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(54) Title: ALTERNATIVE HELICAL FLOW CONTROL DEVICE FOR POLYMER INJECTION IN HORIZONTAL WELLS

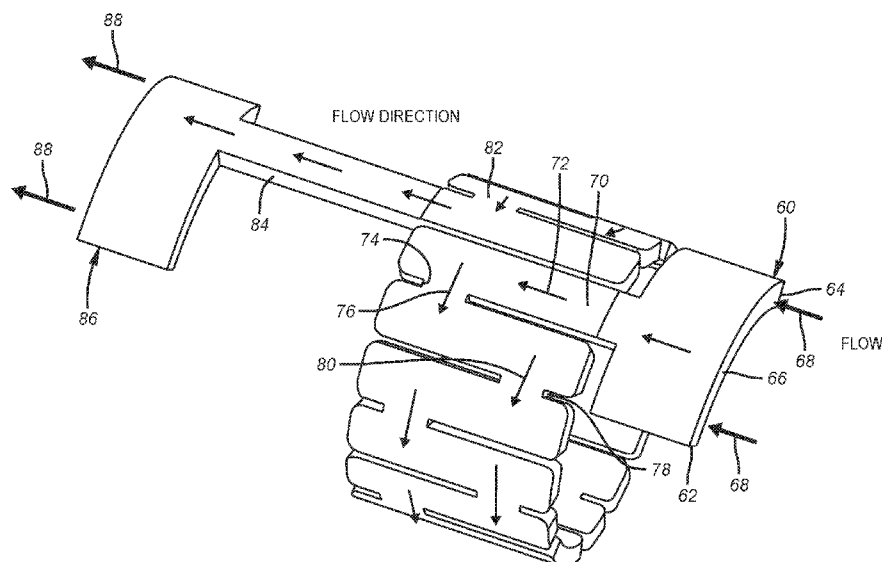


FIG. 4

(57) Abstract: The flow control device comprises one or more stacked spiral paths where the shape of an inlet to an end of a spiral has a taper on one or more sides to gradually increase the polymer velocity to eliminate rapid acceleration points as the flow enters the spiral path. The entrance with its taper can be curved to get into the spiral. The spiral can be entered tangentially or radially or axially.



(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, 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, 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).

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ALTERNATIVE HELICAL FLOW CONTROL DEVICE FOR POLYMER INJECTION IN HORIZONTAL WELLS

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FIELD OF THE INVENTION

[0001] The field of the invention is flow control devices that balance flow and more particularly devices configured to minimize shear effects that adversely affect viscosity of injected polymers.

BACKGROUND OF THE INVENTION

[0002] Hydrocarbons such as oil and gas are recovered from a subterranean formation using a well or wellbore drilled into the formation. In some cases the wellbore is completed by placing a casing along the wellbore length and perforating the casing adjacent each production zone (hydrocarbon bearing zone) to extract fluids (such as oil and gas) from such a production zone. In other cases, the wellbore may be open hole. One or more flow control devices are placed in the wellbore to control the flow of fluids into the wellbore. These flow control devices and production zones are generally separated from each other by installing a packer between them. Fluid from each production zone entering the wellbore is drawn into a tubing that runs to the surface. It is desirable to have a substantially even flow of fluid along the production zone. Uneven drainage may result in undesirable conditions such as invasion of a gas cone or water cone. In the instance of an oil-producing well, for example, a gas cone may cause an in-flow of gas into the wellbore that could significantly reduce oil production. In like fashion, a water cone may cause an in-flow of water into the oil production flow that reduces the amount and quality of the produced oil.

[0003] A deviated or horizontal wellbore is often drilled into a production zone to extract fluid therefrom. Several inflow control devices are placed spaced apart along such a wellbore to drain formation fluid or to inject a fluid into the formation. Formation fluid often contains a layer of oil, a layer of water below the oil and a layer of gas above the oil. For production wells, the horizontal wellbore is typically placed above the water layer. The boundary layers of oil, water and gas may not be even along the entire length of the horizontal well. Also, certain properties of the formation, such as porosity and permeability, may not be the same along the well length. Therefore, fluid between the formation and the wellbore may not flow evenly through the inflow control devices. For production wellbores, it is desirable to have a relatively even flow of the

production fluid into the wellbore and also to inhibit the flow of water and gas through each inflow control device. Active flow control devices have been used to control the fluid from the formation into the wellbores. Such devices are relatively expensive and include moving parts, which require maintenance and may not be very reliable over the life of the wellbore. Passive inflow control devices (“ICDs”) that are able to restrict flow of water and gas into the wellbore are therefore desirable.

[0004] Horizontal wells for injection and production are used to help maximize the sweep efficiency and economic recovery; especially for recovery of viscous oil in offshore environments. Flow control devices (FCDs) are readily used to control the flow along the well in conventional recovery operations leading to improved recovery efficiency. The benefits of polymer flooding and FCDs has been well demonstrated, however the combination of the two technologies has yet to be fully realized. The cause of FCDs not being as utilized in polymer injection application is due to the severe degradation of the polymer through devices.

[0005] Polymer flooding has good potential as an enhanced oil recovery (EOR) option especially for higher conductivity, mature and heavier oil reservoirs. The technique is simply viscosifying the injection water in order to increase the effectiveness of the flooding hence achieving improved sweep efficiency. The polymer is designed in a manner that ensures that the oil phase has a more favourable mobility ratio compared to the pure water injection while working in an injection strategy that has been deemed optimum for the field. Therefore the effectiveness of the polymer flooding strategy is highly dependent on the viscosity of the polymer.

[0006] Polymer enhanced oil recovery has been used as an alternative to water flooding to achieve better sweep efficiency; it works by viscosifying the water in order to get a favourable mobility ratio for the oil, hence maintaining the viscosity of the polymer is imperative to the success of the polymer. However as the polymer viscosity increases the frictional effects increase, this becomes much more critical in long horizontal wellbores. Depending on the reservoir quality there may be a significant heel-to-toe effect occurring hence a significant injection flux will occur in the heel and other higher reservoir quality or low pressure environments rather than the entire length of the horizontal wellbore. Hence this impacts the recovery efficiency. Flow control devices and valves can be used to even out the injection flux along the wellbore increasing the recovery efficiency. However the problem with most flow control systems is that it shears the polymer affecting the polymer viscosity. However the present

invention illustrates a specific design that can be implemented to significantly minimize the unwanted shearing of the polymer while still providing the equalization of injection flux along the wellbore.

[0007] From an economical point of view it is critical that the completion strategy does not adversely impact the polymer quality that would lead to an increase in polymer loading in order to achieve the desired polymer viscosity for the optimum sweep efficiency. Hence the following question emerges: Should Flow Control Devices (FCDs) be utilized when considering that the completion strategy for the injectors should be to eliminate potential nodes that may cause excessively shearing of the polymer? While it has been well understood in the industry that implementation of FCDs can lead to higher recovery efficiency and delaying unwanted fluid breakthrough less is understood about the impact for polymer injectors.

[0008] Inflow control devices for production applications are described in US 8403038 and shown in some detail in FIGS. 1 and 2. These FIGS. use a velocity profile to illustrate restriction points that cause problems when used for polymer injection where excessive shear alters the polymer viscosity and alters the needed flow rates to achieve the desired production enhancement result from the injection. Other art relating to inflow control devices is US 2009/0205834, US 7,942,206 and US 8925633.

[0009] FIGS. 1 and 2 show two rotated views of an inflow control device described in US 8403038 and designed to perform differently depending on the viscosity of the fluids being produced through it. It features an inlet **10** that leads to spaced inlet passages **12** and **14** that continues into a zig-zag flow regime **16** while moving axially initially in the direction of arrow **18**. A direction change occurs at **20** and the zig-zag motion continues as the fluid now travels in the direction of arrow **22** through straight transition passage **24**. As seen in FIG. 2 after passage **24** the flow continues in a zig-zag fashion in the direction of arrow **18** to emerge at an outlet **26**. Typically after a movement in a circumferential direction clockwise, for example, the flow goes through a small transition passage **30** to continue flowing circumferentially in a counterclockwise direction. The transition passages are offset from adjacent transition passages **30** to induce the zig-zag flow pattern to get the needed pressure drop for inflow control. Flow tests have shown that there are high velocities and inlet passages **12** and **14** as well as at or just past the transition passages **30**. While FIGS. 1 and 2 show a single zig-zag movement in the direction of arrow **18** with a transition passage **24** the design can have multiple such generally

axially oriented flow arrangements to get the desired pressure drop for a predetermined flow rate. The problem with using such a device or an alternative device shown in FIG. 3 is that there are high velocity regions which cause fluid shearing that if polymer was used through such devices for balancing flow in an injection application, the result would be excessive shear that adversely affects the viscosity of the polymer. It is important to assure that the volume of polymer concentration is maintained and the device is able to effectively balance flow for the polymer phase injection while also balancing flow for different injection fluid phases (i.e. pure water, steam, etc.) that are injected along with or a different times. It has been realized that to effectively inject polymer through a flow balancing device a key design parameter is to reduce high velocity zones that cause shear that adversely affects the viscosity of the polymer that is being injected.

[0010] FIG. 3 is another known inflow control device that features a flow inlet **40** leading to an inlet passage **42** followed by a spiral flow pattern to an outlet **44**. The velocity at the inlet passage **42** would cause shear affects for the polymer that would adversely affect its viscosity.

