PCT REQUEST

Original (for **SUBMISSION**)

0	**For receiving Office use only**	
0-1	International Application No.	PCT/US19/24626
0-2	International Filing Date	28 March 2019 (28.03.2019)
0-3	Name of receiving Office and "PCT International Application"	PCT INTERNATIONAL APPLICATION RO/US

0-4	**Form PCT/RO/101 PCT Request**	
0-4-1	Prepared Using	PCT-SAFE [EFS-Web mode] Version 3.51.086.262 MT/FOP 20190101/0.20.5.24
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	United States Patent and Trademark Office (USPTO) (RO/US)
0-7	**Applicant's or agent's file reference**	75231981WO01
I	**Title of Invention**	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
II	**Applicant**	
II-1	This person is	Applicant only
II-2	Applicant for	All designated States
II-4	Name	HALLIBURTON ENERGY SERVICES, INC.
II-5	Address	3000 N. Sam Houston Parkway E. Houston, Texas 77032-3219 United States of America
II-6	State of nationality	US
II-7	State of residence	US
III-1	**Applicant and/or inventor**	
III-1-1	This person is	Inventor only
III-1-3	Inventor for	All designated States
III-1-4	Name (LAST, First)	COFFIN, Maxime Philippe
III-1-5	Address	4115 E Crescent Way Frisco, Texas 75034 United States of America
III-2	**Applicant and/or inventor**	
III-2-1	This person is	Inventor only
III-2-3	Inventor for	All designated States
III-2-4	Name (LAST, First)	FROSELL, Thomas Jules
III-2-5	Address	8711 Boundbrook Ave. Dallas, Texas 75243 United States of America

IV-1	**Agent or common representative; or address for correspondence**	
	The person identified below is hereby/ has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	Agent
IV-1-1	Name (LAST, First)	TIDWELL, Mark
IV-1-2	Address	Haynes and Boone, LLP 2323 Victory Avenue, Suite 700 Dallas, Texas 75219 United States of America
IV-1-3	Telephone No.	214-651-5000
IV-1-4	Facsimile No.	214-200-0853
IV-1-5	e-mail	ipdocketing@haynesboone.com
IV-1-5(a)	E-mail authorization The receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority are authorized to use this e-mail address, if the Office or Authority so wishes, to send notifications issued in respect of this international application:	as advance copies followed by paper notifications
IV-1-6	Agent's registration No.	37456
IV-2	**Additional agent(s)**	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	BORLAND, Harold(83236); RAJ, Vinu(59327); LAYE, Jade O.(54255); BROWN, Randall C.(31213); EDWARDS, Gary(42008); HERDA, Alan(50426); SUAREZ, Vera(66087); HALBUR, Zachary(68500); TU, Evert Uy(57004)
IV-3	**Additional agent(s)**	Agent
IV-3-1	Name (LAST, First)	RODDY, Craig
IV-3-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-3-3	Telephone No.	281-575-3000
IV-3-4	Facsimile No.	281-871-7830
IV-3-5	e-mail	fhoupatgrp@halliburton.com
IV-3-6	Agent's registration No.	36256

IV-4	**Additional agent(s)**	Agent
IV-4-1	Name (LAST, First)	BRYSON, Alan C.
IV-4-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-4-3	Telephone No.	281-575-3000
IV-4-4	Facsimile No.	281-871-7830
IV-4-5	e-mail	fhoupatgrp@halliburton.com
IV-4-6	Agent's registration No.	54009
IV-5	**Additional agent(s)**	Agent
IV-5-1	Name (LAST, First)	FITE, Benjamin
IV-5-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-5-3	Telephone No.	281-575-3000
IV-5-4	Facsimile No.	281-871-7830
IV-5-5	e-mail	fhoupatgrp@halliburton.com
IV-5-6	Agent's registration No.	66885
IV-6	**Additional agent(s)**	Agent
IV-6-1	Name (LAST, First)	WUSTENBERG, John W.
IV-6-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-6-3	Telephone No.	281-575-3000
IV-6-4	Facsimile No.	281-871-7830
IV-6-5	e-mail	fhoupatgrp@halliburton.com
IV-6-6	Agent's registration No.	35415
IV-7	**Additional agent(s)**	Agent
IV-7-1	Name (LAST, First)	RICHARDSON, Scott
IV-7-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-7-3	Telephone No.	281-575-3000
IV-7-4	Facsimile No.	281-871-7830
IV-7-5	e-mail	fhoupatgrp@halliburton.com
IV-7-6	Agent's registration No.	64118

IV-8	**Additional agent(s)**	Agent
IV-8-1	Name (LAST, First)	KRUEGER, Tenley
IV-8-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-8-3	Telephone No.	281-575-3000
IV-8-4	Facsimile No.	281-871-7830
IV-8-5	e-mail	fhoupatgrp@halliburton.com
IV-8-6	Agent's registration No.	51253
IV-9	**Additional agent(s)**	Agent
IV-9-1	Name (LAST, First)	ROONEY, Thomas
IV-9-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032 United States of America
IV-9-3	Telephone No.	281-575-3000
IV-9-4	Facsimile No.	281-871-7830
IV-9-5	e-mail	fhoupatgrp@halliburton.com
IV-9-6	Agent's registration No.	59,453
IV-10	**Additional agent(s)**	Agent
IV-10-1	Name (LAST, First)	SEDANO, Jason
IV-10-2	Address	Halliburton Energy Services, Inc. 3000 N. Sam Houston Parkway E. Houston, Texas 77032-3219 United States of America
IV-10-3	Telephone No.	281-575-3000
IV-10-4	Facsimile No.	281-871-7830
IV-10-5	e-mail	fhoupatgrp@halliburton.com
IV-10-6	Agent's registration No.	68622
V	**DESIGNATIONS**	
V-1	**The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.**	
VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	22 June 2018 (22.06.2018)
VI-1-2	Number	62/688,813
VI-1-3	Country or Member of WTO	US

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VI-2	**Priority document request** The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1	
VI-3	**Incorporation by reference :** where an element of the international application referred to in Article 11(1)(iii)(d) or (e) or a part of the description, claims or drawings referred to in Rule 20.5(a) is not otherwise contained in this international application but is completely contained in an earlier application whose priority is claimed on the date on which one or more elements referred to in Article 11(1)(iii) were first received by the receiving Office, that element or part is, subject to confirmation under Rule 20.6, incorporated by reference in this international application for the purposes of Rule 20.6.		
VII-1	**International Searching Authority Chosen**	Korean Intellectual Property Office (ISA/KR)	
VIII	**Declarations**	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	–	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	–	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	–	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	–	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	–	
IX	**Check list**	Number of sheets	Electronic file(s) attached
IX-1	Request (including declaration sheets)	6	✓
IX-2	Description	25	–
IX-3	Claims	6	–
IX-4	Abstract	1	✓
IX-5	Drawings	5	–
IX-7	TOTAL	43	
	Accompanying Items	Paper document(s) attached	Electronic file(s) attached
IX-8	Fee calculation sheet	✓	–
IX-20	**Figure of the drawings which should accompany the abstract**	2	
IX-21	**Language of filing of the international application**	English	

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X-1	**Signature of applicant, agent or common representative**	/Mark Tidwell, Reg. No. 37,456/
X-1-1	Name (LAST, First)	**TIDWELL, Mark**
X-1-3	Capacity (if such capacity is not obvious from reading the request)	

28 March 2019 (28.03.2019)

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10-1	**Date of actual receipt of the purported international application**	28 March 2019 (28.03.2019)
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	**ISA/KR**
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. provisional application no. 62/688,813, filed June 22, 2018.

FIELD OF INVENTION

The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies.

BACKGROUND

In the course of completing an oil and/or gas well, a string of production tubing can be run into the wellbore. During production of the formation fluid, formation sand may be swept into the flow path of the production fluid as it passes along the tubing string. The formation sand tends to be relatively fine sand that can erode production components in the flow path.

When formation sand is expected to be encountered, one or more lower production assemblies may be installed in the production zone between the formation and the production tubing. The lower production assemblies typically include a perforated base pipe surrounded by a sand screen to filter fines from the formation fluid. A packer is customarily set above the production assembly to seal off the annulus in the production zone where formation fluids flow into the production tubing. The annulus around the sand screen can then be "gravel packed" with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of carrier fluid such as water and/or gel and fills the annulus around the sand screen. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation. During the gravel packing process, a premature loss of the carrier fluid into the formation, known as leak-off, can occur,

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resulting in the formation of sand bridges in the annulus about the screening. With a premature loss of carrier fluid, incomplete packing around the sand screen and reduce the filtering efficiency of the gravel pack.

One conventional approach to overcoming this packing sand bridging problem has been to provide each production assembly with a series of shunt tubes that longitudinally extend through the sand screen section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the sand screen section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen assembly. The shunt path operates to permit the inflowing packing sand/gel slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing or screen/open hole annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

In instances where production zones are elongated, a plurality of lower completion assemblies may be deployed end to end to form a lower completion assembly string that may stretch for hundreds of feet. To ensure that gravel packing slurry is deposited along the entire length of the lower completion assembly string from its upstream end to the downstream end, particularly in deep wellbores and deviated wellbores, relatively high pressures must be applied to the carrier fluid. Thus, each individual lower completion assembly utilized in the overall string is designed to withstand the high delivery pressures experienced at the upstream end of the lower completion assembly string.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

FIG. 1 is a cut-away view of a wellbore system having a lower completion system disposed therein.

FIG. 2 is a partial cross-sectional view of a lower completion assembly.

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FIG. 3 is a partial side view of an embodiment of a shunt tube assembly deployed on a base pipe of a lower completion assembly.

FIG. 4A is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A' of FIG. 2.

FIG. 4B is a cross-sectional view of an embodiment of a shunt tube assembly along line B-B' of FIG. 2.

FIG. 5 is a method of installing in a wellbore a lower completion assembly having shunt tube systems with different pressure ratings.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the figures is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Moreover, even though a figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in wellbores having other

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orientations including, deviated wellbores, multilateral wellbores, or the like. Likewise, unless otherwise noted, even though a figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in onshore operations and vice-versa.

Generally, a lower completion assembly made up of at least two sand screen assemblies is provided, namely a first or upper sand screen assembly and a second or lower sand screen assembly. Each sand screen assembly includes a shunt system. Each shunt system includes a transport tube and a packing tube extending from a junction block. Each packing tube includes a plurality of nozzles spaced apart from the junction block and from each other. In one or more embodiments, the cross-sectional area of the transport tube in the first sand screen assembly is less than the cross-sectional area of the transport tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube in the first sand screen assembly is less than the cross-sectional area of the packing tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube nozzles in the first sand screen assembly is less than the cross-sectional area of the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. In one or more embodiments, the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

Turning to Figure 1, shown is an elevation view in partial cross-section of a wellbore production system 10 utilized to complete wells intended to produce hydrocarbons from wellbore 12 extending through various earth strata in an oil and gas formation 14 located below the earth's surface 16. Wellbore 12 may be formed of a single or multiple bores, extending into the formation 14, and disposed in any orientation, such as the horizontal wellbore 12a illustrated in Figure 1. Formation 14 includes production zones 18 from which hydrocarbons are produced.

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Production system 10 includes a rig or derrick 20. Rig 20 may include a hoisting apparatus 22, a travel block 24, and a swivel 26 for raising and lowering casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings or other types of conveyance vehicles such as wireline, slickline, and the like 30. In Figure 1, conveyance vehicle 30 is a substantially tubular, axially extending work string or production tubing, formed of a plurality of pipe joints coupled together end-to-end supporting a completion assembly as described below.

Rig 20 may be located proximate to or spaced apart from wellhead 40, such as in the case of an offshore arrangement as shown in Figure 1. One or more pressure control devices 42, such as blowout preventers (BOPs) and other equipment associated with drilling or producing a wellbore may also be provided at wellhead 40 or elsewhere in the system 10.

For offshore operations, as shown in Figure 1, rig 20 may be mounted on an oil or gas platform 44, such as the offshore platform as illustrated, semi-submersibles, drill ships, and the like (not shown). Although system 10 of Figure 1 is illustrated as being a marine-based production system, system 10 of Figure 1 may be deployed on land. In any event, for marine-based systems, one or more subsea conduits or risers 46 extend from deck 50 of platform 44 to a subsea wellhead 40. Tubing string 30 extends down from rig 20, through subsea conduit 46 and BOP 42 into wellbore 12.

A working or service fluid source 52, such as a storage tank or vessel, may supply, via flow lines 64, a working fluid to equipment disposed in wellbore 12, such as subsurface equipment 56. Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, gravel packing slurry, acidizing fluid, liquid water, steam or some other type of fluid.

Production system 10 may generally be characterized as having a pipe system 58. For purposes of this disclosure, pipe system 58 may include casing, risers, tubing, drill strings, completion or production strings, subs, heads or any other pipes, tubes or equipment that couples or attaches to the foregoing, such as string 30, conduit 46, and casing. In this regard, pipe system 58 may include one or more casing strings 60 that may be cemented in wellbore 12, such as the surface, intermediate and production casings 60 shown in Figure 1. An annulus 62 is formed between the walls of sets of adjacent tubular components, such as concentric casing strings 60 or the exterior of tubing string 30 and the inside wall of wellbore 12 or casing string

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60, as the case may be. While wellbore 12 is shown as uncased in the production zone 18 and along the entire depicted portion of horizontal wellbore 12a, all or a portion of wellbore 12 and/or horizontal wellbore 12a may be cased as well and the disclosure is not limited in that regard.

Production fluids and other debris returning to surface 16 from wellbore 12 are directed by a flow line 64 to storage tanks 54 and/or processing systems 66.

As shown in Figure 1, subsurface equipment 56 is illustrated as completion equipment and tubing string 30 in fluid communication with the completion equipment 56 is illustrated as production tubing 30. Although completion equipment 56 can be disposed in a wellbore 12 of any orientation, for purposes of illustration, completion equipment 56 is shown disposed in a substantially horizontal portion of wellbore 12 and includes a lower completion assembly 82 having various tools such as a packer 86, a sand screen assembly 88, a sand screen assembly 92, a sand screen assembly 96 and a packer 98. In embodiments where lower completion assembly 82 is deployed in a cased wellbore, an additional packer, such as packer 86, would be deployed at the distal end of the lower completion assembly. In the illustrated embodiment, packer 86 is generally located adjacent the upstream or proximal end of a production zone 18 and packer 98 is generally located adjacent the downstream or distal end of a production zone 18. Sand screen assemblies 88, 92 and 96 each include a shunt tube system 97 and are arranged so that the sand screen assembly having a shunt tube system with the highest operating pressure rating is upstream and the sand screen assembly having a shunt tube system with the lowest operating pressure rating is downstream. Thus, for example, in the illustrated embodiment sand screen assembly 88 includes a shunt tube assembly with a higher operating pressure than the shunt tube assembly of sand screen 96.

Disposed in wellbore 12 at the lower end of tubing string 30 is an upper completion assembly 104 that includes various tools such as a packer 106, and a fluid flow control module 112.

Extending uphole from upper completion assembly 104 are one or more lines 116, such as hydraulic tubing, pressurized fluid tubing and the like which extends to the surface 16.

A cross-sectional view of an embodiment of a lower completion assembly 200 is shown in FIG. 2. Lower completion assembly is generally comprised of a first sand screen assembly 202

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interconnected with a second sand screen assembly 204. In some embodiments, lower completion assembly 200 may be comprised of a plurality of interconnected first sand screen assemblies 202 at an upper portion of the lower completion assembly 200 and a plurality of interconnected second sand screen assemblies 204 at a lower portion of the lower completion assembly 200. Each sand screen assembly includes a base pipe 206 having a series of perforations 208 disposed therethrough, the base pipe 206 extending between a first end and a second end. A sand screen or filter media 210 is disposed about a portion of the base pipe 206 and the series of perforations 208 in order to screen incoming fluids from the formation. Each sand screen assembly also includes a shunt tube assembly 220 disposed outwardly of the filter media 220. Generally, shunt tube assembly 220 may include one or more retaining rings 222 supporting one or more shunt tubes 224 in the form of a transport tube or a packing tube disposed along and generally parallel to the base pipe 206. Shunt tubes 224 are tubular members having a passageway 225 defined therein with a cross-sectional flow area. While shown disposed outside of and generally parallel to the base pipe 206, other positions and alignment may be possible. An outer shroud 226 may be disposed about the base pipe 206, one or more shunt tubes 224, and filter media 210. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 224 and/or outer shroud 226 in position relative to the base pipe 206.

While the base pipe 206 is illustrated as being perforated in FIG. 2, the base pipe 206 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 228 and an exterior 230 of the screen assembly.

The filter media 210 may be disposed about the base pipe 206 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the base pipe 206. In an embodiment, the filter media 210 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a base pipe 206, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 210 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 210 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of

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particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

The base pipe 206 may generally comprise a pin end 232 and a box end 234 to allow the base pipe 206 to be coupled to an adjacent base pipe 206. In the illustrated embodiment, base pipe 206a of first sand screen assembly 202 is coupled to base pipe 206b of second sand screen assembly 204 forming a joint 236. As such, the first sand screen assembly 202 and the second sand screen assembly 204 can be joined together end-to-end so that the respective base pipes are in fluid communication with one another along their throughbores 228. As can be seen in FIG. 2, each base pipe 206 may have a coupling section 238 that extends beyond the shunt tube assembly 220 of the respective sand screen assemblies. This exposed portion of the base pipe 206 may be used during the coupling process to allow one or more tools to engage the exposed portion for makeup of the first and second sand screen assemblies 202, 204.

Shunt tubes 224 of adjacent sand screen assemblies may be joined together in fluid communication by a jumper tube 240. In the illustrated embodiment, shunt tube 224a is interconnected to shunt tube 224b by jumper tube 240. An additional shroud 242 may be used to protect jumper tube 240. While the disclosure is not limited to a particular shape for shunt tubes 224 or jumper tubes 240, in some embodiments, shunt tubes 224 may have a non-round cross-section (as shown in FIGs. 3A and 3B), while jumper tubes 240 may have a round cross-section. In such case, the end of each jump tube may include an adaptor or coupling 244 to transition from the non-round cross-section of the shunt tube 224 to the round cross-section of the jumper tubes 240.

Although the particular shape of the tubes described herein are not a limitation in certain embodiments, shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple shunt tubes on adjacent wellbore tubular joints are generally round cross-section while the shunt tubes are non-round in cross-section.

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With reference to FIG. 3, a side view of a lower completion assembly 200 is illustrated, with first sand screen assembly 202 interconnected with second sand screen assembly 204. In the illustrated embodiment, the filter media 210 and outer shrouds 226, 242 shown in FIG. 2 are removed to permit better illustration of the shunt tube assemblies. Additionally, the different types of shunt tubes 224 that comprise a shunt tube assembly 220 are illustrated in more detail. Specifically, in FIG. 3, base pipe assembly 206a is shown interconnected to base pipe assembly 206b at joint 236. First sand screen assembly 202 has two shunt tube assemblies 302 and 304. Likewise, second sand screen assembly 204 is illustrated with two shunt tube assemblies 306 and 308. Each shunt tube assembly described herein, including shunt tube assemblies 220 of FIG. 2, generally include a transport tube 310 and a packing tube 312 extending from a junction block 314 so as to be in fluid communication with one another.

As shown, the shunt tubes 310, 312 may form a branched structure from junction block 314 along the length of a sandscreen assembly 202 with the one or more transport tubes 310 forming the trunk line and the one or more packing tubes 312 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the sandscreen assembly 202. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended. Likewise, while junction block 314 is depicted as having only one inlet and two outlets, the disclosure is not limited to a particular junction block configuration. The "y-block" junction block depicted is for illustration purposes only unless otherwise stated for a particular configuration. In this regard, in certain configurations, the shunt tube assembly may only comprise a junction block 314 having one inlet and two outlets as depicted.

Each packing tube 312 includes one or more nozzles 316. Each nozzle 316 is spaced apart from its respective junction block 314 a distance D1. Likewise, each nozzle 316 along a packing tube 312 may be spaced apart from adjacent nozzles a distance D2. The spacing D2 between nozzles 216 along a particular packing tube 312 may be the same or different. Likewise, the spacing D2 between nozzles 216 of shunt tube assemblies of the same sand screen assembly may be the same or different.

Also shown in FIG. 3 is a jumper tube 240a interconnecting shunt tube assembly 302 with a shunt tube assembly 306 and a jumper tube 240b interconnecting shunt tube assembly 204 with

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shunt tube assembly 308. A coupling 244a is provided at distal end of transport tube 310a to facilitate attachment of jumper tube 240a, while a coupling 244b is provided at distal end of transport tube 310b to facilitate attachment of jumper tube 240b. In particular, jumper tube 240a interconnects junction block 314c with coupling 244a at the distal end of transport tube 310a, thereby allowing fluid communication between upper or high pressure shunt tube assembly 302 and lower or low pressure shunt tube assembly 306. Likewise, jumper tube 240b interconnects junction block 314d with coupling 244b at the distal end of transport tube 310b, spanning joint 236 between the first sand screen assembly 202 and the second sand screen assembly 204.

FIG. 4A illustrates a cross-sectional area A-A of first sand screen assembly 202 and shunt tubes 224a of FIG. 2 and FIG. 4B illustrates a cross-sectional area B-B of second sand screen assembly 204 and shunt tubes 224b of FIG. 2. As generally shown, the one or more shunt tubes 224 generally comprise tubular members disposed outside of and generally parallel to the base pipe 224. While described as tubular members (e.g., having substantially rectangular cross-sections), the one or more shunt tubes 224 may have shapes other cross-sectional shapes, such as round, elliptical, kidney shaped, and/or trapezoidal in shape. The retaining rings 222 may retain the shunt tubes 224 in position relative to the base pipe 206. The one or more shunt tubes 224 may be eccentrically aligned with respect to the base pipe 206 as best seen in FIG. 2. In each of FIGS. 4A and 4B, four shunt tubes 224 are arranged to one side of the base pipe 206. While illustrated in FIGS. 2 and 4 as having an eccentric alignment, other alignments of the one or more shunt tubes about the base pipe 206 may also be possible.

In FIG. 4A, first sand screen assembly 202 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 410 and a packing tube 412. Each transport tube 410 has a cross-sectional flow area A1 bounded by a wall 414 of thickness T1. Likewise, each packing tube 412 has a cross-sectional flow area B1 bounded by a wall 416 of thickness T2. Each packing tube further includes one or more nozzles 418 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 418 may be in the form of a perforation or opening in wall 416 or a short tube with a taper or constriction. Nozzle 418 is characterized by a cross-sectional flow area C1.

Similarly, in FIG. 4B, second sand screen assembly 204 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 420 and a packing tube 422. Each transport

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tube 420 has a cross-sectional flow area A2 bounded by a wall 422 of thickness T3. Likewise, each packing tube 422 has a cross-sectional flow area B2 bounded by a wall 424 of thickness T4. Each packing tube further includes one or more nozzles 4426 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 426 may be in the form of a perforation or opening in wall 424 or a short tube with a taper or constriction. Nozzle 426 is characterized by a cross-sectional flow area C2.

In one or more embodiments, the cross-sectional flow area A1 of the transport tube 410 of first sand screen assembly 202 is less than the cross-sectional flow area A2 of the transport tube 420 of the second sand screen assembly 204. In other words, the downstream sand screen assembly transport tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly transport tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area B1 of the packing tube 412 of first sand screen assembly 202 is less than the cross-sectional flow area B2 of the packing tube 422 of the second sand screen assembly 204. In other words, the downstream sand screen assembly packing tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly packing tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area C1 of a nozzle 418 of first sand screen assembly 202 is less than the cross-sectional flow area C2 of a nozzle 426 of the second sand screen assembly 204. In other words, the downstream sand screen assembly shunt tube nozzles which are closest to the distal end of the production zone, have a larger cross-sectional flow area than the upstream sand screen assembly shunt tube nozzles closest to the proximal end of the production zone.

