

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property

Organization

International Bureau

(43) International Publication Date

10 April 2025 (10.04.2025)



(10) International Publication Number

WO 2025/076293 A1

(51) International Patent Classification:

E21B 34/08 (2006.01)

E21B 34/14 (2006.01)

Published:

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

(21) International Application Number:

PCT/US2024/049886

(22) International Filing Date:

04 October 2024 (04.10.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/588,041

05 October 2023 (05.10.2023)

US

23203177.3

12 October 2023 (12.10.2023)

EP

(71) Applicant (for US only): SHELL USA, INC. [US/US];

P.O. BOX 576, Houston, Texas 77001-0576 (US).

(71) Applicant (for all designated States except US): SHELL

INTERNATIONALE RESEARCH MAATSCHAPPIJ

B.V. [NL/NL]; Carel van Bylandtlaan 30, NL-2596 The

Hague (NL).

(72) Inventors: STAM, Walter; Grasweg 31, 1031 HW Ams-

terdam (NL). JOINSON, Daniel; Grasweg 31, 1031 HW

Amsterdam (NL).

(74) Agent: VANDENHOFF, Deborah G.; SHELL USA,

INC., P.O. BOX 576, Houston, Texas 77001-057 (US).

(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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: TOOL AND METHOD FOR CHOKING FLUID FLOW

(57) Abstract: A downhole tool for choking flow of a fluid to be injected in a subsurface formation, has a choke having an annular choke body with fluid inlet and outlet ports and a choking medium disposed therebetween. The choking medium is deployed by a remote actuator for opening the fluid outlet port to allow fluid flow through the choking medium.

WO 2025/076293 A1

TOOL AND METHOD FOR CHOKING FLUID FLOW

FIELD OF THE INVENTION

[0001] The present invention relates to the field of fluid injection to a subsurface formation and, in particular, to choking fluid during injection.

BACKGROUND OF THE INVENTION

[0002] The increased demand for energy resulting from worldwide economic growth and development has contributed to an increase in concentration of greenhouse gases in the atmosphere. This has been regarded as one of the most important challenges facing humankind in the 21st century. To mitigate the effects of greenhouse gases (GHG), efforts have been made to reduce the global carbon footprint.

[0003] Efforts to mitigate the release of GHG have led to a variety of technologies for CCS (carbon capture and sequestration, or carbon capture and storage) and Negative Emission Technologies. With respect to geologic sequestration, efforts have predominantly been directed towards injecting gaseous or supercritical - close to pure - CO₂ into a subsurface formation.

[0004] The use of depleted hydrocarbon reservoirs has been considered for CO₂ storage. One challenge for injecting the CO₂ into the depleted reservoir is related to CO₂ phase behaviour. Expansion or evaporation of the CO₂ may lead to extremely low temperatures in the well, posing limitations on well design, integrity, and operability, and injectivity as hydrates may form. Alternatively, in case of a strong aquifer, water backfills the porous formation after the hydrocarbons are produced from the reservoir. Accordingly, a significant pressure is required for injecting CO₂ to overcome the water pressure in the formation and limited capacity is available for storage without potential risking caprock integrity. Compression of the gas requires energy, potentially with a related GHG footprint.

[0005] Another challenge facing the injection of CO₂ is the structure of the subsurface formation. Even dense phase CO₂ is light i.e., less dense than water, and will naturally travel upwardly in the formation because of buoyancy. Therefore, the formation should have a high-quality seal to avoid leak paths that could result in release into the environment. When upward mobility is limited, CO₂ will then migrate laterally potentially encountering additional leaks paths related to lack of closure, faults, or improperly abandoned wells. This presents limitations of where CO₂ can be responsibly injected and necessitates extensive CO₂ monitoring activities for a prolonged period to ensure the CO₂ remains in the subsurface formation.

[0006] Similar challenges face efforts to inject hydrogen and other fluids into depleted reservoirs.

[0007] Efforts to address the challenges of CO₂ injection include the tools used to inject the fluid into the subsurface.

[0008] For example, Cawley et al. (US9163489, 20 Oct 2015; EP2406460B1, 11 Nov 2015) describes a method and system for injecting CO₂ into an aquifer or a depleted hydrocarbon reservoir using a fluid injection control valve that closes when the pressure above the valve is less than a pre-set pressure and opens when the pressure opens when the pressure above the valve is greater than or equal to the pre-set pressure. The pre-set pressure is selected to maintain the CO₂ in a liquid or supercritical state. The fluid control valve has an actuating means that provides a biasing force to the valve closure element.

[0009] Another example is Fripp et al. (US2022/0333460A1, 20 Oct 2022; WO2022/221790A1, 20 Oct 2022) relates to a downhole vapor-transition control valve for fluid injection. The fluid control valve has a chamber with a variable volume and filled with a fill fluid comprising CO₂ or an azeotrope of CO₂. The chamber includes a biasing device to apply a biasing force to reduce the pressure level in fill fluid. The biasing device may be a bellows that enclose the chamber and fill fluid, or a spring positioned in the chamber.

[0010] In the Cawley et al. and Fripp et al. devices, the flow control valves are responsive to pressures in the injection tubing to cause opening or closing based on a pressure measurement in efforts to maintain the CO₂ fluid in a dense phase. As such, the choking of fluid flow is concentrated at the valve itself, creating a higher risk for erosion by the fluid. As the flow control valves are eroded, the risk of fluid leaks and valve failure increases.

[0011] Alternatively, a conventional wireline conveyed plug with choke functionality can be used to choke the injected fluid downhole. A disadvantage of this approach is that intervention is required to change the amount of choking provided by the plug. Specifically, the plug must be pulled to surface and replaced with a choke plug with a reduced pressure drop, requiring a well intervention for each choke change out. Each intervention is associated with operational downtime and the associated cost thereof.

