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(71) Applicant: **BAKER HUGHES INCORPORATED** [US/US]; P.o. Box 4740, Houston, TX 77210 (US).

(72) Inventors: **FLORES, Juan, C.**; 62 South Longford Circle, The Woodlands, TX 77382 (US). **CASTRO, Luis, A.**; 47 North Rocky Point Circle, Spring, TX 77389 (US). **PORTER, Andre, J.**; 1717 Edwards Street, Houston, TX 77007 (US).

(74) Agent: **PORTER, Andre J.**; Intellectual Property Counsel, Baker Hughes Incorporated, P.O. Box 4740, Houston, TX 77210-4740 (US).

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(54) Title: PERFORATOR WITH A MECHANICAL DIVERSION TOOL AND RELATED METHODS

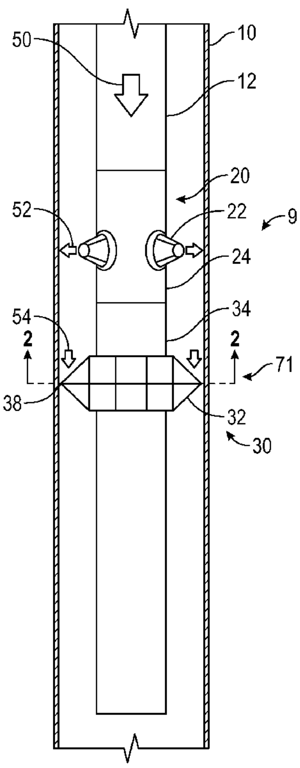

FIG. 1

(57) Abstract: An apparatus can include a well treatment system that supplies a treatment fluid, a conveyance device and a well tool conveyed by the conveyance device. The well tool can include a perforator configured to form at least one hole in the wellbore tubular and a restrictor projecting from an outer surface of the well tool and adjacent to the perforator. A gap may separate the restrictor and the wellbore tubular. The well tool may also include a flow space that provides fluid communication between a location uphole of the restrictor and a location downhole of the restrictor. The flow space is sized to be restricted by particles in the treatment fluid. The restrictor at least restricts fluid flow through an annulus between the restrictor and the wellbore tubular, and the well tool diverts a substantial amount of the treatment fluid through an at least one hole formed by the perforator.

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TITLE: PERFORATOR WITH A MECHANICAL DIVERSION TOOL AND RELATED METHODS

INVENTOR(S): FLORES, Juan C.; CASTRO, Sr., Luis A.; and PORTER, Andre J.

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

[0001] This disclosure relates generally to oilfield downhole tools and more particularly to methods and devices for performing multiple perforation and treatment operations using a perforator and a restrictor.

2. Description of the Related Art

[0002] Wellbore operations such as drilling, wireline logging, completions, perforations and interventions are performed to produce oil and gas from underground reservoirs. Wellbores can extend thousands of feet underground to the underground reservoirs. Many operations require multiple types of operations at a specific depth along the wellbore. Some of these operations require a section of the wellbore to be isolated. In some aspects, the present disclosure is directed to methods and devices for selectively isolating a section of a well during perforating and well treatment operations.

SUMMARY OF THE DISCLOSURE

[0003] In one aspect, the present disclosure provides a downhole tool for performing a downhole operation in a wellbore tubular. The downhole tool may include a well treatment system that supplies a treatment fluid. The downhole tool may also have a conveyance device and a well tool conveyed by the conveyance device. The well tool may include a perforator configured to form at least one hole in the wellbore tubular, and a restrictor projecting from an outer surface of the well tool. The restrictor may be adjacent to the perforator. A gap separates the restrictor and the wellbore tubular. The restrictor at least restricts fluid flow between the restrictor and the wellbore tubular. Also, the restrictor diverts a substantial amount of the treatment fluid through the at least one hole formed by the perforator.

[0004] In another aspect, the present disclosure provides a downhole tool for performing a downhole operation in a wellbore tubular. The downhole tool may include a well treatment system that supplies a treatment fluid. The downhole tool may also have a conveyance device and a well tool conveyed by the conveyance device. The well tool may include a perforator configured to form at least one hole in the wellbore tubular, and a restrictor projecting from an outer surface of the well tool. The restrictor may be adjacent to the perforator. The restrictor restricts fluid flow through an annulus between the restrictor and the wellbore tubular. The well tool may also have a flow space that provides fluid communication between a location uphole of the restrictor and a location downhole of the restrictor. The flow space is sized to allow for the formation of a flow restriction by particles in the treatment fluid. The well tool diverts a substantial amount of the treatment fluid through the at least one hole formed by the perforator.

[0005] In another aspect, the present disclosure provides a method of performing a downhole operation in a wellbore tubular. The method may include deploying a perforator and a restrictor at a target depth using a conveyance device. The restrictor is disposed at least partially in an annulus between the conveyance device and the wellbore tubular. The method may also include activating the perforator, opening an at least one hole in the wellbore tubular, and pumping a treatment fluid into the wellbore tubular. The method may also comprise restricting flow through a gap across the restrictor to divert a substantial amount of the treatment fluid into the opened hole in the wellbore tubular using the restrictor. The gap is sized to allow for the formation of a flow restriction by particles in the treatment fluid.

[0006] Illustrative examples of some features of the disclosure thus have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For detailed understanding of the present disclosure, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIGS. 1 shows an exemplary perforator and restrictor with a single restriction element according to the present disclosure;

FIG. 2 illustrates an exemplary gap between a restrictor and a wellbore tubular around the restrictor;

FIG. 3A-B show an exemplary perforator and restrictor with two restriction elements during perforation and well stimulation, respectively; and

FIG. 4 illustrates an exemplary perforator with an explosive shape charge and a restrictor.

FIGS. 5A-D show axial cross-sections of exemplary restriction elements;

FIGS. 6A-D show axial cross-sections of exemplary restriction elements with mating elements.