In one or more embodiments, the packing tube assembly 412 of the first sand screen assembly 202 has fewer nozzles 418 than the number of nozzles 426 of the packing tube assembly 422 of the second sand screen assembly 204.

Referring back to FIG. 3, in one or more embodiments, the distance D1 of the first nozzle 316 of packing tube assembly 312a from the junction block 314a is greater than the distance D1 of

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the first nozzle 316 of packing tube assembly 312c from the junction block 314c for the interconnected shunt tube assemblies 302 and 306. Likewise, the distance D1 of the first nozzle 316 of packing tube assembly 312b from the junction block 314b is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312d from the junction block 314d for the interconnected shunt tube assemblies 304 and 308.

Similarly, in one or more embodiments, the distance D2 between adjacent nozzle 316 of packing tube assembly 312a of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312c of the second sand screen assembly 204 for interconnected shunt tube assemblies 302 and 306. Likewise, the distance D2 between adjacent nozzle 316 of packing tube assembly 312b of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312d of the second sand screen assembly 204 for interconnected shunt tube assemblies 304 and 308.

While each of the different geometries of a shunt tube assembly have been described, it will be appreciated that any one or more of the geometries can be combined to achieve the desired flow regime for a particular shunt tube assembly. In some cases, certain of the geometries will remain the same. For example, the transport tubes 410 and 420 may be the same with the same flow areas A1, A2, but the geometries of the respective packing tubes 412, 244 may differ in number of nozzles and/or cross-sectional flow areas B1, B2 and/or nozzle spacing along the respective packing tubes.

Traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the same pressure rating. In this regard, the shunt tube assemblies are selected based on the expected operating conditions of the shunt tube assemblies. For shorter gravel packing intervals, the gravel pack slurry flows into the wellbore annulus at about the same fluid pressure along the length of the interval. Of course, as gravel pack intervals have increased, an increased operating pressure is needed to ensure that gravel pack slurry flows along the entire length of the gravel pack interval. Thus, as gravel pack intervals increase, it has been necessary to employ shunt tube assemblies with increased operating pressure ratings or burst pressures, resulting in heavier and/or bulkier tubing and components to ensure that the shunt tube assemblies will not be subject to burst pressure. Since shunt tube assemblies for an entire lower production assembly are selected based on the highest

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operating pressure expected to be required across the entire length of the gravel packing interval, individual sand screen assemblies in a lower production assemblies have become increasingly heavier. However, as the slurry flows from the upstream portion of these elongated production zone to the downstream portion of the production zone, the pressure of the slurry drops off. As such, only the shunt tube assemblies deployed adjacent the upper portion of the production zone experience the highest pressures.

In addition, because of the high pressure experienced by shunt tube assemblies at the upper or upstream end of such lower production assemblies deployed in elongated production zones, there is a tendency for greater leak-off in the upstream portion of the production zone.

These drawbacks are addressed by above-described lower production assembly where the shunt tube system flow regime in the second sand screen assembly 204 is selected to allow a larger volume of fluid to flow therethrough than that of the first sand screen assembly 202 by adjusting cross-sectional flow areas, location and number of nozzles. In this regard, the geometries of the shunt tube assemblies 220 of the first sand screen assembly 202 may be selected to have a higher operating pressure than the shunt tube assemblies 220 of the second sandscreen assembly 204. In one or more embodiments, the thickness T1 of wall 414 of transport tube 410 of the first sand screen assembly 202 may be greater than thickness T3 of wall 422 of transport tube 420 of the second sandscreen assembly 204. Likewise, in one or more embodiments, the thickness T2 of wall 416 of packing tube 412 of the first sand screen assembly 202 may be greater than the thickness T4 of wall 424 of packing tube 422 of the second sandscreen assembly 204. In other embodiments, where geometries and dimensions are the same, the material of construction of transport tube 410 may be selected to be stronger than the material of construction of transport tube 420. In other words, the material of construction of transport tube 410 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of transport tube 420 of the second sandscreen assembly 204. In other embodiments, the material of construction of packing tube 412 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of packing tube 422 of the second sandscreen assembly 204. As such, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 may be selected to have an operating pressure at or above a select threshold, while the shunt tube assemblies 220 of the second sandscreen assembly 204 may be selected to have an operating pressure at or below a select threshold. In one or more embodiments, the shunt tube

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assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure or are otherwise rated at over 5000 psi while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 5000 psi. In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating or are otherwise rated between 5000 and 10000 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 4000 psi. More broadly, it will be appreciated that the first and second sandscreen assemblies 202, 204 have different shunt tube assembly operating pressure ratings, with the shunt tube assembly 220 of the first sandscreen assembly 202 having a higher operating pressure rating than the shunt tube assembly 220 of the second sandscreen assembly 204.

In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating of between approximately 6,500 to 7,500 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure of approximately 3,500 to 3,750 psi. In certain embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have are rated at or have an operating pressure of approximately 10,000 psi. In other words, the shunt tube assemblies upstream are selected to have a higher burst pressure than the shunt tube assemblies downstream in the overall lower production assembly.

Turning to FIG. 5, a method 500 of installing a completion assembly in a wellbore is generally illustrated. In a first step 502, a portion of the wellbore passing through a production zone to be gravel packed is identified for placement of a lower production assembly. The production zone portion of the wellbore can be characterized as having an upstream proximal end closest to the wellhead along the wellbore measured depth (MD) and a downstream distal end farthest from the wellhead in terms of MD. In step 504, the surface injection pressure necessary to deliver a gravel packing slurry to the most distal end of the production zone portion of the wellbore is determined, and based on this injection pressure, a high pressure shunt tube system to be positioned adjacent the proximal end of the production zone portion of the wellbore is selected for incorporation in a first or upstream sand screen assembly as described above. In step 506, the anticipated gravel pack slurry pressure at the distal end of the production zone portion of the wellbore is calculated, and based on this anticipated pressure, a low pressure shunt tube system to be positioned adjacent the distal end of the production zone portion of the

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wellbore is selected for incorporation in a second or downstream sand screen assembly as described above. Having selected the two sandscreen assemblies with their respective relative high pressure and low pressure shunt tube systems, the lower completion assembly can be made up into a tubing string by joining the first and second sandscreen assemblies together. In this regard, the base pipes of the assemblies are interconnected, and likewise, as described above, adjacent shunt tube assemblies are interconnected using jump tubes to establish fluid communication therebetween. In particular, the packing tube of an upstream sand screen assembly is interconnected to the shunt tube junction block of a downstream sandscreen assembly.

It will be appreciated that in one or more embodiments, the lower completion assembly will be made up of a plurality of sand screen assemblies, each carrying one or more shunt tube assemblies. In such case, it will be necessary to estimate the grave pack slurry injection pressure profile along the length of the production zone portion of the wellbore, and then select the appropriate number of first or second sandscreen assemblies for makeup into the tubing string, it being understood at used here that "first" sandscreen assemblies refers to those sandscreen assemblies with a high pressure shunt system and "second" sandscreen assemblies refers to those sandscreen assemblies with a low pressure shunt system. For example, a lower production assembly may be comprised of 10 first sandscreen assemblies and 15 second sandscreen assemblies, all joined end-to-end to form the tubing string.

In any event, once lower production assembly having the desired number of first and second sandscreen assemblies is assembled, the lower production assembly is installed in the production zone portion of the wellbore. In so doing, at step 508, the second sandscreen assembly is deployed at the distal end of the wellbore portion so that the low pressure shunt tube system is positioned in the wellbore adjacent the production zone distal end. Likewise, in step 510, in positioning the low pressure shunt tube system, the first sandscreen assembly is deployed at the proximal end of the wellbore portion. In so doing, the high pressure shunt tube system is accordingly positioned adjacent the production zone proximal end.

Lastly, in step 512, a working fluid, such as a gravel pack slurry, gel or other desired fluid, is pumped into the interconnected shunt tube assemblies. The working fluid may be pressurized in accordance with the operating pressure of the high pressure shunt tube system deployed adjacent the upper end of the wellbore production zone. Because the pressure of the working

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fluid drops along the length of the production zone, only those "first" sandscreen assemblies are subjected to the higher pressure working fluid, whereas the "second" sandscreen assemblies are only subject to the lower pressure working fluid. Moreover, in certain embodiments, because of the shunt tube system geometry of the "first" sandscreen assemblies, leak-off at the higher pressure is minimized in the upper sandscreen assemblies, thereby minimizing the likelihood of blockage along the shunt tube system or in the gravel pack adjacent the packing tubes. In any event, the working fluid is pumped into the interconnected shunt tube assemblies and injected via the nozzles of the packing tubes into the annulus around the lower production assembly. To the extent the working fluid is a gravel pack slurry, a gravel pack is formed around the lower production assembly so as to support the formation and/or filter production fluids before introduction into the production tubing of the system.

Thus, a wellbore completion assembly has been described. The completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube

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assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the transport tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the transport tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block

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where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly. Other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. Still yet other embodiments of the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a

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portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. Still yet other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen

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assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi. Other embodiments of the wellbore completion assembly may include a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi. In other embodiments, the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first operational pressure rating and the second sand screen assembly comprises a shunt tube assembly with a second operational pressure rating less than the first operational pressure rating. In other embodiments, the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

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For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

Transport tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a transport tube of the second sandscreen assembly.

Packing tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a packing tube of the second sandscreen assembly.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

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A cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly.

A cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

The distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly.

The distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly.

The number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

The cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

The cross-sectional flow areas of the first and second transport tubes is substantially round.

The cross-sectional flow areas of the first and second transport tubes is substantially rectangular.

The cross-sectional flow areas of the first and second transport tubes is oval shaped.

The second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen

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assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

At least two screen assemblies each comprise a shunt tube assembly having first and second sets of transport tube and packing tubes, wherein each set of tubes extends from a junction block.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

The first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

A method of installing a completion assembly in a wellbore has been described. The installation method may include installing a lower sand screen assembly having a low pressure shunt tube system in a wellbore adjacent a production zone; and attaching an upper sand screen assembly having a high pressure shunt tube system to the lower sand screen assembly upstream of the lower sand screen assembly. Other embodiments of the method may include installing

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a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system. Still yet other embodiments of the method may include installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent a production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies, wherein each first sand screen assembly has a low pressure shunt tube system and each second sand screen assembly has a high pressure shunt tube system. Yet other methods of the installation method may include identifying an elongated production zone having an upstream proximal end and a downstream distal end; determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure; determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end. Likewise, other installation methods may include identifying an elongated production zone wellbore portion having an upstream proximal end and a downstream distal end; selecting a high pressure shunt tube system based on a proximal end shunt tube system operating pressure; selecting a low pressure shunt tube system based on a distal end shunt tube system operating pressure; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end; introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

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The high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

The high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

Introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

Injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

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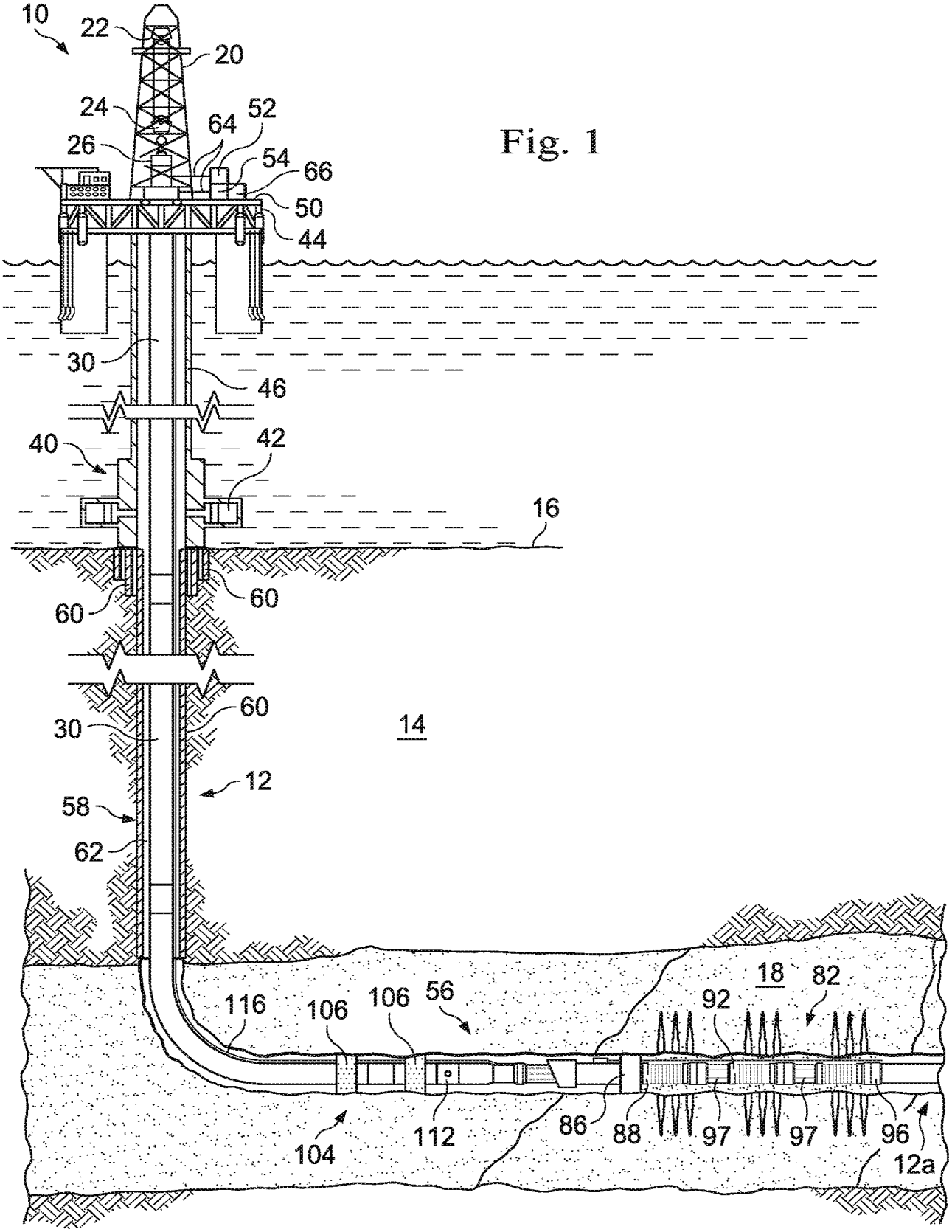
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Fig. 1

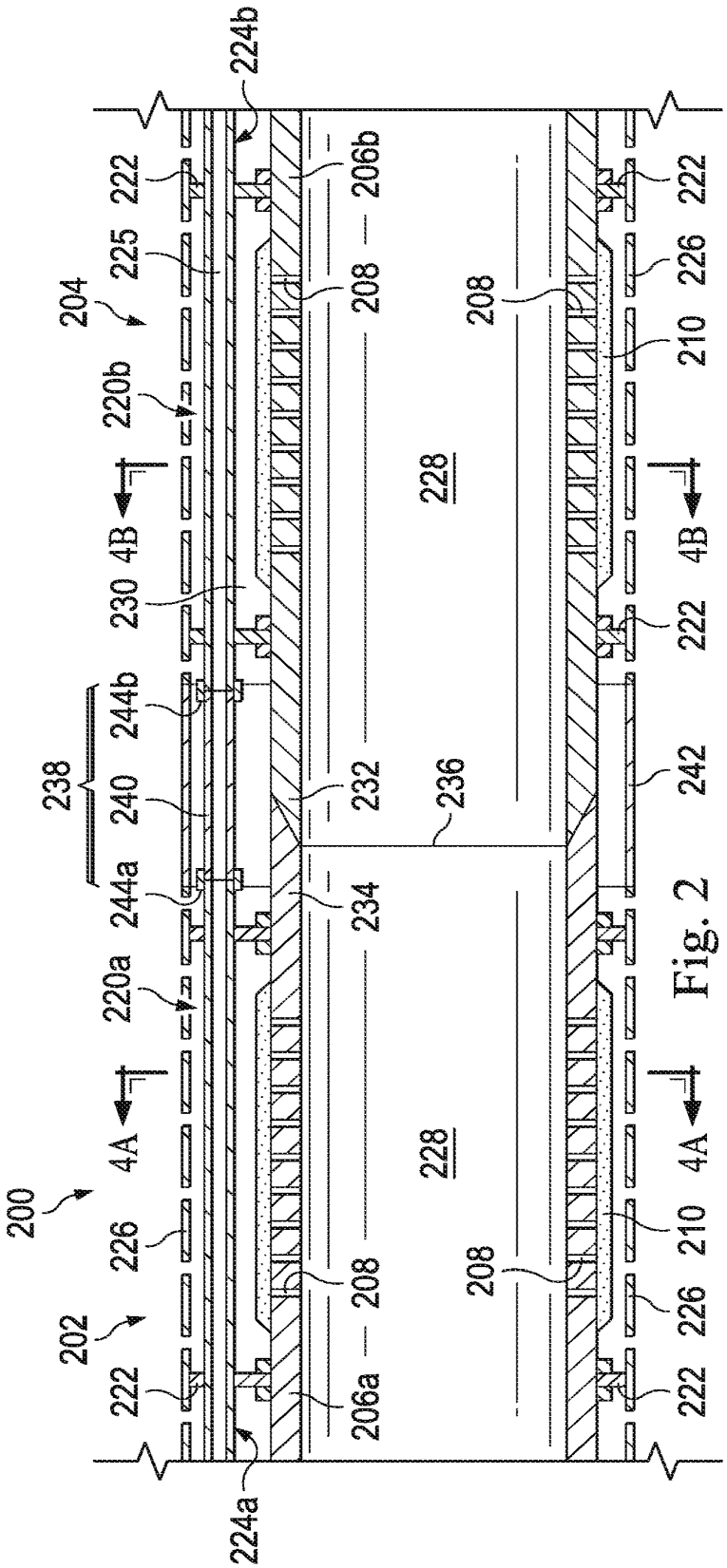
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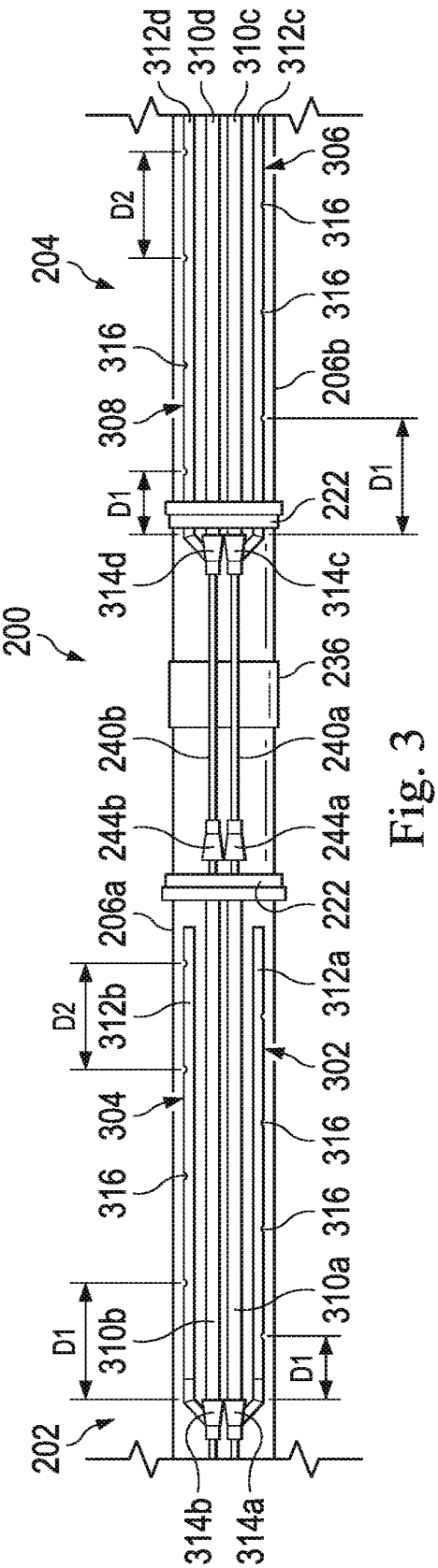
Fig. 2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D2

Fig. 3

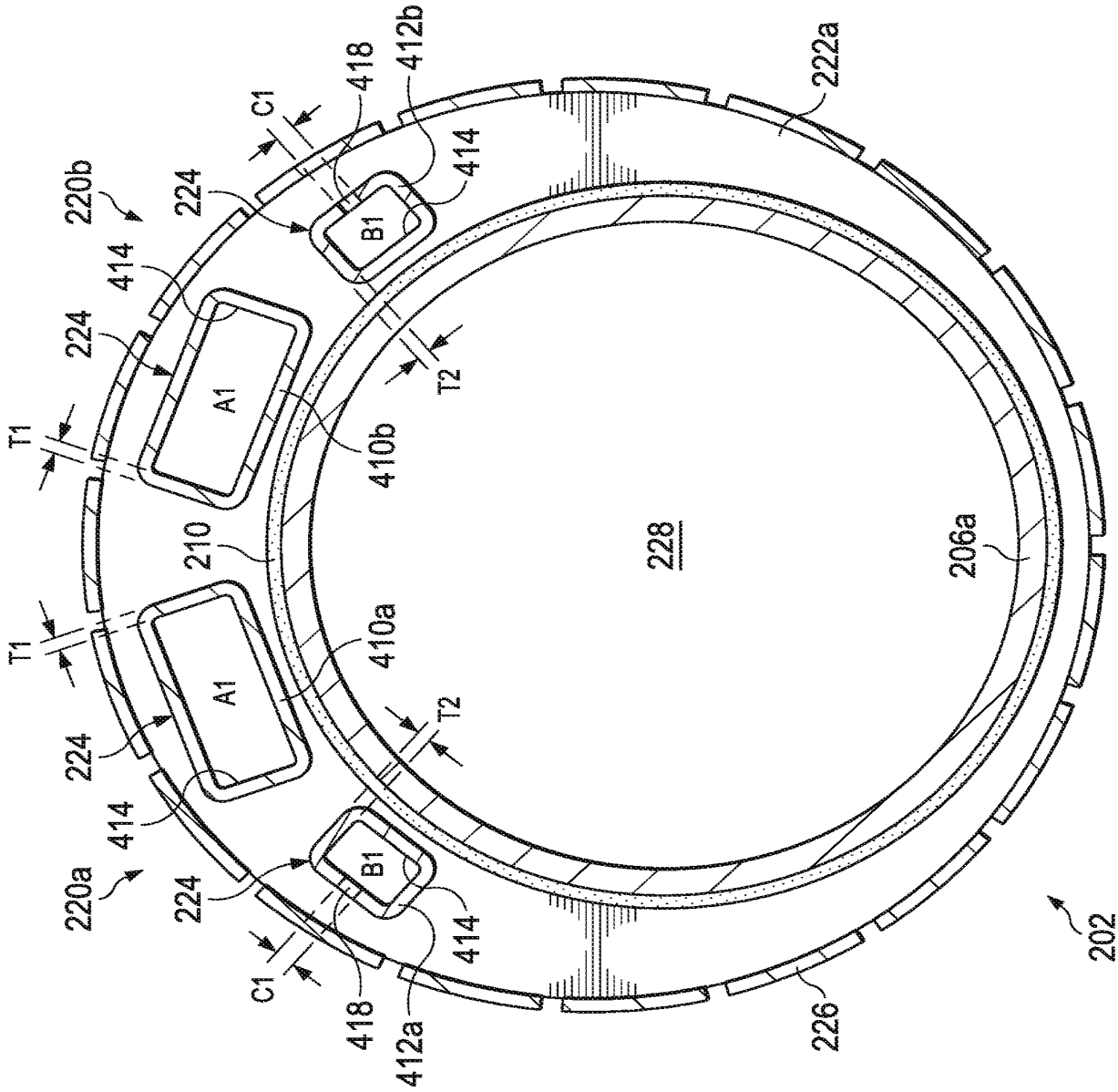
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Fig. 4A