[0011] What is needed and provided by the present invention is a flow distribution device for polymer injection operation that has a configuration of reducing shear effects on the polymer to minimize adverse effects on its viscosity. Some of the ways this is accomplished is a broad circumferential inlet to a flow path that is circumferentially oriented while providing a zig-zag flow pattern that uses large transition passages to get the zig-zag flow effect which is a design feature enabled by the circumferential orientation of the zig-zag flow. Another way is to introduce the polymer into one or more stacked spiral paths where the entrance to the spiral is a taper that gradually increases polymer velocity and eliminates rapid acceleration approaching the entrance to the spiral. These and other aspects of the device and polymer injection method using the device will be more readily apparent to those skilled in the art from a review of the detailed description of the preferred embodiment and the associated drawings while recognizing that the full scope of the invention is to be found in the appended claims.

SUMMARY OF THE INVENTION

[0012] A flow balancing device facilitates polymer injection in a horizontal formation in a manner that minimizes shear effects on the injected polymer. Features of the device reduce velocity using a broad circumferentially oriented inlet plenum that leads to a circumferentially oriented path having zig-zag fluid movement characterized by broad passages that define the zig-

zag pattern so as to reduce velocity at such transition locations. Because the path is circumferentially oriented there is room for broad transition passages independent of the housing diameter. The broad crescent shaped inlet plenum also reduces inlet velocity to preserve the viscosity of the injected polymer. Other materials can be injected or the device can be employed in production service as well as injection. A related method employs the described device for injection.

[0013] In another embodiment the flow control device comprises one or more stacked spiral paths where the shape of an inlet to an end of a spiral has a taper on one or more sides to gradually increase the polymer velocity and eliminates the rapid acceleration as the flow enters the spiral path. The entrance with its taper can be curved to get into the spiral. The spiral can be entered tangentially or radially or axially.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a schematic view of a prior art device from a first orientation showing entering flow;

[0015] FIG. 2 is the view of FIG. 1 slightly rotated to show the exiting flow;

[0016] FIG. 3 is another prior art inflow control device featuring a spiral flow path;

[0017] FIG. 4 shows the orientation of the inlet and circumferential flow path leading to the outlet in the present invention;

[0018] FIG. 5 is the view of FIG. 4 showing the velocity of the flow;

[0019] FIG. 6 is the view of FIG. 4 showing the wall shear from the flow;

[0020] FIG. 7 is a performance graph showing the relatively lower velocities and wall shear of the present invention compared to the FIGS. 1-3 designs;

[0021] FIG. 8 illustrates an inlet taper configuration oriented tangentially and radially; and

[0022] FIG. 9 shows a tapering inlet that tracks the spiral curvature of the restriction path.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] FIG. 4 shows the flow path in the device without the outer housing for greater clarity. The inlet **60** extends between opposed ends **62** and **64** in between which is a height **66** so that the inlet flow represented by arrows is aligned with the crescent-shaped opening or slot that defines the inlet **60**. From there the flow goes axially into passage **70** as indicated by arrow **72** and then turns circumferentially into passage **74** as indicated by arrow **76**. Transition passage **78** is axially and circumferentially offset from passage **74** to induce the zig-zag flow pattern that repeats as

the flow goes back and forth axially as it progresses circumferentially until reaching passage **82** to move into axial path **84** for continuation to the outlet **86** which has the same crescent shape of inlet **60** and results in flow indicated by arrows **88** exiting axially from the outlet **86** to minimize the exit velocity from the broad outlet and elimination of turns using the axial flow out of outlet **86** as indicated by arrows **88**.

[0024] Variations are contemplated such as when flow exits passage **82** and enters passage **84** for axial flow, another circumferential zig-zag array can be entered or the path can continue as a scroll with a smaller diameter than the initial circumferential pass. More than two circular paths are also envisioned. The length of each axial path can be varied. What is shown is the axial paths such as **70** extending about half way between the inlet **60** and the outlet **86** with each axial path equally long. This can be varied so that the axial paths can extend further or less than shown to the point where they extend the full distance between the inlet **60** and the outlet **86**. The axial paths in a given circular path can have different or the same lengths. The crossover passages between the axial runs such as **74**, **76** and **82** can have the same cross-sectional areas or different areas. The shape of such openings is preferably rectangular but can also be square, round or another shape that promotes smooth flow therethrough to reduce shear effects from high velocity zones. The opening shapes for crossover passages between the axial runs such as **74**, **76** and **82** can be the same or different. Since the flow regime is circumferential there is always room to extend the length of the passages such as **74** independently of the housing that is around the structure of FIG. 4 that is not shown.

[0025] The circumferential paths that can be used can be stacked axially and have the same diameter. The flow through multiple paths stacked axially can be in series or in parallel. The diameter of the circumferential paths can be the same or different. Multiple circumferential paths can also be partially or totally nested axially which means they will have differing diameters and can have series or parallel flow. Parallel flows involve multiple inlets and outlets that can be configured to be side by side in a circular array or radially nested in whole or in part with different diameters to allow for the nesting. The inlet opening **66** can have an inlet flare such as a taper or a rounded edge to reduce turbulence and resulting fluid shear that can stem from such turbulence.

[0026] FIGS. 5 and 6 respectively illustrate the velocity through the device illustrated in FIG. 4 and the wall shear. FIG. 7 is a graph with the top line representing the performance of the FIG. 3

device and the middle line the performance of the FIGS. 1 and 2 device. The present invention shown in FIG. 4 has its performance illustrated in the lowest line indicating that the peak velocities are lower which results in a lower wall shear than the known designs of FIGS 1-3 for a given flow rate.

[0027] The FIG. 4 devices can be used in injection methods to balance flow while minimizing shear effects on a polymer or for injection other materials or even for producing from a formation.

[0028] Referring now to FIG. 8, a dual stacked spiral shape comprising coils **100** and **102** has respective inlet shapes **104** and **106**. Inlet **104** has opposed sides **108** and **110** at least one of which is tapered toward the other such that the cross-sectional area at **112** is larger than the area at location **114** at the coil **100** inlet. As a result the injected polymer flowing from **112** into coil **100** increases in velocity gradually and eliminates rapid acceleration points as observed in alternative designs seen in FIG. 3 at item **42**. The degree of wall taper is somewhat dependent on the available space but taper angles of 30 degrees or less are contemplated. A cross-sectional area difference over the length of the inlet can be as much as 50% and the length of the inlet can be as long as half the axial length of the associated coiled path. As shown with inlet **104** the entry orientation is tangential while the inlet **106** is illustrated as radial. Outlets **116** and **118** are shown in a more axial orientation and the illustrated inlets **104** and **106** can alternatively be oriented in a more axial orientation the same as the illustrated outlets putting them within about 30 degrees of the longitudinal axis. Although two stacked coils are shown one or more than two coils can be used. The tapers for the inlets gradually increase the injected polymer velocity to control the amount of shearing of the polymer that can adversely affect its physical properties and the needed injection rate to get the optimum production benefit from the formation.

[0029] FIG. 9 shows an axially oriented connection **120** that reduces in cross-sectional area **122** gradually as it turns to tangentially enter the coiled section **124**. Here the cross-section is round and decreasing in diameter at the same time it is being coiled to enter the coil **124** tangentially which also reduces the shear effect on the polymer being pumped through. The outlet can have the same tapering feature but with the diameter growing as the flow exits the coil **124**. As in the FIG. 8 version the inlet orientation can be axial or radial and the inlet cross-section can also be a quadrilateral or some other shape that gradually transitions to a smaller dimension to incrementally so as to minimize the shearing effect on the pumped polymer that flows through.

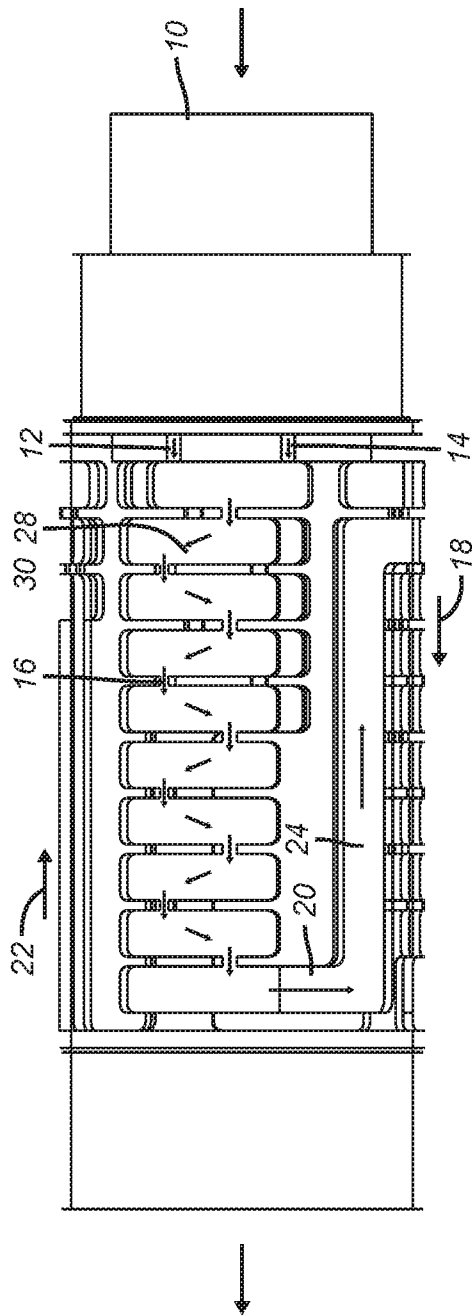
[0030] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