[0012] In another conventional approach, a series of shrouded inflow control valves may be provided with internal diverted plugs/fixed chokes. A disadvantage of this approach is that is not designed for controlled choking of CO₂ flow. Also, it does not overcome the disadvantage of the Cawley et al. and Fripp et al. devices discussed above.

[0013] There remains a need for improved tools and methods for injecting CO₂ and other fluids, especially fluids subject to phase change behaviour at injection conditions.

SUMMARY OF THE INVENTION

[0014] According to one aspect of the present invention, there is provided a downhole tool for choking flow of a fluid to be injected in a subsurface formation, the downhole tool comprising: a choke having an annular choke body having an internal wall defining an annular tube and an external wall, the internal wall having a fluid inlet port proximate an upper end of the choke body, the choke body having a fluid outlet port proximate a lower end of the choke body; a choking medium disposed within the choke body; the fluid outlet port provided in a closed position by an actuatable seal; and a remote actuator for actuating the seal, thereby causing the fluid outlet port to open and allowing fluid flow through the fluid inlet port and the choking medium to the fluid outlet port.

[0015] According to another aspect of the present invention, there is provided a method for injecting a fluid from a surface into a target formation, the method comprising: providing a tubing string in a casing to provide an open-hole annulus between the injection tubing and the casing, wherein a portion of the open-hole annulus in a region of the target formation is fluidly isolated from the surface with a production packer; providing the tubing string with at least two chokes, wherein a first of the at least two chokes is located upstream of a second of the at least two chokes, wherein each of the at least two chokes has a choking medium; controlling at least one of pressure and flowrate of the fluid into the target formation by selectively opening a flow path in one or more of the at least two chokes; wherein the flow path is selectively opened a remote actuator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The process of the present invention will be better understood by referring to the following detailed description of preferred embodiments and the drawings referenced therein, in which:

[0017] Figs. 1, 2 and 3 are cross-sectional views of embodiments of the downhole tool of the present invention; and

[0018] Figs. 4A – 4C, and 5 are cross-sectional views of embodiments for deploying the downhole tool of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention provides a downhole tool and a method for choking flow of a fluid to be injected in a subsurface formation. The downhole tool has a choke and a remote actuator to cooperatively allow the injected fluid to flow into the formation.

[0020] The present invention addresses shortcomings of conventional techniques by choking fluid flow without the need for a spring-loaded valve. Further, the choking configuration can be controlled from surface without intervention. The downhole tool and method are suitable for the injection of fluids that undergo phase change during injection, such as for example, without limitation, CO₂ and H₂

[0021] The downhole tool and method of the present invention are particularly suitable for Carbon Capture and Storage (CCS) projects, where CO₂ is injected into depleted stores. Such depleted stores can be oil or gas reservoirs that are no longer economically viable for production. The purpose of this invention is to choke the flow of CO₂, keeping the CO₂ in dense phase within the tubing during CO₂ injection. Without the downhole tool and method of the present invention to choke fluid flow to provide, the needed pressure drop would not be applied and, therefore, the fluid, such as CO₂, will convert into the gas phase, resulting in uncontrolled cooling of the well caused by evaporation, expansion due to the Joule-Thompson effect, and/or subject the reservoir formation to an extreme pressure, which may cause damage due to the creation of fractures. This invention provides a choke to fluid flow that can be fully integrated into the lower completion of a CCS well.

[0022] Referring now to the drawings, Figs. 1, 2 and 3 are cross-sectional views of embodiments of the downhole tool 10 of the present invention. The downhole tool 10 has a choke 12 and a remote actuator 14. The choke 12 has an annular choke body having an internal wall 16 defining an annular tube and an external wall 18. A choking medium 20 is disposed within the choke body. The internal wall 16 has a fluid inlet port 22 proximate an upper end of the choke body. A fluid outlet port 24 is located proximate a lower end of the choke body.

[0023] In Figs. 1, 2 and 3, the fluid outlet port 24 is initially in a closed position with a seal (not shown) that is responsive to a remote actuator 14 at the surface. The seal may be melted or ruptured by the remote actuator 14. The seal may be melted or ruptured as a whole. Alternatively, a non-melting seal may be held in place in the fluid outlet port 24 by a material that is meltable.

[0024] Examples of materials that may be melted by remote actuator 14 include, for example, without limitation, an alloy that has a low melting temperature such as tin or bismuth. In this case, the remote actuator 14 is an electrical line that activates a heating element located at the fluid outlet port 24, such that when the meltable material is heated, the fluid outlet port 24 is open to fluid flow.

[0025] Alternatively, the fluid outlet port 24 may be initially in a closed position with a seal that can be opened with pyrotechnics. In this embodiment, the remote actuator 14 is an electrical line that initiates an energetic process that ruptures the seal, such that when the pyrotechnic material is energized, the fluid outlet port 24 is open to fluid flow.

[0026] An alternative to an electrical line, the remote actuator 14 may be actuated using a telemetry to which power may be provided, for example, by battery.

[0027] In the embodiments of Figs. 1, 2 and 3, the fluid outlet port 24 is located proximate a lower end of the external wall 18 of the choke 12.

[0028] The choking medium 20 is provided to choke fluid flow through the choke body when injected fluid flows through the fluid inlet port 22. The choking medium may be, for example, without limitation, packing material, tubing defining a spiral fluid flow path, corrugations integrated into choke body defining a spiral or other tortuous fluid flow path, and combinations thereof. As discussed below, the choking medium 20 may be integral with and/or added to the choke body. The choking medium 20 is preferably disposed between the fluid inlet port 22 and the fluid outlet port 24. Depending on the nature of the choking medium 20 used, the choking medium 20 may be positioned and or defined in the choke body, for example, in an encasement or with a flange 36. The flange 36 is provided with openings that further provide a tortuous path for fluid flow.

[0029] The amount and/or tortuosity of choking medium 20 is selected to provide a suitable pressure drop of fluid flowing therethrough.