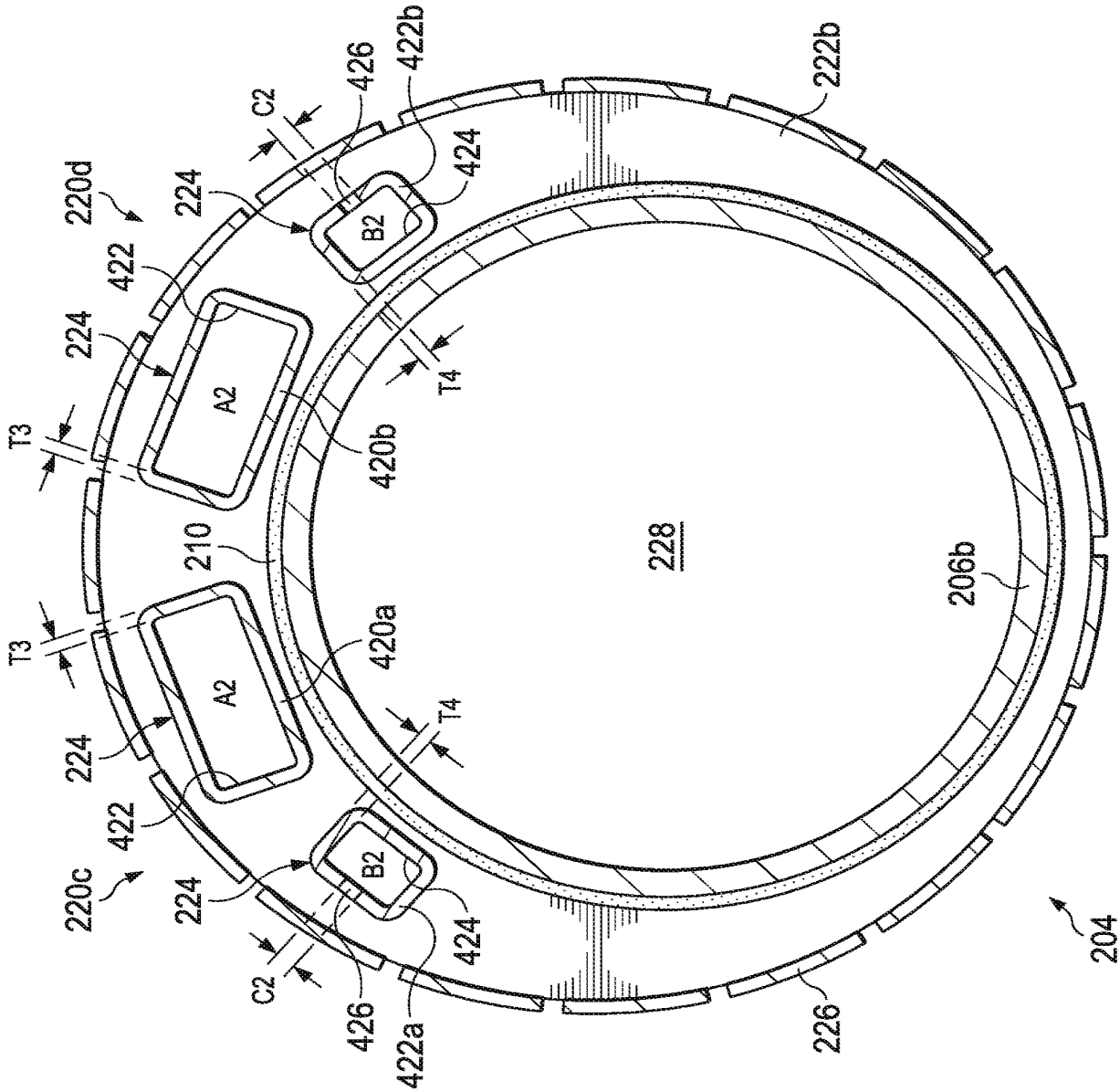
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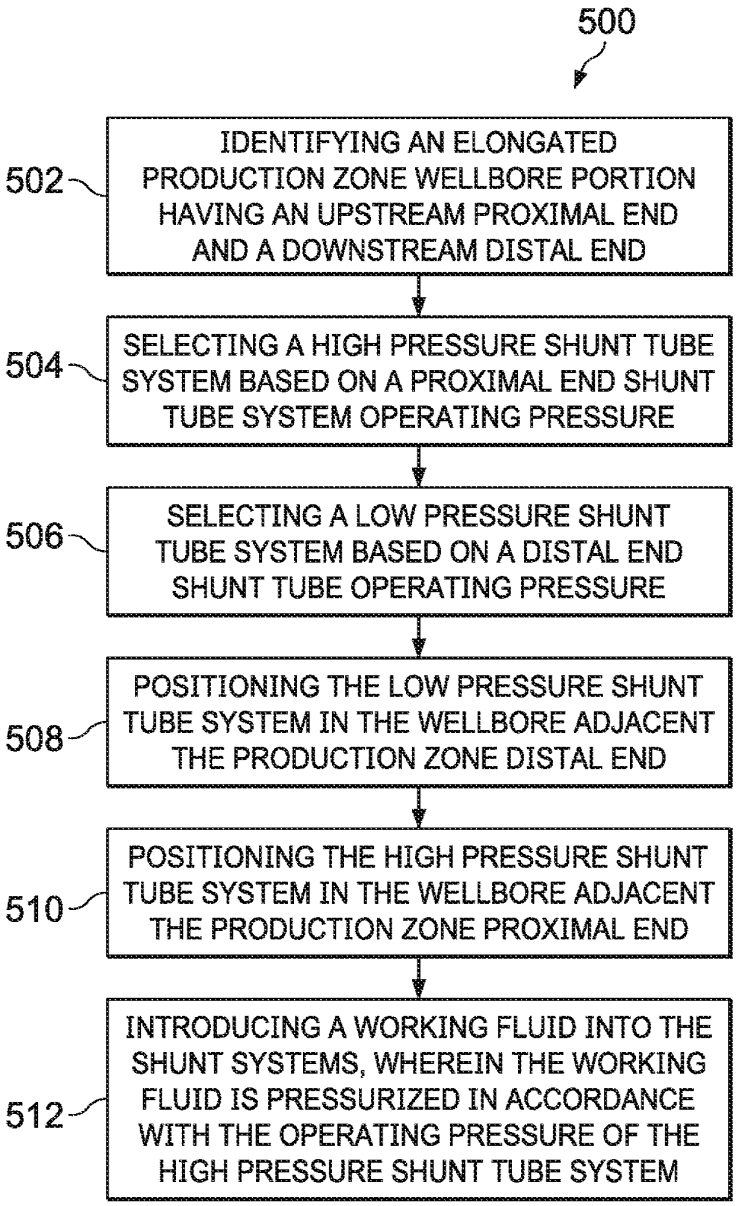
Fig. 4B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IDENTIFYING AN ELONGATED PRODUCTION ZONE WELLBORE PORTION HAVING AN UPSTREAM PROXIMAL END AND A DOWNSTREAM DISTAL END
504
SELECTING A HIGH PRESSURE SHUNT TUBE SYSTEM BASED ON A PROXIMAL END SHUNT TUBE SYSTEM OPERATING PRESSURE
506
SELECTING A LOW PRESSURE SHUNT TUBE SYSTEM BASED ON A DISTAL END SHUNT TUBE OPERATING PRESSURE
508
POSITIONING THE LOW PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE DISTAL END
510
POSITIONING THE HIGH PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE PROXIMAL END
512
INTRODUCING A WORKING FLUID INTO THE SHUNT SYSTEMS, WHEREIN THE WORKING FLUID IS PRESSURIZED IN ACCORDANCE WITH THE OPERATING PRESSURE OF THE HIGH PRESSURE SHUNT TUBE SYSTEM

Fig. 5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Coffin	§	
	§	Attorney Docket No.: 7523.1981US01
Serial No.: (filed concurrently herewith)	§	
	§	Art Unit: TBD
Confirmation No.: TBD	§	
	§	Examiner: TBD
For: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	
	§	

PRELIMINARY AMENDMENT

Commissioner for Patents
P.O. Box 145
Alexandria, VA 22313-1450

Dear Commissioner:

Please accept this preliminary amendment filed concurrently with the referenced continuation application. Any fees deemed necessary for any reason in connection with this amendment are authorized to be deducted from Deposit Account No. 08-1394, Order No. 7523.1981US01. Please amend the application as follows:

Amendments to the Specification begin on page 2 of this paper.

Remarks begin on page 3 of this paper.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Coffin et al.	§	
	§	Confirmation No.: TBD
Serial No.: (concurrently herewith)	§	
	§	Art Unit: TBD
Filing Date: (concurrently herewith)	§	
	§	Examiner: TBD
For: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	
	§	

INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Commissioner:

In compliance with the duty of disclosure under 37 CFR §1.56, and in accordance with the practice under 37 CFR §1.97 and §1.98, the Examiner's attention is directed to the documents listed on the enclosed modified Form PTO-1449. No inference should be made that the documents are in fact material, are in fact prior art, or that no better art exists. The documents are listed in numerical order and are not in any order based on their pertinence.

Pursuant to 37 CFR § 1.98(a)(2)(i), copies of the U.S. patent documents listed on the enclosed modified Form PTO-1449 are not attached.

This Information Disclosure Statement is being filed within three months of the United States filing date or before the mailing date of a first Office Action on the merits. No certification or fee is required (37 CFR §1.97(b)).

An early action on the merits is respectfully requested.

Should additional fees be deemed necessary for any reason in connection with the present submission, the Commissioner is hereby authorized to deduct any necessary amounts from (or credit any overpayments to) Haynes and Boone, LLP's Deposit Account No. 08-1394, Order No. 7523.1981US01.

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It is respectfully requested that the above information be considered by the Examiner and that a copy of the enclosed modified Form PTO-1449 be returned indicating that such information has been considered.

Respectfully submitted,

/Harold A. Borland/

Harold A. Borland
Registration No. 57,854

Date: May 6, 2019

HAYNES AND BOONE, LLP
2323 Victory Ave., Suite 700
Dallas, Texas 75219
Telephone: 713-547-2881
Facsimile: 214-200-0853
File: 7523.1981US01

Certificate of Transmission

I hereby certify that this correspondence is being transmitted via EFS-Web to the United States Patent and Trademark Office, on May 6, 2019.

/Delaunda N. Lanford/
Delaunda N. Lanford

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Page 39

In place of PTO-1449 Form	U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE			*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(use as many sheets as necessary)*				Application Number	Unassigned
				Filing Date	Filed Herewith
				First Inventor Name	Coffin
				Art Unit	Unassigned
				Examiner Name	Unassigned
SHEET	1	OF	1	Attorney Docket Number	7523.1981US01

U. S. PATENTS

Examiner's Initials	Cite No.	Document Number	Issue Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document
	A1	6,588,506 B2	07-08-2003	Jones

U. S. PATENT APPLICATION PUBLICATIONS

Examiner's Initials	Cite No.	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document
	B1	2004/0140089 A1	07-22-2004	Gunneroed

FOREIGN PATENT DOCUMENTS

Examiner's Initials	Cite No.	Foreign Patent Document (Country Code – Number – Kind)	Publication Date MM-DD-YYYY	Patentee or Applicant of Cited Document	Translation Y/N

NON-PATENT LITERATURE DOCUMENTS

Examiner's Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article, title of the item, date, page(s), volume-issue number(s), publisher, city/country where published

Examiner Signature		Date Considered	

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include a copy of this form with next communication to applicant.

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Filer:	Harold Borland/Delaunda Lanford
Attorney Docket Number:	7523.1981US01

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
NATIONAL STAGE FEE	1631	1	300	300
NATL STAGE SEARCH FEE - REPORT PROVIDED	1642	1	520	520
NATIONAL STAGE EXAM - ALL OTHER CASES	1633	1	760	760
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	1615	3	100	300
INDEPENDENT CLAIMS IN EXCESS OF 3	1614	1	460	460
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2340**

Electronic Acknowledgement Receipt

EFS ID:	35926959
Application Number:	16347711
International Application Number:	PCT/US2019/024626
Confirmation Number:	5449
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Customer Number:	27683
Filer:	Harold Borland/Delaunda Lanford
Filer Authorized By:	Harold Borland
Attorney Docket Number:	7523.1981US01
Receipt Date:	06-MAY-2019
Filing Date:	
Time Stamp:	15:27:54
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$2340
RAM confirmation Number	050719INTEFSW15291200
Deposit Account	081394
Authorized User	Delaunda Lanford

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.21 (Miscellaneous fees and charges)

37 CFR 1.492 (National application filing, search, and examination fees)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		7523-1981US01_PatentApplication.pdf	183675 d303c13a56ac5b35bc33b5a831c0a724a959eaec	yes	33

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Abstract	33	33
	Claims	27	32
	Specification	1	26

Warnings:					
Information:					
2	Drawings-only black and white line drawings	7523-1981US01_Drawings.pdf	362668 8fb8193d8fae62f5bf9f9730a6615634358 79ab1	no	5
Warnings:					
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3	Oath or Declaration filed	7523-1981US01_Declaration.pdf	1546796 bc8f4cedd826c54a796e2fb422c489519893a092	no	2
Warnings:					
Information:					
4	Application Data Sheet	7523-1981US01_ADS.pdf	110068 88f82d03d9d623c6026c370e2d3c52ab96dc22ba	no	7
Warnings:					
Information:					
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5		7523-1981US01_PreliminaryAmendment.pdf	37150 e2b8ad38b41fb3810bc905c3092bdf4222d80073	yes	4
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Applicant Arguments/Remarks Made in an Amendment		3	4	
	Specification		2	2	
	Preliminary Amendment		1	1	
Warnings:					
Information:					
6	Transmittal Letter	7523-1981US01_IDS.pdf	27610 e0b9337bb7123ca4eaba9ff7713aafcc0fef0adb	no	2
Warnings:					
Information:					
7	Information Disclosure Statement (IDS) Form (SB08)	7523-1981US01_SB08.pdf	24923 08994e405961de0727b10fe7ad79a824ece03014	no	1
Warnings:					
Information:					
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8	Fee Worksheet (SB06)	fee-info.pdf	38590 0900fdd3aae7954006e062b7d60243004ccaac44	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	2331480		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Abstract

A lower completion assembly made up of an upper sand screen assembly and a lower sand screen assembly. Each sand screen assembly includes a shunt system. Each shunt system includes a transport tube and a packing tube extending from a junction block. Each packing tube includes a plurality of nozzles spaced apart from the junction block and from each other. The shunt system of the upper sand screen assembly has a higher pressure rating than the shunt system of the lower sand screen assembly. The wall thickness of the transport tubes of the upper sand screen assembly shunt system is greater than the wall thickness of the transport tubes of the lower sand screen assembly shunt system.

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CLAIMS

What is claimed is:

1. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

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2. The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

3. The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

4. The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

5. The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

6. The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

7. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

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8. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 4000 psi.

9. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

10. The completion assembly of claim 1, wherein a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

11. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

12. The completion assembly of claim 11, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi.

13. The completion assembly of claim 11, further comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

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14. A method of installing a completion assembly in a wellbore, the method comprising: installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system.

15. The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies.

16. The method of claim 14, further comprising:

identifying an elongated production zone having an upstream proximal end and a downstream distal end;

determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting the high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting the low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system;

positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and

positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end.

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17. The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

18. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

19. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

20. The method of claim 17, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

21. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

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wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

22. The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

23. The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first pressure rating.

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MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. provisional application no. 62/688,813, filed June 22, 2018.

FIELD OF INVENTION

The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies.

BACKGROUND

In the course of completing an oil and/or gas well, a string of production tubing can be run into the wellbore. During production of the formation fluid, formation sand may be swept into the flow path of the production fluid as it passes along the tubing string. The formation sand tends to be relatively fine sand that can erode production components in the flow path.

When formation sand is expected to be encountered, one or more lower production assemblies may be installed in the production zone between the formation and the production tubing. The lower production assemblies typically include a perforated base pipe surrounded by a sand screen to filter fines from the formation fluid. A packer is customarily set above the production assembly to seal off the annulus in the production zone where formation fluids flow into the production tubing. The annulus around the sand screen can then be "gravel packed" with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of carrier fluid such as water and/or gel and fills the annulus around the sand screen. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation. During the gravel packing process, a premature loss of the carrier fluid

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into the formation, known as leak-off, can occur, resulting in the formation of sand bridges in the annulus about the screening. With a premature loss of carrier fluid, incomplete packing around the sand screen and reduce the filtering efficiency of the gravel pack.

One conventional approach to overcoming this packing sand bridging problem has been to provide each production assembly with a series of shunt tubes that longitudinally extend through the sand screen section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the sand screen section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen assembly. The shunt path operates to permit the inflowing packing sand/gel slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing or screen/open hole annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

In instances where production zones are elongated, a plurality of lower completion assemblies may be deployed end to end to form a lower completion assembly string that may stretch for hundreds of feet. To ensure that gravel packing slurry is deposited along the entire length of the lower completion assembly string from its upstream end to the downstream end, particularly in deep wellbores and deviated wellbores, relatively high pressures must be applied to the carrier fluid. Thus, each individual lower completion assembly utilized in the overall string is designed to withstand the high delivery pressures experienced at the upstream end of the lower completion assembly string.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

FIG. 1 is a cut-away view of a wellbore system having a lower completion system disposed therein.

FIG. 2 is a partial cross-sectional view of a lower completion assembly.

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FIG. 3 is a partial side view of an embodiment of a shunt tube assembly deployed on a base pipe of a lower completion assembly.

FIG. 4A is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A′ of FIG. 2.

FIG. 4B is a cross-sectional view of an embodiment of a shunt tube assembly along line B-B′ of FIG. 2.

FIG. 5 is a method of installing in a wellbore a lower completion assembly having shunt tube systems with different pressure ratings.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the figures is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The apparatus may be otherwise oriented

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(rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Moreover, even though a figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in wellbores having other orientations including, deviated wellbores, multilateral wellbores, or the like. Likewise, unless otherwise noted, even though a figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in onshore operations and vice-versa.

Generally, a lower completion assembly made up of at least two sand screen assemblies is provided, namely a first or upper sand screen assembly and a second or lower sand screen assembly. Each sand screen assembly includes a shunt system. Each shunt system includes a transport tube and a packing tube extending from a junction block. Each packing tube includes a plurality of nozzles spaced apart from the junction block and from each other. In one or more embodiments, the cross-sectional area of the transport tube in the first sand screen assembly is less than the cross-sectional area of the transport tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube in the first sand screen assembly is less than the cross-sectional area of the packing tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube nozzles in the first sand screen assembly is less than the cross-sectional area of the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. In one or more embodiments, the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

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Turning to Figure 1, shown is an elevation view in partial cross-section of a wellbore production system 10 utilized to complete wells intended to produce hydrocarbons from wellbore 12 extending through various earth strata in an oil and gas formation 14 located below the earth's surface 16. Wellbore 12 may be formed of a single or multiple bores, extending into the formation 14, and disposed in any orientation, such as the horizontal wellbore 12a illustrated in Figure 1. Formation 14 includes production zones 18 from which hydrocarbons are produced.

Production system 10 includes a rig or derrick 20. Rig 20 may include a hoisting apparatus 22, a travel block 24, and a swivel 26 for raising and lowering casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings or other types of conveyance vehicles such as wireline, slickline, and the like 30. In Figure 1, conveyance vehicle 30 is a substantially tubular, axially extending work string or production tubing, formed of a plurality of pipe joints coupled together end-to-end supporting a completion assembly as described below.

Rig 20 may be located proximate to or spaced apart from wellhead 40, such as in the case of an offshore arrangement as shown in Figure 1. One or more pressure control devices 42, such as blowout preventers (BOPs) and other equipment associated with drilling or producing a wellbore may also be provided at wellhead 40 or elsewhere in the system 10.

For offshore operations, as shown in Figure 1, rig 20 may be mounted on an oil or gas platform 44, such as the offshore platform as illustrated, semi-submersibles, drill ships, and the like (not shown). Although system 10 of Figure 1 is illustrated as being a marine-based production system, system 10 of Figure 1 may be deployed on land. In any event, for marine-based systems, one or more subsea conduits or risers 46 extend from deck 50 of platform 44 to a subsea wellhead 40. Tubing string 30 extends down from rig 20, through subsea conduit 46 and BOP 42 into wellbore 12.

A working or service fluid source 52, such as a storage tank or vessel, may supply, via flow lines 64, a working fluid to equipment disposed in wellbore 12, such as subsurface equipment 56. Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, gravel packing slurry, acidizing fluid, liquid water, steam or some other type of fluid.

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Production system 10 may generally be characterized as having a pipe system 58. For purposes of this disclosure, pipe system 58 may include casing, risers, tubing, drill strings, completion or production strings, subs, heads or any other pipes, tubes or equipment that couples or attaches to the foregoing, such as string 30, conduit 46, and casing. In this regard, pipe system 58 may include one or more casing strings 60 that may be cemented in wellbore 12, such as the surface, intermediate and production casings 60 shown in Figure 1. An annulus 62 is formed between the walls of sets of adjacent tubular components, such as concentric casing strings 60 or the exterior of tubing string 30 and the inside wall of wellbore 12 or casing string 60, as the case may be. While wellbore 12 is shown as uncased in the production zone 18 and along the entire depicted portion of horizontal wellbore 12a, all or a portion of wellbore 12 and/or horizontal wellbore 12a may be cased as well and the disclosure is not limited in that regard.

Production fluids and other debris returning to surface 16 from wellbore 12 are directed by a flow line 64 to storage tanks 54 and/or processing systems 66.

As shown in Figure 1, subsurface equipment 56 is illustrated as completion equipment and tubing string 30 in fluid communication with the completion equipment 56 is illustrated as production tubing 30. Although completion equipment 56 can be disposed in a wellbore 12 of any orientation, for purposes of illustration, completion equipment 56 is shown disposed in a substantially horizontal portion of wellbore 12 and includes a lower completion assembly 82 having various tools such as a packer 86, a sand screen assembly 88, a sand screen assembly 92, a sand screen assembly 96 and a packer 98. In embodiments where lower completion assembly 82 is deployed in a cased wellbore, an additional packer, such as packer 86, would be deployed at the distal end of the lower completion assembly. In the illustrated embodiment, packer 86 is generally located adjacent the upstream or proximal end of a production zone 18 and packer 98 is generally located adjacent the downstream or distal end of a production zone 18. Sand screen assemblies 88, 92 and 96 each include a shunt tube system 97 and are arranged so that the sand screen assembly having a shunt tube system with the highest operating pressure rating is upstream and the sand screen assembly having a shunt tube system with the lowest operating pressure rating is downstream. Thus, for example, in the illustrated embodiment sand screen assembly 88 includes a shunt tube assembly with a higher operating pressure than the shunt tube assembly of sand screen 96.

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Disposed in wellbore 12 at the lower end of tubing string 30 is an upper completion assembly 104 that includes various tools such as a packer 106, and a fluid flow control module 112.

Extending uphole from upper completion assembly 104 are one or more lines 116, such as hydraulic tubing, pressurized fluid tubing and the like which extends to the surface 16.