We claim:

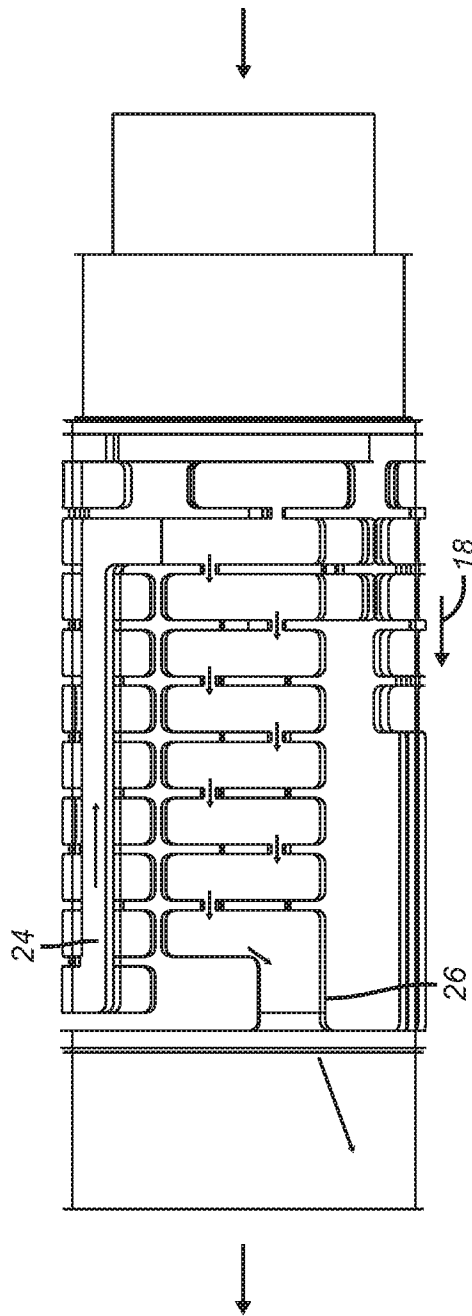
1. A flow control assembly for borehole use, comprising:
at least one housing having opposed end connections adapted for connection to a tubular string; **characterized by**
at least one coiled path (102) having at least one inlet (104,106) and at least one outlet (116,118) and disposed in said housing, said inlet (104,106) and outlet (116,118) communicating with pressure in the tubular string, said inlet (104,106) comprising a reduction in cross-sectional area (108,110) in the direction of fluid movement into said inlet (104,106).
2. The assembly of claim 1, wherein:
said inlet (104,106) comprising at least one tapered flat side (108,110) to accomplish said reduction in cross-sectional area.
3. The assembly of claim 1, wherein:
said inlet (104,106) enters said coiled (102) path tangentially.
4. The assembly of claim 1, wherein:
said inlet (104,106) enters said coiled path (102) radially.
5. The assembly of claim 1, wherein:
said inlet(104,106) enters said coiled path (102) axially.
6. The assembly of claim 1, wherein:
said at least one coiled path (102) comprises a plurality of nested coiled paths.
7. The assembly of claim 1, wherein:
said inlet (104,106) tapers to a smaller dimension and is coiled so that an end of said inlet (104,106) aligns axially with an opposing end of the coiled path (102).
8. A flow control assembly for borehole use, comprising:
at least one housing having opposed end connections adapted for connection to a tubular string; **characterized by**
at least one tortuous path comprising an opposed inlet (60) and an outlet (86) for flow through said housing, said path extending circumferentially substantially around an inner wall of said housing in a zig-zag pattern (72,76,80) formed substantially by axially oriented segments (70) connected with circumferentially oriented connecting paths (74).

9. The assembly of claim **8**, wherein:
adjacent circumferentially oriented connecting paths (74) are axially offset to define said zig-zag pattern (72,76,80).
10. The assembly of claim **8**, wherein:
said inlet (60) is connected by a said axially oriented segment (70) as an entry to said tortuous path.
11. The assembly of claim **8**, wherein:
said inlet (60) comprises a curved slot (66).
12. The assembly of claim **11**, wherein:
said slot is wider than a said axially oriented segment (70).
13. The assembly of claim **11**, wherein:
said curved slot has an inlet flare or a rounded edge.
14. The assembly of claim **11**, wherein:
said outlet (86) comprises a curved slot.
15. The assembly of claim **14**, wherein:
said slot is wider than a said axially oriented segment.
16. The assembly of claim **14**, wherein:
said curved slot has an inlet flare or a rounded edge.
17. The assembly of claim **8**, wherein:
said tortuous path defines a scroll shape with a variable diameter.
18. The assembly of claim **8**, wherein:
said axially oriented segments (70) have a quadrilateral shape.
19. The assembly of claim **8**, wherein:
said circumferentially oriented connecting paths (74) have a quadrilateral or round shape.
20. The assembly of claim **8**, wherein:
said at least one tortuous path extends circumferentially for at least two revolutions.

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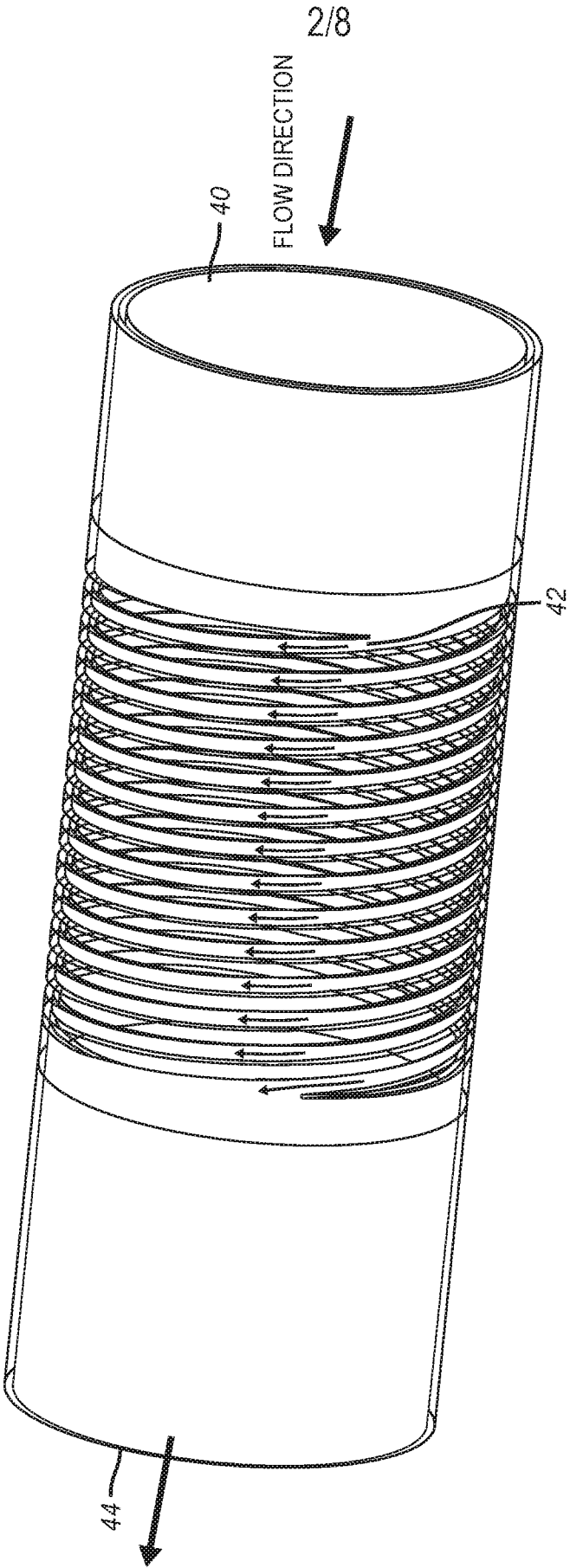
(PRIOR ART)
FIG. 1