FIG. 7 shows an exemplary flow space with an opening.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0008] The present disclosure relates to devices and methods for performing a well treatment job using a perforator and a well treatment tool. The well treatment tool includes a restrictor that can isolate a section of a wellbore tubular in which the well treatment tool is positioned. A flow space provides selective communication between the location uphole the restrictor and the downhole of the restrictor. In one embodiment, the flow space includes a gap separating the wellbore tubular and the restrictor, and is sized to allow the restrictor to travel through a bore of the wellbore tubular with relative ease. In another embodiment, the flow space can include an opening that communicates fluid across the restrictor. During operation, the flow space becomes partially or completely blocked with material(s) pumped downhole, which provides the desired isolation. Illustrative well tools including perforators and restrictors are described below.

[0009] **Fig. 1** shows one non-limiting embodiment of the well tool **9** for perforation and well treatment operations. The well tool **9** may be run in conjunction with other bottom hole assemblies inside a wellbore tubular **10** such as a casing, liner, tubing or other suitable tubular. The well tool **9** has a perforator **20** positioned next to a restrictor **30**. A conveyance device **12** is used to deploy and retrieve the well tool **9** into the wellbore tubular **10**.

[0010] The perforator **20** is used to open holes **16** (not shown) in the wellbore tubular **10** before the treatment operation. The perforator **20** includes a housing **24** that has hydraulic jet nozzles **22**. The conveyance device **12** provides perforating fluid to the perforator **20** through its flow bore in a downhole direction **50**. The flow rate may range from 0.5 barrel per minute (bpm) up to 12 bpm. The nozzles **22** create a hydraulic jet directed at the wellbore tubular **10**. The nozzles **22** can be shaped to focus the perforating fluid on the wellbore tubular **10**. The perforating fluid includes abrasive particles, which may be sand, ceramic, calcium carbonate, soda glass and other mineral and synthetic materials. Among the factors that determine the hole size and depth, and the time it takes to open the holes are the distance between the nozzle

22 and wellbore tubular **10**, the type of the perforating fluid and the particles, the flow rate of the perforating fluid, the pressure across the nozzle **22**, the backpressure and the design of the nozzle **22**.

[0011] Adjacent to the perforator is the restrictor **30**. The restrictor **30** changes the flow direction from substantially parallel to the wellbore to substantially transverse to the wellbore. The restrictor **30** can have a single restriction element **32** attached to a restrictor housing **34**. The restriction element **32** projects radially from the well tool toward an inner surface of the wellbore tubular **10**. The restriction element **32** has an outer surface **38** that faces the wellbore tubular **10**.

[0012] The gap **70** separating the outer surface **38** and the wellbore tubular **10** is sized to facilitate movement of the restrictor **30** through the wellbore tubular **10** while providing the necessary fluid sealing effect during operation. For example, the gap **70** is sufficiently large to reduce the likelihood that the restrictor **30** will impact or get caught on a shoulder, ledge, or other feature on the inner surface of the wellbore tubular **10**. At the same time, the gap **70** is sufficiently small to allow materials pumped from the surface to substantially block flow across the gap **70**.

[0013] For instance, after the perforation is completed, fluids with entrained materials may be pumped through the annulus between the wellbore tubular **10** and the conveyance device **12**. The treatment fluid can include mixtures and entrained particles, which may be solids or semi-solids. The particles of the treatment fluid or the perforation fluid fall in the range of 12 mesh to 200 mesh. The mesh of the particles is determined by a standardized sieve series. 12 mesh sieve has 0.0661 inch openings, and 200 mesh sieve has 0.0029 inch openings. Particle size is measured in mesh size ranges within which 90% of the particles fall. The size of the flow space **71** causes these particles to accumulate along the outer surface **38** and at least restrict the treatment fluid flow across the restrictor **30**. Herein, at least restricting means limiting the flow by the assistance of the particles in the flow mixture. For example, the particles may reduce or block the available flow space. Thus, the flow can be fully restricted, but the gap **70** still remains. The restrictor **30** diverts a substantial amount of the treatment fluid through the holes **16** formed by the perforator **20**. Herein, substantial amount means 90 percent or more of the treatment fluid pumped. Therefore, it is not necessary that the treatment fluid particles completely block fluid pass. In this regards, the isolation provided is, at least initially, not a perfect seal, therefore, a certain amount of leakage will occur.

[0014] **Fig. 2** illustrates the gap **70** between the restrictor **30** and the wellbore tubular **10** before treatment fluid particles accumulate around the restrictor **30**. The space between the outer surface **38** of the restrictor **30** and the inner surface of the wellbore tubular **10** provides the predetermined gap **70**. Here, "predetermined" is used to represent an engineered calculation to have certain characteristics.

[0015] The gap **70** provides a functional space, not necessarily a minuscule space. Initially, fluid escapes through the gap **70** so that deployment of the well tool **9** is convenient because swab and surge effects may be reduced. Also, the perforating fluid may escape through the gap. The particles in the treatment fluid may be the only source to restrict the gap **70**. Particle size pumped may be changed during the treatment operation. For example, the treatment may start with large particles and end with smaller particles.

[0016] Another non-limiting embodiment of the restrictor **30** utilizing the gap **70** is described in reference to **Fig. 3A-B**. The restrictor **30** has one or more ports **36** on the restrictor housing **34** that are positioned between two restriction elements **32**. This arrangement can be used with wells with pre-existing perforations or other flow paths. The restrictor **30** directs the flow from a longitudinal direction **56** to a transverse direction **58** so that a substantial amount of the treatment fluid finds its way into the formation.

[0017] In this configuration during the treatment operation, the perforator **20** does not allow fluid to pass from the annulus into the flow bore of the conveyance device **12**. A cross-over sub (not shown) located between the perforator **20** and the restrictor **30** may be used to direct the treatment fluid from the annulus to the restrictor **30**. The cross-over sub allows the fluid flowing down the annulus of the conveyance device **12** above the well tool **9** to cross over into the lower flowbore below the perforator **20**. In another embodiment, the treatment fluid may be pumped down the flowbore of the conveyance device **10** (and not through the annulus), therefore, not requiring a cross-over sub.

[0018] The restriction elements **32** may be a fixed cone, an expandable cone, a ring, a swab cup, an elastomeric body, or a cylindrical compartment. The first restriction element **32** may be different from the second restriction element **32** of the same restrictor **30**. The restrictor **30** may have more than two restriction elements **32**. The distance between the restriction elements **32** may be equal to, or more or less than the length of the span of set of nozzles **22**.