A cross-sectional view of an embodiment of a lower completion assembly 200 is shown in FIG. 2. Lower completion assembly is generally comprised of a first sand screen assembly 202 interconnected with a second sand screen assembly 204. In some embodiments, lower completion assembly 200 may be comprised of a plurality of interconnected first sand screen assemblies 202 at an upper portion of the lower completion assembly 200 and a plurality of interconnected second sand screen assemblies 204 at a lower portion of the lower completion assembly 200. Each sand screen assembly includes a base pipe 206 having a series of perforations 208 disposed therethrough, the base pipe 206 extending between a first end and a second end. A sand screen or filter media 210 is disposed about a portion of the base pipe 206 and the series of perforations 208 in order to screen incoming fluids from the formation. Each sand screen assembly also includes a shunt tube assembly 220 disposed outwardly of the filter media 220. Generally, shunt tube assembly 220 may include one or more retaining rings 222 supporting one or more shunt tubes 224 in the form of a transport tube or a packing tube disposed along and generally parallel to the base pipe 206. Shunt tubes 224 are tubular members having a passageway 225 defined therein with a cross-sectional flow area. While shown disposed outside of and generally parallel to the base pipe 206, other positions and alignment may be possible. An outer shroud 226 may be disposed about the base pipe 206, one or more shunt tubes 224, and filter media 210. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 224 and/or outer shroud 226 in position relative to the base pipe 206.

While the base pipe 206 is illustrated as being perforated in FIG. 2, the base pipe 206 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 228 and an exterior 230 of the screen assembly.

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The filter media 210 may be disposed about the base pipe 206 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the base pipe 206. In an embodiment, the filter media 210 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a base pipe 206, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 210 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 210 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

The base pipe 206 may generally comprise a pin end 232 and a box end 234 to allow the base pipe 206 to be coupled to an adjacent base pipe 206. In the illustrated embodiment, base pipe 206a of first sand screen assembly 202 is coupled to base pipe 206b of second sand screen assembly 204 forming a joint 236. As such, the first sand screen assembly 202 and the second sand screen assembly 204 can be joined together end-to-end so that the respective base pipes are in fluid communication with one another along their throughbores 228. As can be seen in FIG. 2, each base pipe 206 may have a coupling section 238 that extends beyond the shunt tube assembly 220 of the respective sand screen assemblies. This exposed portion of the base pipe 206 may be used during the coupling process to allow one or more tools to engage the exposed portion for makeup of the first and second sand screen assemblies 202, 204.

Shunt tubes 224 of adjacent sand screen assemblies may be joined together in fluid communication by a jumper tube 240. In the illustrated embodiment, shunt tube 224a is interconnected to shunt tube 224b by jumper tube 240. An additional shroud 242 may be used to protect jumper tube 240. While the disclosure is not limited to a particular shape for shunt tubes 224 or jumper tubes 240, in some embodiments, shunt tubes 224 may have a non-round cross-section (as shown in FIGs. 3A and 3B), while jumper tubes 240 may have a round cross-section. In such case, the end of each

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jump tube may include an adaptor or coupling 244 to transition from the non-round cross-section of the shunt tube 224 to the round cross-section of the jumper tubes 240.

Although the particular shape of the tubes described herein are not a limitation in certain embodiments, shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple shunt tubes on adjacent wellbore tubular joints are generally round cross-section while the shunt tubes are non-round in cross-section.

With reference to FIG. 3, a side view of a lower completion assembly 200 is illustrated, with first sand screen assembly 202 interconnected with second sand screen assembly 204. In the illustrated embodiment, the filter media 210 and outer shrouds 226, 242 shown in FIG. 2 are removed to permit better illustration of the shunt tube assemblies. Additionally, the different types of shunt tubes 224 that comprise a shunt tube assembly 220 are illustrated in more detail. Specifically, in FIG. 3, base pipe assembly 206a is shown interconnected to base pipe assembly 206b at joint 236. First sand screen assembly 202 has two shunt tube assemblies 302 and 304. Likewise, second sand screen assembly 204 is illustrated with two shunt tube assemblies 306 and 308. Each shunt tube assembly described herein, including shunt tube assemblies 220 of FIG. 2, generally include a transport tube 310 and a packing tube 312 extending from a junction block 314 so as to be in fluid communication with one another.

As shown, the shunt tubes 310, 312 may form a branched structure from junction block 314 along the length of a sandscreen assembly 202 with the one or more transport tubes 310 forming the trunk line and the one or more packing tubes 312 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the sandscreen assembly 202. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended. Likewise, while junction block 314 is depicted as having only one inlet and two outlets, the disclosure is not limited to a particular junction block configuration. The "y-block" junction block depicted is for illustration purposes only unless otherwise stated for a

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particular configuration. In this regard, in certain configurations, the shunt tube assembly may only comprise a junction block 314 having one inlet and two outlets as depicted.

Each packing tube 312 includes one or more nozzles 316. Each nozzle 316 is spaced apart from its respective junction block 314 a distance D1. Likewise, each nozzle 316 along a packing tube 312 may be spaced apart from adjacent nozzles a distance D2. The spacing D2 between nozzles 216 along a particular packing tube 312 may be the same or different. Likewise, the spacing D2 between nozzles 216 of shunt tube assemblies of the same sand screen assembly may be the same or different.

Also shown in FIG. 3 is a jumper tube 240a interconnecting shunt tube assembly 302 with a shunt tube assembly 306 and a jumper tube 240b interconnecting shunt tube assembly 204 with shunt tube assembly 308. A coupling 244a is provided at distal end of transport tube 310a to facilitate attachment of jumper tube 240a, while a coupling 244b is provided at distal end of transport tube 310b to facilitate attachment of jumper tube 240b. In particular, jumper tube 240a interconnects junction block 314c with coupling 244a at the distal end of transport tube 310a, thereby allowing fluid communication between upper or high pressure shunt tube assembly 302 and lower or low pressure shunt tube assembly 306. Likewise, jumper tube 240b interconnects junction block 314d with coupling 244b at the distal end of transport tube 310b, spanning joint 236 between the first sand screen assembly 202 and the second sand screen assembly 204.

FIG. 4A illustrates a cross-sectional area A-A of first sand screen assembly 202 and shunt tubes 224a of FIG. 2 and FIG. 4B illustrates a cross-sectional area B-B of second sand screen assembly 204 and shunt tubes 224b of FIG. 2. As generally shown, the one or more shunt tubes 224 generally comprise tubular members disposed outside of and generally parallel to the base pipe 224. While described as tubular members (e.g., having substantially rectangular cross-sections), the one or more shunt tubes 224 may have shapes other cross-sectional shapes, such as round, elliptical, kidney shaped, and/or trapezoidal in shape. The retaining rings 222 may retain the shunt tubes 224 in position relative to the base pipe 206. The one or more shunt tubes 224 may be eccentrically aligned with respect to the base pipe 206 as best seen in FIG. 2. In each of FIGS. 4A and 4B, four shunt tubes 224 are arranged to one side of the base pipe 206. While illustrated in FIGS. 2 and 4

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as having an eccentric alignment, other alignments of the one or more shunt tubes about the base pipe 206 may also be possible.

In FIG. 4A, first sand screen assembly 202 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 410 and a packing tube 412. Each transport tube 410 has a cross-sectional flow area A1 bounded by a wall 414 of thickness T1. Likewise, each packing tube 412 has a cross-sectional flow area B1 bounded by a wall 416 of thickness T2. Each packing tube further includes one or more nozzles 418 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 418 may be in the form of a perforation or opening in wall 416 or a short tube with a taper or constriction. Nozzle 418 is characterized by a cross-sectional flow area C1.

Similarly, in FIG. 4B, second sand screen assembly 204 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 420 and a packing tube 422. Each transport tube 420 has a cross-sectional flow area A2 bounded by a wall 422 of thickness T3. Likewise, each packing tube 422 has a cross-sectional flow area B2 bounded by a wall 424 of thickness T4. Each packing tube further includes one or more nozzles 4426 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 426 may be in the form of a perforation or opening in wall 424 or a short tube with a taper or constriction. Nozzle 426 is characterized by a cross-sectional flow area C2.

In one or more embodiments, the cross-sectional flow area A1 of the transport tube 410 of first sand screen assembly 202 is less than the cross-sectional flow area A2 of the transport tube 420 of the second sand screen assembly 204. In other words, the downstream sand screen assembly transport tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly transport tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area B1 of the packing tube 412 of first sand screen assembly 202 is less than the cross-sectional flow area B2 of the packing tube 422 of the second sand screen assembly 204. In other words, the downstream sand screen assembly packing tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area

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than the upstream sand screen assembly packing tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area C1 of a nozzle 418 of first sand screen assembly 202 is less than the cross-sectional flow area C2 of a nozzle 426 of the second sand screen assembly 204. In other words, the downstream sand screen assembly shunt tube nozzles which are closest to the distal end of the production zone, have a larger cross-sectional flow area than the upstream sand screen assembly shunt tube nozzles closest to the proximal end of the production zone.

In one or more embodiments, the packing tube assembly 412 of the first sand screen assembly 202 has fewer nozzles 418 than the number of nozzles 426 of the packing tube assembly 422 of the second sand screen assembly 204.

Referring back to FIG. 3, in one or more embodiments, the distance D1 of the first nozzle 316 of packing tube assembly 312a from the junction block 314a is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312c from the junction block 314c for the interconnected shunt tube assemblies 302 and 306. Likewise, the distance D1 of the first nozzle 316 of packing tube assembly 312b from the junction block 314b is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312d from the junction block 314d for the interconnected shunt tube assemblies 304 and 308.

Similarly, in one or more embodiments, the distance D2 between adjacent nozzle 316 of packing tube assembly 312a of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312c of the second sand screen assembly 204 for interconnected shunt tube assemblies 302 and 306. Likewise, the distance D2 between adjacent nozzle 316 of packing tube assembly 312b of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312d of the second sand screen assembly 204 for interconnected shunt tube assemblies 304 and 308.

While each of the different geometries of a shunt tube assembly have been described, it will be appreciated that any one or more of the geometries can be combined to achieve the desired flow

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regime for a particular shunt tube assembly. In some cases, certain of the geometries will remain the same. For example, the transport tubes 410 and 420 may be the same with the same flow areas A1, A2, but the geometries of the respective packing tubes 412, 244 may differ in number of nozzles and/or cross-sectional flow areas B1, B2 and/or nozzle spacing along the respective packing tubes.

Traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the same pressure rating. In this regard, the shunt tube assemblies are selected based on the expected operating conditions of the shunt tube assemblies. For shorter gravel packing intervals, the gravel pack slurry flows into the wellbore annulus at about the same fluid pressure along the length of the interval. Of course, as gravel pack intervals have increased, an increased operating pressure is needed to ensure that gravel pack slurry flows along the entire length of the gravel pack interval. Thus, as gravel pack intervals increase, it has been necessary to employ shunt tube assemblies with increased operating pressure ratings or burst pressures, resulting in heavier and/or bulkier tubing and components to ensure that the shunt tube assemblies will not be subject to burst pressure. Since shunt tube assemblies for an entire lower production assembly are selected based on the highest operating pressure expected to be required across the entire length of the gravel packing interval, individual sand screen assemblies in a lower production assemblies have become increasingly heavier. However, as the slurry flows from the upstream portion of these elongated production zone to the downstream portion of the production zone, the pressure of the slurry drops off. As such, only the shunt tube assemblies deployed adjacent the upper portion of the production zone experience the highest pressures.

In addition, because of the high pressure experienced by shunt tube assemblies at the upper or upstream end of such lower production assemblies deployed in elongated production zones, there is a tendency for greater leak-off in the upstream portion of the production zone.

These drawbacks are addressed by above-described lower production assembly where the shunt tube system flow regime in the second sand screen assembly 204 is selected to allow a larger volume of fluid to flow therethrough than that of the first sand screen assembly 202 by adjusting cross-sectional flow areas, location and number of nozzles. In this regard, the geometries of the

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shunt tube assemblies 220 of the first sand screen assembly 202 may be selected to have a higher operating pressure than the shunt tube assemblies 220 of the second sandscreen assembly 204. In one or more embodiments, the thickness T1 of wall 414 of transport tube 410 of the first sand screen assembly 202 may be greater than thickness T3 of wall 422 of transport tube 420 of the second sandscreen assembly 204. Likewise, in one or more embodiments, the thickness T2 of wall 416 of packing tube 412 of the first sand screen assembly 202 may be greater than the thickness T4 of wall 424 of packing tube 422 of the second sandscreen assembly 204. In other embodiments, where geometries and dimensions are the same, the material of construction of transport tube 410 may be selected to be stronger than the material of construction of transport tube 420. In other words, the material of construction of transport tube 410 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of transport tube 420 of the second sandscreen assembly 204. In other embodiments, the material of construction of packing tube 412 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of packing tube 422 of the second sandscreen assembly 204. As such, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 may be selected to have an operating pressure at or above a select threshold, while the shunt tube assemblies 220 of the second sandscreen assembly 204 may be selected to have an operating pressure at or below a select threshold. In one or more embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure or are otherwise rated at over 5000 psi while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 5000 psi. In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating or are otherwise rated between 5000 and 10000 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 4000 psi. More broadly, it will be appreciated that the first and second sandscreen assemblies 202, 204 have different shunt tube assembly operating pressure ratings, with the shunt tube assembly 220 of the first sandscreen assembly 202 having a higher operating pressure rating than the shunt tube assembly 220 of the second sandscreen assembly 204.

In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating of between approximately 6,500 to 7,500 psi, while

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the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure of approximately 3,500 to 3,750 psi. In certain embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have are rated at or have an operating pressure of approximately 10,000 psi. In other words, the shunt tube assemblies upstream are selected to have a higher burst pressure than the shunt tube assemblies downstream in the overall lower production assembly.

Turning to FIG. 5, a method 500 of installing a completion assembly in a wellbore is generally illustrated. In a first step 502, a portion of the wellbore passing through a production zone to be gravel packed is identified for placement of a lower production assembly. The production zone portion of the wellbore can be characterized as having an upstream proximal end closest to the wellhead along the wellbore measured depth (MD) and a downstream distal end farthest from the wellhead in terms of MD. In step 504, the surface injection pressure necessary to deliver a gravel packing slurry to the most distal end of the production zone portion of the wellbore is determined, and based on this injection pressure, a high pressure shunt tube system to be positioned adjacent the proximal end of the production zone portion of the wellbore is selected for incorporation in a first or upstream sand screen assembly as described above. In step 506, the anticipated gravel pack slurry pressure at the distal end of the production zone portion of the wellbore is calculated, and based on this anticipated pressure, a low pressure shunt tube system to be positioned adjacent the distal end of the production zone portion of the wellbore is selected for incorporation in a second or downstream sand screen assembly as described above. Having selected the two sandscreen assemblies with their respective relative high pressure and low pressure shunt tube systems, the lower completion assembly can be made up into a tubing string by joining the first and second sandscreen assemblies together. In this regard, the base pipes of the assemblies are interconnected, and likewise, as described above, adjacent shunt tube assemblies are interconnected using jump tubes to establish fluid communication therebetween. In particular, the packing tube of an upstream sand screen assembly is interconnected to the shunt tube junction block of a downstream sandscreen assembly.

It will be appreciated that in one or more embodiments, the lower completion assembly will be made up of a plurality of sand screen assemblies, each carrying one or more shunt tube assemblies.

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In such case, it will be necessary to estimate the grave pack slurry injection pressure profile along the length of the production zone portion of the wellbore, and then select the appropriate number of first or second sandscreen assemblies for makeup into the tubing string, it being understood at used here that "first" sandscreen assemblies refers to those sandscreen assemblies with a high pressure shunt system and "second" sandscreen assemblies refers to those sandscreen assemblies with a low pressure shunt system. For example, a lower production assembly may be comprised of 10 first sandscreen assemblies and 15 second sandscreen assemblies, all joined end-to-end to form the tubing string.

In any event, once lower production assembly having the desired number of first and second sandscreen assemblies is assembled, the lower production assembly is installed in the production zone portion of the wellbore. In so doing, at step 508, the second sandscreen assembly is deployed at the distal end of the wellbore portion so that the low pressure shunt tube system is positioned in the wellbore adjacent the production zone distal end. Likewise, in step 510, in positioning the low pressure shunt tube system, the first sandscreen assembly is deployed at the proximal end of the wellbore portion. In so doing, the high pressure shunt tube system is accordingly positioned adjacent the production zone proximal end.

Lastly, in step 512, a working fluid, such as a gravel pack slurry, gel or other desired fluid, is pumped into the interconnected shunt tube assemblies. The working fluid may be pressurized in accordance with the operating pressure of the high pressure shunt tube system deployed adjacent the upper end of the wellbore production zone. Because the pressure of the working fluid drops along the length of the production zone, only those "first" sandscreen assemblies are subjected to the higher pressure working fluid, whereas the "second" sandscreen assemblies are only subject to the lower pressure working fluid. Moreover, in certain embodiments, because of the shunt tube system geometry of the "first" sandscreen assemblies, leak-off at the higher pressure is minimized in the upper sandscreen assemblies, thereby minimizing the likelihood of blockage along the shunt tube system or in the gravel pack adjacent the packing tubes. In any event, the working fluid is pumped into the interconnected shunt tube assemblies and injected via the nozzles of the packing tubes into the annulus around the lower production assembly. To the extent the working fluid is a gravel pack slurry, a gravel pack is formed around the lower production assembly so as to support

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the formation and/or filter production fluids before introduction into the production tubing of the system.

Thus, a wellbore completion assembly has been described. The completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart

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from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the transport tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the transport tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed

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outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly. Other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. Still yet other embodiments of the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the

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junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. Still yet other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly

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comprises a shunt tube assembly with a burst pressure less than the first burst pressure. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi. Other embodiments of the wellbore completion assembly may include a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi. In other embodiments, the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first operational pressure rating and the second sand screen assembly comprises a shunt tube assembly with a second operational pressure rating less than the first operational pressure rating. In other embodiments, the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand

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screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

Transport tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a transport tube of the second sandscreen assembly.

Packing tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a packing tube of the second sandscreen assembly.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

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Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

A cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly.

A cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

The distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly.

The distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly.

The number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

The cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

The cross-sectional flow areas of the first and second transport tubes is substantially round.

The cross-sectional flow areas of the first and second transport tubes is substantially rectangular.

The cross-sectional flow areas of the first and second transport tubes is oval shaped.

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The second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

At least two screen assemblies each comprise a shunt tube assembly having first and second sets of transport tube and packing tubes, wherein each set of tubes extends from a junction block.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

The first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

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A method of installing a completion assembly in a wellbore has been described. The installation method may include installing a lower sand screen assembly having a low pressure shunt tube system in a wellbore adjacent a production zone; and attaching an upper sand screen assembly having a high pressure shunt tube system to the lower sand screen assembly upstream of the lower sand screen assembly. Other embodiments of the method may include installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system. Still yet other embodiments of the method may include installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent a production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies, wherein each first sand screen assembly has a low pressure shunt tube system and each second sand screen assembly has a high pressure shunt tube system. Yet other methods of the installation method may include identifying an elongated production zone having an upstream proximal end and a downstream distal end; determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure; determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end. Likewise, other installation methods may include identifying an elongated production zone wellbore portion having an upstream proximal end and a downstream distal end; selecting a high pressure shunt tube system based on a proximal end shunt tube system operating pressure; selecting a low pressure shunt tube system based on a distal end shunt tube system operating pressure; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end; introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

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For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

The high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

The high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

Introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

Injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

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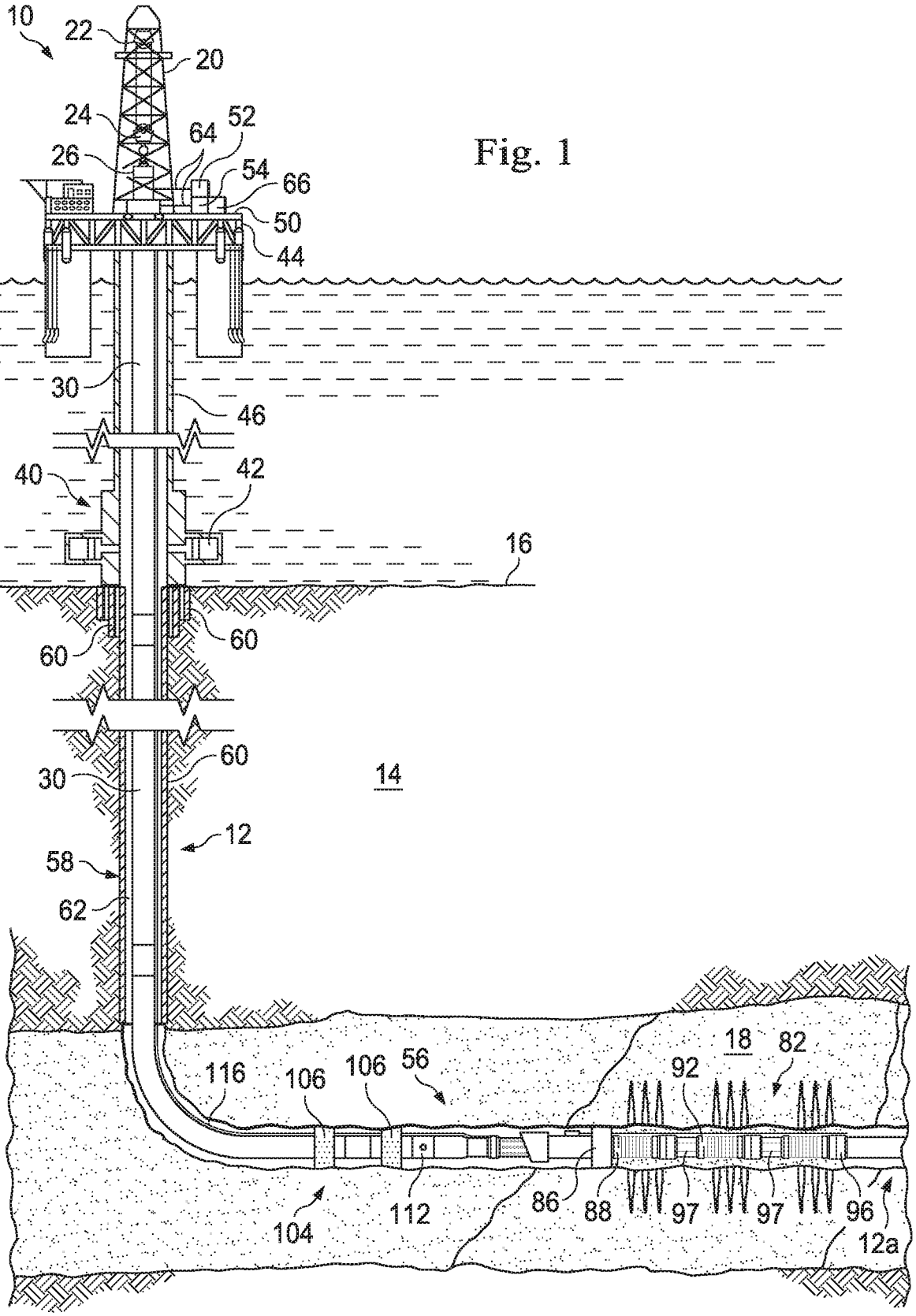
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Fig. 1