[0030] In the case where the choking medium 20 is a packing material, the packing material is preferably formed from a wear-resistant material for high-temperature, oxidation, and/or chemical resistance. An example of a suitable material is a ceramic, such as silicon nitride. The packing may be in the form of spheres, rings, and the like. A packing material may also be provided in the form of stacked discs arranged to create a tortuous fluid flow path by limiting flow through certain portions of a disc and/or rotating openings in the discs to form a labyrinth. The option of packing material as choking medium 20 is depicted in Fig. 1.

[0031] In the embodiment where the choking medium 20 is provided by corrugations, the exterior of the internal wall 16 and/or the interior surface of the external wall 18 may be machined with a rough and/or tortuous pattern to increase friction, as compared with a smooth wall. Alternatively, a cylindrical hollow body may have interior surfaces machined with a rough and/or tortuous pattern to increase friction. The option of corrugation as choking medium is depicted in Fig. 2.

[0032] The corrugation of Fig. 2 may be supplemented, in whole or in part, with a packing material, such as spheres, provided in the interstitial spaces of the corrugations.

[0033] In the embodiment where the choking medium 20 is a tubing, the tubing may be wrapped around the internal wall 16 or the tubing may be integral in the body of the internal wall 16 and/or the external wall 18 with machined channels on one or both surfaces. Alternatively, a cylindrical hollow body may have machined channels on the interior surface thereof. The tubing may have a uniform internal diameter throughout the length of the choking medium 20. Alternatively, the tubing may have a change in internal diameter along the length thereof. For example, the tubing may have a smaller internal diameter closer to the fluid outlet port 24, as compared with the internal diameter closer to the fluid inlet port 22. The option of tubing as choking medium is depicted in Fig. 3.

[0034] The tubing of Fig. 3 may be supplemented, in whole or in part, with a packing material, such as spheres, provided in the interstitial spaces of the tubing. An advantage of the embodiment of Fig. 3 is that vibrations caused by choked fluid passing through the choking medium 20 are reduced.

[0035] In the embodiment of Fig. 2, the choke body is provided with a non-return valve 38 in an opening in the flange 36 upstream of the fluid outlet port 24. The non-return valve 38 may alternatively be provided at the fluid inlet port 22 to reduce fluid velocity and/or erosion risk. The purpose of the non-return valve 38 is to avoid back flow from the open hole annulus 62 into the choke body and tubing string when injection of fluid is stopped. By controlling the flow of fluid back into the choke body, the formation of deleterious pressure waves is reduced. Another purpose of the non-return valve 38 is to reduce migration of fines, such as small sand particles, from the formation back into the tubing annulus 10, thereby avoiding fill or plugging of the choking medium 20 when backflow occurs.

[0036] The options provided for the choking medium 20 described above may be formed as a monolithic structure with a porosity formed by chemical etching or by 3D printing.

[0037] The choking medium encasement or flange 36 may be provided with a nozzle or a diffuser to supplement the fluid choking. In the case of a tubing option (Fig. 3), the outlet of the tubing may be provided with additional tubing fitted to the fluid outlet port 24.

[0038] Figs. 4A, 4B and 4C illustrate one embodiment for deploying the downhole tool 10 of the present invention. Figs. 4A, 4B and 4C are schematic drawings of an integrated completion system using three chokes 12.1, 12.2, 12.3 in a pre-drilled section. The actual number of chokes 12 used can be tailored the specific deployment. Preferably, two or more chokes 12 will be used. By using two or more chokes, it is possible to change the degree of fluid-choking without the need for intervention. Additional chokes 12 may be provided. Alternatively, the degree of choking may be selected so that following the second choke 12, the reservoir pressure is sufficient to maintain the injection fluid in a dense phase, thereby no further choking may be required. For clarity, the drawing only shows a partial and simplified completion that would typically comprise other downhole equipment. Further, the chokes 12.1, 12.2, 12.3 are depicted as being integral with the tubing string. Preferably, the chokes 12.1, 12.2, 12.3 are connected with lengths of tubing string in the same manner as conventional tubing string lengths are connected to one another. Additionally, reference numerals for elements of the chokes 12 are not provided in Figs. 4A, 4B and 4C. The reader is asked to refer to Figs. 1, 2 and 3 that provide more detail for the choke 12 and the reference numerals therefor.

[0039] A tubing string 52 is landed and positioned inside a production casing 54, which is typically anchored and sealed on the backside with cement 56 and installed across impermeable formation 58. Tubing string 52 further extends into an open hole annulus 62 across permeable formation 64 (e.g., depleted reservoir), which is the target formation to inject fluid, such as CO₂. The bottom of the tubing string 52 may include a bullnose 66 with a non-return-valve to separate the tubing annulus 66 from the open hole annulus 62 and to allow fluid to flow from the tubing annulus 68 into the open hole annulus 62. The open hole annulus 62 is isolated with a production packer 72, preventing the injected fluid from flowing to surface.

[0040] Each choke 12.1, 12.2, 12.3 is configured for a change in pressure drop with depth by increasing the amount of choking medium 20. The deepest choke 12.1 provides the highest pressure drop, while the shallowest choke 12.3 provides the least pressure drop.

[0041] As shown in Fig. 4A, all chokes 12.1, 12.2, 12.3 are initially closed and there is no circulation of fluid through the chokes from the tubing annulus 68 into the open-hole annulus 62.

[0042] Fig. 4B illustrates that the bottom choke 12.1 was opened with remote actuator 14. This action allows the injected fluid to pass through the fluid inlet port 22 of choke 12.1 as depicted by the arrows in Fig. 4B.

[0043] The injected fluid passes through the choking medium 20 of choke 12.1 to the fluid outlet port 24. The choking medium 20 provides that the injected fluid remains in liquid phase inside the tubing annulus 68 above the activated choke 12 during injection. When the injected fluid passes through the choking medium 20, the phase may change to gas phase or supercritical phase, depending in the reservoir pressure. As shown in Fig. 4B, the injected fluid flows through the fluid outlet port 24 to the open hole annulus 62 to the permeable formation 64.