[0019] The restriction elements **32** may be made of a degradable material, phenolics, polyvinyl alcohols, polyacrylamide, polyacrylic acids, rare earth elements, glasses (e.g. hollow glass microspheres), carbon, elastic material, or a combination of these materials or above sintered powder compact material. Elastic material herein includes elastomers and means that the degradable diverter can flex. The structure of the degradable material is explained below in detail.

[0020] The restrictor **30** may be connected to the conveyance device **12** through any suitable means. The conveyance device **20** may be tubing, coiled tubing, drillpipe, wireline, slickline, electric line or a combination thereof. The conveyance device **12** is fluidly connected to a well treatment system (not shown) including one or more pumps, or other fluid mover (not shown) preferably located at the surface. The well treatment system moves the perforating fluid through the flow bore **26** and through the perforator nozzles **22**. The fluid mover also pumps treatment fluid to the well tool **9**.

[0021] In one method of use, during the operation mode, the conveyance device **12** is used to deploy the well tool **9** at a specific target depth along the wellbore tubular **10**. The well treatment system supplies the perforating fluid through the flow bore of the conveyance device **12**. The perforating fluid exists through the nozzles **22** and performs the jetting job. After holes **16** are created on the wellbore tubular **10**, the well treatment system supplies the treatment fluid through the annulus. The subterranean formation may be fractured with the treatment fluid. After fracturing is completed, the conveyance device **12** pulls the well tool **9** up the wellbore to repeat the process at another depth.

[0022] In another mode of operation, the conveyance device **12** may push the well tool **9** in the downhole direction to treat a lower subterranean zone. In that mode of operation, the restrictor **30** may be in the uphole direction of the perforator **20**. Also, in another mode of operation where two restriction elements **32** are used, as shown in **Fig. 3A-B**, after the perforation is completed, the well treatment system may provide the treatment fluid through the annulus and into the restrictor **30** via a cross-over sub. The treatment fluid exits through the ports **36** of the restrictor **30** and through the holes **16** and flows into the subterranean formation.

[0023] It should be appreciated that the well tool **9** of the present disclosure is subject to various embodiments. In one non-limiting embodiment of the present disclosure is shown in **Fig. 4**. The perforator **20** may have explosive shape charges that may be activated by a detonator. Other perforators **20** may use electrical, chemical or mechanical means to create holes in the wellbore tubular **10**. In this embodiment, the annulus is used to flow the treatment fluid.

[0024] In another embodiment and method, a polymer fluid supplied by the fluid mover (not shown) may plug the perforator nozzles **22**. The polymer fluid may be provided through the flow bore of the conveyance device **12**. After the polymer fluid flows through the well tool **9**, the treatment fluid can be supplied through the flow bore.

[0025] Optionally, the gap **70** may only to be restricted by particles in the treatment fluid. Alternatively, particles in the perforating fluid may also restrict the gap **70**. The perforating fluid and the treatment fluid may have the same type or size of particles at a different mass fraction. Or, the perforating fluid and the treatment fluid may have different sized and shaped particles.

[0026] In another embodiment and method, the treatment fluid or the perforating fluid can be directed to the restrictor **30** or the perforator **20**, selectively via valve actuators well know in the art. The restrictor **30** or the perforator **20** may be activated by mechanical actuators, J-slot mechanisms, hydrostatic fluid pressure or hydraulic control lines and seated ball valves, other ball valves, check valves, choke valves, butterfly valves, poppet valves, shear mechanisms, servo valves, other electronic controls etc.

[0027] The well tool according to the present disclosure can be used for various well treatment operations. The well treatment operation includes well cleaning, hydraulic fracturing, acidizing, cementing, plugging, pin point tracer injection or other well stimulation or intervention operations. Stimulation operation is an operation that changes the characteristic of the formation or the fluid inside the formation. The use of well tools according to the present disclosure is explained above in connection with, but not limited to, hydraulic fracturing operations.

[0028] In one non-limiting embodiment, the restriction element **32** may have a fixed dimension. **Fig. 5A** shows an axial cross-section of the restriction element **32** that continuously and circumferentially surrounds the restrictor housing **34**. The restriction element **32** may be formed as a collar and have a chamfered rectangular axial cross-section. The restriction element **32** may be formed as a single body or as segmented assembly.

[0029] **Figs. 5B-D** show other shapes and configurations of the restriction element **32**. **Fig. 5B** shows the restriction element **32** that has a triangular cross-section. **Fig. 5C** shows the restriction element **32** with a semi-circular cross section. **Fig. 5D** shows the cross section of the restriction element **32** defined by two concave arcs and an outer surface of the restrictor housing **34**. Other polygons, concave or convex shapes, and shapes defined by an arc, or a combination of these as axial cross sections can be used for the design of the restriction element **32**.

[0030] In other embodiments, the restriction element **32** may have an adjustable outer diameter, *e.g.*, the restriction element **32** may expand and retract by hydrostatic or hydraulic pressure, or mechanical, acoustic, electrical or electromagnetic means. **Fig. 6A-D** illustrate the restriction elements **32** that have adjustable outer diameters. Specifically, the diameters of the **Fig. 6A-D** restriction elements **32** can be increased to reduce the gap **70** between the restrictor **30** and the wellbore tubular **10**. For simplicity, a hydraulic actuation will be used in the following discussion.

[0031] The **Fig. 6A** embodiment includes a restrictor **30** that has two cooperating mating elements (mates) **652a,b** and **654a,b** that are initially fixed to one another with a locking device (not shown). The treatment fluid exits from the port **640**, applies hydraulic pressure on the mates **652a,b**. Applied pressure shears the locking mechanism and moves the mates **652a,b** towards mates **654a,b** respectively. The mates **652a,b** move radially outward as the mates **652a,b** travel along the inclined surface of the mates **654a,b**. The mates **652a,b** may have slots or elastic or plastic properties to allow them shift radially outward. Before activation, the mates may have a clearance in between as shown by **652a** and **654a**, or may be in full contact on their respective inclined surfaces as shown by **652b** and **654b** as depicted in **Fig. 6A**.