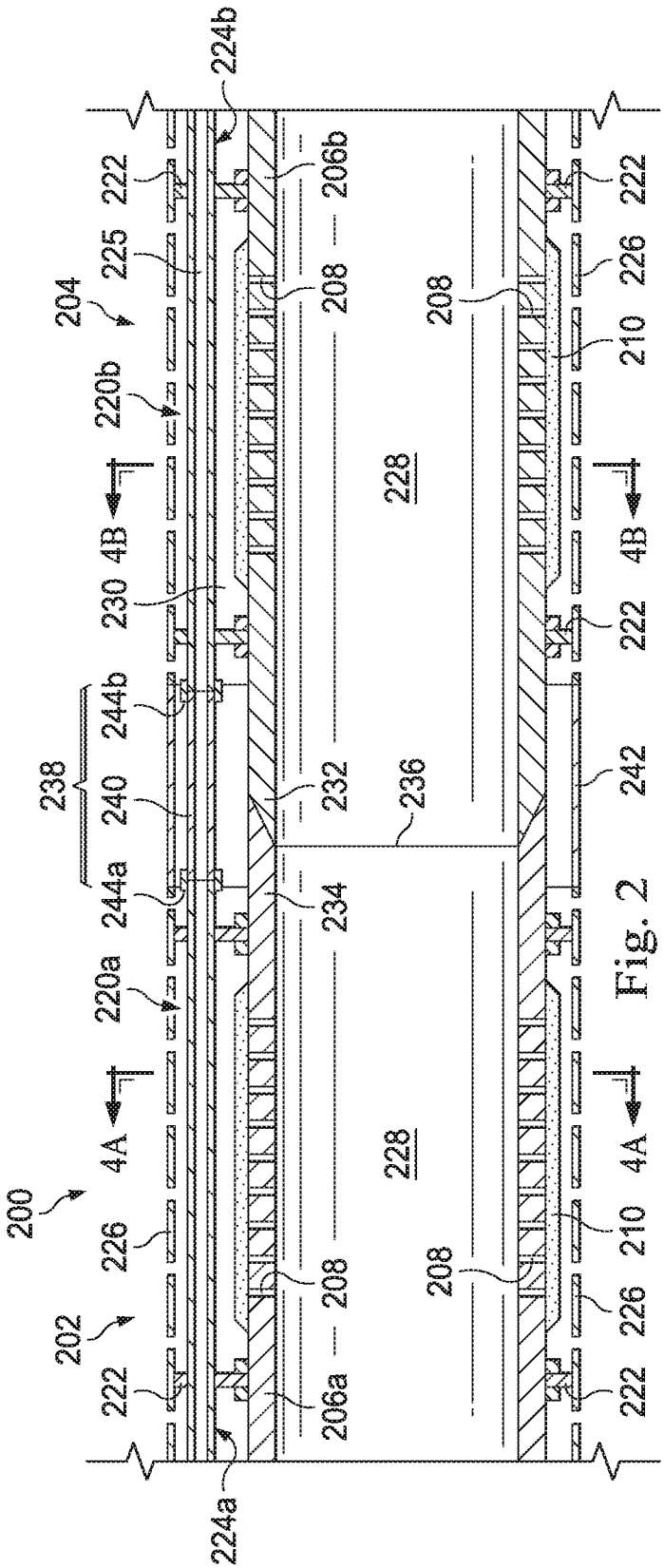
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Fig. 2

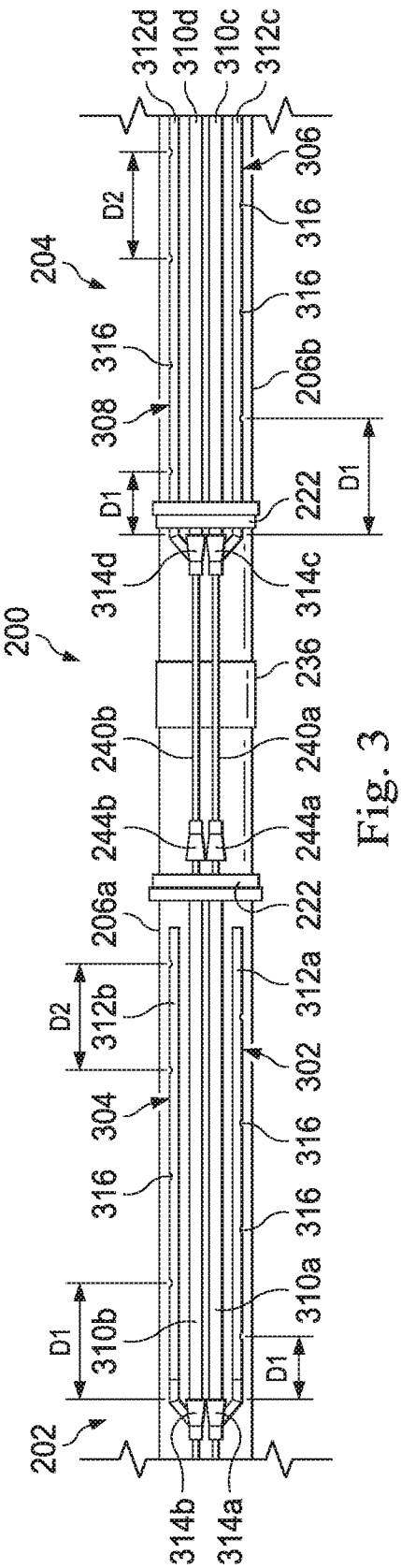
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Fig. 3

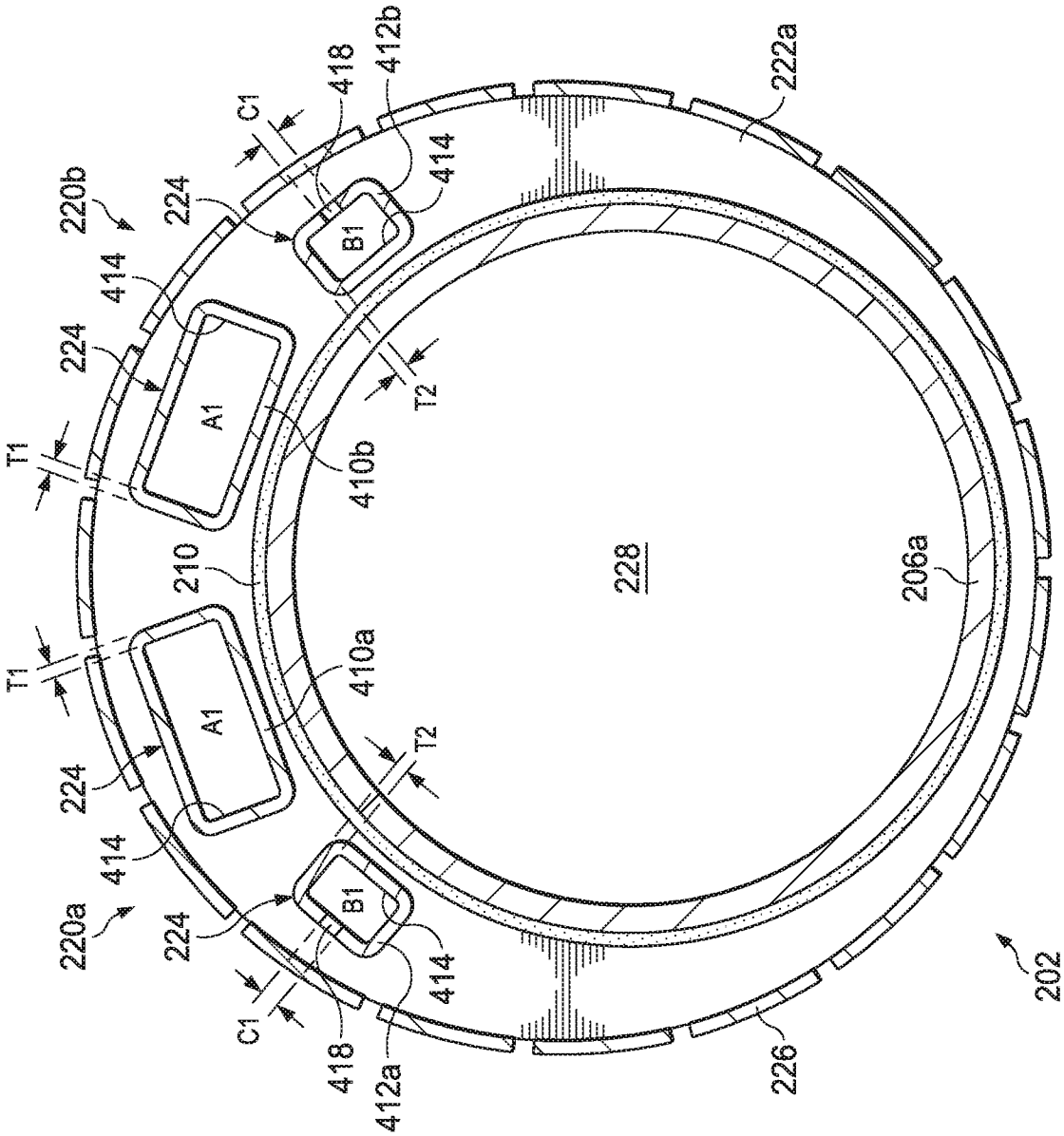
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Fig. 4A

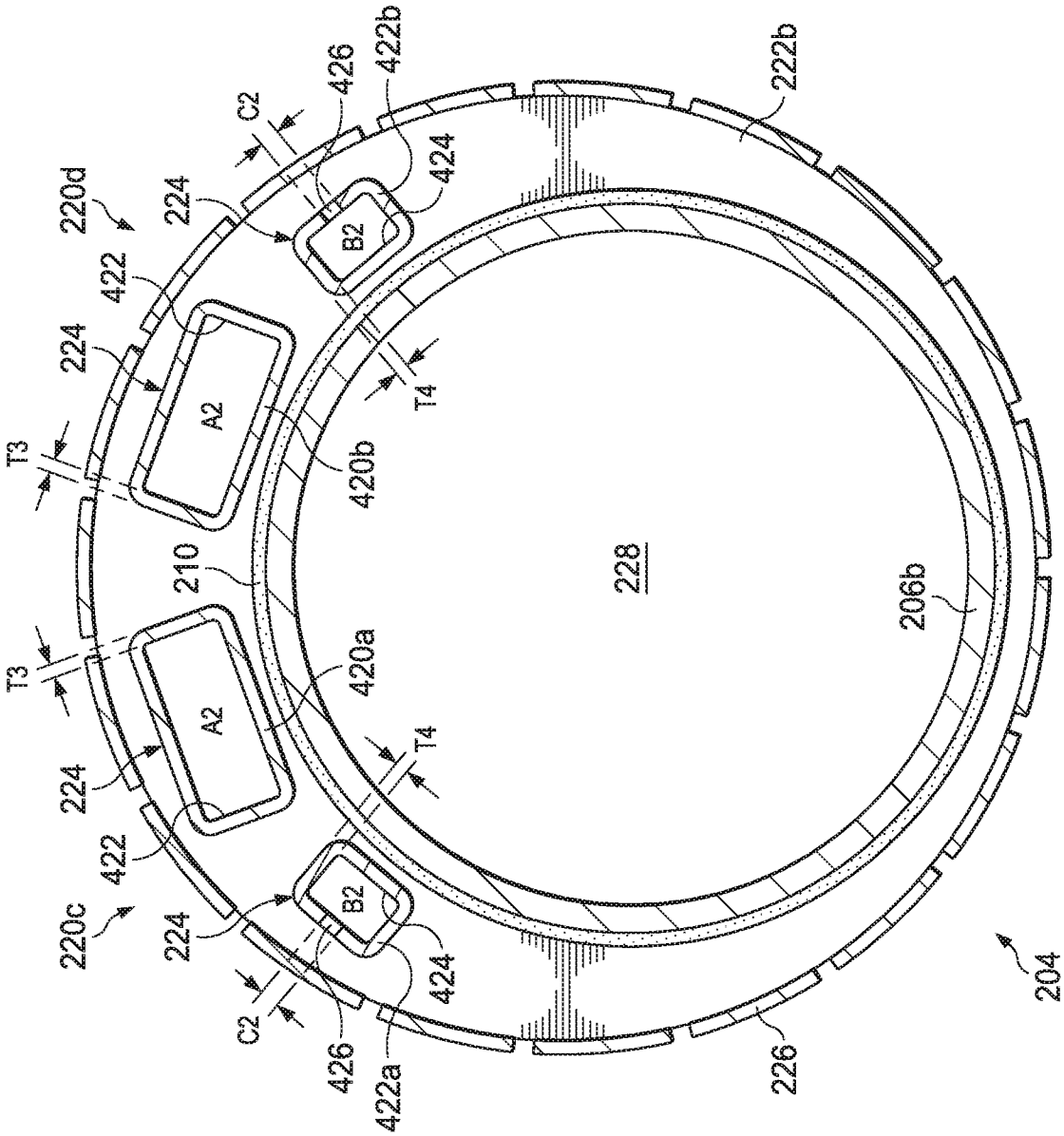
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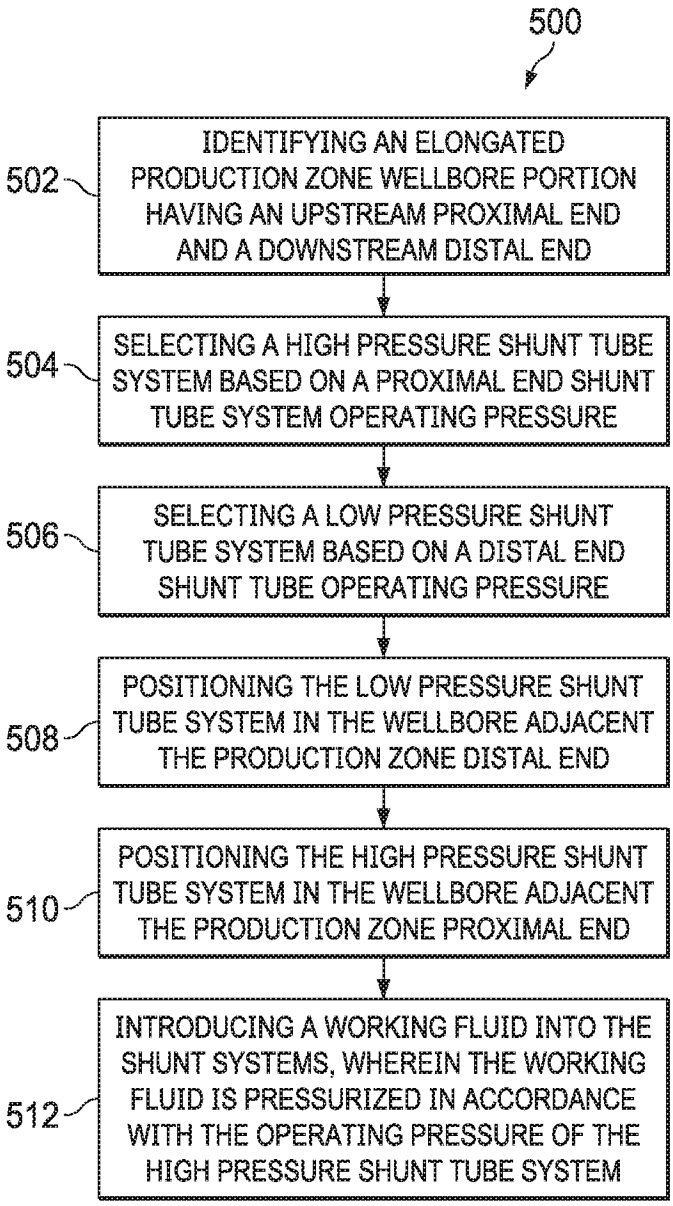
Fig. 4B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IDENTIFYING AN ELONGATED PRODUCTION ZONE WELLBORE PORTION HAVING AN UPSTREAM PROXIMAL END AND A DOWNSTREAM DISTAL END
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SELECTING A HIGH PRESSURE SHUNT TUBE SYSTEM BASED ON A PROXIMAL END SHUNT TUBE SYSTEM OPERATING PRESSURE
506
SELECTING A LOW PRESSURE SHUNT TUBE SYSTEM BASED ON A DISTAL END SHUNT TUBE OPERATING PRESSURE
508
POSITIONING THE LOW PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE DISTAL END
510
POSITIONING THE HIGH PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE PROXIMAL END
512
INTRODUCING A WORKING FLUID INTO THE SHUNT SYSTEMS, WHEREIN THE WORKING FLUID IS PRESSURIZED IN ACCORDANCE WITH THE OPERATING PRESSURE OF THE HIGH PRESSURE SHUNT TUBE SYSTEM

Fig. 5

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 62/688,813

filed on June 22, 2018.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Maxime Philippe COFFIN Date (Optional): _____

Signature: _____

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

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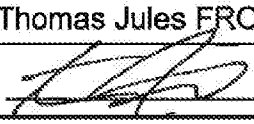
LEGAL NAME OF INVENTOR

Inventor: Thomas Jules FROSELL Date (Optional): 6/26/18

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Maxime	Philippe	Coffin	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Frisco	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	4115 E. Crescent Way		
Address 2			
City	Frisco	State/Province	TX
Postal Code	75034	Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Thomas	Jules	Frosell	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Dallas	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	8711 Boundbrook Avenue		
Address 2			
City	Dallas	State/Province	TX
Postal Code	75243	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	27683		
Email Address	ipdocketing@haynesboone.com	Add Email	Remove Email

Application Information:

Title of the Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING		
Attorney Docket Number	7523.1981US01	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	**Suggested Figure for Publication (if any)**	2

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	27683		

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	a 371 of international	PCT/US2019/024626	2019-03-28
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
PCT/US2019/024626	Claims benefit of provisional	62/688813	2018-06-22

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	Halliburton Energy Services, Inc.

Mailing Address Information For Applicant:

Address 1	3000 N. Sam Houston Parkway E.		
Address 2			
City	Houston	**State/Province**	TX
Country	US	Postal Code	77032
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
	Application Number	
Title of Invention	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Harold A. Borland/			Date (YYYY-MM-DD)	2019-05-06
First Name	Harold A.	Last Name	Borland	Registration Number	57854

Additional Signature may be generated within this form by selecting the Add button.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981US01
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REMARKS

NATIONALIZATION

This application represents the U.S. national stage filing of International Patent Application No. PCT/US2019/024626, filed on March 28, 2019.

As the text of the International Application was transmitted by the International Bureau, an additional copy is not required to satisfy 35 U.S.C. § 371(c)(2). Nonetheless, for the Examiner's convenience, a copy of the international application PCT/US2019/024626 as filed is enclosed. Additionally, a copy of the International Search Report and Written Opinion of the International Searching Authority is included.

After according a U.S. filing date, entry of the foregoing amendments is respectfully requested.

STATUS OF THE CLAIMS

Claims 1-23 are pending. As such, no new matter has been added as each claim is supported by the description.

FEES AND FORMALITIES

The national-stage filing and claims fees are provided for separately by credit card. Any fees required for any reason in connection with the present submission should be deducted from the undersigned's Deposit Account identified *supra*.

CONCLUSION

Should the Office have any questions or comments regarding this submission, the Examiner is invited to contact Applicants' undersigned representative at the number listed below.

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Authorization is hereby given to charge Deposit Account No. 08-1394, Order No. 7523.1981US01 for any deficiency of fees arising in connection with the present submission.

Respectfully submitted,

/Harold A. Borland/

Harold A. Borland
Registration No. 57,854

Date: May 6, 2019
HAYNES AND BOONE, LLP
2323 Victory Ave., Suite 700
Dallas, Texas 75219
Telephone: 713-547-2881
Facsimile: 214-200-0853
File: 7523.1981US01

Certificate of Transmission

I hereby certify that this correspondence is being transmitted via EFS-Web to the United States Patent and Trademark Office, on May 6, 2019.

/Delaunda N. Lanford/
Delaunda N. Lanford

AMENDMENTS TO THE SPECIFICATION

On page 1, please insert the following paragraph after PRIORITY:

The present application is a U.S. National Stage patent application of International Application No. PCT/US2019/024626, filed on March 28, 2019, which ~~**This application**~~ claims the benefit of U.S. provisional application no. 62/688,813, filed June 22, 2018**, both entitled "MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING," the disclosures of which are hereby incorporated by reference in their entirety**.

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989957

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

April 06, 2019

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: *62/688,813*
FILING DATE: *June 22, 2018*
RELATED PCT APPLICATION NUMBER: *PCT/US19/24626*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/688,813*

Certified by

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

DocCode – SCORE

SCORE Placeholder Sheet for IFW Content

Application Number: 62688813 Document Date: 06/22/2018

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

- Drawing

At the time of document entry (noted above):

- USPTO employees may access SCORE content via eDAN using the Supplemental Content tab, or via the SCORE web page.
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Form Revision Date: August 26, 2013

MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

FIELD OF INVENTION

The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies.

BACKGROUND

In the course of completing an oil and/or gas well, a string of production tubing can be run into the wellbore. During production of the formation fluid, formation sand may be swept into the flow path. The formation sand tends to be relatively fine sand that can erode production components in the flow path.

When formation sand is expected to be encountered, one or more lower production assemblies may be installed in the production zone between the formation and the production tubing. The lower production assemblies typically include a perforated base pipe surrounded by a sand screen to filter fines from the formation fluid. A packer is customarily set above the production assembly to seal off the annulus in the production zone where formation fluids flow into the production tubing. The annulus around the sand screen can then be "gravel packed" with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of carrier fluid such as water and/or gel and fills the annulus around the sand screen. In well installations in

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which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation. During the gravel packing process, a premature loss of the carrier fluid into the formation, known as leak-off, can occur, resulting in the formation of sand bridges in the annulus about the screening. With a premature loss of carrier fluid, incomplete packing around the sand screen and reduce the filtering efficiency of the gravel pack.

One conventional approach to overcoming this packing sand bridging problem has been to provide each production assembly with a series of shunt tubes that longitudinally extend through the sand screen section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the sand screen section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen assembly. The shunt path operates to permit the inflowing packing sand/gel slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing or screen/open hole annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

In instances where production zones are elongated, a plurality of lower completion assemblies may be deployed end to end to form a lower completion assembly string that may stretch for hundreds of feet. To ensure that gravel packing slurry is deposited along the entire length of the lower completion assembly string from its upstream end to the downstream end, particularly in deep wellbores and deviated wellbores, relatively high pressures must be applied to the carrier fluid. Thus, each individual lower completion assembly utilized in the overall string is designed

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to withstand the high delivery pressures experienced at the upstream end of the lower completion assembly string.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

FIG. 1 is a cut-away view of a wellbore system having a lower completion system disposed therein.

FIG. 2 is a partial cross-sectional view of a lower completion assembly.

FIG. 3 is a partial side view of an embodiment of a shunt tube assembly deployed on a base pipe of a lower completion assembly.

FIG. 4A is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A′ of FIG. 2.

FIG. 4B is a cross-sectional view of an embodiment of a shunt tube assembly along line B-B′ of FIG. 2.

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FIG. 5 is a method of installing in a wellbore a lower completion assembly having shunt tube systems with different pressure ratings.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the figures is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Moreover, even though a figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in wellbores having other orientations including, deviated wellbores, multilateral wellbores, or the like. Likewise, unless otherwise noted, even though a figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in onshore operations and vice-versa.

Generally, a lower completion assembly made up of at least two sand screen assemblies is provided, namely a first or upper sand screen assembly and a second or lower sand screen assembly. Each sand screen assembly includes a shunt system. Each shunt system includes a transport tube and a packing tube extending from a junction block. Each packing tube includes a plurality of nozzles spaced apart from the junction block and from each other. In one or more embodiments, the cross-sectional area of the transport tube in the first sand screen assembly is less than the cross-sectional area of the transport tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube in the first sand screen assembly is less than the cross-sectional area of the packing tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube nozzles in the first sand screen assembly is less than the cross-sectional area of the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between adjacent packing tube nozzles is greater in the

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first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. In one or more embodiments, the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

Turning to Figure 1, shown is an elevation view in partial cross-section of a wellbore production system 10 utilized to complete wells intended to produce hydrocarbons from wellbore 12 extending through various earth strata in an oil and gas formation 14 located below the earth's surface 16. Wellbore 12 may be formed of a single or multiple bores, extending into the formation 14, and disposed in any orientation, such as the horizontal wellbore 12a illustrated in Figure 1. Formation 14 includes production zones 18 from which hydrocarbons are produced.