(PRIOR ART)
FIG. 2

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(PRIOR ART)
FIG. 3

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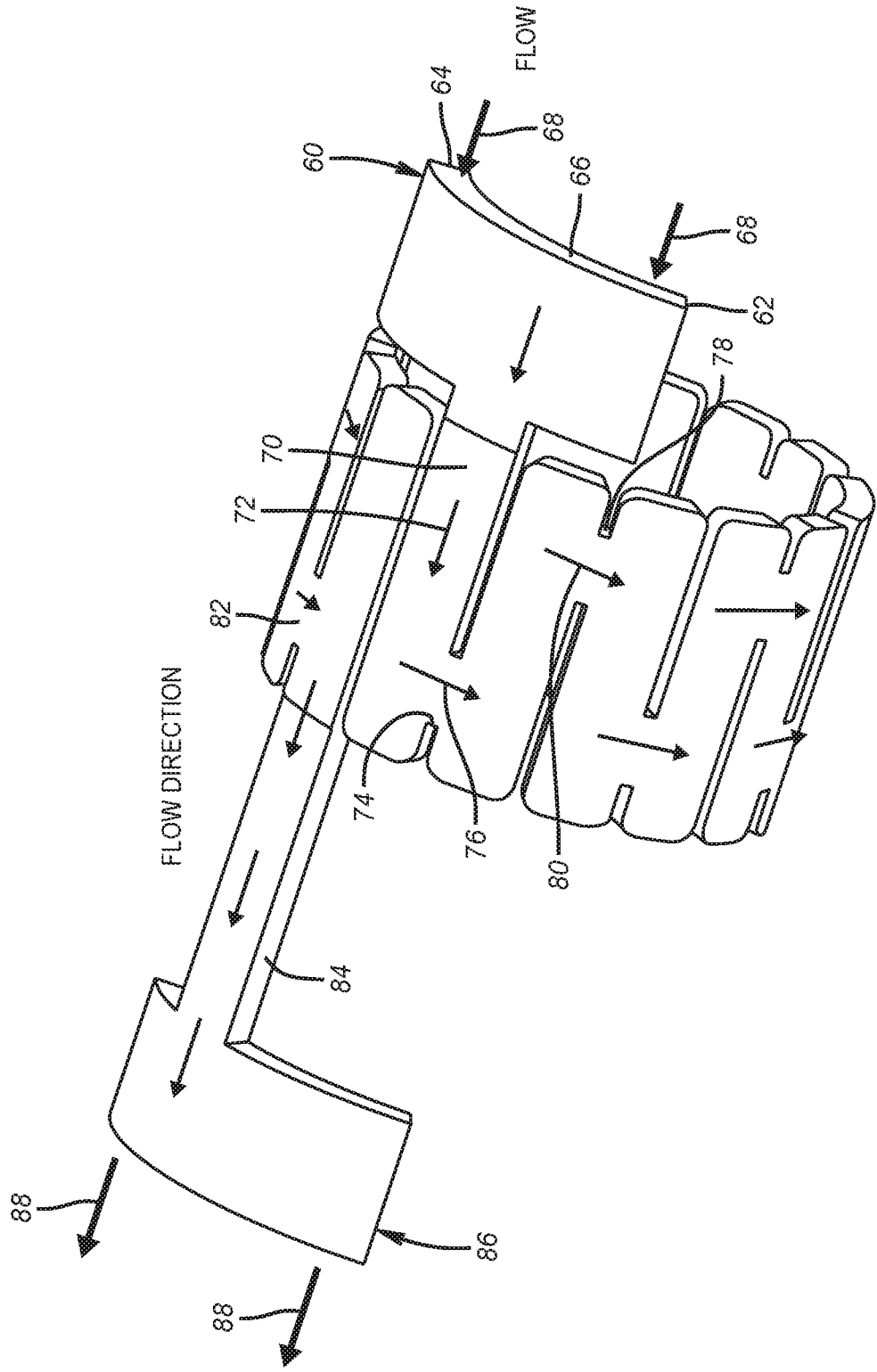
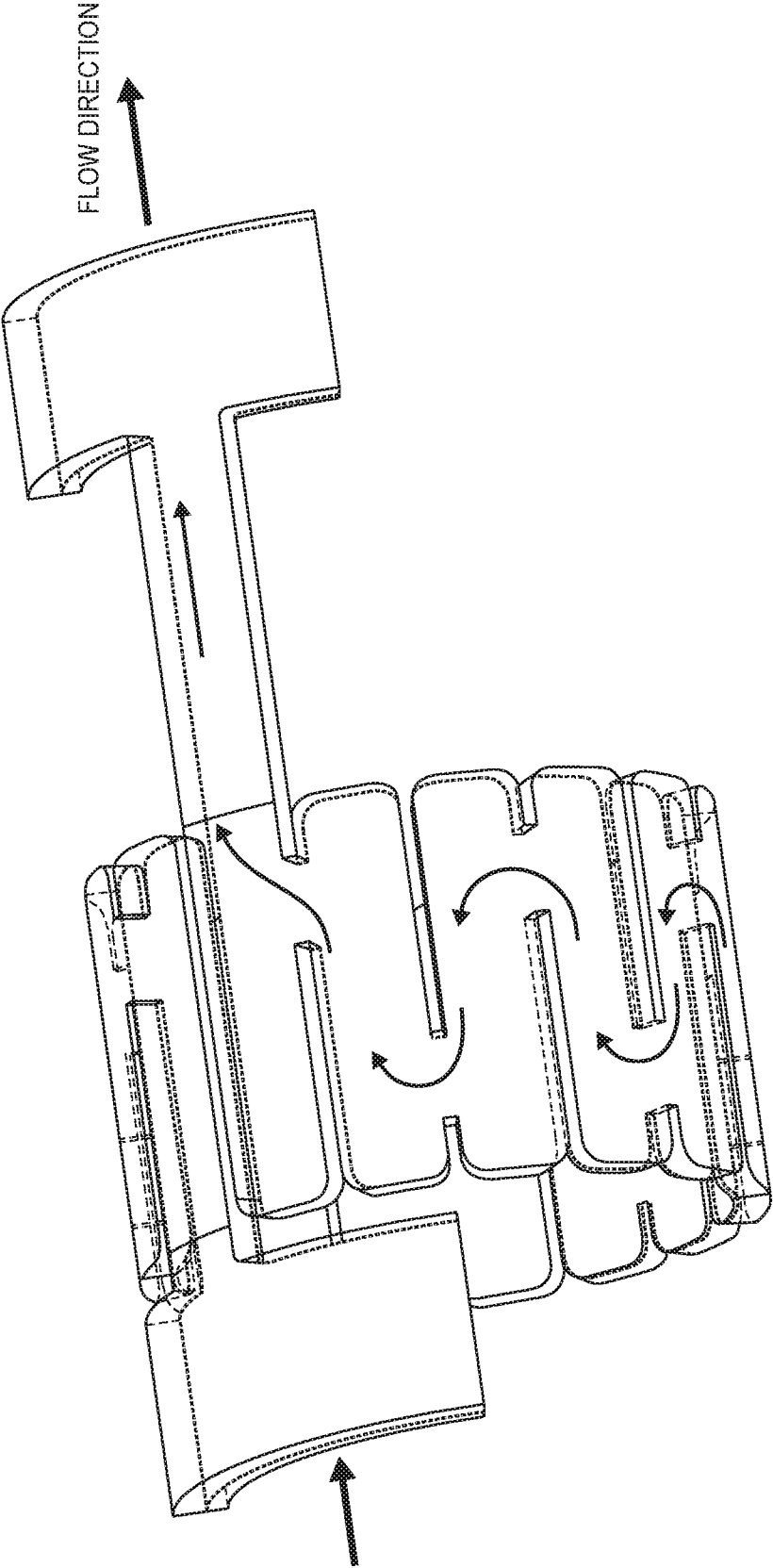


FIG. 4

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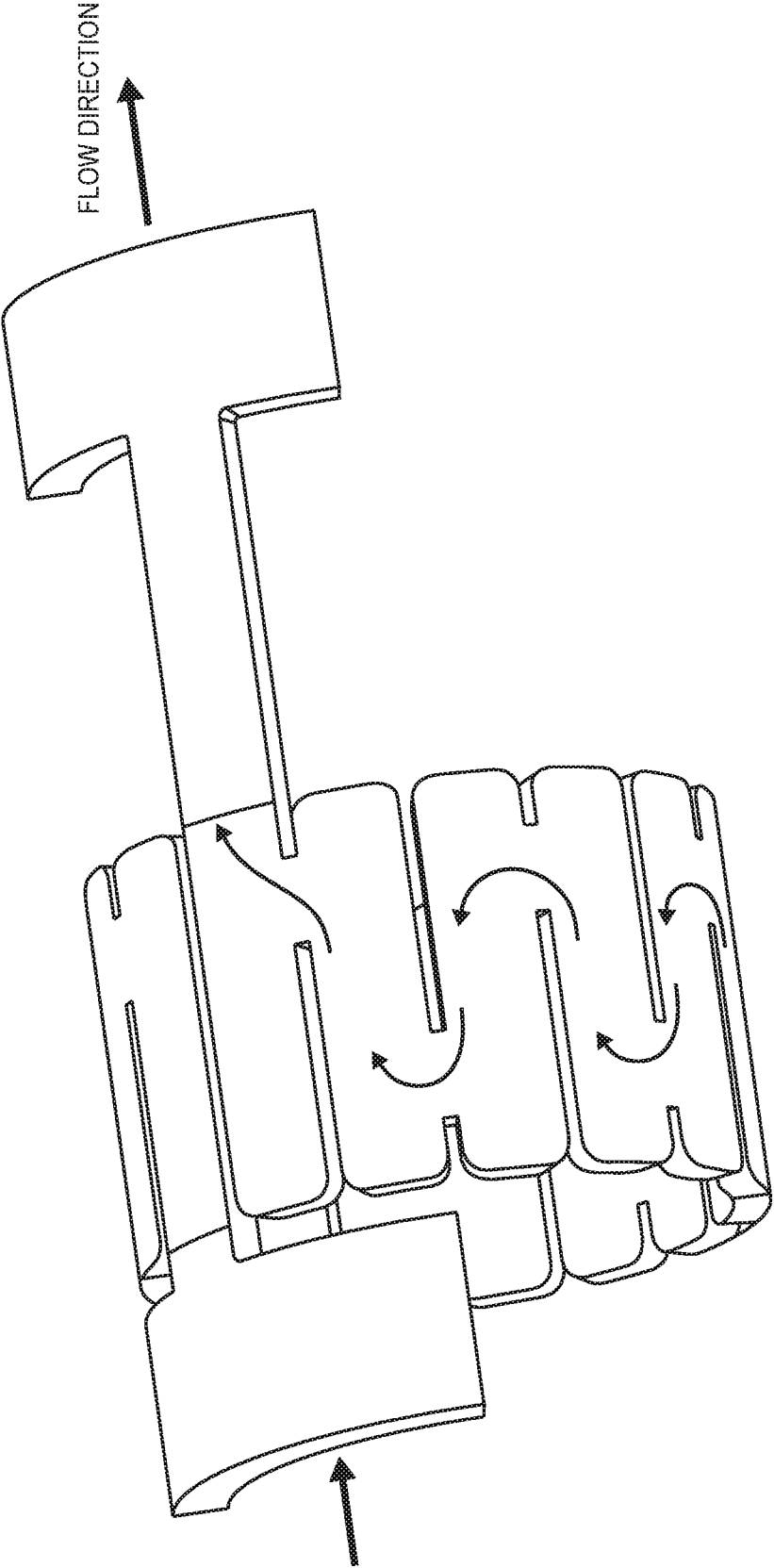