[0032] **Fig. 6B** shows the mates **652a,b** as a ratchet mechanism that allows movement in one direction but prevents movement in the opposite direction. The movement increases the outer diameter of the restrictor **30**. **Fig. 6C** shows the mates **652a** and **654a** as collet fingers that are adjustable to extend radially outward by a lever **664**. The lever **664** may be attached to the mate **654a** or the restrictor housing **34**. **Fig. 6D** shows the restrictor **30** with two elements **650a,b** as swap cups. The treatment fluid can exit from the port **640** and pressurize the volume **670**. The treatment fluid can extend the lips **672** radially outward and increase the outer diameter of the restrictor **30**. A combination of above elements **650a,b** in **Figs. 5A-D** and **6A-D** may be used in the restrictor **30**.

[0033] Also, the restrictor **30** may be used to locate perforations or other flow paths **16** formed during previous operations. For example, to locate flow paths formed during a previous separate trip into the wellbore, the restrictor **30** can have two restriction elements **32** with a sensor estimating the pressure of the volume of fluid trapped between two restriction elements **32**.

[0034] Alternatively, the restriction element **32** may be "degradable." Herein, "degradable" means disintegrable, corrodible, decomposable, soluble, or at least partially formed of a material that can undergo an irreversible change in its structure. Examples of suitable materials and their methods of manufacture are given in United States Patent Publications No. 2013/0025849 (Richard and Doane) and 2014/0208842 (Miller et al.), and United States Patent No.8,783,365 (McCoy and Solfronk), which Patent Publications and Patents are hereby incorporated by reference in their entirety. A structural degradation may be a change in phase, dimension or shape, density, material composition, volume, mass, etc. The degradation may also be a change in a material property; e.g., rigidity, porosity, permeability, etc. Also, the degradation occurs over an engineered time interval; i.e., a predetermined time interval that is not incidental. Illustrative time intervals include minutes (e.g., 5 to 55 minutes), hours (1 to 23 hours), or days (2 to 3 or more days).

[0035] The restriction element **32** can be high-strength and lightweight, and have fully-dense, sintered powder compacts formed from coated powder materials that include various lightweight particle cores and core materials having various single layer and multilayer nanoscale coatings. These powder compacts are made from coated metallic powders that include various electrochemically-active (e.g., having relatively higher standard oxidation potentials) lightweight, high-strength particle cores and core materials, such as electrochemically active metals, that are dispersed within a cellular nanomatrix formed from the various nanoscale metallic coating layers of metallic coating materials, and are particularly useful in borehole applications.

[0036] Suitable core materials include electrochemically active metals having a standard oxidation potential greater than or equal to that of Zn, including as Mg, Al, Mn or Zn or alloys or combinations thereof. For example, tertiary Mg—Al—X alloys may include, by weight, up to about 85% Mg, up to about 15% Al and up to about 5% X, where X is another material. In one embodiment, the material has a substantially uniform average thickness between dispersed particles of about 50 nanometers (nm) to about 5000 nm. In one embodiment, the coating layers are formed from Al, Ni, W or Al2O3, or combinations thereof. In one embodiment, the coating is a multi-layer coating, for example, comprising a first Al layer, a Al2O3 layer and a second Al layer. In some embodiments, the coating may have a thickness of about 25 nm to about 2500 nm. In addition, surface irregularities to increase a surface area of the restriction element 32, such as grooves, corrugations, depressions, etc. may be used.

[0037] As noted above, the degradation is initiated by exposing the degradable material to a stimulus. In embodiments, the restriction element **32** degrades in response to exposure to a fluid. Illustrative fluids include engineered fluids (e.g., frac fluid, acidizing fluid, acid, brine, water, drilling mud, etc.) and naturally occurring fluids (e.g., hydrocarbon oil, produced water, etc.). The fluid used for stimulus may be one or more liquids, one or more gases, or mixtures thereof. In other embodiments, the stimulus may be thermal energy from surrounding formation. Thus, the stimulus may be engineered and / or naturally occurring in the well or wellbore tubular **10** and formation.

[0038] In another embodiment and method, as shown in **Fig. 7**, the flow space **71** includes an opening **62** and an interior channel **64**, and is located on the uphole side of the restrictor **30**. The restrictor **30** may be a packer or may include a restriction element **32a**. The work string is deployed at the desired depth and the restriction element **32a** is expanded to form the restriction element **32b**. In one method, the outer surface of the restrictor **30** may seal the wellbore tubular **10**. The perforating fluid is pumped through the flowbore and out through the nozzles **22**. After the perforation is completed, the treatment fluid is pumped through the annulus along direction **60**. The opening **62** of the flow space **71** may be located on the restrictor housing **34**, or at another location along the conveyance device **12**. The flow space **71** may connect the annulus to the flowbore. The treatment fluid flows into the opening **62**, and the interior channel **64** allows the fluid to bypass across the restriction element **32**. The interior channel **64** is radially inside the restrictor **30**. Alternatively, the flow space **71** and the perforator **20** may be located on the downhole side of the restrictor **30**. Or, the restrictor **30** may have two restriction elements **32**.

[0039] The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above or embodiments of different forms are possible without departing from the scope of the disclosure. It is intended that the following claims be interpreted to embrace all such modifications and changes.

THE CLAIMS

We claim:

1. An apparatus for performing a downhole operation in a wellbore tubular, comprising:

a well treatment system that supplies a treatment fluid;

a conveyance device; and

a well tool conveyed by the conveyance device (12), the well tool (9) including:

a perforator (20) configured to form at least one hole (16) in the wellbore tubular (10); and

a restrictor (30) projecting from an outer surface of the well tool (9) and adjacent to the perforator (20), wherein a gap (70) separates the restrictor (30) and the wellbore tubular (10), the restrictor (30) at least restricting fluid flow between the restrictor (30) and the wellbore tubular (10), and the restrictor (30) diverting a substantial amount of the treatment fluid through the at least one hole (16) formed by the perforator (20).

2. The apparatus of claim 1, wherein the perforator (20) comprises at least one of: (i) explosive shape charges, (ii) nozzles (22) directing an abrasive jet against the wellbore tubular, (iii) nozzles directing a water jet against the wellbore tubular, (iv) bullet gun, and (v) a mechanical cutter.