Production system 10 includes a rig or derrick 20. Rig 20 may include a hoisting apparatus 22, a travel block 24, and a swivel 26 for raising and lowering casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings or other types of conveyance vehicles such as wireline, slickline, and the like 30. In Figure 1, conveyance vehicle 30 is a substantially tubular, axially extending work string or production tubing, formed of a plurality of pipe joints coupled together end-to-end supporting a completion assembly as described below.

Rig 20 may be located proximate to or spaced apart from wellhead 40, such as in the case of an offshore arrangement as shown in Figure 1. One or more pressure control devices 42, such as blowout preventers (BOPs) and other equipment associated with drilling or producing a wellbore may also be provided at wellhead 40 or elsewhere in the system 10.

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For offshore operations, as shown in Figure 1, rig 20 may be mounted on an oil or gas platform 44, such as the offshore platform as illustrated, semi-submersibles, drill ships, and the like (not shown). Although system 10 of Figure 1 is illustrated as being a marine-based production system, system 10 of Figure 1 may be deployed on land. In any event, for marine-based systems, one or more subsea conduits or risers 46 extend from deck 50 of platform 44 to a subsea wellhead 40. Tubing string 30 extends down from rig 20, through subsea conduit 46 and BOP 42 into wellbore 12.

A working or service fluid source 52, such as a storage tank or vessel, may supply, via flow lines 64, a working fluid to equipment disposed in wellbore 12, such as subsurface equipment 56. Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, gravel packing slurry, acidizing fluid, liquid water, steam or some other type of fluid.

Production system 10 may generally be characterized as having a pipe system 58. For purposes of this disclosure, pipe system 58 may include casing, risers, tubing, drill strings, completion or production strings, subs, heads or any other pipes, tubes or equipment that couples or attaches to the foregoing, such as string 30, conduit 46, and casing. In this regard, pipe system 58 may include one or more casing strings 60 that may be cemented in wellbore 12, such as the surface, intermediate and production casings 60 shown in Figure 1. An annulus 62 is formed between the walls of sets of adjacent tubular components, such as concentric casing strings 60 or the exterior of tubing string 30 and the inside wall of wellbore 12 or casing string 60, as the case may be. While wellbore 12 is shown as uncased in the production zone 18 and along the entire depicted portion of horizontal wellbore 12a, all or a portion of wellbore 12 and/or horizontal wellbore 12a may be cased as well and the disclosure is not limited in that regard.

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Production fluids and other debris returning to surface 16 from wellbore 12 are directed by a flow line 64 to storage tanks 54 and/or processing systems 66.

As shown in Figure 1, subsurface equipment 56 is illustrated as completion equipment and tubing string 30 in fluid communication with the completion equipment 56 is illustrated as production tubing 30. Although completion equipment 56 can be disposed in a wellbore 12 of any orientation, for purposes of illustration, completion equipment 56 is shown disposed in a substantially horizontal portion of wellbore 12 and includes a lower completion assembly 82 having various tools such as a packer 86, a sand screen assembly 88, a sand screen assembly 92, a sand screen assembly 96 and a packer 98. In embodiments where lower completion assembly 82 is deployed in a cased wellbore, an additional packer, such as packer 86, would be deployed at the distal end of the lower completion assembly. In the illustrated embodiment, packer 86 is generally located adjacent the upstream or proximal end of a production zone 18 and packer 98 is generally located adjacent the downstream or distal end of a production zone 18. Sand screen assemblies 88, 92 and 96 each include a shunt tube system 97 and are arranged so that the sand screen assembly having a shunt tube system with the highest operating pressure rating is upstream and the sand screen assembly having a shunt tube system with the lowest operating pressure rating is downstream. Thus, for example, in the illustrated embodiment sand screen assembly 88 includes a shunt tube assembly with a higher operating pressure than the shunt tube assembly of sand screen 96.

Disposed in wellbore 12 at the lower end of tubing string 30 is an upper completion assembly 104 that includes various tools such as a packer 106, and a fluid flow control module 112.

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Extending uphole from upper completion assembly 104 are one or more lines 116, such as hydraulic tubing, pressurized fluid tubing and the like which extends to the surface 16.

A cross-sectional view of an embodiment of a lower completion assembly 200 is shown in FIG. 2. Lower completion assembly is generally comprised of a first sand screen assembly 202 interconnected with a second sand screen assembly 204. In some embodiments, lower completion assembly 200 may be comprised of a plurality of interconnected first sand screen assemblies 202 at an upper portion of the lower completion assembly 200 and a plurality of interconnected second sand screen assemblies 204 at a lower portion of the lower completion assembly 200. Each sand screen assembly includes a base pipe 206 having a series of perforations 208 disposed therethrough, the base pipe 206 extending between a first end and a second end. A sand screen or filter media 210 is disposed about a portion of the base pipe 206 and the series of perforations 208 in order to screen incoming fluids from the formation. Each sand screen assembly also includes a shunt tube assembly 220 disposed outwardly of the filter media 220. Generally, shunt tube assembly 220 may include one or more retaining rings 222 supporting one or more shunt tubes 224 in the form of a transport tube or a packing tube disposed along and generally parallel to the base pipe 206. Shunt tubes 224 are tubular members having a passageway 225 defined therein with a cross-sectional flow area. While shown disposed outside of and generally parallel to the base pipe 206, other positions and alignment may be possible. An outer shroud 226 may be disposed about the base pipe 206, one or more shunt tubes 224, and filter media 210. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 224 and/or outer shroud 226 in position relative to the base pipe 206.

While the base pipe 206 is illustrated as being perforated in FIG. 2, the base pipe 206 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 228 and an exterior 230 of the screen assembly.

The filter media 210 may be disposed about the base pipe 206 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the base pipe 206. In an embodiment, the filter media 210 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a base pipe 206, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 210 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 210 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

The base pipe 206 may generally comprise a pin end 232 and a box end 234 to allow the base pipe 206 to be coupled to an adjacent base pipe 206. In the illustrated embodiment, base pipe 206a of first sand screen assembly 202 is coupled to base pipe 206b of second sand screen assembly 204 forming a joint 236. As such, the first sand screen assembly 202 and the second

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sand screen assembly 204 can be joined together end-to-end so that the respective base pipes are in fluid communication with one another along their throughbores 228. As can be seen in FIG. 2, each base pipe 206 may have a coupling section 238 that extends beyond the shunt tube assembly 220 of the respective sand screen assemblies. This exposed portion of the base pipe 206 may be used during the coupling process to allow one or more tools to engage the exposed portion for makeup of the first and second sand screen assemblies 202, 204.

Shunt tubes 224 of adjacent sand screen assemblies may be joined together in fluid communication by a jumper tube 240. In the illustrated embodiment, shunt tube 224a is interconnected to shunt tube 224b by jumper tube 240. An additional shroud 242 may be used to protect jumper tube 240. While the disclosure is not limited to a particular shape for shunt tubes 224 or jumper tubes 240, in some embodiments, shunt tubes 224 may have a non-round cross-section (as shown in FIGs. 3A and 3B), while jumper tubes 240 may have a round cross-section. In such case, the end of each jump tube may include an adaptor or coupling 244 to transition from the non-round cross-section of the shunt tube 224 to the round cross-section of the jumper tubes 240.

Although the particular shape of the tubes described herein are not a limitation in certain embodiments, shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple

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shunt tubes on adjacent wellbore tubular joints are generally round cross-section while the shunt tubes are non-round in cross-section.

With reference to FIG. 3, a side view of a lower completion assembly 200 is illustrated, with first sand screen assembly 202 interconnected with second sand screen assembly 204. In the illustrated embodiment, the filter media 210 and outer shrouds 226, 242 shown in FIG. 2 are removed to permit better illustration of the shunt tube assemblies. Additionally, the different types of shunt tubes 224 that comprise a shunt tube assembly 220 are illustrated in more detail. Specifically, in FIG. 3, base pipe assembly 206a is shown interconnected to base pipe assembly 206b at joint 236. First sand screen assembly 202 has two shunt tube assemblies 302 and 304. Likewise, second sand screen assembly 204 is illustrated with two shunt tube assemblies 306 and 308. Each shunt tube assembly described herein, including shunt tube assemblies 220 of FIG. 2, generally include a transport tube 310 and a packing tube 312 extending from a junction block 314 so as to be in fluid communication with one another.

As shown, the shunt tubes 310, 312 may form a branched structure from junction block 314 along the length of a sandscreen assembly 202 with the one or more transport tubes 310 forming the trunk line and the one or more packing tubes 312 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the sandscreen assembly 202. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended. Likewise, while junction block 314 is depicted as having only one inlet and two outlets, the disclosure is not limited to a particular junction block configuration. The "y-block" junction block depicted is for illustration purposes only unless

otherwise stated for a particular configuration. In this regard, in certain configurations, the shunt tube assembly may only comprise a junction block 314 having one inlet and two outlets as depicted.

Each packing tube 312 includes one or more nozzles 316. Each nozzle 316 is spaced apart from its respective junction block 314 a distance D1. Likewise, each nozzle 316 along a packing tube 312 may be spaced apart from adjacent nozzles a distance D2. The spacing D2 between nozzles 216 along a particular packing tube 312 may be the same or different. Likewise, the spacing D2 between nozzles 216 of shunt tube assemblies of the same sand screen assembly may be the same or different.

Also shown in FIG. 3 is a jumper tube 240a interconnecting shunt tube assembly 302 with a shunt tube assembly 306 and a jumper tube 240b interconnecting shunt tube assembly 204 with shunt tube assembly 308. A coupling 244a is provided at distal end of transport tube 310a to facilitate attachment of jumper tube 240a, while a coupling 244b is provided at distal end of transport tube 310b to facilitate attachment of jumper tube 240b. In particular, jumper tube 240a interconnects junction block 314c with coupling 244a at the distal end of transport tube 310a, thereby allowing fluid communication between upper or high pressure shunt tube assembly 302 and lower or low pressure shunt tube assembly 306. Likewise, jumper tube 240b interconnects junction block 314d with coupling 244b at the distal end of transport tube 310b, spanning joint 236 between the first sand screen assembly 202 and the second sand screen assembly 204.

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FIG. 4A illustrates a cross-sectional area A-A of first sand screen assembly 202 and shunt tubes 224a of FIG. 2 and FIG. 4B illustrates a cross-sectional area B-B of second sand screen assembly 204 and shunt tubes 224b of FIG. 2. As generally shown, the one or more shunt tubes 224 generally comprise tubular members disposed outside of and generally parallel to the base pipe 224. While described as tubular members (e.g., having substantially rectangular cross-sections), the one or more shunt tubes 224 may have shapes other cross-sectional shapes, such as round, elliptical, kidney shaped, and/or trapezoidal in shape. The retaining rings 222 may retain the shunt tubes 224 in position relative to the base pipe 206. The one or more shunt tubes 224 may be eccentrically aligned with respect to the base pipe 206 as best seen in FIG. 2. In each of FIGS. 4A and 4B, four shunt tubes 224 are arranged to one side of the base pipe 206. While illustrated in FIGS. 2 and 4 as having an eccentric alignment, other alignments of the one or more shunt tubes about the base pipe 206 may also be possible.

In FIG. 4A, first sand screen assembly 202 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 410 and a packing tube 412. Each transport tube 410 has a cross-sectional flow area A1 bounded by a wall 414 of thickness T1. Likewise, each packing tube 412 has a cross-sectional flow area B1 bounded by a wall 416 of thickness T2. Each packing tube further includes one or more nozzles 418 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 418 may be in the form of a perforation or opening in wall 416 or a short tube with a taper or constriction. Nozzle 418 is characterized by a cross-sectional flow area C1.

Similarly, in FIG. 4B, second sand screen assembly 204 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 420 and a packing tube 422. Each transport tube 420 has a cross-sectional flow area A2 bounded by a wall 422 of thickness T3. Likewise, each packing tube 422 has a cross-sectional flow area B2 bounded by a wall 424 of thickness T4. Each packing tube further includes one or more nozzles 4426 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 426 may be in the form of a perforation or opening in wall 424 or a short tube with a taper or constriction. Nozzle 426 is characterized by a cross-sectional flow area C2.

In one or more embodiments, the cross-sectional flow area A1 of the transport tube 410 of first sand screen assembly 202 is less than the cross-sectional flow area A2 of the transport tube 420 of the second sand screen assembly 204. In other words, the downstream sand screen assembly transport tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly transport tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area B1 of the packing tube 412 of first sand screen assembly 202 is less than the cross-sectional flow area B2 of the packing tube 422 of the second sand screen assembly 204. In other words, the downstream sand screen assembly packing tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly packing tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area C1 of a nozzle 418 of first sand screen assembly 202 is less than the cross-sectional flow area C2 of a nozzle 426 of the second sand screen assembly 204. In other words, the downstream sand screen assembly shunt tube nozzles which are closest to the distal end of the production zone, have a larger cross-sectional flow area than the upstream sand screen assembly shunt tube nozzles closest to the proximal end of the production zone.

In one or more embodiments, the packing tube assembly 412 of the first sand screen assembly 202 has fewer nozzles 418 than the number of nozzles 426 of the packing tube assembly 422 of the second sand screen assembly 204.

Referring back to FIG. 3, in one or more embodiments, the distance D1 of the first nozzle 316 of packing tube assembly 312a from the junction block 314a is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312c from the junction block 314c for the interconnected shunt tube assemblies 302 and 306. Likewise, the distance D1 of the first nozzle 316 of packing tube assembly 312b from the junction block 314b is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312d from the junction block 314d for the interconnected shunt tube assemblies 304 and 308.

Similarly, in one or more embodiments, the distance D2 between adjacent nozzle 316 of packing tube assembly 312a of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312c of the second sand screen assembly 204 for interconnected shunt tube assemblies 302 and 306. Likewise, the distance D2 between adjacent

nozzle 316 of packing tube assembly 312b of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312d of the second sand screen assembly 204 for interconnected shunt tube assemblies 304 and 308.

While each of the different geometries of a shunt tube assembly have been described, it will be appreciated that any one or more of the geometries can be combined to achieve the desired flow regime for a particular shunt tube assembly. In some cases, certain of the geometries will remain the same. For example, the transport tubes 410 and 420 may be the same with the same flow areas A1, A2, but the geometries of the respective packing tubes 412, 244 may differ in number of nozzles and/or cross-sectional flow areas B1, B2 and/or nozzle spacing along the respective packing tubes.

Traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the same pressure rating. In this regard, the shunt tube assemblies are selected based on the expected operating conditions of the shunt tube assemblies. For shorter gravel packing intervals, the gravel pack slurry flows into the wellbore annulus at about the same fluid pressure along the length of the interval. Of course, as gravel pack intervals have increased, an increased operating pressure is needed to ensure that gravel pack slurry flows along the entire length of the gravel pack interval. Thus, as gravel pack intervals increase, it has been necessary to employ shunt tube assemblies with increased operating pressure ratings or burst pressures, resulting in heavier and/or bulkier tubing and components to ensure that the shunt tube assemblies will not be subject to burst pressure. Since shunt tube assemblies for an

entire lower production assembly are selected based on the highest operating pressure expected to be required across the entire length of the gravel packing interval, individual sand screen assemblies in a lower production assemblies have become increasingly heavier. However, as the slurry flows from the upstream portion of these elongated production zone to the downstream portion of the production zone, the pressure of the slurry drops off. As such, only the shunt tube assemblies deployed adjacent the upper portion of the production zone experience the highest pressures.

In addition, because of the high pressure experienced by shunt tube assemblies at the upper or upstream end of such lower production assemblies deployed in elongated production zones, there is a tendency for greater leak-off in the upstream portion of the production zone.

These drawbacks are addressed by above-described lower production assembly where the shunt tube system flow regime in the second sand screen assembly 204 is selected to allow a larger volume of fluid to flow therethrough than that of the first sand screen assembly 202 by adjusting cross-sectional flow areas, location and number of nozzles. In this regard, the geometries of the shunt tube assemblies 220 of the first sand screen assembly 202 may be selected to have a higher operating pressure than the shunt tube assemblies 220 of the second sandscreen assembly 204. For example, the thickness T1 of walls 414 of transport tube 410 may be greater than thickness T3 of wall 422. Likewise, the thickness T2 of wall 416 of packing tube 412 may be greater than the thickness T4 of wall 424 of packing tube 422. As such, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 may be selected to have an operating pressure at or above a select threshold, while the shunt tube assemblies 220 of the second sandscreen assembly

204 may be selected to have an operating pressure at or below a select threshold. In one or more embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure or are otherwise rated at over 5000 psi while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 5000 psi. In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating or are otherwise rated between 5000 and 10000 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 4000 psi. More broadly, it will be appreciated that the first and second sandscreen assemblies 202, 204 have different shunt tube assembly operating pressure ratings, with the shunt tube assembly 220 of the first sandscreen assembly 202 having a higher operating pressure rating than the shunt tube assembly 220 of the second sandscreen assembly 204.

In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating of between approximately 6,500 to 7,500 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure of approximately 3,500 to 3,750 psi. In certain embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have are rated at or have an operating pressure of approximately 10,000 psi. In other words, the shunt tube assemblies upstream are selected to have a higher burst pressure than the shunt tube assemblies downstream in the overall lower production assembly.

Turning to FIG. 5, a method 500 of installing a completion assembly in a wellbore is generally illustrated. In a first step 502, a portion of the wellbore passing through a production zone to be

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gravel packed is identified for placement of a lower production assembly. The production zone portion of the wellbore can be characterized as having an upstream proximal end closest to the wellhead along the wellbore measured depth (MD) and a downstream distal end farthest from the wellhead in terms of MD. In step 504, the surface injection pressure necessary to deliver a gravel packing slurry to the most distal end of the production zone portion of the wellbore is determined, and based on this injection pressure, a high pressure shunt tube system to be positioned adjacent the proximal end of the production zone portion of the wellbore is selected for incorporation in a first or upstream sand screen assembly as described above. In step 506, the anticipated gravel pack slurry pressure at the distal end of the production zone portion of the wellbore is calculated, and based on this anticipated pressure, a low pressure shunt tube system to be positioned adjacent the distal end of the production zone portion of the wellbore is selected for incorporation in a second or downstream sand screen assembly as described above. Having selected the two sandscreen assemblies with their respective relative high pressure and low pressure shunt tube systems, the lower completion assembly can be made up into a tubing string by joining the first and second sandscreen assemblies together. In this regard, the base pipes of the assemblies are interconnected, and likewise, as described above, adjacent shunt tube assemblies are interconnected using jump tubes to establish fluid communication therebetween. In particular, the packing tube of an upstream sand screen assembly is interconnected to the shunt tube junction block of a downstream sandscreen assembly.

It will be appreciated that in one or more embodiments, the lower completion assembly will be made up of a plurality of sand screen assemblies, each carrying one or more shunt tube assemblies. In such case, it will be necessary to estimate the grave pack slurry injection pressure

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profile along the length of the production zone portion of the wellbore, and then select the appropriate number of first or second sandscreen assemblies for makeup into the tubing string, it being understood at used here that "first" sandscreen assemblies refers to those sandscreen assemblies with a high pressure shunt system and "second" sandscreen assemblies refers to those sandscreen assemblies with a low pressure shunt system. For example, a lower production assembly may be comprised of 10 first sandscreen assemblies and 15 second sandscreen assemblies, all joined end-to-end to form the tubing string.

In any event, once lower production assembly having the desired number of first and second sandscreen assemblies is assembled, the lower production assembly is installed in the production zone portion of the wellbore. In so doing, at step 508, the second sandscreen assembly is deployed at the distal end of the wellbore portion so that the low pressure shunt tube system is positioned in the wellbore adjacent the production zone distal end. Likewise, in step 510, in positioning the low pressure shunt tube system, the first sandscreen assembly is deployed at the proximal end of the wellbore portion. In so doing, the high pressure shunt tube system is accordingly positioned adjacent the production zone proximal end.

Lastly, in step 512, a working fluid, such as a gravel pack slurry, gel or other desired fluid, is pumped into the interconnected shunt tube assemblies. The working fluid may be pressurized in accordance with the operating pressure of the high pressure shunt tube system deployed adjacent the upper end of the wellbore production zone. Because the pressure of the working fluid drops along the length of the production zone, only those "first" sandscreen assemblies are subjected to the higher pressure working fluid, whereas the "second" sandscreen assemblies are only subject

to the lower pressure working fluid. Moreover, in certain embodiments, because of the shunt tube system geometry of the "first" sandscreen assemblies, leak-off at the higher pressure is minimized in the upper sandscreen assemblies, thereby minimizing the likelihood of blockage along the shunt tube system or in the gravel pack adjacent the packing tubes. In any event, the working fluid is pumped into the interconnected shunt tube assemblies and injected via the nozzles of the packing tubes into the annulus around the lower production assembly. To the extent the working fluid is a gravel pack slurry, a gravel pack is formed around the lower production assembly so as to support the formation and/or filter production fluids before introduction into the production tubing of the system.

1. Thus, a wellbore completion assembly has been described. The completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced

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apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid

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communication with one another; and wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly. Other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. Still yet other embodiments of the wellbore completion assembly may include a first sand screen

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assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. Still yet other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway

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defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi. Other embodiments of the wellbore completion assembly may include a plurality of first sand

screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi. In other embodiments, the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first operational pressure rating and the second sand screen assembly comprises a shunt tube assembly with a second operational pressure rating less than the first operational pressure rating.

For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

The cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

The cross-sectional flow areas of the first and second transport tubes is substantially round.

The cross-sectional flow areas of the first and second transport tubes is substantially rectangular.

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The cross-sectional flow areas of the first and second transport tubes is oval shaped.

The second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

At least two screen assemblies each comprise a shunt tube assembly having first and second sets of transport tube and packing tubes, wherein each set of tubes extends from a junction block.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 5000 psi.

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The first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

A method of installing a completion assembly in a wellbore has been described. The installation method may include installing a lower sand screen assembly having a low pressure shunt tube system in a wellbore adjacent a production zone; and attaching an upper sand screen assembly having a high pressure shunt tube system to the lower sand screen assembly upstream of the lower sand screen assembly. Other embodiments of the method may include installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system. Still yet other embodiments of the method may include installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent a production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies, wherein each first sand screen assembly has a low pressure shunt tube system and each second sand screen assembly has a high pressure shunt tube system. Yet other methods of the installation method may include identifying an elongated production zone having an upstream proximal end and a downstream distal end; determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure; determining a shunt tube system operating pressure

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associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end. Likewise, other installation methods may include identifying an elongated production zone wellbore portion having an upstream proximal end and a downstream distal end; selecting a high pressure shunt tube system based on a proximal end shunt tube system operating pressure; selecting a low pressure shunt tube system based on a distal end shunt tube system operating pressure; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end; introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

The high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

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The high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

Introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

Injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

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CLAIMS

2. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

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wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly.

3. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

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wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

4. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

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wherein the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly.

5. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

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wherein the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly.

6. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

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wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

7. The completion assembly of claims 1-5, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

8. The completion assembly of claims 1-5, wherein the cross-sectional flow areas of the first and second transport tubes is substantially round.

9. The completion assembly of claims 1-5, wherein the cross-sectional flow areas of the first and second transport tubes is substantially rectangular.

10. The completion assembly of claims 1-5, wherein the cross-sectional flow areas of the first and second transport tubes is oval shaped.

