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(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, 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).

[Continued on next page]

(54) **Title**: GRAVEL PACKING SYSTEM AND METHOD

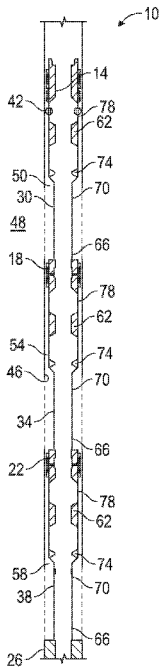

FIG. 1A

(57) **Abstract**: A gravel packing system includes at least two packers with at least one of the two packers being sealable to an open hole, a barrier sealably engaged with the at least two packers defining an annular space between the open hole and the barrier, a cross-over tool operably connectable to at least one of the at least two packers and the barrier, and at least one regulator in operable communication with the barrier configured to maintain a substantially constant pressure in the annular space while gravel is packed at a location downstream of at least one of the at least two packers, downstream being defined by a direction of travel of gravel being packed.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

GRAVEL PACKING SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 61/721252, filed on November 1, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Gravel packing is performed to provide structural support to walls of an open borehole. Typical gravel packing systems employ a casing within a borehole thereby allowing gravel to be packed in an annular space defined between the casing and walls of the open borehole. There are applications wherein it is desirable to gravel pack an open borehole without a casing positioned therewith. Systems and methods to enable and improve on such operations are of interest to the industry.

BRIEF DESCRIPTION

[0003] Disclosed herein is a gravel packing system. The system includes at least two packers with at least one of the two packers being sealable to an open hole, a barrier sealably engaged with the at least two packers defining an annular space between the open hole and the barrier, a cross-over tool operably connectable to at least one of the at least two packers and the barrier, and at least one regulator in operable communication with the barrier configured to maintain a substantially constant pressure in the annular space maintain a substantially constant while gravel is packed at a location downstream of at least one of the at least two packers, downstream is defined by a direction of travel of gravel that is being packed.

[0004] Further disclosed herein is a method of packing gravel. The method includes running a cross-over tool within an open borehole, engaging the cross-over tool with at least one of at least two packers wherein at least one of the at least two packers is set in the open borehole and a barrier sealed to the at least two packers defining an annular space between the barrier and the open borehole, packing gravel at a location downstream of at least one of the at least two packers, and maintaining a substantially constant pressure in the annular space.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0006] Figures 1A-1B depict a cross sectional view of a gravel packing system disclosed herein; and

[0007] Figures 2A-2L depict cross sectional views of the gravel packing system of Figures 1A-1B during various operational positions.

DETAILED DESCRIPTION

[0008] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0009] Referring to Figures 1A and 1B, an embodiment of a gravel packing system disclosed herein is illustrated at 10. The gravel packing system 10 includes at least two packers 14, 18, 22, 26, with four being illustrated herein, fluidic barriers 30, 34, 38, in the shape of tubulars, a regulator 42 and a cross-over tool 44. At least one of the packers 14, 18, 22, 26 is sealably engagable with an open borehole 46 in an earth formation 48, while the barriers 30, 34, 38 are sealably engaged to the packers 14, 18, 22, 26 thereby defining annular spaces 50, 54, 58 between the barriers 30, 34, 38 and the open borehole 46. Any of the packers 14, 18, 22, 26 not sealably engaged with the open borehole 46 can be sealed to a cased section above the open borehole 46, for example. The regulator 42 is configured to maintain a substantially constant pressure in at least one of the annular spaces 50, 54, 58 at a selected pressure regardless of the pressure within the barriers 30, 34, 38 or any other spaces adjacent to the regulator 42. The regulator 42 in this embodiment sets the selected pressure to be maintained as the hydrostatic pressure at the position of the regulator 42 when a first of the packers 14, 18, 22, 26 is set. The cross-over tool 44 is sealably connectable to various portions of the packers 14, 18, 22, 26 and the barriers 30, 34, 38 such that gravel pumped therethrough can be packed into the annular spaces 50, 54 and 58.