3. The apparatus of claim 1, wherein the restrictor (30) comprises a valve actuator that blocks flow between the flow bore and the annulus, wherein the conveyance device (12) has a flow bore, and wherein the conveyance device (12) comprises at least one of: (i) casing, (ii) pipe, (iii) liner tubing, (iv) coil tubing, (v) wireline (vi) drillpipe, (vii) tubing, (viii) slickline, and (ix) electric line.

4. The apparatus of claim 1, wherein the gap (70) is sized to allow for the formation of a flow restriction only by particles in the treatment fluid.

5. The apparatus of claim 1, wherein the restrictor (30) comprises an at least one port (36) and a restriction element (32), wherein the flow restriction element (32) is between the perforator (20) and the at least one port (36).

6. The apparatus of claim 1, wherein the restrictor (30) comprises a restriction element (32), wherein the flow restriction element (32) has a concave outer surface to accumulate particles of a treatment fluid and minimize fluid force acting on the gap (70).

7. The apparatus of claim 1, wherein the restrictor (30) comprises at least two restriction elements (32) and at least one port (36) between the flow restriction elements (32).

8. The apparatus of claim 1, wherein the restrictor (30) comprises at least one of (i) ceramics, (ii) phenolics, (iii) metals, (iv) polyvinyl alcohols, (v) polyacrylamide, (vi) polyacrylic acids, (vii) rare earth elements, (viii) glasses, (ix) carbon, and (x) degradable materials.

9. The apparatus of claim 1, wherein the restrictor (30) has an adjustable outer diameter, the outer diameter expanding from a first diameter during run-in to a second larger diameter during operation.

10. The apparatus of claim 1, and wherein the treatment fluid comprises at least one of: (i) hydraulic fracturing fluid, (ii) acidizing fluid, (iii) tracer, (iv) injection fluid, (v) well cleaning fluid, and (vi) other stimulation fluids.

11. A method of performing a downhole operation in a wellbore tubular, comprising:

deploying a perforator (20) and a restrictor (30) at a target depth using a conveyance device (12), wherein the restrictor (30) is disposed at least partially in an annulus between the conveyance device (12) and the wellbore tubular (10);

activating the perforator (20);

opening an at least one hole (16) in the wellbore tubular(10);

pumping a treatment fluid into the wellbore tubular (10); and

restricting flow through a gap (70) across the restrictor (30) to divert a substantial amount of the treatment fluid into the opened hole (16) in the wellbore tubular (10) using the restrictor (30), wherein the gap (70) is sized to allow for the formation of a flow restriction by particles in the treatment fluid.

12. The method of claim 11, further comprising repeating the steps of claim 11 at a plurality of target depths.

13. The method of claim 13, further comprising:

pumping a testing fluid through the wellbore tubular (10) and through at least one port adjacent to the restrictor (30);

locating at least one flow path in the wellbore tubular (10) by estimating a pressure adjacent to the restrictor (30); and

positioning the perforator (20) with reference to the located at least one flow path.

14. The method of claim 11, wherein the gap (70) is sized to allow for the formation of a flow restriction only by particles in the treatment fluid.

15. The method of claim 11, wherein the at least one hole (16) is opened using a perforating fluid flowing through a plurality of nozzles (22) of the perforator (20), and wherein the treatment fluid is pumped through the annulus.

16. The method of claim 13, further comprising pumping a polymer fluid into a flow bore of the conveyance device and plugging a plurality of nozzles of the perforator with the polymer fluid.

17. The method of claim 13, wherein the gap is only restricted by the treatment fluid flowing therethrough, wherein a geometry of the gap is substantially unchanged, and wherein the flow restriction element has a concave outer surface engineered to accumulate particles in the treatment fluid.

18. The method of claim 13, further comprising treating a subterranean formation with the treatment fluid, and the treatment includes at least one of: (i) hydraulic fracturing, (ii) acidizing, (iii) tracer logging, (iv) injection, (v) well cleaning, and (vi) stimulation operation.