FIG. 6

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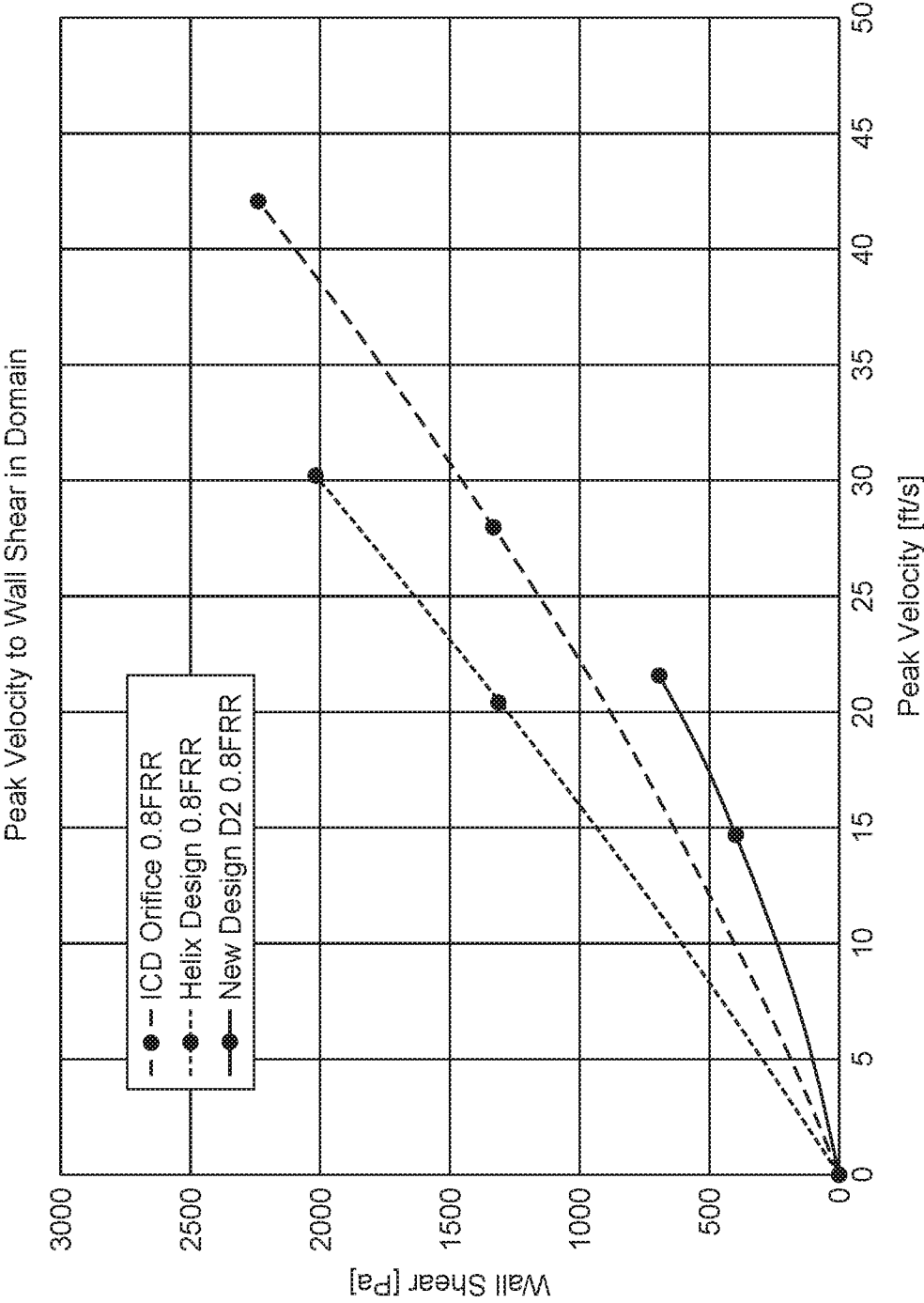


FIG. 7

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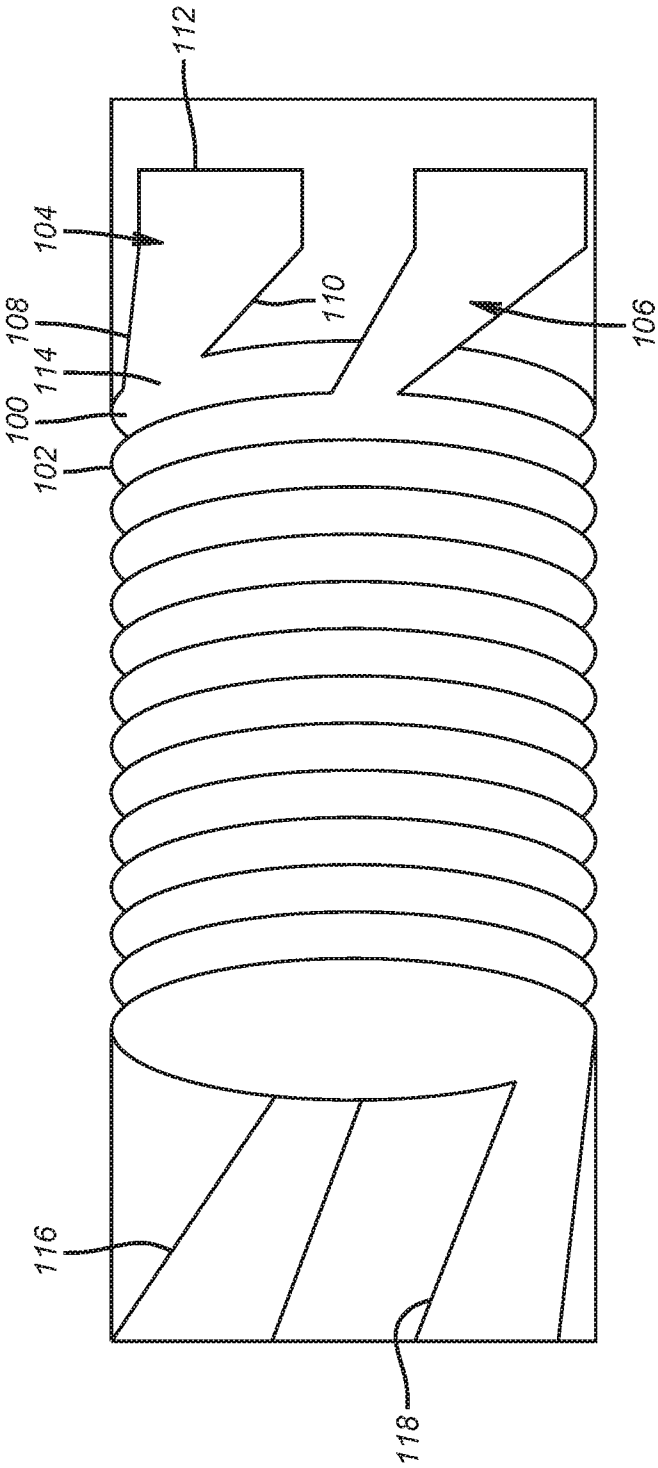