[0044] In the early stages of injection, the permeable formation 64 requires the lowest pressure drop as injected fluid slowly increases the reservoir pressure. As the reservoir pressure increases, the fluid can be safely injected at higher pressures and higher flow rates. To allow for more injection volume whilst keeping the fluid in dense phase in tubing 52, less fluid choke is required. Accordingly, a shallower choke 12.2 is then opened. Injection rate increases with less choking medium 20 in the shallower choke 12.2. This provides sufficient pressure drop to maintain the fluid inside the tubing 52 in liquid/dense phase.

[0045] Fig. 4C illustrates operation where all three chokes 12.1, 12.2, 12.3 are opened as lower pressure drop is required. The remote actuator 14 is used to successively open the fluid outlet ports 24 of chokes 12.2 and 12.3 to allow injected fluid to flow through the respective choking medium 20. In the embodiment of Fig. 4C, choke 12.3 redirects the fluid flow from the tubing annulus 68 through fluid outlet port 24 of choke 12.3 into open hole annulus 62 into the permeable formation 64, as depicted by arrows in Fig. 4C.

[0046] A cemented downhole completion with a cemented bottom hole 74 is illustrated in Fig. 5. In this embodiment, a flow diverter 78 is provided below the lowest choke 12.1. Injected fluid flows from the tubing annulus 68 below the deepest choke 12.1 into the permeable formation 64 via perforations 76. As illustrated by the arrows in Fig. 5, injected fluid travels from the tubing annulus above choke 12.3 through the choking medium 20 of choke 12.3 through the open hole annulus 62 and back to the tubing annulus 68 through tubing perforations. The injected fluid then flows via the perforations 76. Such perforations may be provided by perforations in the tubing string 52 or by a conventional sliding side door, as will be understood by those skilled in the art of well completion.

[0047] The drawings depict different embodiments of certain elements of the invention. It should be understood that pairings of one embodiment of an element is not necessarily limited to an embodiment of another element in the same drawing.

[0048] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions, and improvements are possible. Various combinations of the techniques provided herein may be used.

CLAIMS

1. A downhole tool for choking flow of a fluid to be injected in a subsurface formation, the downhole tool comprising:
 - a choke having
 - an annular choke body having an internal wall defining an annular tube and an external wall, the internal wall having a fluid inlet port proximate an upper end of the choke body, the choke body having a fluid outlet port proximate a lower end of the choke body; and
 - a choking medium disposed within the choke body;
 - the fluid outlet port provided in a closed position by an actuatable seal; and
 - a remote actuator for actuating the seal,
 - thereby causing the fluid outlet port to open and allowing fluid flow through the fluid inlet port and the choking medium to the fluid outlet port.
2. The downhole tool of claim 1, wherein the choking medium is selected from the group consisting of packing material, tubing defining a spiral fluid flow path, corrugations integrated into choke body defining a spiral or other tortuous fluid flow path, and combinations thereof.
3. The downhole tool of claim 1 wherein the choking medium is integrated in an interior surface of the outer body.
4. The downhole tool of claim 3, wherein the choking medium is selected from the group consisting of corrugations, channels, and combinations thereof.
5. The downhole tool of claim 1, wherein the fluid outlet port is provided in the external wall of the choke body.
6. The downhole tool of claim 1, wherein the choke further comprises a non-return valve.
7. The downhole tool of claim 1, wherein the choke is provided in a tubing string.

8. The downhole tool of claim 7, wherein tubing string is provided with at least two chokes, wherein a first of the at least two chokes is located upstream of a second of the at least two chokes.
9. The downhole tool of claim 8, wherein the second of the at least two chokes is configured to provide a higher pressure drop to the fluid than the first of the at least two chokes.
10. The downhole tool of claim 7, wherein the tubing string comprises a bullnose with a non-return valve.
11. The downhole tool of claim 7, wherein the tubing string comprises a bottom hole assembly.
12. A method for injecting a fluid from a surface into a target formation, the method comprising:
 - providing a tubing string in a casing to provide an open-hole annulus between the injection tubing and the casing, wherein a portion of the open-hole annulus in a region of the target formation is fluidly isolated from the surface with a production packer;
 - providing the tubing string with at least two chokes, wherein a first of the at least two chokes is located upstream of a second of the at least two chokes, wherein each of the at least two chokes has a choking medium;
 - controlling at least one of pressure and flowrate of the fluid into the target formation by selectively opening a flow path in one or more of the at least two chokes; wherein the flow path is selectively opened by a remote actuator.
13. The method of claim 12, wherein the fluid is CO₂.
14. The method of claim 12, wherein the second of the at least two chokes is configured to provide a higher pressure drop to the fluid than the first of the at least two chokes.
15. The method of claim 12, wherein the target formation is a reservoir depleted in oil or gas.

16. The method of claim 12, wherein the tubing string comprises a bullnose with a non-return valve for allowing flow from the injection tubing to the open-hole annulus.
17. The method of claim 12, wherein the tubing string comprises a bottom hole assembly, and, prior to the step of providing the fluid, further comprising the steps of drilling an injection well with the bottom hole assembly; and activating the production packer.
18. The method of claim 12, wherein a choke having an annular choke body having an internal wall defining an annular tube and an external wall, the internal wall having a fluid inlet port proximate an upper end of the choke body, the choke body having a fluid outlet port proximate a lower end of the choke body; and the choking medium is disposed within the choke body.
19. The method of claim 18, wherein the fluid outlet port is provided in a closed position by an actuatable seal.