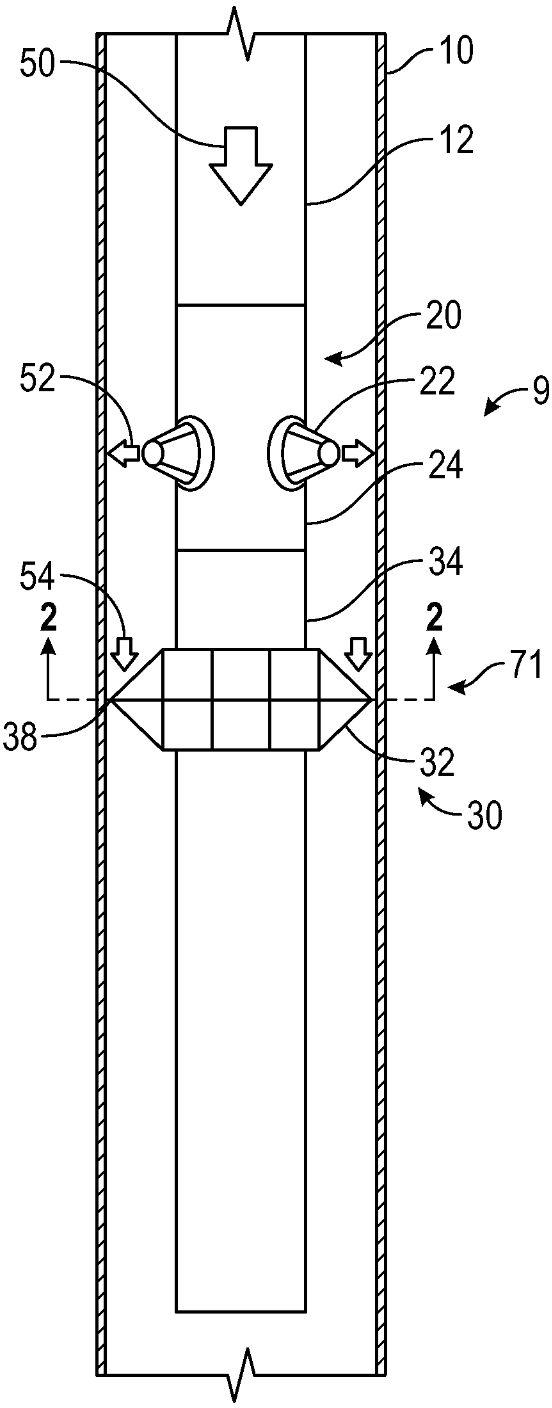

FIG. 1

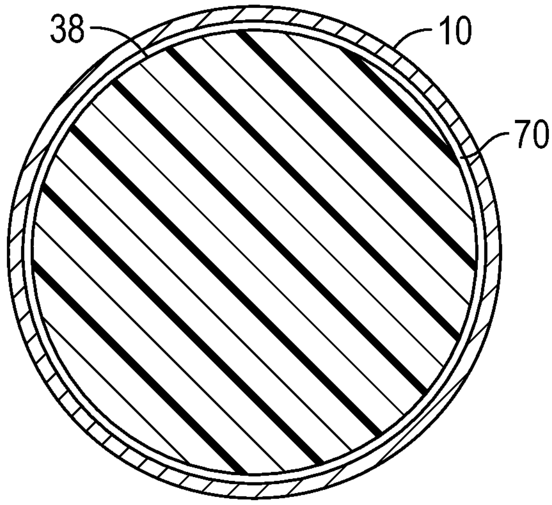

FIG. 2

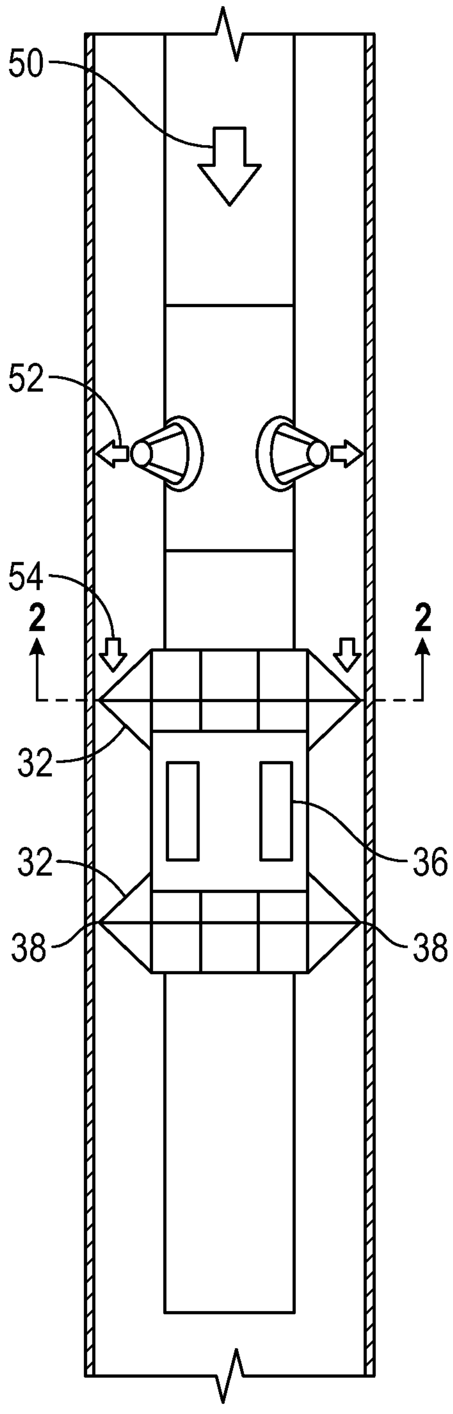

FIG. 3A

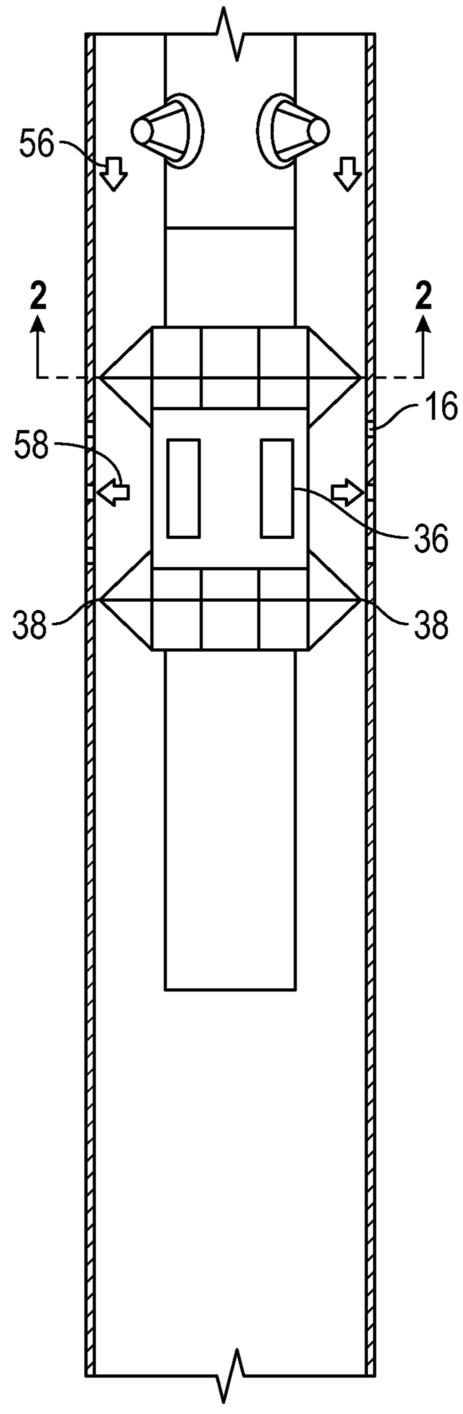

FIG. 3B

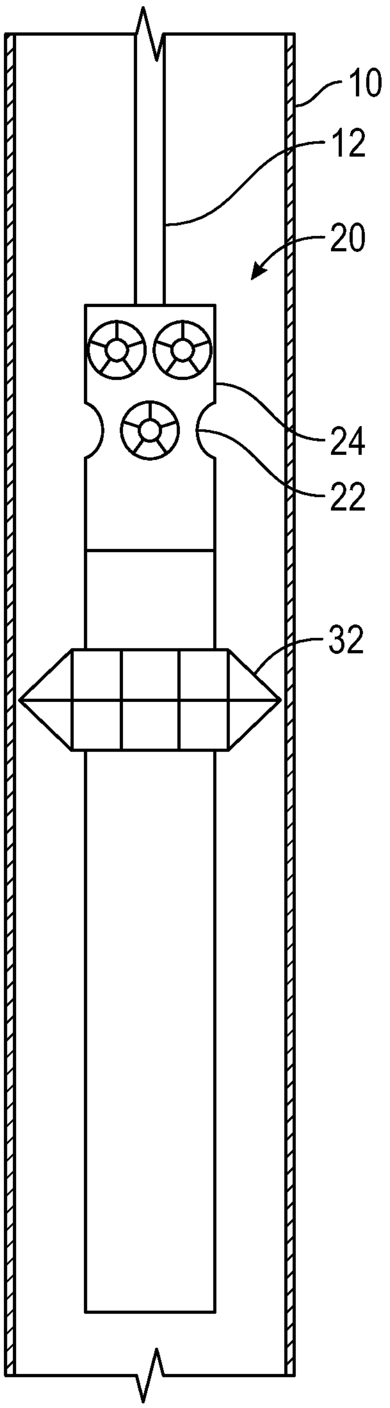

FIG. 4

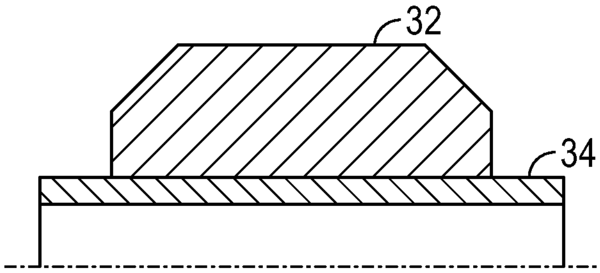

FIG. 5A

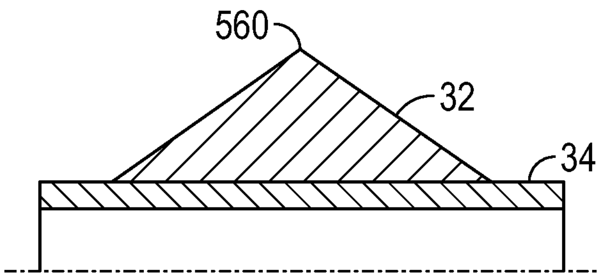

FIG. 5B

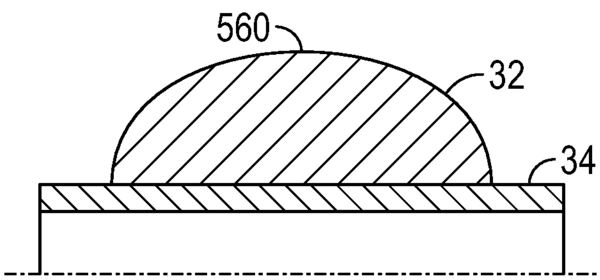

FIG. 5C

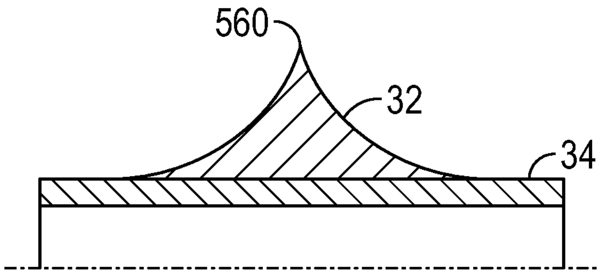

FIG. 5D

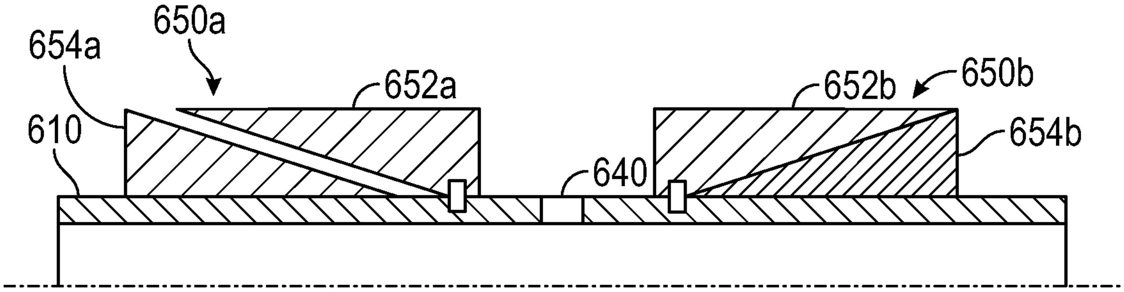

FIG. 6A

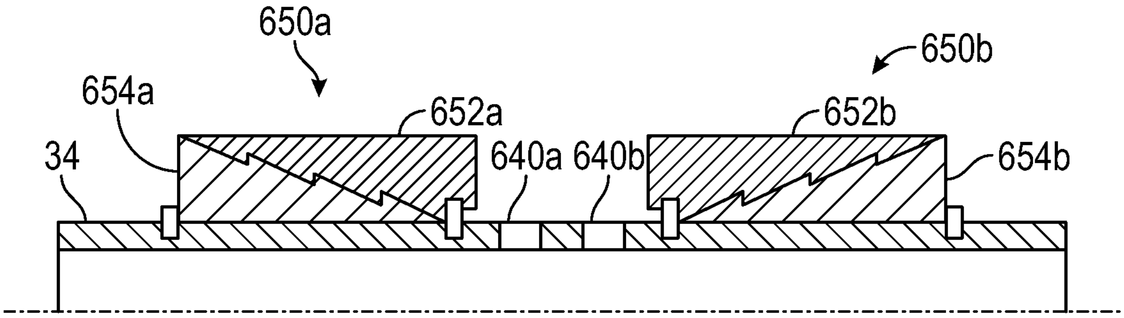

FIG. 6B

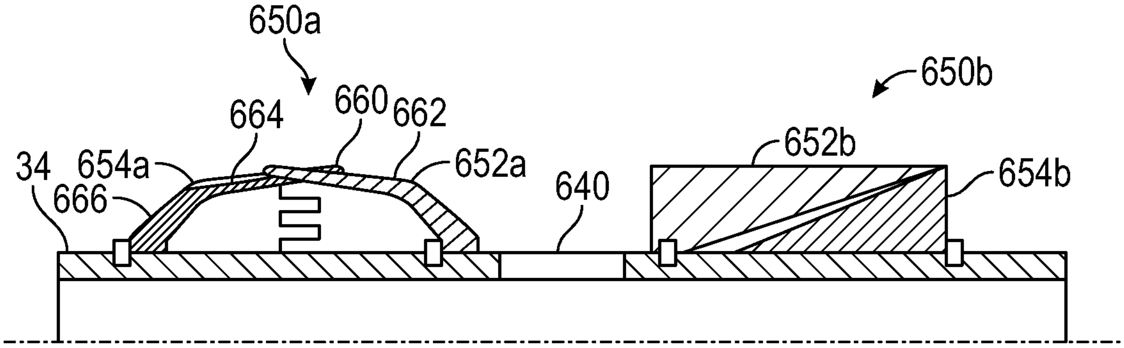

FIG. 6C

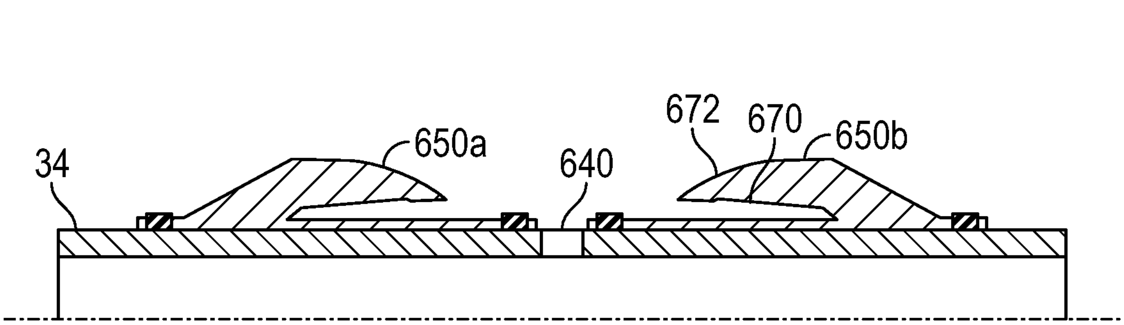

FIG. 6D

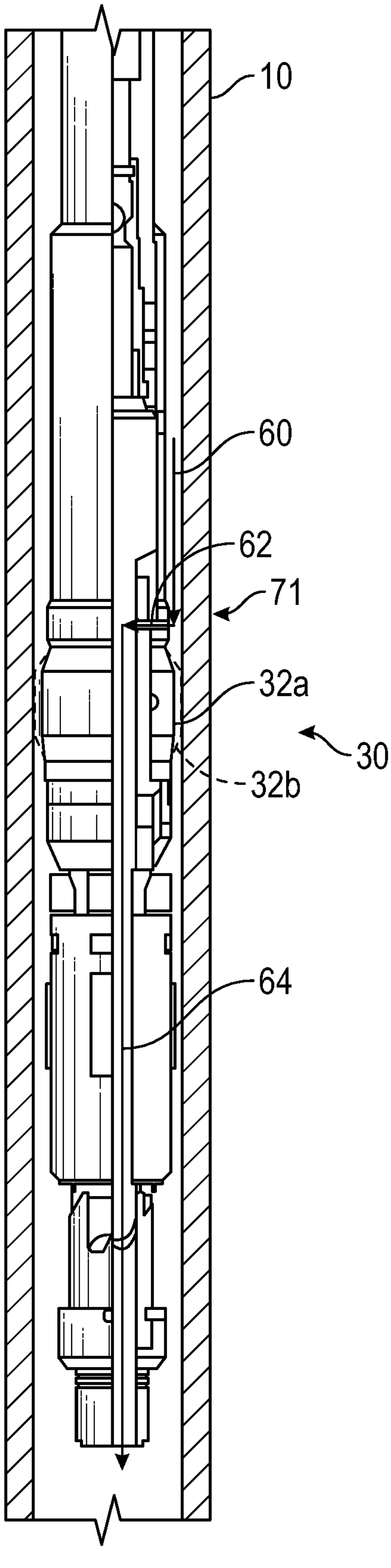

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/027766