[0010] Additionally, the gravel packing system 10 has features such as, seal bores 62, circulating sleeves 66, production sleeves 70, indicator couplings 74 and, gravel pack sleeves 78, that are connected to the packers 18, 22, 26 and the barriers 30, 34 and 38, as well as a packer setting tool 82, tubing 84, return port coupling 88, gravel packing port 92, gravel packing sleeve opening tool 96, set down indicator 100, pick up indicator 104, close-only tool 108 and open-only tool 112 that are connected to the cross-over tool 44. These additional

features allow operators to perform such operations as positional indicating, setting, actuating valves, opening ports and closing ports, for example, to facilitate the gravel packing that will be discussed below.

[0011] Referring to Figures 2A-2L, the gravel packing system 10 disclosed is shown in various positions. By positioning the cross-over tool 44 at different locations relative to the packers 14, 18, 22, 26 and the barriers 30, 34, 38 and flowing fluid and/or gravel 120 therethrough and applying pressure against a plug 116 seated thereat, the packers 14, 18, 22, 26 can be set and the sleeves 66, 70, 78, 96 moved to actuate valves, open or close various ports as will be described next, all without fully removing the cross-over tool 44 from the packers 14, 18, 22, 26. Figure 2A shows the cross-over tool 44, which includes the packer setting tool 82, in a position fully run in the borehole 46. Figure 2B shows the cross-over tool 44 with the plug 116 run thereagainst and blocking flow therethrough such that pressure applied thereagainst sets the packer 14 that is located most upstream as defined by flow built behind the plug 116. In Figure 2C the cross-over tool 44 has been moved to a location to set the packer 26 that is located furthest downstream. Downstream being defined by a direction of travel of gravel being packed. This position isolates the annular spaces 50, 54 from the inside of the barriers 30, 34, 38 while leaving the annular space 58 connected thereto through the cross-over tool 44. Figure 2D shows gravel 120 being circulated through the cross-over tool 44 and into the annular space 58, after the cross-over tool 44 had been moved again. Reverse circulation to remove any extra gravel 120 is illustrated in Figure 2E again after having moved the cross-over tool 44 to realign flow out through the gravel packing port 92. In Figure 2F the gravel packing port 92 has been aligned with the packer 22 to allow it to be set through pressure applied thereto. Gravel 120 is shown being packed into the annular space 54 in Figure 2G. An adjustment in location of the cross-over tool 44 allows for reverse flow to again remove excess gravel 120 as seen in Figure 2H. In Figure 2K gravel 120 is circulated into the annular space 50, followed by a reverse flow operation shown in Figure 2L.

[0012] Throughout all of the operations in Figures 2A-2L the pressure in each of the annular spaces 50, 54 and 58, when isolated, remains at the hydrostatic pressure set by the regulator 42 regardless of the higher pressures applied against the plug 116 during the various operations. This hydrostatic pressure supports the open borehole 46 while not allowing fracturing of the earth formation 48 that could occur had the regulator 42 not prevented pressure in the annular spaces 50, 54, 58 from exceeding the desired set pressure. The regulator 42 also prevents drops in pressure within the annular spaces 50, 54 and 58 below

the hydrostatic pressure even if pressure within the barriers 30, 34, 38 drops below the hydrostatic set pressure of the regulator 42.

[0013] It should be noted that although the illustrated embodiment of the system 10 includes just one of the regulators 42, alternate embodiments could employ a plurality of the regulators 42. Such a system could have one of the regulators 42 in operable communication with each of the annular spaces 50, 54, 58.

[0014] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

CLAIMS

What is claimed is:

1. A gravel packing system comprising:

at least two packers with at least one of the two packers being sealable to an open hole;

a barrier sealably engaged with the at least two packers defining an annular space between the open hole and the barrier;

a cross-over tool operably connectable to at least one of the at least two packers and the barrier; and

at least one regulator in operable communication with the barrier configured to maintain a substantially constant pressure in the annular space while gravel is being packed at a location downstream of at least one of the at least two packers, downstream being defined by a direction of travel of gravel being packed.