11. The completion assembly of claim 1-9, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

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12. The completion assembly of claim 1-9, wherein at least two screen assemblies each comprise a shunt tube assembly having first and second sets of transport tube and packing tubes, wherein each set of tubes extends from a junction block.

13. The completion assembly of claim 1-9, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

14. The completion assembly of claim 1-9, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 4000 psi.

15. The completion assembly of claim 1-9, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

16. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first operational pressure rating and the second sand screen assembly comprises a shunt tube

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assembly with a second operational pressure rating less than the first operational pressure rating.

17. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

18. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi.

19. A completion assembly for deployment in a wellbore, the completion assembly comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

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20. A method of installing a completion assembly in a wellbore, the method comprising: installing a lower sand screen assembly having a low pressure shunt tube system in a wellbore adjacent a production zone; and attaching an upper sand screen assembly having a high pressure shunt tube system to the lower sand screen assembly upstream of the lower sand screen assembly.

21. A method of installing a completion assembly in a wellbore, the method comprising: installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system.

22. A method of installing a completion assembly in a wellbore, the method comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent a production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies, wherein each first sand screen assembly has a low pressure shunt tube system and each second sand screen assembly has a high pressure shunt tube system.

23. A method of installing a completion assembly in a wellbore, the method comprising: identifying an elongated production zone having an upstream proximal end and a downstream distal end;

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determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system;

positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and

positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end.

24. A method of installing a completion assembly in a wellbore, the method comprising:

identifying an elongated production zone wellbore portion having an upstream proximal end and a downstream distal end;

selecting a high pressure shunt tube system based on a proximal end shunt tube system operating pressure;

selecting a low pressure shunt tube system based on a distal end shunt tube system operating pressure;

positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end;

positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end;

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introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

25. The method of claims 16-23, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

26. The method of claims 16-23, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

27. The method of claim 16-22, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

28. The method of claims 16-23, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

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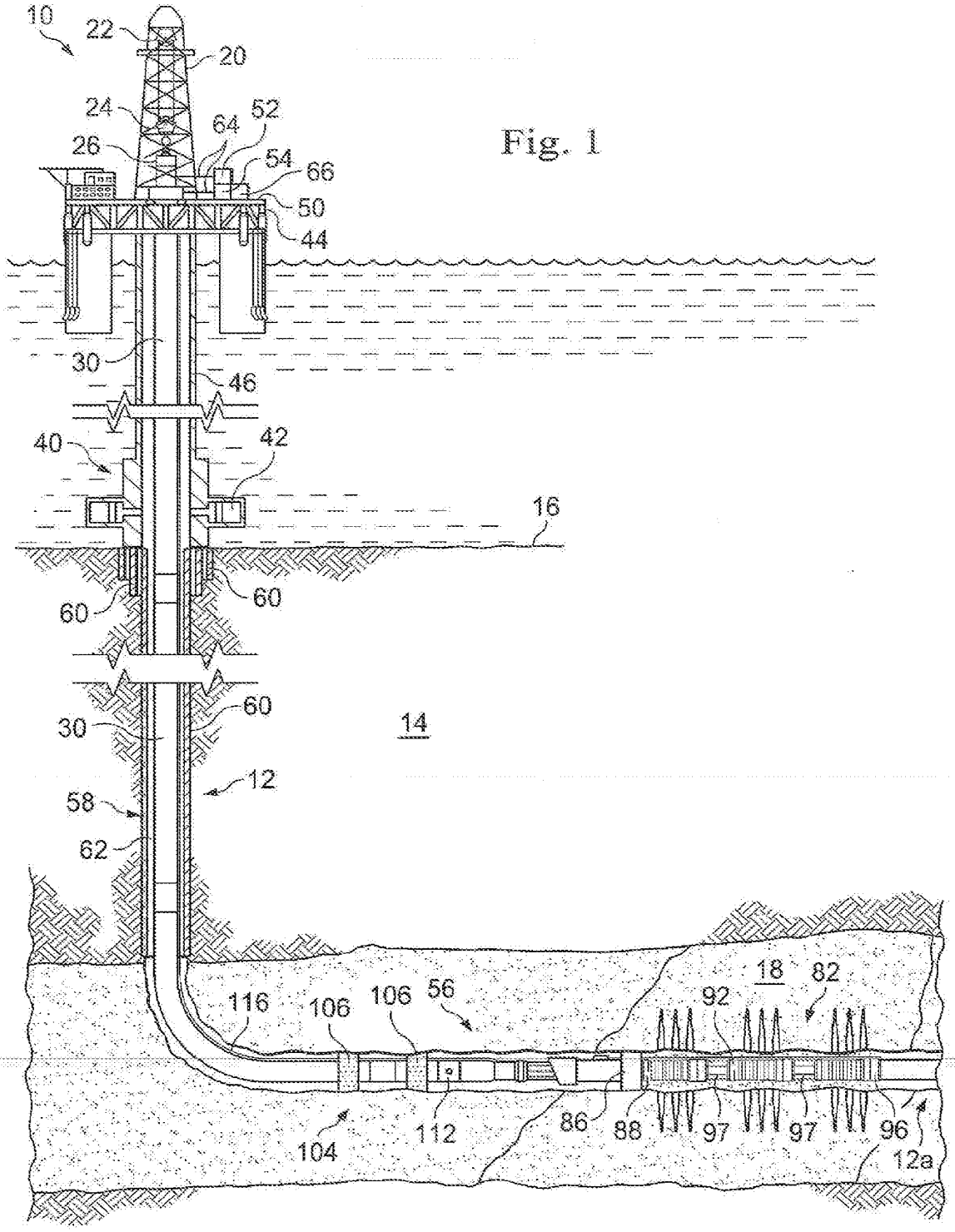
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Fig. 1

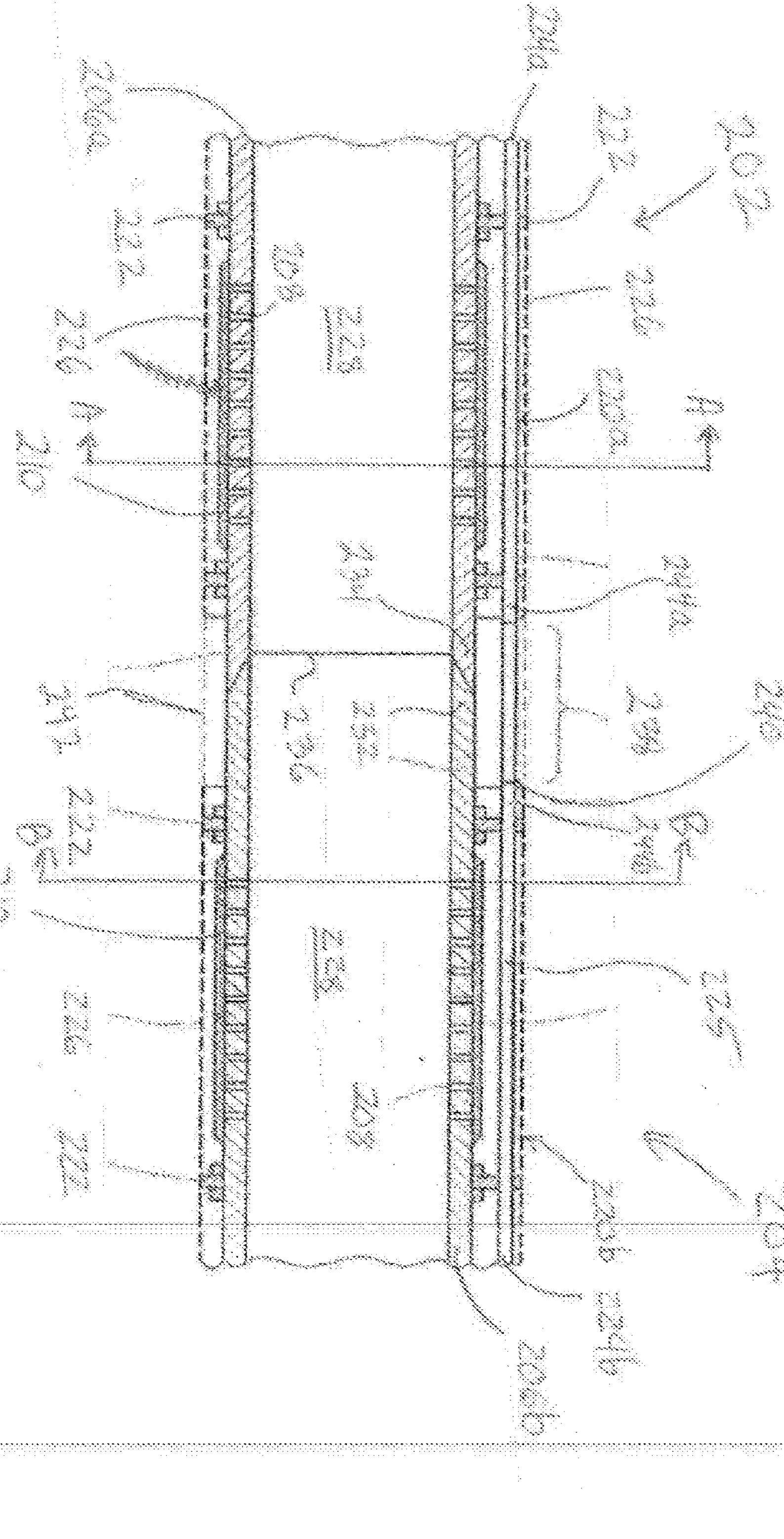
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FIG. 2

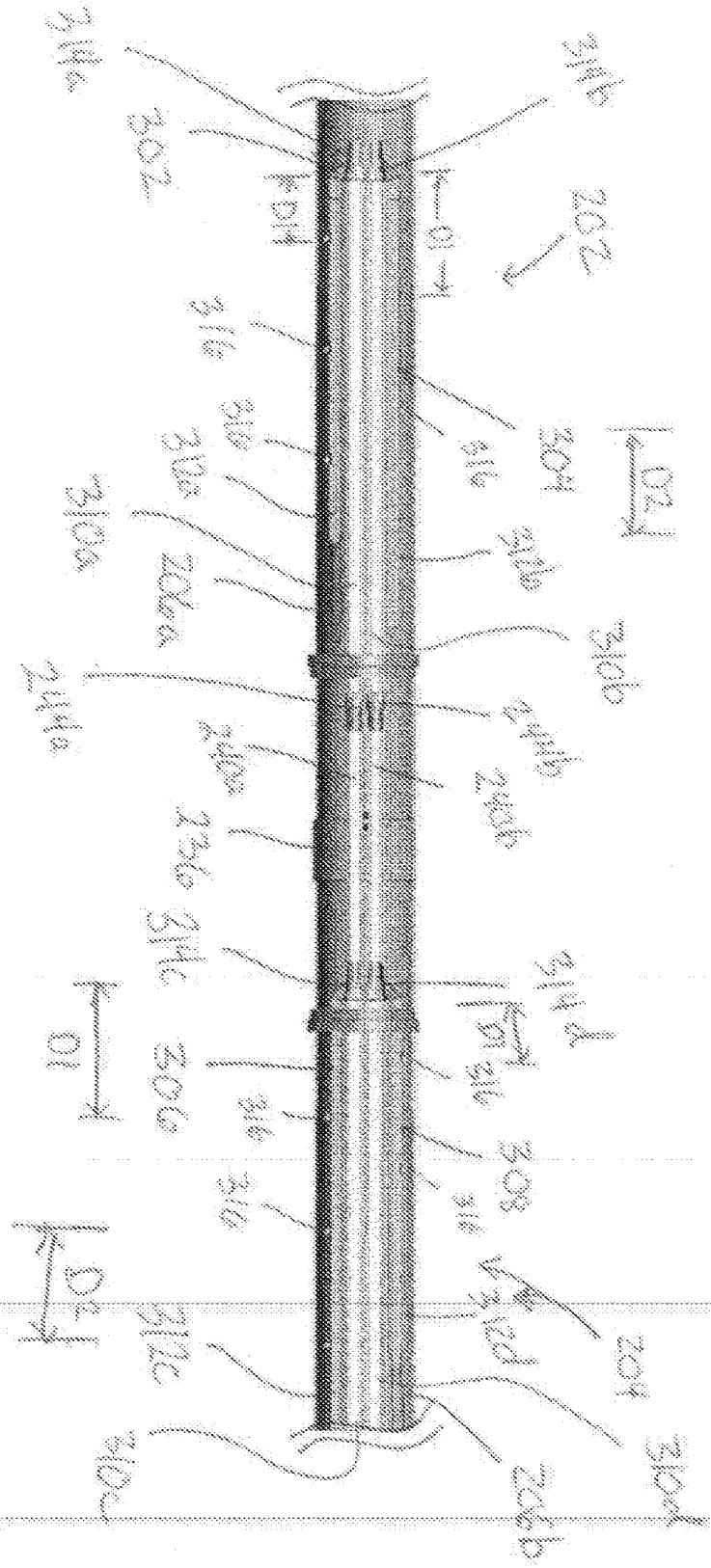
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FIG. 3

FIG 4A
FIG 4B

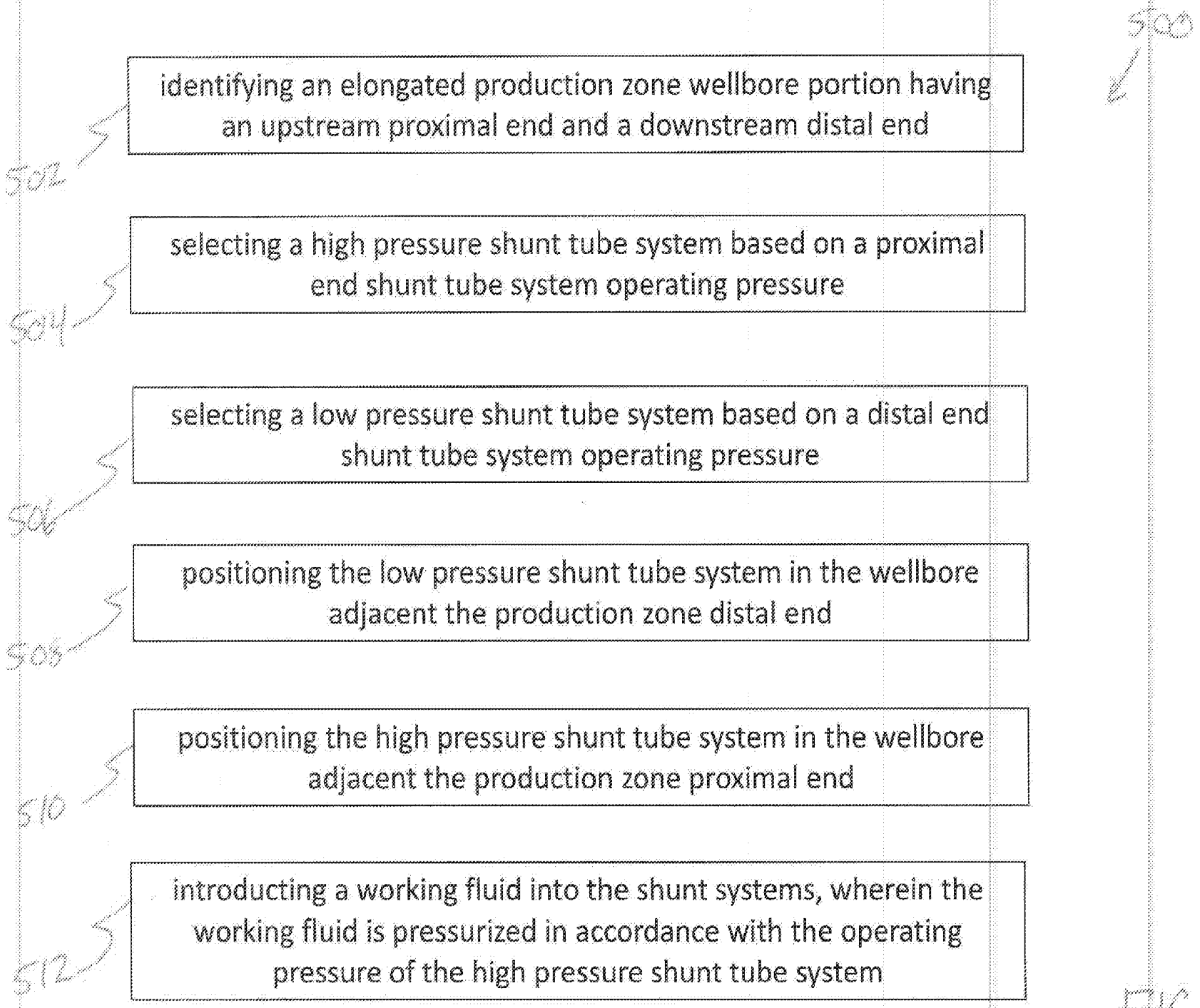

FIG. 5

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Maxime	Philippe	Coffin	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Frisco	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	4115 E. Crescent Way
Address 2	

City	Frisco	State/Province	TX
Postal Code	75034	Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Thomas	Jules	Frosell	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Dallas	State/Province	TX	Country of Residence	US

Mailing Address of Inventor:

Address 1	8711 Boundbrook Avenue
Address 2	

City	Dallas	State/Province	TX
Postal Code	75243	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	27683		
Email Address	ipdocketing@haynesboone.com	Add Email	Remove Email

Application Information:

Title of the Invention	Multiple Shunt Pressure Assembly for Gravel Packing		
Attorney Docket Number	7523.1981PV01	**Small Entity Status Claimed**	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	27683		

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:	
If the Applicant is an Organization check here.	☒
Organization Name	Halliburton Energy Services, Inc.

Mailing Address Information For Applicant:

Address 1	3000 N. Sam Houston Parkway E.		
Address 2			
City	Houston	**State/Province**	TX
Country	US	Postal Code	77032
Phone Number		Fax Number	
Email Address			

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

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Signature	/Mark A. Tidwell/			Date (YYYY-MM-DD)	2018-06-22
First Name	Mark A.	Last Name	Tidwell	Registration Number	37,456

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	7523.1981PV01
	Application Number	
Title of Invention	Multiple Shunt Pressure Assembly for Gravel Packing	

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EFS ID:	32982097
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Title of Invention:	Multiple Shunt Pressure Assembly for Gravel Packing
First Named Inventor/Applicant Name:	Maxime P. Coffin
Customer Number:	27683
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		7523-1981PV01_PatentApplication.pdf	181645 724d661cc5681d35a2168a1316e27e6c1dd85f77	yes	42
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Specification		1	31	
	Claims		32	42	
Warnings:					
Information:					
2	Drawings-other than black and white line drawings	7523-1981PV01_Drawings.pdf	2597930 2d0dcf1b0eeaa6aad36817359ae21cb4bb71a01f	no	5
Warnings:					
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3	Application Data Sheet	7523-1981PV01_ADS.pdf	1254643 cf557c868168eba9686028d5ba42a8251346657c	no	7
Warnings:					
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4	Fee Worksheet (SB06)	fee-info.pdf	30316 b9cb477c9edb8ee35aca369b6db6605caa0de7a6	no	2
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(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 3000 N. Sam Houston Parkway E., Houston, Texas 77032-3219 (US).

(72) Inventors: **COFFIN, Maxime Philippe**; 4115 E Crescent Way, Frisco, Texas 75034 (US). **FROSELL, Thomas Jules**; 8711 Boundbrook Ave., Dallas, Texas 75243 (US).

(74) Agent: **TIDWELL, Mark** et al.; Haynes and Boone, LLP, 2323 Victory Avenue, Suite 700, Dallas, Texas 75219 (US).

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

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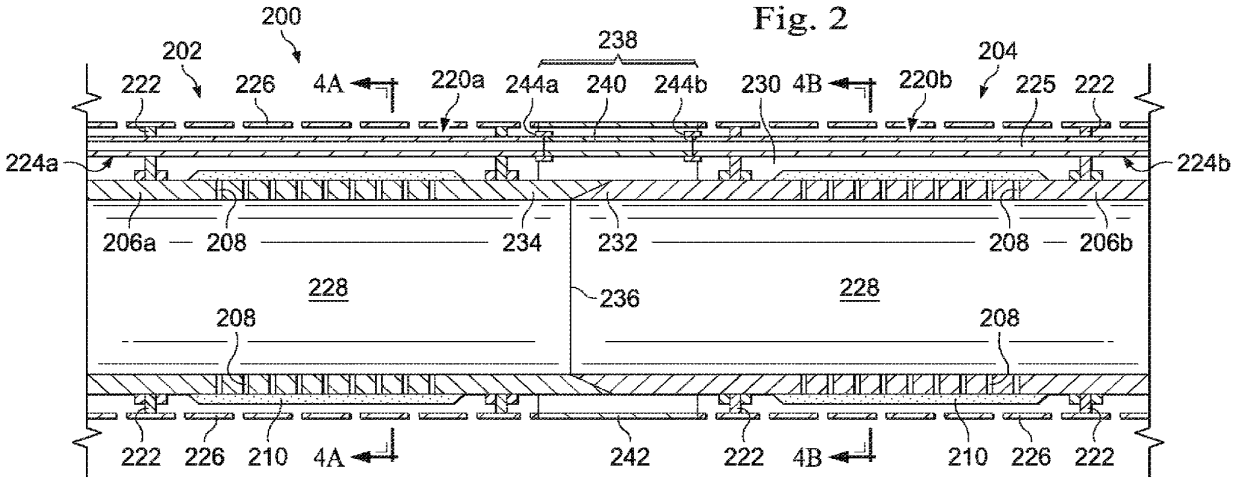
(54) Title: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Fig. 2



(57) Abstract: The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies. A completion assembly for deployment in a wellbore, comprises a first sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, and a second sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, wherein the first and second sand screen assemblies are arranged end to end relative to one another. And the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

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CLAIMS

What is claimed is:

1. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

2. The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

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3. The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

4. The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

5. The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

6. The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

7. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

8. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 4000 psi.

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9. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

10. The completion assembly of claim 1, wherein a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

11. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

12. The completion assembly of claim 11, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi.

13. The completion assembly of claim 11, further comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

14. A method of installing a completion assembly in a wellbore, the method comprising: installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system.

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15. The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies.

16. The method of claim 14, further comprising:

identifying an elongated production zone having an upstream proximal end and a downstream distal end;

determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting the high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting the low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system;

positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and

positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end.

17. The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

18. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

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19. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

20. The method of claim 17, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

21. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

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22. The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

23. The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first pressure rating.

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I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

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OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

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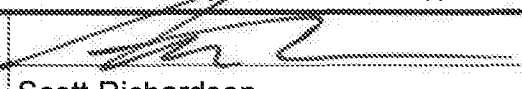
Assignee Name and Address: Halliburton Energy Services, Inc.
3000 N. Sam Houston Parkway E.
Houston, Texas 77032

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be Filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of The practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record
The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	May 9, 2019
Name	Scott Richardson	Telephone	
Title	Senior Counsel		

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STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Coffin

Application No./Patent No.: 16/347711 Filed/Issue Date: May 6, 2019

Titled: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Halliburton Energy Services, Inc., a corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. [✓] The assignee of the entire right, title, and interest.

2. [ ] An assignee of less than the entire right, title, and interest (check applicable box):

   [ ] The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   [ ] There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. [ ] The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

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[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature

May 9, 2019
Date

Scott Richardson
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Title or Registration Number

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(use as many sheets as necessary)*				Application Number	16/347711
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				Art Unit	TBD
				Examiner Name	TBD
SHEET	1	OF	1	Attorney Docket Number	7523.1981US01

U. S. PATENTS

Examiner's Initials	Cite No.	Document Number	Issue Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document

U. S. PATENT APPLICATION PUBLICATIONS

Examiner's Initials	Cite No.	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document
	A1	2003/0029613 A1	02-13-2003	Danos et al.
	A2	2010/0139919 A1	06-10-2010	Yeh et al.
	A3	2013/0008652 A1	01-10-2013	Broussard et al.
	A4	2014/0110131 A1	04-24-2014	Cunningham et al.