FIG. 8

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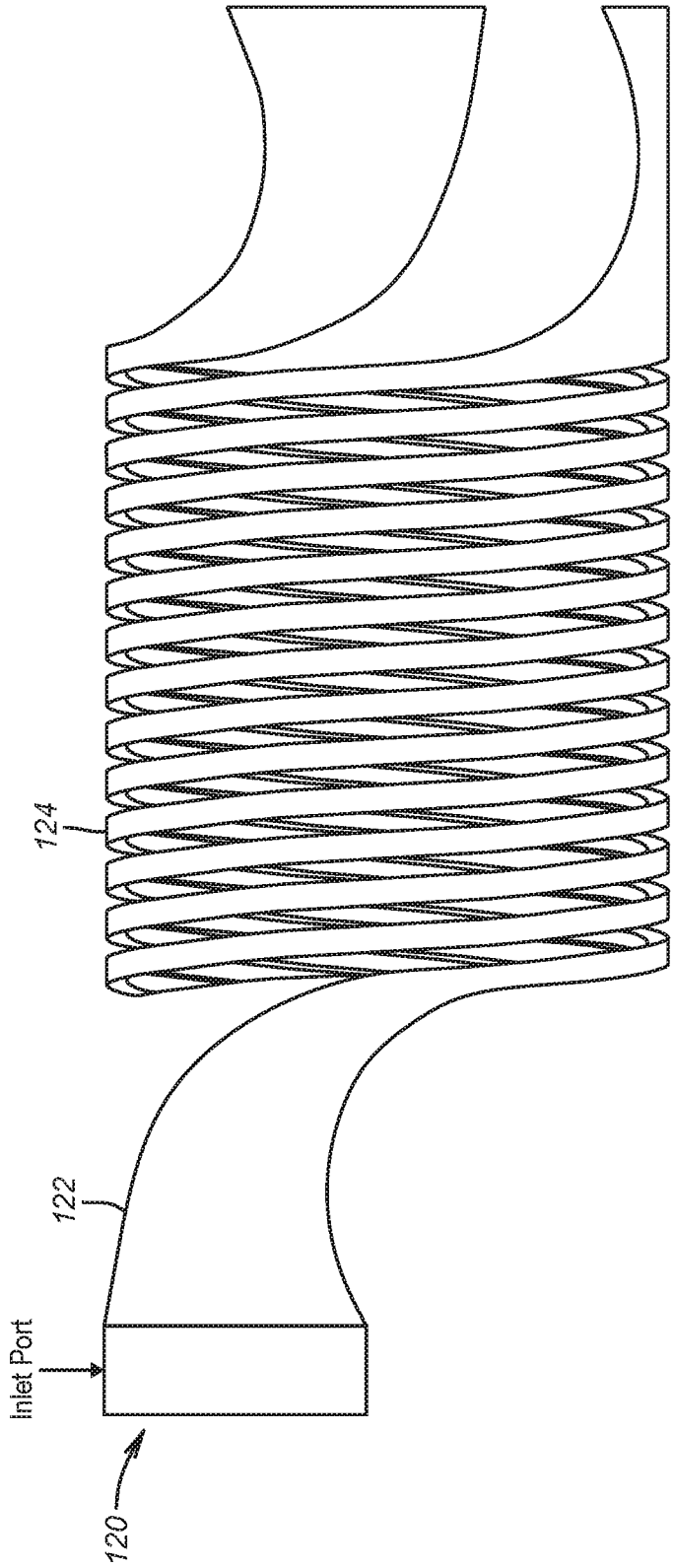


FIG. 9

A. CLASSIFICATION OF SUBJECT MATTER**E21B 43/16(2006.01)i, E21B 43/12(2006.01)i**

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 43/16; E21B 43/12; E03B 3/18; E21B 33/076; E21B 33/12; F16K 3/316; E21B 19/00; E21B 34/02; E21B 21/08

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:

flow control device, polymer, shear, viscosity, inlet, cross-sectional area, coiled, tortuous

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0275612 A1 (CAMERON INTERNATIONAL CORPORATION) 01 October 2015 See paragraphs [0007], [0107]; and figures 13-14.	1-7
Y		8-20
Y	US 2011-0061877 A1 (ZAZOVSKY et al.) 17 March 2011 See paragraphs [0052]-[0053]; and figure 6A.	8-20
A	US 2016-0084038 A1 (TYPHONIX AS) 24 March 2016 See paragraphs [0050]-[0053]; and figures 1-3.	1-20
A	US 2011-0297399 A1 (DYCK, STEVEN PETER) 08 December 2011 See paragraphs [0026]-[0033]; and figure 1.	1-20
A	WO 2016-044059 A1 (SHELL OIL COMPANY et al.) 24 March 2016 See page 3, lines 23-31; page 13, line 14 - page 14, line 27; and figure 2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

19 September 2017 (19.09.2017)

Date of mailing of the international search report

19 September 2017 (19.09.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/038148

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US 2011-0297399 A1	08/12/2011	None	
WO 2016-044059 A1	24/03/2016	None	

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference ICD4-61636-WO	FOR FURTHER ACTION	See item 4 below
International application No. PCT/US2017/038148	International filing date (<i>day/month/year</i>) 19 June 2017 (19.06.2017)	Priority date (<i>day/month/year</i>) 08 July 2016 (08.07.2016)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant BAKER HUGHES, A GE COMPANY, LLC		

1.	This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).																								
2.	This REPORT consists of a total of 10 sheets, including this cover sheet.																								
In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.																									
3.	This report contains indications relating to the following items: <table style="width: 100%;"> <tr> <td style="width: 5%; text-align: center;">☒</td> <td style="width: 25%;">Box No. I</td> <td style="width: 70%;">Basis of the report</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. II</td> <td>Priority</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. III</td> <td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. IV</td> <td>Lack of unity of invention</td> </tr> <tr> <td style="text-align: center;">☒</td> <td>Box No. V</td> <td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VI</td> <td>Certain documents cited</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VII</td> <td>Certain defects in the international application</td> </tr> <tr> <td style="text-align: center;">☒</td> <td>Box No. VIII</td> <td>Certain observations on the international application</td> </tr> </table>	☒	Box No. I	Basis of the report	☐	Box No. II	Priority	☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability	☐	Box No. IV	Lack of unity of invention	☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement	☐	Box No. VI	Certain documents cited	☐	Box No. VII	Certain defects in the international application	☒	Box No. VIII	Certain observations on the international application
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☒	Box No. VIII	Certain observations on the international application																							
4.	The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).																								

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Date of issuance of this report 08 January 2019 (08.01.2019) Authorized officer Agnès Wittmann-Regis e-mail: pct.team6@wipo.int
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PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

To:
DUPHORNE, DARIN H.

INTELLECTUAL PROPERTY COUNSEL BAKER
HUGHES INCORPORATED 17021 ALDINE WESTFIELD
HOUSTON TX 77073 USA

Date of mailing
(day/month/year) **19 September 2017 (19.09.2017)**

Applicant's or agent's file reference ICD4-61636-WO		FOR FURTHER ACTION See paragraph 2 below	
International application No. PCT/US2017/038148	International filing date (day/month/year) 19 June 2017 (19.06.2017)	Priority date(day/month/year) 08 July 2016 (08.07.2016)	
International Patent Classification (IPC) or both national classification and IPC E21B 43/16(2006.01)i, E21B 43/12(2006.01)i			
Applicant BAKER HUGHES INCORPORATED			

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis. I(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

 Name and mailing address of the ISA/KR International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	Date of completion of this opinion 19 September 2017 (19.09.2017)	Authorized officer LEE, Se Gyoung Telephone No. +82-42-481-8740 
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**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. 1 Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :

- ☒ the international application in the language in which it was filed
- ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*. I(a))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

- a. ☐ forming part of the international application as filed:
☐ in the form of an Annex C/ST.25 text file.
☐ on paper or in the form of an image file.
- b. ☐ furnished together with the international application under PCT Rule 13*ter*. I(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*. I(a)).
☐ on paper or in the form of an image file (Rule 13*ter*. I(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: US 2015-0275612 A1 (CAMERON INTERNATIONAL CORPORATION)

01 October 2015

D2: US 2011-0061877 A1 (ZAZOVSKY et al.) 17 March 2011

1. Novelty and Inventive Step

1.1 Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a choke trim (18) flowing a chemical for injection into a subsea well, comprising: a flow path cylinder (200) having a first axial end (208) and a second axial end (212); characterized by a spiral flow path (202) having an entry port (206) and an exit port (210) and formed on the flow path cylinder (200), wherein the entry port (206) is gradually tapered down to allow for gradual acceleration of fluid and hence reduce polymer degradation (see paragraphs [0007], [0107]; and figures 13-14).

Claim 1 differs from D1 in that a flow control assembly is characterized by an inlet and an outlet communicating with pressure in a tubular string. However, this feature would be easily conceived from the disclosure of D1 considering that polymer enters the spiral flow path (202) through the entry port (206) and exits the spiral flow path (202) through the exit port (210) (see paragraph [0107]; and figures 13-14).

Accordingly, claim 1 would have been obvious over D1. Therefore, claim 1 does not involve an inventive step under PCT Article 33(3).

Continued on Supplemental Box

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. In claim 1, "the direction" has not been previously defined. Therefore, claim 1 does not meet the requirements of PCT Article 6.

(Note: The international search report and the written opinion have been established on the assumption that the phrase "the direction" in claim 1 is regarded as "a direction".)

2. Claim 3 is unclear in that the phrase "coiled (102) path" seems to be a writing error for "coiled path (102)". Therefore, claim 3 does not meet the requirements of PCT Article 6.

3. Claims 10, 12 and 15 are unclear in that the phrase "a said axially oriented segment" seems to be a writing error for "said axially oriented segment". Therefore, claims 10, 12 and 15 do not meet the requirements of PCT Article 6.

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of : Box No. V

1.2 Dependent Claims 2-7

1.2.1 Concerning Claim 2

The additional feature of claim 2 is identical to the feature of D1 in that the entry port (206) is gradually tapered down to allow for gradual acceleration of fluid and hence reduce polymer degradation (see paragraph [0107]; and figures 13-14). Accordingly, claim 2 would have been obvious over D1. Therefore, claim 2 does not involve an inventive step under PCT Article 33(3).