2. The gravel packing system of claim 1, wherein the at least one regulator sets the substantially constant pressure as the hydrostatic pressure at a position of the at least one regulator when a first of the at least two packers is set.

3. The gravel packing system of claim 1, wherein the at least one regulator prevents pressure in the annular space from exceeding a set pressure level.

4. The gravel packing system of claim 1, wherein the location downstream of at least one of at least two packers is downstream of both of the at least two packers.

5. The gravel packing system of claim 4, wherein subsequent packing of gravel at the location downstream of both of the at least two packers, the cross-over tool can be shifted to thereby allow gravel packing of another annular space.

6. The gravel packing system of claim 1, wherein the at least two packers is more than two packers and the cross-over tool can be moved to sequentially pack gravel at a plurality of locations.

7. The gravel packing system of claim 6, wherein the sequentially packing of gravel is from a furthest downstream location first to ever less downstream locations.

8. The gravel packing system of claim 1, wherein the cross-over tool is configured to be moved relative to at least the at least two packers and the barrier to allow actuation of the at least two packers, alteration of valves, transporting of gravel therethrough and allowing reverse flows therethrough to purge excess gravel therefrom.

9. The gravel packing system of claim 8, wherein the actuation of the at least two packers, alteration of valves, transporting of gravel therethrough and reversing of flow

therethrough can all be accomplished without fully withdrawing the cross-over tool from the at least two packers.

10. A method of packing gravel comprising:

running a cross-over tool within an open borehole;

engaging the cross-over tool with at least one of at least two packers wherein at least one of the at least two packers is set in the open borehole and a barrier sealed to the at least two packers defining an annular space between the barrier and the open borehole;

packing gravel at a location downstream of at least one of the at least two packers; and

maintaining a substantially constant pressure in the annular space.

11. The method of packing gravel of claim 10, further comprising preventing pressure in the annular space from exceeding a set pressure.

12. The method of packing gravel of claim 10, further comprising setting the substantially constant pressure in the annular space to be substantially equal to hydrostatic pressure in the annular space prior to setting the at least two packers.

13. The method of packing gravel of claim 10, further comprising packing gravel in the annular space.

14. The method of packing gravel of claim 10, further comprising packing gravel at additional locations with each location being located upstream of previously packed locations.

15. The method of packing gravel of claim 13, wherein the packing gravel at the location and at additional locations is completed without withdrawing of the cross-over tool from the at least two packers.

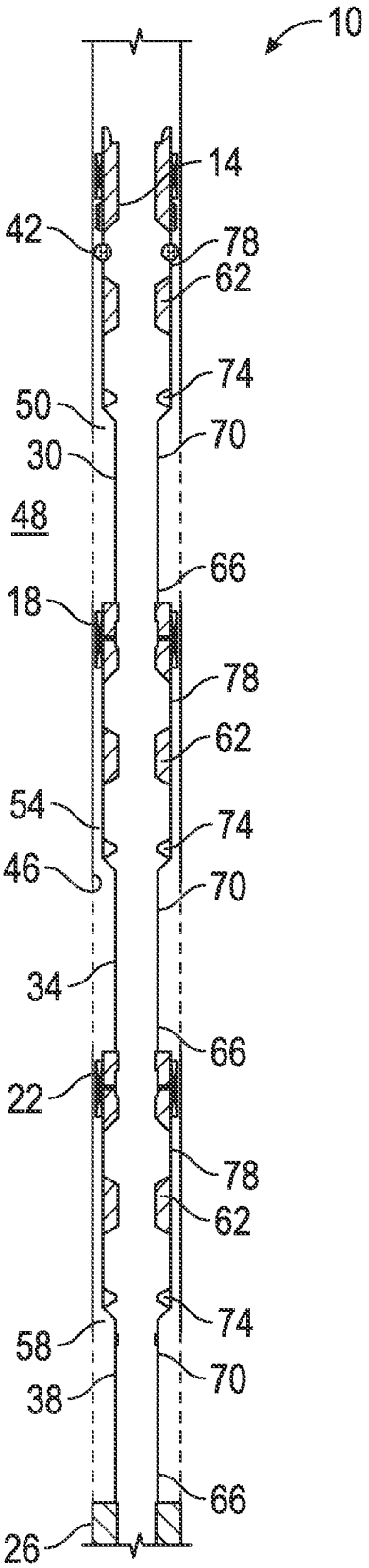
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FIG. 1A