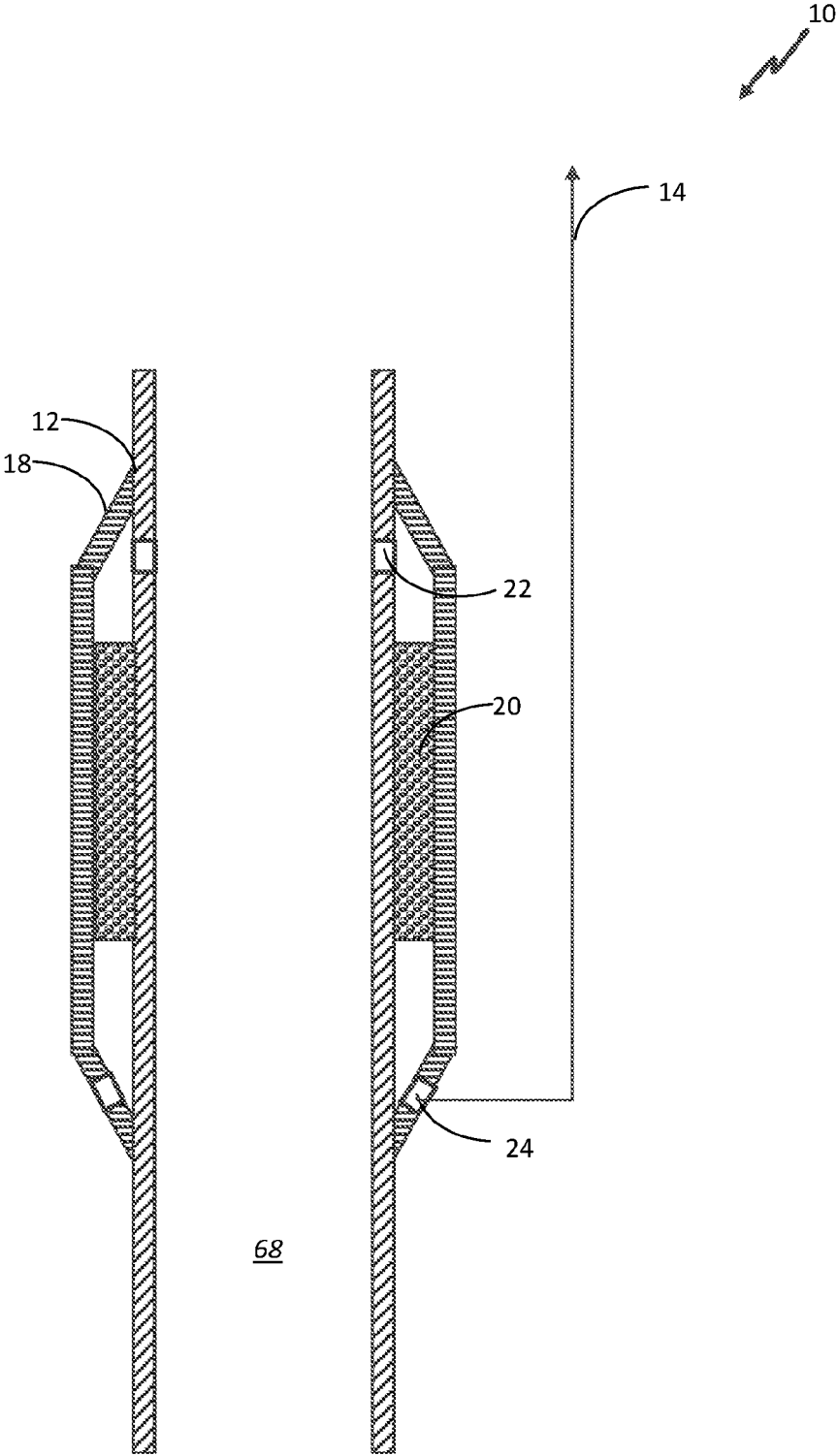


FIG. 1

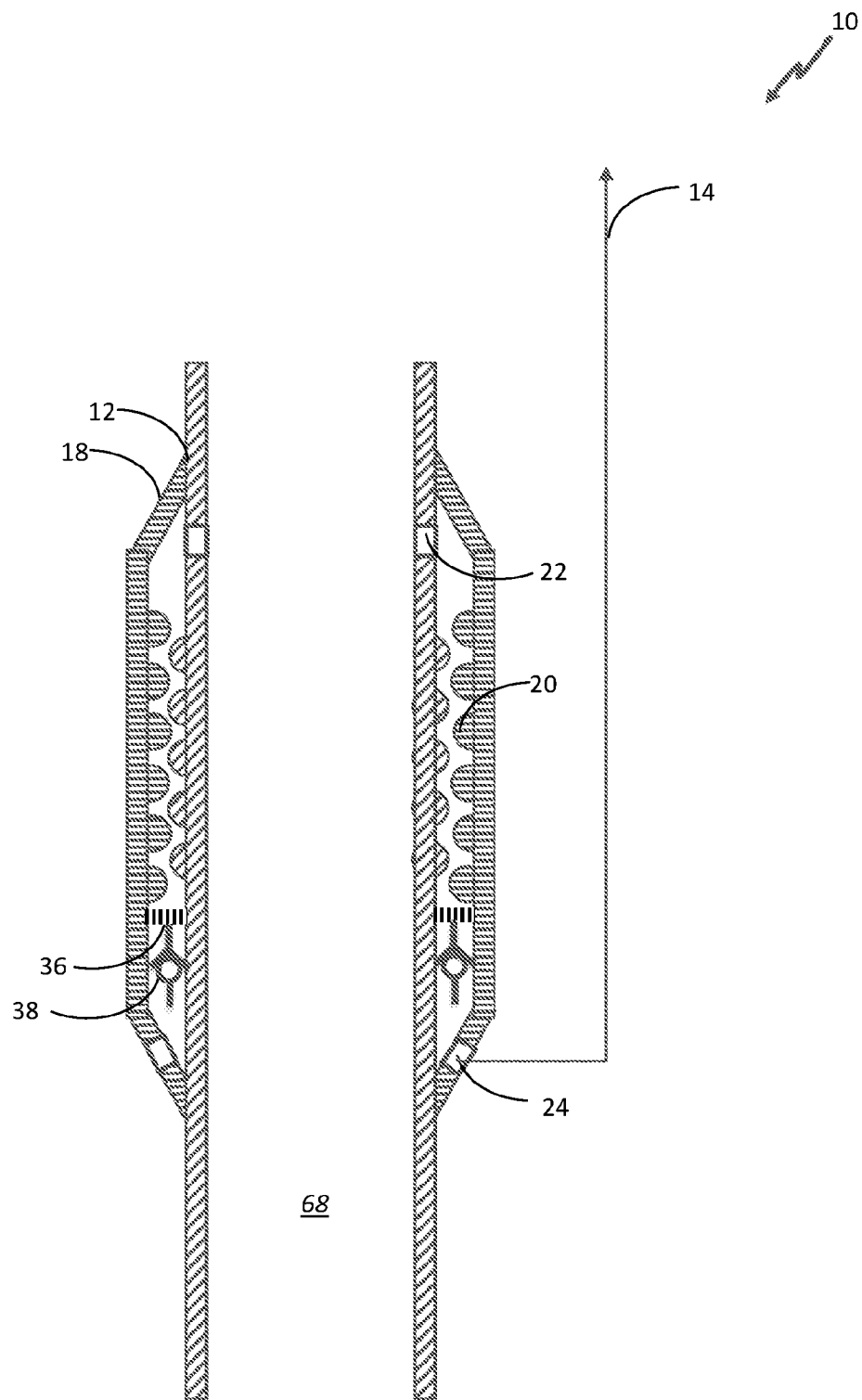


FIG. 2

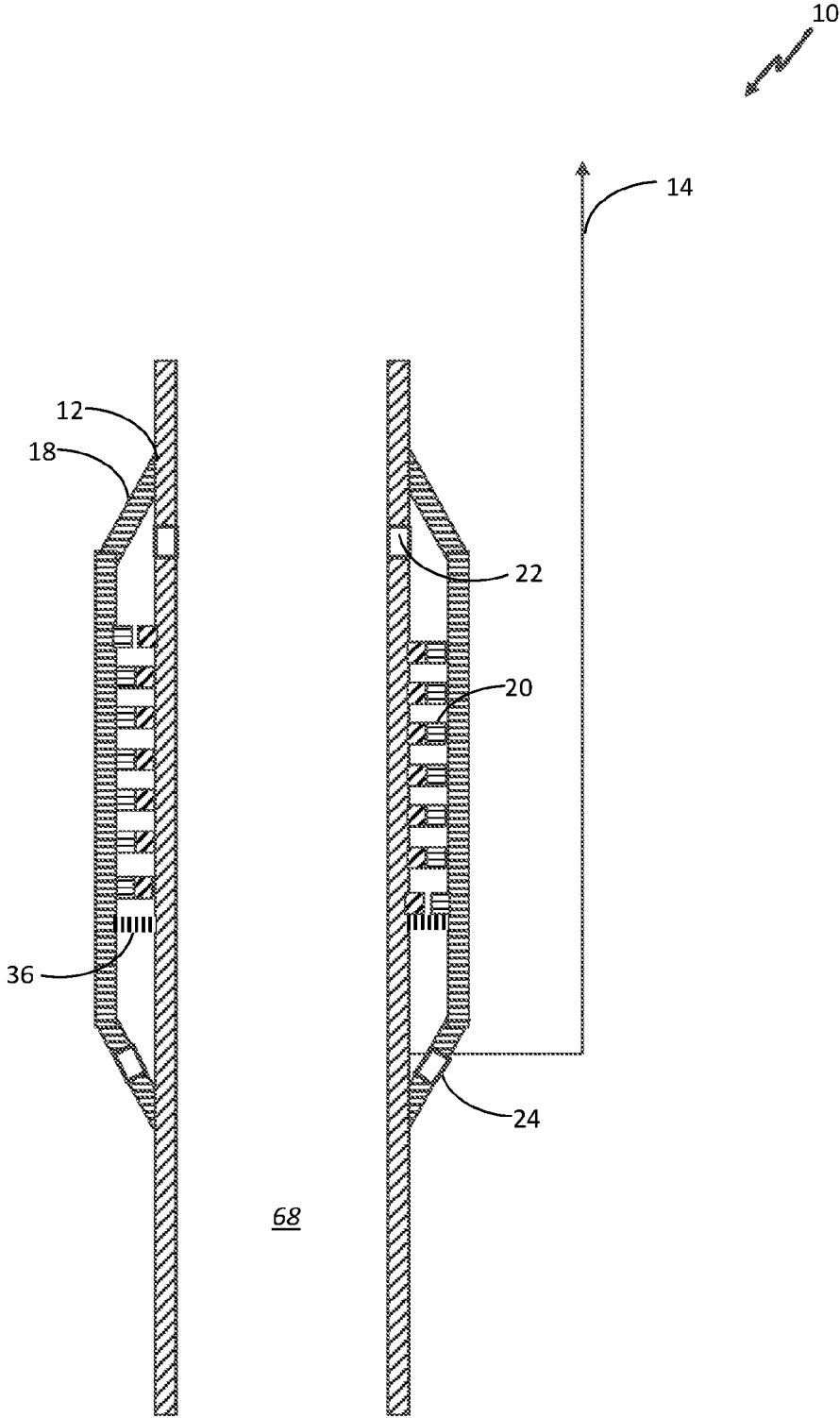


FIG. 3

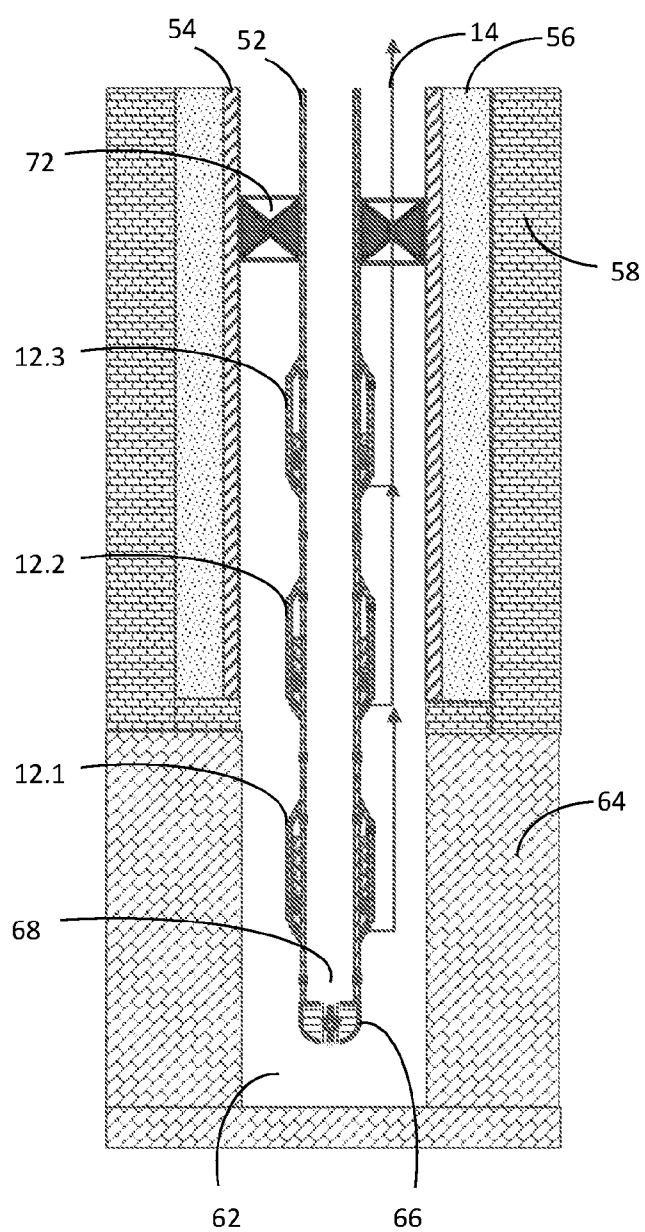


FIG. 4A

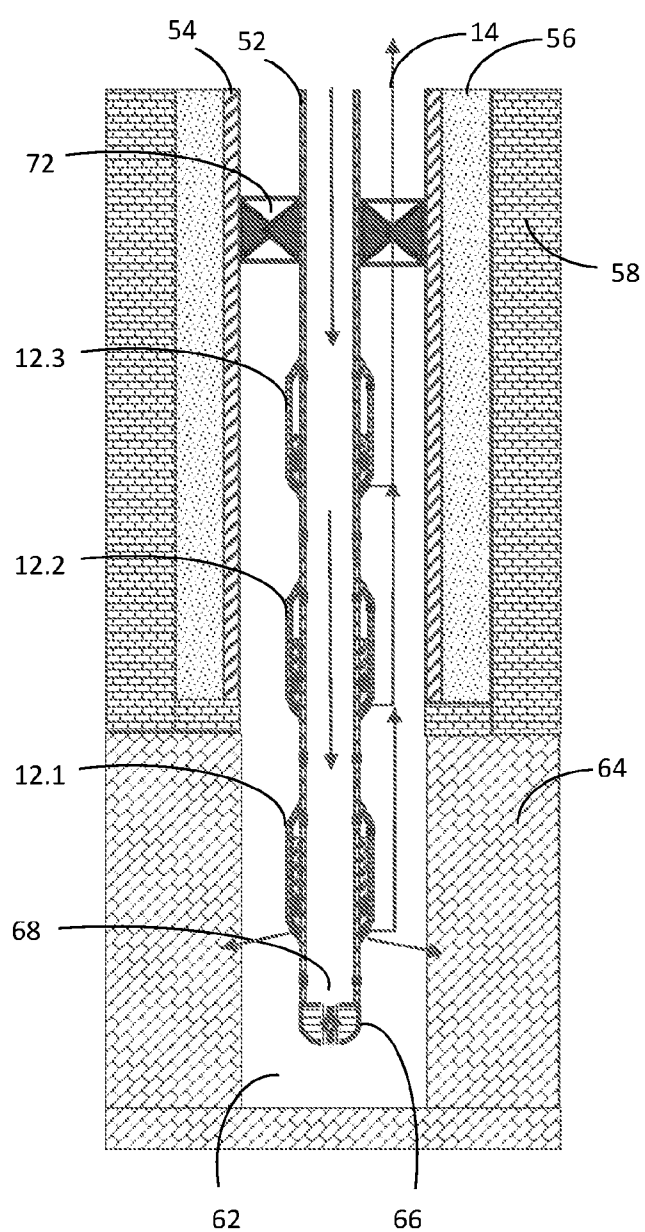


FIG. 4B

5/5

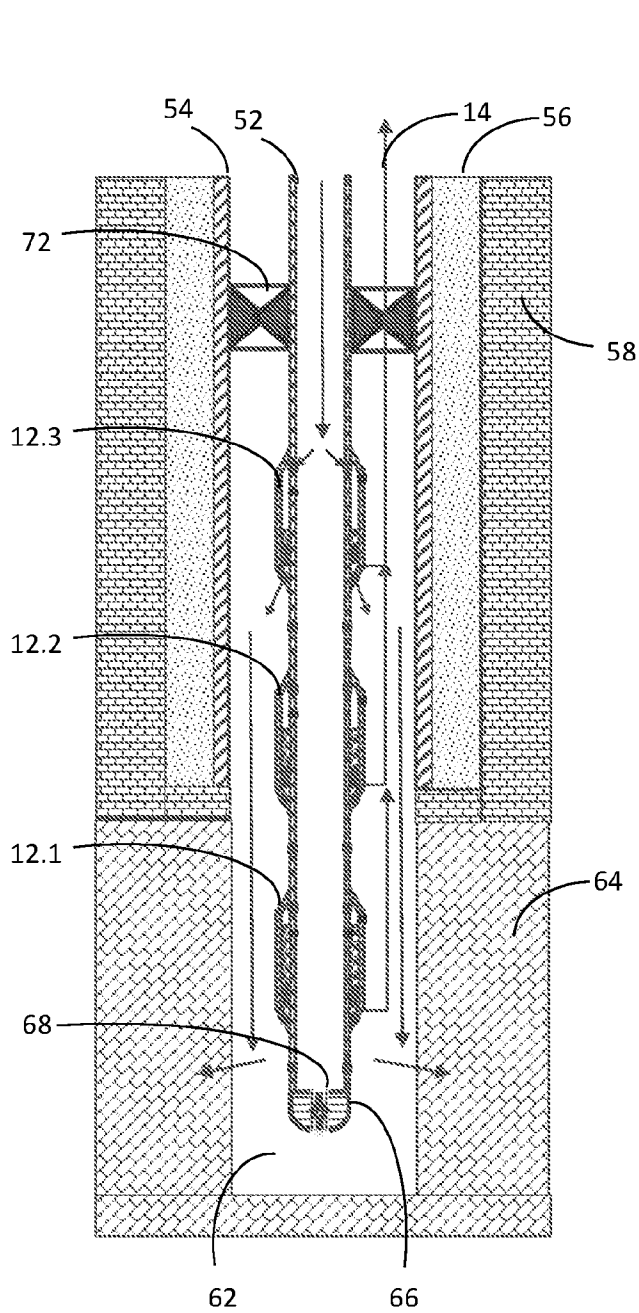


FIG. 4C

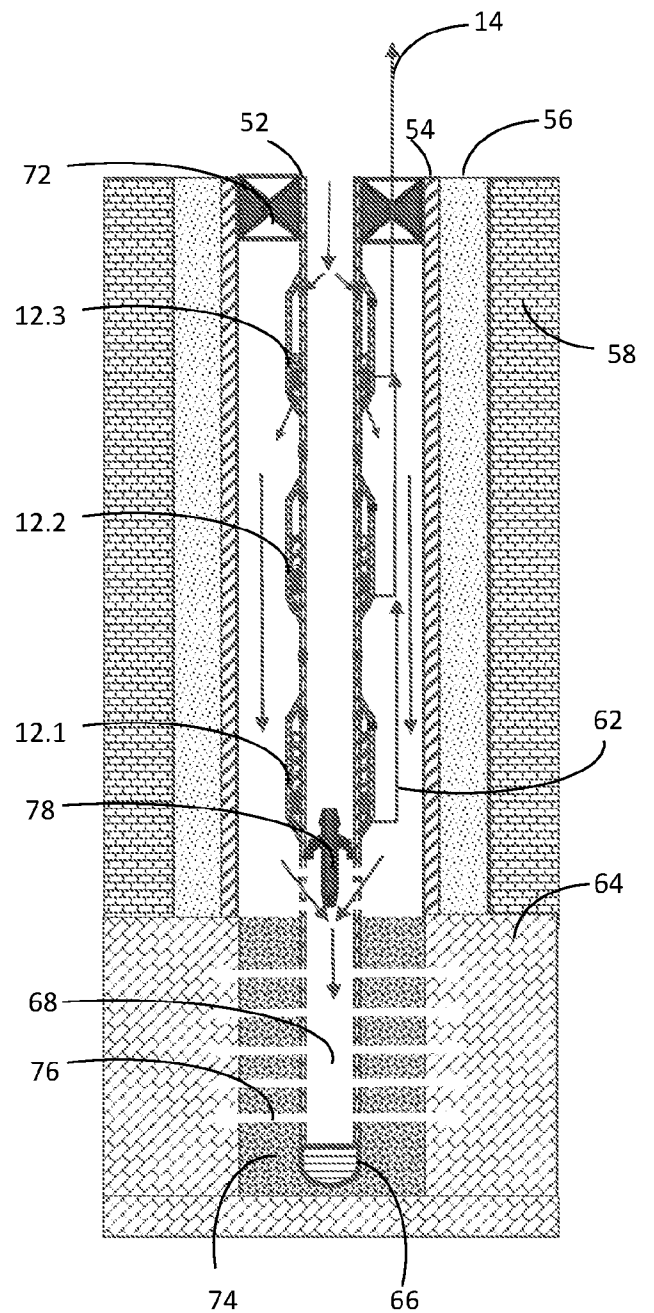


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/049886