1.2.2 Concerning Claim 3

The additional feature of claim 3 is identical to the feature of D1 in that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 3 would have been obvious over D1. Therefore, claim 3 does not involve an inventive step under PCT Article 33(3).

1.2.3 Concerning Claim 4

The additional feature of claim 4, characterized in that the inlet enters the coiled path radially, is merely a design option from the disclosure of D1 considering that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 4 would have been obvious over D1. Therefore, claim 4 does not involve an inventive step under PCT Article 33(3).

1.2.4 Concerning Claim 5

The additional feature of claim 5, characterized in that the inlet enters the coiled path axially, is merely a design option from the disclosure of D1 considering that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 5 would have been obvious over D1. Therefore, claim 5 does not involve an inventive step under PCT Article 33(3).

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In case the space in any of the preceding boxes is not sufficient.

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1.2.5 Concerning Claim 6

The additional feature of claim 6 is identical to the feature of D1 in that the spiral flow path (202) comprises a plurality of spiral flow path grooves (see paragraph [0107]; and figures 13-14). Accordingly, claim 6 would have been obvious over D1. Therefore, claim 6 does not involve an inventive step under PCT Article 33(3).

1.2.6 Concerning Claim 7

The additional feature of claim 7 is identical to the feature of D1 in that the entry port (206) is gradually tapered down and is coiled so that an end of the entry ports (206) aligns axially with an opposing end of the exit ports (210) (see paragraph [0107]; and figures 13-14). Accordingly, claim 7 would have been obvious over D1. Therefore, claim 7 does not involve an inventive step under PCT Article 33(3).

1.3 Independent Claim 8

D1, which is considered to be the closest prior art to the subject matter of claim 8, discloses a choke trim (18) flowing a chemical for injection into a subsea well, comprising: a flow path cylinder (200) having a first axial end (208) and a second axial end (212); characterized by a flow path (202) having an entry port (206) and an exit port (210) and formed on the flow path cylinder (200) (see paragraphs [0007], [0107]; and figures 13-14).

Claim 8 differs from D1 in that a flow control assembly is characterized by at least one tortuous path extending circumferentially substantially around an inner wall of a housing in a zig-zag pattern formed substantially by axially oriented segments connected with circumferentially oriented connecting paths. However, this feature would be easily conceived from the disclosure of D2 considering that a tortuous flow path (612) is formed by fingers (68) of a first cylindrically-shaped structure (600) and fingers (610) of a second cylindrically-shaped structure (602) (see paragraph [0052]; and figure 6A).

Accordingly, it would have been obvious to a person skilled in the art to combine D1 and D2 to arrive at the flow control assembly of claim 8. Therefore, claim 8 does not involve an inventive step under PCT Article 33(3).

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In case the space in any of the preceding boxes is not sufficient.

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1.4 Dependent Claims 9-20

1.4.1 Concerning Claim 9

The additional feature of claim 9, characterized in that adjacent circumferentially oriented connecting paths are axially offset to define the zig-zag pattern, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) are intertwined to define the tortuous flow path (612) (see paragraph [0052]; and figure 6A). Accordingly, claim 9 would have been obvious over D1 in view of D2. Therefore, claim 9 does not involve an inventive step under PCT Article 33(3).

1.4.2 Concerning Claim 10

The additional feature of claim 10, characterized in that the inlet is connected by the axially oriented segment as an entry to the tortuous path, would be easily conceived from the disclosure of D2 considering that fluid flows into the tortuous flow path (612) at an inlet (604) (see paragraph [0053]; and figure 6A). Accordingly, claim 10 would have been obvious over D1 in view of D2. Therefore, claim 10 does not involve an inventive step under PCT Article 33(3).

1.4.3 Concerning Claim 11

The additional feature of claim 11 is identical to the feature of D1 in that the entry port (206) comprises a curved slot (see figures 13-14). Accordingly, claim 11 would have been obvious over D1 in view of D2. Therefore, claim 11 does not involve an inventive step under PCT Article 33(3).

1.4.4 Concerning Claim 12

The additional feature of claim 12 is identical to the feature of D1 in that the entry port (206) is wider than the spiral flow path grooves (202) (see figures 13-14). Accordingly, claim 12 would have been obvious over D1 in view of D2. Therefore, claim 12 does not involve an inventive step under PCT Article 33(3).

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In case the space in any of the preceding boxes is not sufficient.

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1.4.5 Concerning Claim 13

The additional feature of claim 13 is identical to the feature of D1 in that the entry port (206) is gradually tapered down (see paragraph [0107]; and figures 13-14). Accordingly, claim 13 would have been obvious over D1 in view of D2. Therefore, claim 13 does not involve an inventive step under PCT Article 33(3).

1.4.6 Concerning Claim 14

The additional feature of claim 14 is identical to the feature of D1 in that the exit port (210) comprises a curved slot (see figures 13-14). Accordingly, claim 14 would have been obvious over D1 in view of D2. Therefore, claim 14 does not involve an inventive step under PCT Article 33(3).

1.4.7 Concerning Claim 15

The additional feature of claim 15 is identical to the feature of D1 in that the exit port (210) is wider than the spiral flow path grooves (202) (see figures 13-14). Accordingly, claim 15 would have been obvious over D1 in view of D2. Therefore, claim 15 does not involve an inventive step under PCT Article 33(3).

1.4.8 Concerning Claim 16

The additional feature of claim 16 is identical to the feature of D1 in that the exit port (210) is gradually tapered up (see figures 13-14). Accordingly, claim 16 would have been obvious over D1 in view of D2. Therefore, claim 16 does not involve an inventive step under PCT Article 33(3).

1.4.9 Concerning Claim 17

The additional feature of claim 17, characterized in that the tortuous path defines a scroll shape with a variable diameter, would be easily conceived from the disclosure of D2 considering that the cylindrically-shaped structures (600, 602) are movable with respect to each other to adjust the cross-sectional flow area of the tortuous flow path (612) (see

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of : Previous Page

paragraph [0052]; and figure 6A). Accordingly, claim 17 would have been obvious over D1 in view of D2. Therefore, claim 17 does not involve an inventive step under PCT Article 33(3).

1.4.10 Concerning Claim 18

The additional feature of claim 18, characterized in that the axially oriented segments have a quadrilateral shape, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) have a quadrilateral shape (see figure 6A). Accordingly, claim 18 would have been obvious over D1 in view of D2. Therefore, claim 18 does not involve an inventive step under PCT Article 33(3).

1.4.11 Concerning Claim 19

The additional feature of claim 19, characterized in that the circumferentially oriented connecting paths have a quadrilateral or round shape, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) have a quadrilateral shape (see figure 6A). Accordingly, claim 19 would have been obvious over D1 in view of D2. Therefore, claim 19 does not involve an inventive step under PCT Article 33(3).

1.4.12 Concerning Claim 20

The additional feature of claim 20, characterized in that the at least one tortuous path extends circumferentially for at least two revolutions, would be easily conceived from the disclosure of D2 considering that the cylindrically-shaped structures (600, 602) are provided around the circumference of a pipe (204) (see paragraph [0052]; and figure 6A). Accordingly, claim 20 would have been obvious over D1 in view of D2. Therefore, claim 20 does not involve an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-20 are industrially applicable under PCT Article 33(4).

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

To:
DUPHORNE, DARIN H.

INTELLECTUAL PROPERTY COUNSEL BAKER
HUGHES INCORPORATED 17021 ALDINE WESTFIELD
HOUSTON TX 77073 USA

Date of mailing
(day/month/year) **19 September 2017 (19.09.2017)**

Applicant's or agent's file reference
ICD4-61636-WO

FOR FURTHER ACTION

See paragraph 2 below

International application No. PCT/US2017/038148	International filing date (day/month/year) 19 June 2017 (19.06.2017)	Priority date(day/month/year) 08 July 2016 (08.07.2016)
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International Patent Classification (IPC) or both national classification and IPC

E21B 43/16(2006.01)i, E21B 43/12(2006.01)i

Applicant

BAKER HUGHES INCORPORATED

1. This opinion contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|--|
| ☒ | Box No. I | Basis of the opinion |
| ☐ | Box No. II | Priority |
| ☐ | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| ☐ | Box No. IV | Lack of unity of invention |
| ☒ | Box No. V | Reasoned statement under Rule 43bis. I(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement |
| ☐ | Box No. VI | Certain documents cited |
| ☐ | Box No. VII | Certain defects in the international application |
| ☒ | Box No. VIII | Certain observations on the international application |

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

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For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon,
35208, Republic of Korea
Facsimile No. +82-42-481-8578



Date of completion of this opinion

19 September 2017 (19.09.2017)

Authorized officer

LEE, Se Gyoung

Telephone No. +82-42-481-8740



**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. 1 Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :

- ☒ the international application in the language in which it was filed
- ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*. I(a))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

- a. ☐ forming part of the international application as filed:
☐ in the form of an Annex C/ST.25 text file.
☐ on paper or in the form of an image file.
- b. ☐ furnished together with the international application under PCT Rule 13*ter*. I(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*. I(a)).
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4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: US 2015-0275612 A1 (CAMERON INTERNATIONAL CORPORATION)

01 October 2015

D2: US 2011-0061877 A1 (ZAZOVSKY et al.) 17 March 2011

1. Novelty and Inventive Step

1.1 Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a choke trim (18) flowing a chemical for injection into a subsea well, comprising: a flow path cylinder (200) having a first axial end (208) and a second axial end (212); characterized by a spiral flow path (202) having an entry port (206) and an exit port (210) and formed on the flow path cylinder (200), wherein the entry port (206) is gradually tapered down to allow for gradual acceleration of fluid and hence reduce polymer degradation (see paragraphs [0007], [0107]; and figures 13-14).