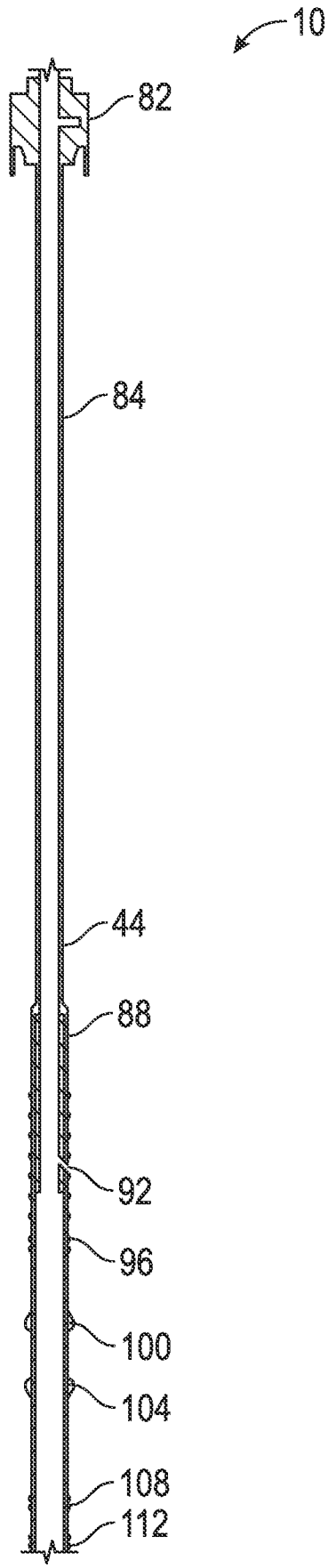
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FIG. 1B