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B34/08 E21B34/14
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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/034308 A1 (HOLDERMAN LUKE [US] ET AL) 6 February 2014 (2014-02-06) paragraphs [0024] - [0034]; figures 1-5 -----	1 - 19
A	US 2016/215595 A1 (LOPEZ JEAN MARC [US] ET AL) 28 July 2016 (2016-07-28) the whole document -----	1 - 19
A	US 8 931 565 B2 (DESRANLEAU CHRISTOPHER DENIS [CA]; THEMIG DANIEL JON [CA] ET AL.) 13 January 2015 (2015-01-13) the whole document -----	1 - 19
A	US 2010/051289 A1 (CONSTANTINE JESSE J [US] ET AL) 4 March 2010 (2010-03-04) the whole document -----	1 - 19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

2 January 2025

Date of mailing of the international search report

20/01/2025

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kecman, Ivan

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/049886

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014034308 A1	06-02-2014	US 2014034308 A1	06-02-2014
		WO 2014021899 A1	06-02-2014

US 2016215595 A1	28-07-2016	US 2016215595 A1	28-07-2016
		WO 2015065373 A1	07-05-2015

US 8931565 B2	13-01-2015	CA 2810423 A1	29-03-2012
		EP 2619403 A1	31-07-2013
		US 2012111574 A1	10-05-2012
		WO 2012037646 A1	29-03-2012

US 2010051289 A1	04-03-2010	US 2010051289 A1	04-03-2010
		WO 2010027738 A2	11-03-2010