Claim 1 differs from D1 in that a flow control assembly is characterized by an inlet and an outlet communicating with pressure in a tubular string. However, this feature would be easily conceived from the disclosure of D1 considering that polymer enters the spiral flow path (202) through the entry port (206) and exits the spiral flow path (202) through the exit port (210) (see paragraph [0107]; and figures 13-14).

Accordingly, claim 1 would have been obvious over D1. Therefore, claim 1 does not involve an inventive step under PCT Article 33(3).

Continued on Supplemental Box

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2017/038148

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. In claim 1, "the direction" has not been previously defined. Therefore, claim 1 does not meet the requirements of PCT Article 6.

(Note: The international search report and the written opinion have been established on the assumption that the phrase "the direction" in claim 1 is regarded as "a direction".)

2. Claim 3 is unclear in that the phrase "coiled (102) path" seems to be a writing error for "coiled path (102)". Therefore, claim 3 does not meet the requirements of PCT Article 6.

3. Claims 10, 12 and 15 are unclear in that the phrase "a said axially oriented segment" seems to be a writing error for "said axially oriented segment". Therefore, claims 10, 12 and 15 do not meet the requirements of PCT Article 6.

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of : Box No. V

1.2 Dependent Claims 2-7

1.2.1 Concerning Claim 2

The additional feature of claim 2 is identical to the feature of D1 in that the entry port (206) is gradually tapered down to allow for gradual acceleration of fluid and hence reduce polymer degradation (see paragraph [0107]; and figures 13-14). Accordingly, claim 2 would have been obvious over D1. Therefore, claim 2 does not involve an inventive step under PCT Article 33(3).

1.2.2 Concerning Claim 3

The additional feature of claim 3 is identical to the feature of D1 in that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 3 would have been obvious over D1. Therefore, claim 3 does not involve an inventive step under PCT Article 33(3).

1.2.3 Concerning Claim 4

The additional feature of claim 4, characterized in that the inlet enters the coiled path radially, is merely a design option from the disclosure of D1 considering that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 4 would have been obvious over D1. Therefore, claim 4 does not involve an inventive step under PCT Article 33(3).

1.2.4 Concerning Claim 5

The additional feature of claim 5, characterized in that the inlet enters the coiled path axially, is merely a design option from the disclosure of D1 considering that the entry port (206) enters the spiral flow path (202) tangentially (see figures 13-14). Accordingly, claim 5 would have been obvious over D1. Therefore, claim 5 does not involve an inventive step under PCT Article 33(3).

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In case the space in any of the preceding boxes is not sufficient.

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1.2.5 Concerning Claim 6

The additional feature of claim 6 is identical to the feature of D1 in that the spiral flow path (202) comprises a plurality of spiral flow path grooves (see paragraph [0107]; and figures 13-14). Accordingly, claim 6 would have been obvious over D1. Therefore, claim 6 does not involve an inventive step under PCT Article 33(3).

1.2.6 Concerning Claim 7

The additional feature of claim 7 is identical to the feature of D1 in that the entry port (206) is gradually tapered down and is coiled so that an end of the entry ports (206) aligns axially with an opposing end of the exit ports (210) (see paragraph [0107]; and figures 13-14). Accordingly, claim 7 would have been obvious over D1. Therefore, claim 7 does not involve an inventive step under PCT Article 33(3).

1.3 Independent Claim 8

D1, which is considered to be the closest prior art to the subject matter of claim 8, discloses a choke trim (18) flowing a chemical for injection into a subsea well, comprising: a flow path cylinder (200) having a first axial end (208) and a second axial end (212); characterized by a flow path (202) having an entry port (206) and an exit port (210) and formed on the flow path cylinder (200) (see paragraphs [0007], [0107]; and figures 13-14).

Claim 8 differs from D1 in that a flow control assembly is characterized by at least one tortuous path extending circumferentially substantially around an inner wall of a housing in a zig-zag pattern formed substantially by axially oriented segments connected with circumferentially oriented connecting paths. However, this feature would be easily conceived from the disclosure of D2 considering that a tortuous flow path (612) is formed by fingers (68) of a first cylindrically-shaped structure (600) and fingers (610) of a second cylindrically-shaped structure (602) (see paragraph [0052]; and figure 6A).

Accordingly, it would have been obvious to a person skilled in the art to combine D1 and D2 to arrive at the flow control assembly of claim 8. Therefore, claim 8 does not involve an inventive step under PCT Article 33(3).

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1.4 Dependent Claims 9-20

1.4.1 Concerning Claim 9

The additional feature of claim 9, characterized in that adjacent circumferentially oriented connecting paths are axially offset to define the zig-zag pattern, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) are intertwined to define the tortuous flow path (612) (see paragraph [0052]; and figure 6A). Accordingly, claim 9 would have been obvious over D1 in view of D2. Therefore, claim 9 does not involve an inventive step under PCT Article 33(3).

1.4.2 Concerning Claim 10

The additional feature of claim 10, characterized in that the inlet is connected by the axially oriented segment as an entry to the tortuous path, would be easily conceived from the disclosure of D2 considering that fluid flows into the tortuous flow path (612) at an inlet (604) (see paragraph [0053]; and figure 6A). Accordingly, claim 10 would have been obvious over D1 in view of D2. Therefore, claim 10 does not involve an inventive step under PCT Article 33(3).

1.4.3 Concerning Claim 11

The additional feature of claim 11 is identical to the feature of D1 in that the entry port (206) comprises a curved slot (see figures 13-14). Accordingly, claim 11 would have been obvious over D1 in view of D2. Therefore, claim 11 does not involve an inventive step under PCT Article 33(3).

1.4.4 Concerning Claim 12

The additional feature of claim 12 is identical to the feature of D1 in that the entry port (206) is wider than the spiral flow path grooves (202) (see figures 13-14). Accordingly, claim 12 would have been obvious over D1 in view of D2. Therefore, claim 12 does not involve an inventive step under PCT Article 33(3).

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1.4.5 Concerning Claim 13

The additional feature of claim 13 is identical to the feature of D1 in that the entry port (206) is gradually tapered down (see paragraph [0107]; and figures 13-14). Accordingly, claim 13 would have been obvious over D1 in view of D2. Therefore, claim 13 does not involve an inventive step under PCT Article 33(3).

1.4.6 Concerning Claim 14

The additional feature of claim 14 is identical to the feature of D1 in that the exit port (210) comprises a curved slot (see figures 13-14). Accordingly, claim 14 would have been obvious over D1 in view of D2. Therefore, claim 14 does not involve an inventive step under PCT Article 33(3).

1.4.7 Concerning Claim 15

The additional feature of claim 15 is identical to the feature of D1 in that the exit port (210) is wider than the spiral flow path grooves (202) (see figures 13-14). Accordingly, claim 15 would have been obvious over D1 in view of D2. Therefore, claim 15 does not involve an inventive step under PCT Article 33(3).

1.4.8 Concerning Claim 16

The additional feature of claim 16 is identical to the feature of D1 in that the exit port (210) is gradually tapered up (see figures 13-14). Accordingly, claim 16 would have been obvious over D1 in view of D2. Therefore, claim 16 does not involve an inventive step under PCT Article 33(3).

1.4.9 Concerning Claim 17

The additional feature of claim 17, characterized in that the tortuous path defines a scroll shape with a variable diameter, would be easily conceived from the disclosure of D2 considering that the cylindrically-shaped structures (600, 602) are movable with respect to each other to adjust the cross-sectional flow area of the tortuous flow path (612) (see

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paragraph [0052]; and figure 6A). Accordingly, claim 17 would have been obvious over D1 in view of D2. Therefore, claim 17 does not involve an inventive step under PCT Article 33(3).

1.4.10 Concerning Claim 18

The additional feature of claim 18, characterized in that the axially oriented segments have a quadrilateral shape, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) have a quadrilateral shape (see figure 6A). Accordingly, claim 18 would have been obvious over D1 in view of D2. Therefore, claim 18 does not involve an inventive step under PCT Article 33(3).

1.4.11 Concerning Claim 19

The additional feature of claim 19, characterized in that the circumferentially oriented connecting paths have a quadrilateral or round shape, would be easily conceived from the disclosure of D2 considering that the fingers (68) and the fingers (610) have a quadrilateral shape (see figure 6A). Accordingly, claim 19 would have been obvious over D1 in view of D2. Therefore, claim 19 does not involve an inventive step under PCT Article 33(3).

1.4.12 Concerning Claim 20

The additional feature of claim 20, characterized in that the at least one tortuous path extends circumferentially for at least two revolutions, would be easily conceived from the disclosure of D2 considering that the cylindrically-shaped structures (600, 602) are provided around the circumference of a pipe (204) (see paragraph [0052]; and figure 6A). Accordingly, claim 20 would have been obvious over D1 in view of D2. Therefore, claim 20 does not involve an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-20 are industrially applicable under PCT Article 33(4).