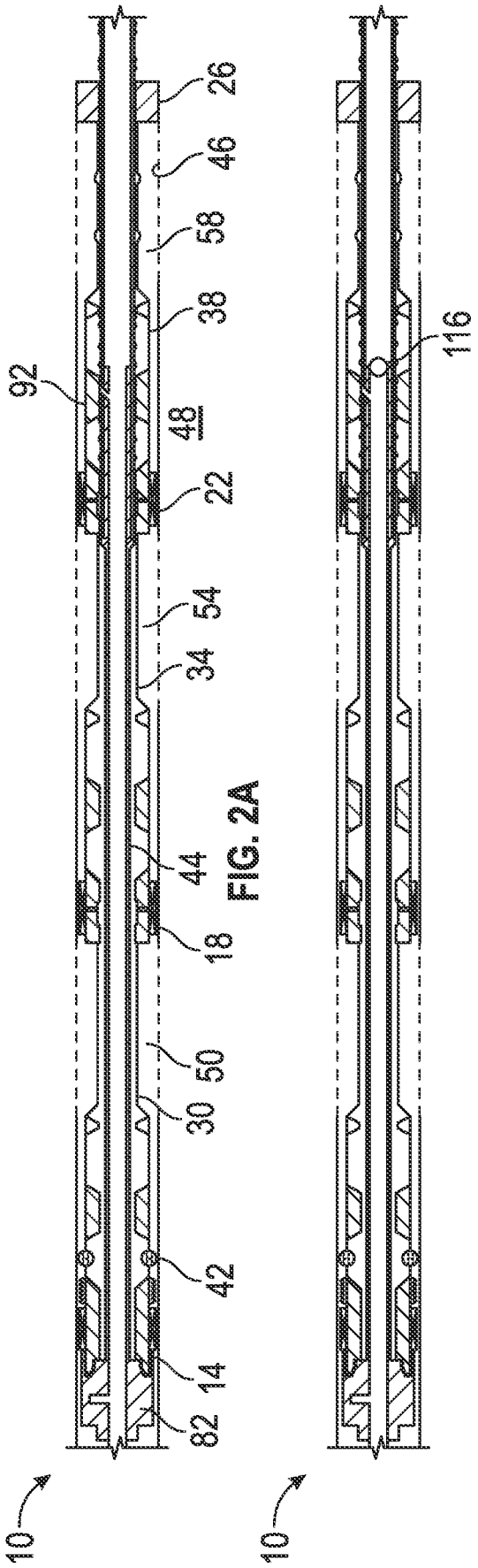

FIG. 2A

FIG. 2B

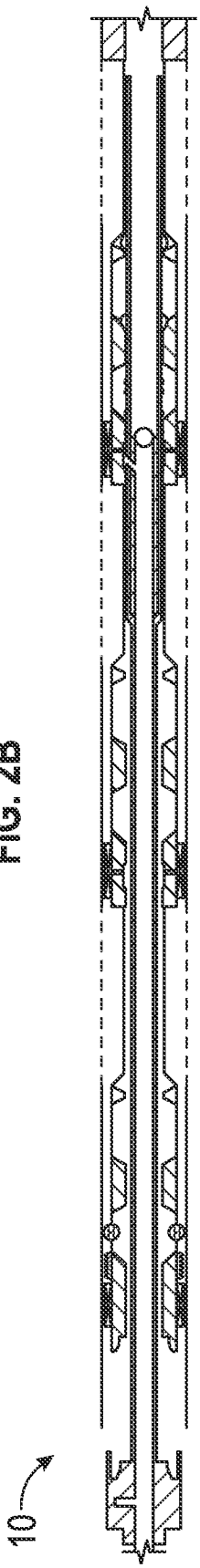

FIG. 2C

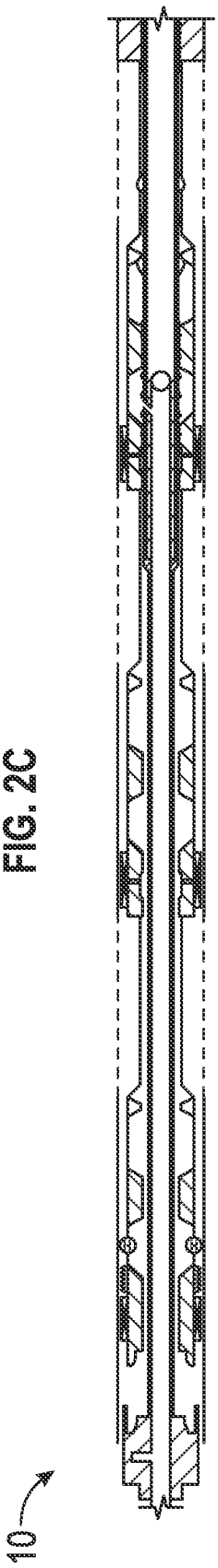

FIG. 2D

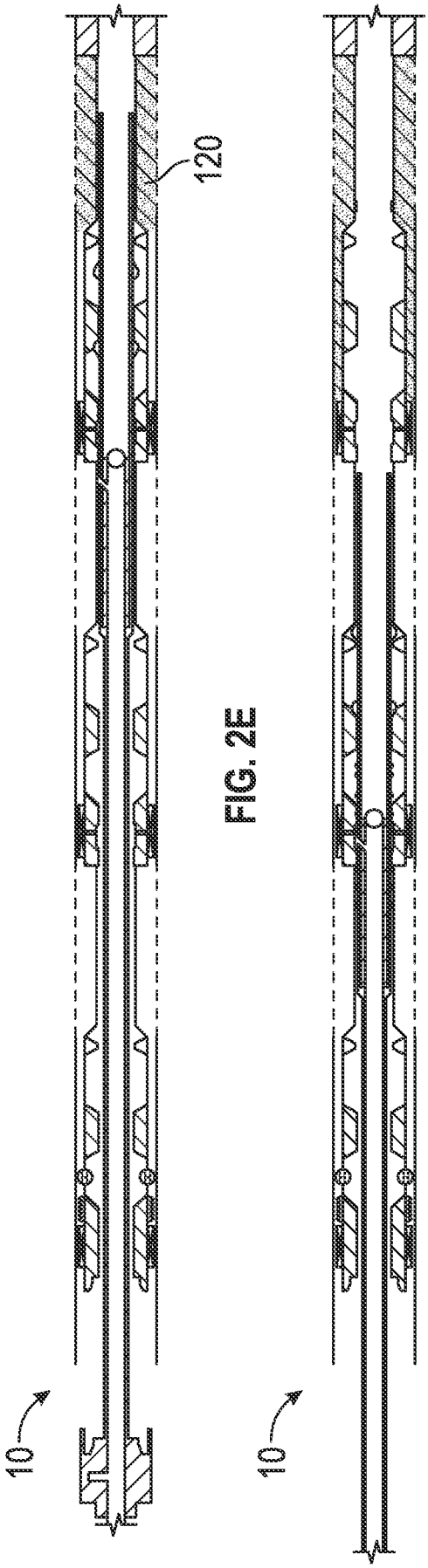

FIG. 2E

FIG. 2F

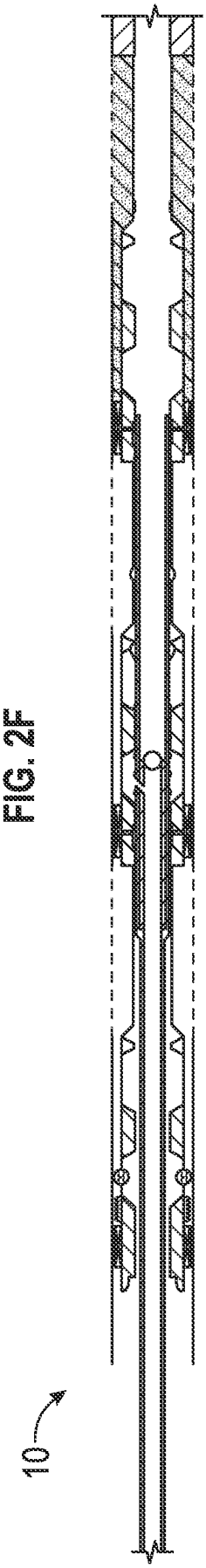

FIG. 2G

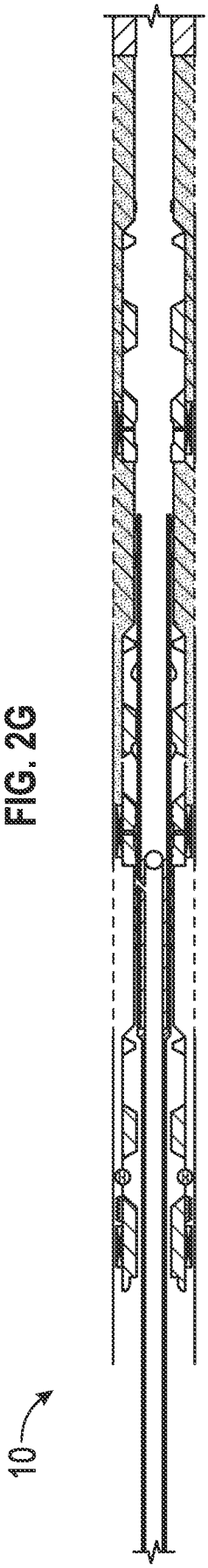

FIG. 2H

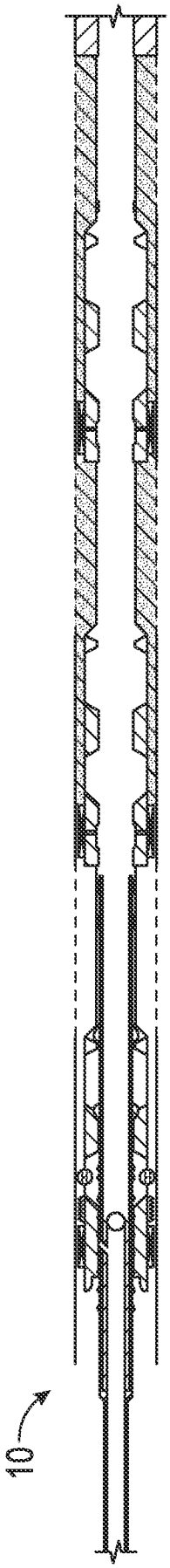

FIG. 2J

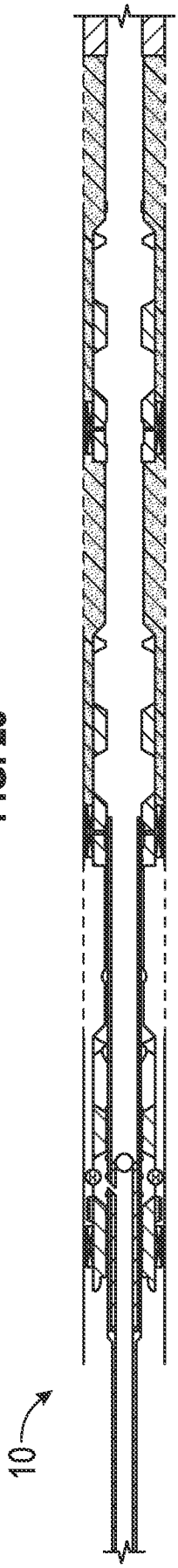

FIG. 2K

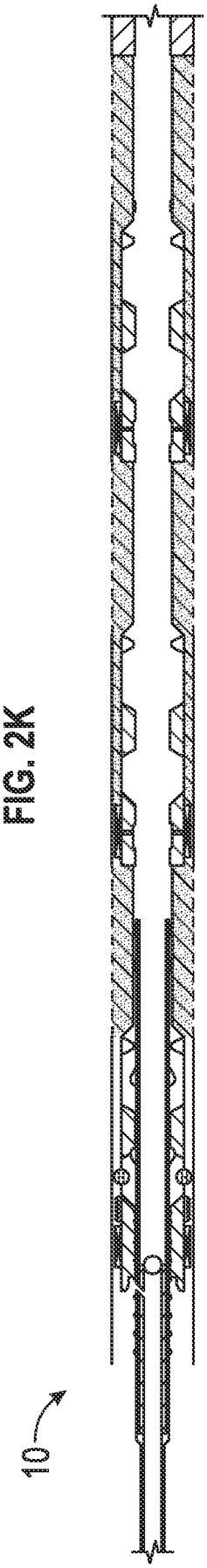

FIG. 2L

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/04(2006.01)i, E21B 33/122(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 43/04; E21B 19/24; E21B 43/00; E21B 33/12; E21B 33/122

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: packer, barrier, cross-over tool, regulator, and gravel packing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009-0188674 A1 (GUIGNARD et al.) 30 July 2009 See abstract, paragraphs [0024]-[0025],[0032]-[0035], and figures 1,6-11.	1-15
Y	US 2012-0199362 A1 (GRIGSBY et al.) 09 August 2012 See abstract, paragraphs [0028]-[0031], and figure 1.	1-15
A	US 6230801 B1 (HILL, JR. et al.) 15 May 2001 See abstract, column 2, line 60 - column 5, line 17, and figures 1A-2D.	1-15
A	US 6789623 B2 (HILL, JR. et al.) 14 September 2004 See abstract, column 7, line 53 - column 8, line 15, and figures 5-6.	1-15
A	US 2012-0175112 A1 (ATKINSON et al.) 12 July 2012 See abstract, paragraphs [0019]-[0022], and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 January 2014 (06.01.2014)	**07 January 2014 (07.01.2014)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/063667

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Information on patent family members

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