A. CLASSIFICATION OF SUBJECT MATTER

E21B 41/00(2006.01)i, E21B 43/11(2006.01)i, E21B 43/16(2006.01)i, E21B 43/25(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 41/00; E21B 23/08; E21B 23/04; E21B 43/263; E21B 34/06; E21B 34/00; E21B 33/1295; E21B 43/10; E21B 34/08; E21B 43/11; E21B 43/16; E21B 43/25

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: restictor, perforator, gap, restriction element, port

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014-0158350 A1 (BAKER HUGHES INCORPORATED) 12 June 2014 See paragraphs [0024]-[0025], [0032], [0041], [0046] and figures 1-2, 11.	1-18
Y	US 2006-0185839 A1 (TIERNAN, JOHN P.) 24 August 2006 See paragraphs [0010], [0018], [0020]-[0024] and figure 1.	1-18
A	US 2002-0092654 A1 (CORONADO et al.) 18 July 2002 See paragraphs [0007], [0049]-[0054] and figure 14.	1-18
A	WO 00-63520 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 26 October 2000 See page 2, line 27 - page 3, line 10 and figure 14.	1-18
A	US 2011-0036590 A1 (WILLIAMSON et al.) 17 February 2011 See paragraphs [0005]-[0008] and figure 2.	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"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	Date of mailing of the international search report
26 July 2016 (26.07.2016)	**27 July 2016 (27.07.2016)**

Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea	LEE, Hun Gil
Facsimile No. +82-42-481-8578	Telephone No. +82-42-481-8525

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