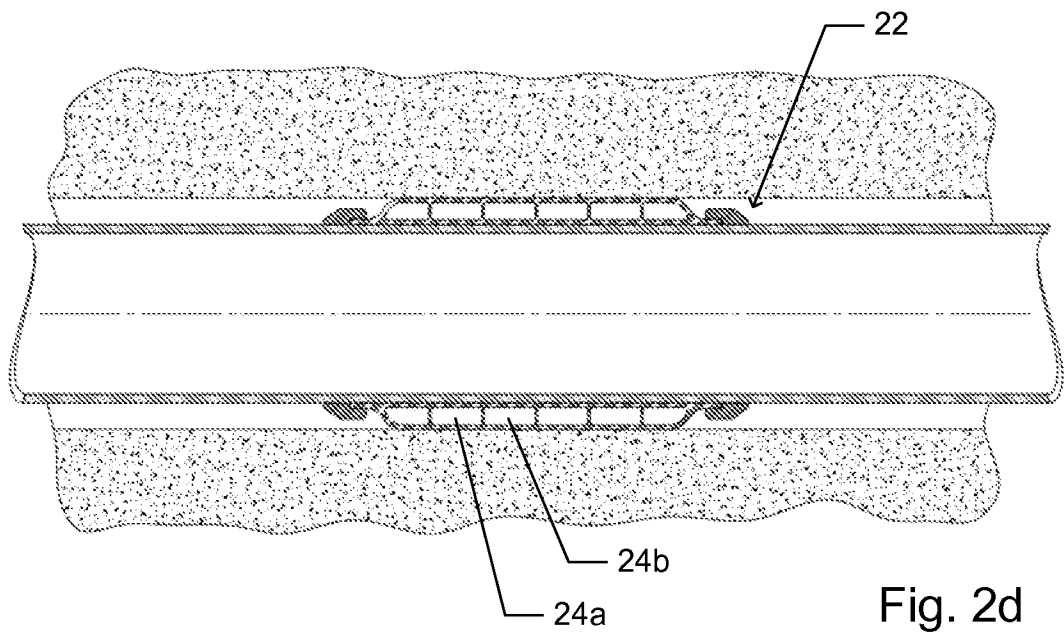
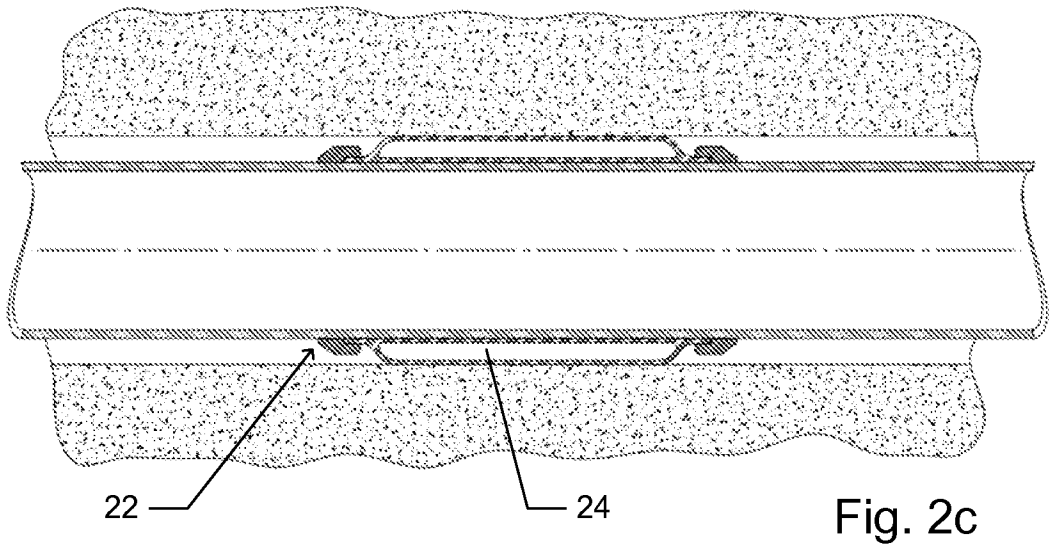


Fig. 2b



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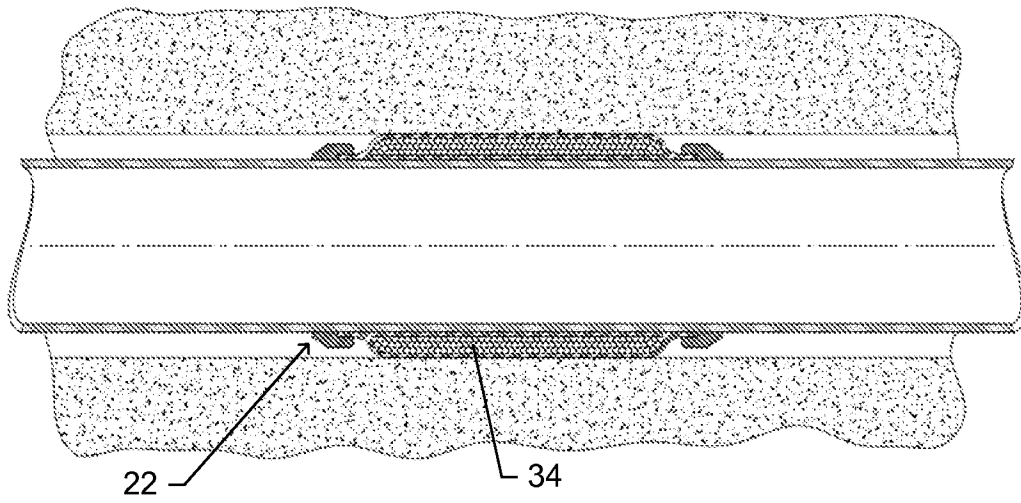


Fig. 2e

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/055414

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B23/06 E21B33/127 E21B43/24 E21B43/12 E21B43/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 352 359 A (SUTLIFF WAYNE N ET AL) 14 November 1967 (1967-11-14) column 2, line 45 - line 71; figures 2,3 column 3, line 24 - line 53 column 3, line 74 - column 4, line 10 -----	1-16
E	WO 2011/056394 A2 (CHEVRON USA INC [US]; CORBETT THOMAS G [US]; CHRUSCH LARRY J [CA]; SIM) 12 May 2011 (2011-05-12) paragraph [0009]; figures 1-3 paragraph [0044] paragraph [0056] - paragraph [0058] -----	1-16
A	US 3 716 101 A (MCGOWEN H ET AL) 13 February 1973 (1973-02-13) abstract; figures 1,2 ----- -/-	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 December 2011

Date of mailing of the international search report

19/12/2011

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2011/055414

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/075341 A1 (KURLENYA MIKHAIL VLADIMIROVICH [RU] ET AL) 24 April 2003 (2003-04-24) cited in the application abstract; figures 1,2 -----	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/055414

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