FOREIGN PATENT DOCUMENTS

Examiner's Initials	Cite No.	Foreign Patent Document (Country Code – Number – Kind)	Publication Date MM-DD-YYYY	Patentee or Applicant of Cited Document	Translation Y/N
	B1	WO 2013/187878 A1	12-19-2013	Halliburton Energy Services, Inc.	

NON-PATENT LITERATURE DOCUMENTS

Examiner's Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article, title of the item, date, page(s), volume-issue number(s), publisher, city/country where published
	C1	International Search Report and Written Opinion issued for International Patent Application No. PCT/US2019/024626, dated August 7, 2019, 20 pages.

Examiner Signature		Date Considered	

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(71) Applicant *(for all designated States except US)*: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 10200 Bellaire Boulevard, Houston, Texas 77072 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **CUNNINGHAM, Gregory Scott** [US/US]; 532 Chasewood Drive, Grapevine, Texas 76051 (US). **LEAST, Brandon Thomas** [US/US]; 3218 Jubilee Trail, Dallas, Texas 75229 (US). **GRECI, Stephen Michael** [US/US]; 4416 San Mateo Lane, McKinney, Texas 75070 (US). **LOPEZ, Jean Marc** [FR/US]; 7308 Stoddard Lane, Piano, Texas 75025 (US). **VEIT, Jan** [CZ/US]; 3201 Dover Drive, Piano, Texas 75075 (US).

(74) Agent: **CONLEY ROSE, P.C.**; 5601 Granite Parkway, Suite 750, Piano, Texas 75024 (US).

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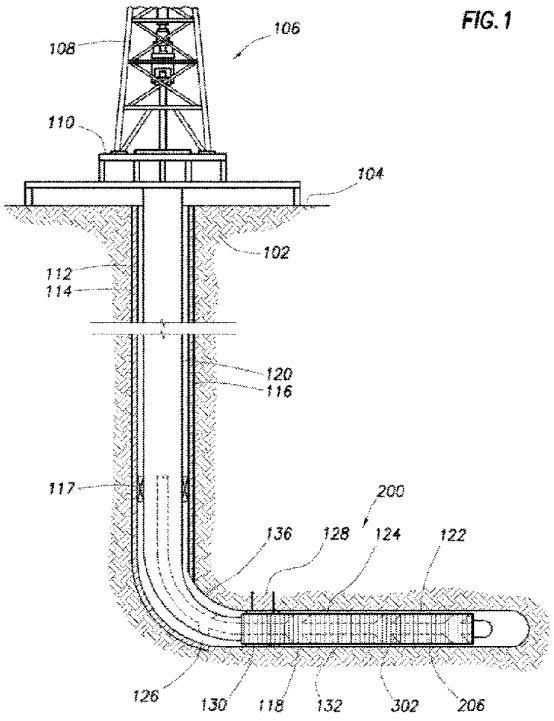
(54) Title: SHUNT TUBE CONNECTION ASSEMBLY AND METHOD

(57) Abstract: A shunt tube assembly comprises a shunt tube and a jumper tube comprising a first end. The shunt tube comprises a non-round cross section, and the first end of the jumper tube is coupled to the shunt tube at a coupling. The first end of the jumper tube comprises a substantially round cross section at the coupling.

FIG. 1



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SHUNT TUBE CONNECTION ASSEMBLY AND METHOD

BACKGROUND

[0001] In the course of completing an oil and/or gas well, a string of protective casing can be run into the wellbore followed by production tubing inside the casing. The casing can be perforated across one or more production zones to allow production fluids to enter the casing bore. During production of the formation fluid, formation sand may be swept into the flow path. The formation sand tends to be relatively fine sand that can erode production components in the flow path. In some completions, the wellbore is uncased, and an open face is established across the oil or gas bearing zone. Such open bore hole (uncased) arrangements are typically utilized, for example, in water wells, test wells, and horizontal well completions.

[0002] When formation sand is expected to be encountered, one or more sand screens can be installed in the flow path between the production tubing and the perforated casing (cased) and/or the open well bore face (uncased). A packer is customarily set above the sand screen to seal off the annulus in the zone where production fluids flow into the production tubing. The annulus around the screen can then be packed with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of water and/or gel and fills the annulus between the sand screen and the well casing. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation.

[0003] During the sand packing process, annular sand "bridges" can form around the sand screen that may prevent the complete circumscribing of the screen structure with packing sand in the completed well. This incomplete screen structure coverage by the packing sand may leave an axial portion of the sand screen exposed to the fine formation sand, thereby undesirably lowering the overall filtering efficiency of the sand screen structure.

[0004] One conventional approach to overcoming this packing sand bridging problem has been to provide each generally tubular filter section with a series of shunt tubes that longitudinally extend through the filter section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the filter section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen structure. The shunt path operates to permit the inflowing packing sand/gel

slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

SUMMARY

[0005] In an embodiment, a shunt tube assembly comprises a shunt tube and a jumper tube comprising a first end. The shunt tube comprises a non-round cross section, and the first end of the jumper tube is coupled to the shunt tube at a coupling. The first end of the jumper tube comprises a substantially round cross section at the coupling.

[0006] In an embodiment, a shunt tube assembly comprises a shunt tube comprising a first cross-sectional shape, a jumper tube comprising a second cross-sectional shape, and a coupling member comprising a first end and a second end. The coupling member is configured to provide a sealing engagement between the coupling member and the shunt tube at the first end, and the coupling member is configured to provide a sealing engagement between the coupling member and the jumper tube at the second end.

[0007] In an embodiment, a shunt tube assembly comprises a plurality of shunt tubes, a jumper tube, and a coupling member configured to provide fluid communication between the jumper tube and the plurality of shunt tubes.

[0008] In an embodiment, a coupling member for use with a shunt tube assembly comprises a body member comprising a first side and a second side, a first opening disposed through the first side, and a second opening disposed through the second side. The body member is configured to be disposed about a wellbore tubular, the first opening is configured to engage a shunt tube, and the second opening is configured to engage a jumper tube. The first opening is in fluid communication with the second opening.

[0009] In an embodiment, a coupling member for use with a shunt tube assembly comprises a first body member, a second body member, and a chamber defined between the first body member and the second body member. The first body member is configured to be rotatably disposed about a wellbore tubular, and the first body member comprises a first opening configured to receive a jumper tube. The second body member is configured to be disposed about a wellbore tubular, and the second body member comprises one or more second openings configured to receive one or more shunt tubes. The first opening is in fluid communication with the one or more second openings through the chamber.

[0010] In an embodiment, a method of forming a shunt tube coupling comprises aligning a first end of a jumper tube with a shunt tube, where the shunt tube comprises a non-round cross section, and coupling the first end of the jumper tube to the shunt tube at a coupling, where the first end of the jumper tube comprises a substantially round cross section at the coupling.

[0011] In an embodiment, a method of gravel packing comprises passing a slurry through a first shunt tube, where the first shunt tube comprises a first cross-sectional shape, passing the slurry through a coupling, where the coupling comprises a coupling between the first shunt tube and a jumper tube, and where the jumper tube comprises a substantially round cross-section at the coupling, and disposing the slurry about a well screen assembly below the coupling.

[0012] In an embodiment, a method of forming a shunt tube coupling comprises rotating a first ring about a wellbore tubular, engaging a jumper tube with the first ring, rotating a second ring about the wellbore tubular, engaging one or more shunt tubes with the second ring, and forming a sealing engagement between the first ring and the second ring.

[0013] These and other features will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

[0015] Figure 1 is a cut-away view of an embodiment of a wellbore servicing system according to an embodiment.

[0016] Figure 2 is a cross-sectional view of an embodiment of a shunt tube assembly.

[0017] Figure 3 is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A' of Figure 2.

[0018] Figure 4 is a partial cross-sectional view of an embodiment of a shunt tube assembly.

[0019] Figure 5 is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0020] Figure 6A is still another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0021] Figures 6B-6E are schematic cross-sectional views of an embodiment of a jumper tube.

[0022] Figure 7A is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0023] Figure 7B is a schematic isometric view of an embodiment of a coupling member.

[0024] Figure 8 is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0025] Figure 9 is yet another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0026] Figure 10 is a partial cross-sectional view of an embodiment of a coupling member.

[0027] Figures 11A and 11B are schematic isometric views of an embodiment of a retaining ring.

[0028] Figure 11C is a partial cross-sectional view of an embodiment of a retaining ring.

[0029] Figures 12A-12D are isometric views of various embodiments of a retaining ring.

[0030] Figure 13 is a schematic cross-sectional view of an embodiment of a coupling member.

[0031] Figure 14 is another schematic cross-sectional view of an embodiment of a coupling member.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0032] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawing figures are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness.

[0033] Unless otherwise specified, any use of any form of the terms "connect," "engage," "couple," "attach," or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to ...". Reference to up or down will be made for purposes of description with "up," "upper," "upward," "upstream," or "above" meaning toward the surface of the wellbore and with "down," "lower," "downward," "downstream," or "below" meaning toward the terminal end of the well, regardless of the wellbore orientation. Reference to inner or outer will be made for purposes of description with "in," "inner," or "inward"

meaning towards the central longitudinal axis of the wellbore and/or wellbore tubular, and "out," "outer," or "outward" meaning towards the wellbore wall. As used herein, the term "longitudinal" or "longitudinally" refers to an axis substantially aligned with the central axis of the wellbore tubular, and "radial" or "radially" refer to a direction perpendicular to the longitudinal axis. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0034] Shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple shunt tubes on adjacent wellbore tubular joints are generally of the same non-round cross section as the shunt tubes to allow for a flow path having a continuous cross-sectional shape along the length of the shunt tube system. However, the use of couplings having non-round cross sections may lead to unreliable connections and the need to closely align the ends of the shunt tubes on adjacent joints of wellbore tubulars. Further, the use of couplings having non-round cross sections may result in a limit to the pressure rating of the coupling.

[0035] Rather than use couplings having non-round cross sections matching those of the shunt tubes, the system disclosed herein utilizes couplings having substantially round cross-sections. The use of couplings with substantially round cross-sections may allow for an improved seal at the couplings, thereby improving the pressure ratings of the couplings. These benefits may provide for more reliable couplings to be formed and improve the assembly time for forming the shunt tube system.

[0036] Referring to Figure 1, an example of a wellbore operating environment in which a well screen assembly may be used is shown. As depicted, the operating environment comprises a workover and/or drilling rig 106 that is positioned on the earth's surface 104 and extends over and around a wellbore 114 that penetrates a subterranean formation 102 for the purpose of recovering hydrocarbons. The wellbore 114 may be drilled into the subterranean formation 102 using any suitable drilling technique. The wellbore 114 extends substantially vertically away from the earth's surface 104 over a vertical wellbore portion 116, deviates from vertical relative

to the earth's surface 104 over a deviated wellbore portion 136, and transitions to a horizontal wellbore portion 118. In alternative operating environments, all or portions of a wellbore may be vertical, deviated at any suitable angle, horizontal, and/or curved. The wellbore 114 may be a new wellbore, an existing wellbore, a straight wellbore, an extended reach wellbore, a sidetracked wellbore, a multi-lateral wellbore, and other types of wellbores for drilling and completing one or more production zones. Further, the wellbore may be used for both producing wells and injection wells. The wellbore 114 may also be used for purposes other than hydrocarbon production such as geothermal recovery and the like.

[0037] A wellbore tubular 120 may be lowered into the subterranean formation 102 for a variety of drilling, completion, workover, treatment, and/or production processes throughout the life of the wellbore. The embodiment shown in Figure 1 illustrates the wellbore tubular 120 in the form of a completion assembly string comprising a well screen assembly 122, which in turn comprises a shunt tube assembly, disposed in the wellbore 114. It should be understood that the wellbore tubular 120 is equally applicable to any type of wellbore tubulars being inserted into a wellbore including as non-limiting examples drill pipe, casing, liners, jointed tubing, and/or coiled tubing. Further, the wellbore tubular 120 may operate in any of the wellbore orientations (e.g., vertical, deviated, horizontal, and/or curved) and/or types described herein. In an embodiment, the wellbore may comprise wellbore casing 112, which may be cemented into place in at least a portion of the wellbore 114.

[0038] In an embodiment, the wellbore tubular 120 may comprise a completion assembly string comprising one or more downhole tools (e.g., zonal isolation devices 117, screen assemblies 122, valves, etc.). The one or more downhole tools may take various forms. For example, a zonal isolation device 117 may be used to isolate the various zones within a wellbore 114 and may include, but is not limited to, a packer (e.g., production packer, gravel pack packer, frac-pac packer, etc.). While Figure 1 illustrates a single screen assembly 122, the wellbore tubular 120 may comprise a plurality of screen assemblies 122. The zonal isolation devices 117 may be used between various ones of the screen assemblies 122, for example, to isolate different gravel pack zones or intervals along the wellbore 114 from each other.

[0039] The workover and/or drilling rig 106 may comprise a derrick 108 with a rig floor 110 through which the wellbore tubular 120 extends downward from the drilling rig 106 into the wellbore 114. The workover and/or drilling rig 106 may comprise a motor driven winch and

other associated equipment for conveying the wellbore tubular 120 into the wellbore 114 to position the wellbore tubular 120 at a selected depth. While the operating environment depicted in Figure 1 refers to a stationary workover and/or drilling rig 106 for conveying the wellbore tubular 120 within a land-based wellbore 114, in alternative embodiments, mobile workover rigs, wellbore servicing units (such as coiled tubing units), and the like may be used to convey the wellbore tubular 120 within the wellbore 114. It should be understood that a wellbore tubular 120 may alternatively be used in other operational environments, such as within an offshore wellbore operational environment.

[0040] In use, the screen assembly 122 can be positioned in the wellbore 114 as part of the wellbore tubular string adjacent a hydrocarbon bearing formation. An annulus 124 is formed between the screen assembly 122 and the wellbore 114. A gravel slurry 126 may travel through the annulus 124 between the well screen assembly 122 and the wellbore 114 wall as it is pumped down the wellbore 114 around the screen assembly 122. Upon encountering a section of the subterranean formation 102 including an area 128 of highly permeable material, the highly permeable area 128 can draw liquid from the slurry, thereby dehydrating the slurry. As the slurry dehydrates in the permeable area 128, the remaining solid particles form a sand bridge 130 and prevent further filling of the annulus 124 with gravel. One or more shunt tubes 132 may be used to create an alternative path for gravel around the sand bridge 130. The shunt tube 132 allows a slurry of sand to enter an apparatus and travel in the shunt tube 132 past the sand bridge 130 to reenter the annulus 124 downstream. The shunt tube 132 may be placed on the outside of the wellbore tubular 120 or run along the interior thereof.

[0041] The screen assembly 122 comprises one or more interconnected joints of threaded wellbore tubulars having shunt tube assemblies disposed about each joint of the wellbore tubulars. Adjacent sections may generally be substantially longitudinally aligned to allow the ends of adjacent shunt tubes on adjacent sections to be coupled with jumper tubes. The present disclosure teaches the use of various jumper tube and coupling mechanism configurations to improve the coupling between the various shunt tubes on adjacent sections. In an embodiment, the shunt tube and the jumper tube may comprise substantially round (e.g., circular) ends, thereby allowing for a coupling between the two components comprising a substantially round cross-section. In an embodiment, a coupling member may be used to couple to a shunt tube having an end with a non-round (e.g., non-circular) cross-section and a jumper tube having an

end with a substantially round cross-section. The coupling member may be configured to provide fluid communication between a jumper tube and one or more shunt tubes, for example, a transport tube and a packing tube. In an embodiment, the jumper tube may comprise a non-uniform cross-sectional shape along its length. For example, one or more of the ends of the jumper tube may have a substantially round cross-section, and one or more portions between the ends of the jumper tube may have non-round cross-sections. Such an embodiment may be useful in reducing the outer diameter of the jumper tubes while maintaining the available flow area for fluid transport.

[0042] A cross-sectional view of an embodiment of an individual joint of wellbore tubular comprising a shunt tube assembly 200 disposed thereabout is shown in Figure 2. The wellbore tubular 120 generally comprises a series of perforations 202 disposed therethrough. A filter media 204 is disposed about the wellbore tubular 120 and the series of perforations 202 to screen the incoming fluids from the formation. The shunt tube assembly 200 comprises one or more retaining rings 212 and one or more shunt tubes 206 disposed along and generally parallel to the wellbore tubular 120. An outer body member 208 may be disposed about the wellbore tubular 120, one or more shunt tubes 206, and filter media 204. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 206 and/or outer body member 208 in position relative to the wellbore tubular 120.

[0043] The wellbore tubular 120 comprises the series of perforations 202 through the wall thereof. The wellbore tubular 120 may comprise any of those types of wellbore tubular described above with respect to Figure 1. While the wellbore tubular 120 is illustrated as being perforated in Figure 2, the wellbore tubular 120 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 214 and an exterior 216 of the shunt tube assembly 200.

[0044] The wellbore tubular 120 may generally comprise a pin end 209 and a box end to allow the wellbore tubular 120 to be coupled to other wellbore tubulars having corresponding connections. As can be seen in Figure 2, the wellbore tubular 120 may have a coupling section that extends beyond the shunt tube assembly 200. The exposed portion 211 of the wellbore tubular 120 may be used during the coupling process to allow one or more tools to engage the exposed portion 211 and thread the joint to an adjacent joint of wellbore tubular. In an embodiment, the exposed portion may be about 1 to about 5 feet, or alternatively about 2 feet to

about 4 feet, though any distance suitable for allowing the wellbore tubular 120 to be coupled to an adjacent joint of wellbore tubular may be used.

[0045] The filter media 204 may be disposed about the wellbore tubular 120 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the wellbore tubular 120. In an embodiment, the filter media 204 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a wellbore tubular 120, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 204 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 204 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

[0046] The one or more shunt tubes 206 generally comprise tubular members disposed outside of and generally parallel to the wellbore tubular 120, though other positions and alignment may be possible. While described as tubular members (e.g., having substantially circular cross-sections), the one or more shunt tubes 206 may have shapes other than cylindrical and may generally be rectangular, elliptical, kidney shaped, and/or trapezoidal in cross-section. The retaining rings 212 may retain the shunt tubes 206 in position relative to the wellbore tubular 120. The one or more shunt tubes 206 may be eccentrically aligned with respect to the wellbore tubular 120 as best seen in Figure 3. In this embodiment, four shunt tubes 206, 302 are arranged to one side of the wellbore tubular 120 within the outer body member 208. While illustrated in Figures 2 and 3 as having an eccentric alignment, other alignments of the one or more shunt tubes about the wellbore tubular 120 may also be possible.

[0047] Various configurations for providing fluid communication between the interior of the one or more shunt tubes 206 and the exterior 216 of the outer body member 208 are possible. In an embodiment, the one or more shunt tubes 206 may comprise a series of perforations (e.g., openings and/or nozzles). Upon the formation of a sand bridge, a back pressure generated by the blockage may cause the slurry carrying the sand to be diverted through the one or more shunt

tubes 206 until bypassing the sand bridge. The slurry may then pass out of the one or more shunt tubes 206 through the perforations in both the shunt tubes 206 and outer body member 208 and into the annular space between the wellbore tubular and casing/wellbore wall to form a gravel pack.

[0048] In an embodiment, the shunt tubes 206 may comprise transport tubes and/or packing tubes 302. The one or more packing tubes 302 may be disposed in fluid communication with the one or more transport tubes. As illustrated in Figures 1 and 3, the packing tubes 302 may generally comprise tubular members disposed outside of and generally parallel to the wellbore tubular 120. The transport tubes and packing tubes 302 may be disposed generally parallel to the wellbore tubular 120 and may be retained in position relative to the wellbore tubular 120 by the retaining rings 212. A first end of the packing tubes 302 may be coupled to the one or more transport tubes at various points along the length of the transport tubes, and the packing tubes may comprise a series of perforations providing fluid communication within and/or through the outer body member 208 at a second end. As shown schematically in Figure 1, the shunt tubes may form a branched structure along the length of a screen assembly 122 with the one or more transport tubes forming the trunk line and the one or more packing tubes 302 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the screen assembly 122. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended.

[0049] In use, the branched configuration of the transport tubes and packing tubes 302 may provide the fluid pathway for a slurry to be diverted around a sand bridge. Upon the formation of a sand bridge, a back pressure generated by the blockage may cause the slurry carrying the sand to be diverted through the one or more transport tubes 206 until bypassing the sand bridge. The slurry may then pass out of the one or more transport tubes 206 into the one or more packing tubes 302. While flowing through the one or more packing tubes 302, the slurry may pass through the perforations in the packing tubes 302 and into the annular space about the wellbore tubular 120 to form a gravel pack.

[0050] To protect the shunt tubes 206 and/or filter media 204 from damage during installation of the screen assembly comprising the shunt tube assembly 200 within the wellbore, the outer body member 208 may be positioned about a portion of the shunt tube assembly 200.

The outer body member 208 comprises a generally cylindrical member formed from a suitable material (e.g. steel) that can be secured at one or more points, for example to the retaining rings 212, which in turn, are secured to wellbore tubular 120. The outer body member 208 may have a plurality of openings 218 (only one of which is numbered in Figure 2) through the wall thereof to provide an exit for fluid (e.g., gravel slurry) to pass through the outer body member 208 as it flows out of one or more openings in the shunt tubes 206 (e.g., through openings in the packing tubes 302), and/or an entrance for fluids into the outer body member 208 and through the permeable section of the filter media 204 during production. By positioning the outer body member 208 over the shunt tube assembly 200, the shunt tubes 206 and/or filter media 204 may be protected from any accidental impacts during the assembly and installation of the screen assembly in the wellbore that might otherwise damage or destroy one or more components of the screen assembly or the shunt tube assembly 200.

[0051] As illustrated in Figures 2 and 3, the shunt tubes 206, outer body member 208, and/or in some embodiments, the filter media 204 can be retained in position relative to the wellbore tubular 120 using the retaining rings 212. The retaining rings 212 generally comprise rings and/or clamps configured to engage and be disposed about the wellbore tubular 120. The retaining ring 212 may engage the wellbore tubular using any suitable coupling including, but not limited to, corresponding surface features, adhesives, curable components, spot welds, any other suitable retaining mechanisms, and any combination thereof. For example, the inner surface of the retaining ring 212 may comprise corrugations, castellations, scallops, and/or other surface features, which in an embodiment, may be aligned generally parallel to the longitudinal axis of the wellbore tubular 120. The corresponding outer surface of the wellbore tubular 120 may comprise corresponding surface features that, when engaged, couples the retaining rings 212 to the wellbore tubular 120.

[0052] Figure 3 illustrates a cross-sectional view along line A-A' of Figure 2 that shows the cross-section of a retaining ring 212. In the embodiment shown in Figure 3, the retaining ring extends around the wellbore tubular 120. A plurality of through passages are provided in the retaining ring 212 to allow the one or more shunt tubes 206, 302 to pass through a portion of the retaining ring 212. The retaining ring 212 may also be configured to engage and retain the outer body member 208 in position about the wellbore tubular 120. The retaining ring 212 may also

be used to couple the shunt tubes 206, 302 to the jumper tubes, as described in more detail herein.

[0053] While the joints of wellbore tubular described herein are generally described as comprising a series of perforations 202 and filter media 204, one or more joints of wellbore tubular 120 may only have the shunt tube assemblies disposed thereabout. Such a configuration may be used between joints of wellbore tubular 120 comprising production sections to act as spacers or blank sections while still allowing for a continuous fluid path through the shunt tubes 206 along the length of the interval being completed.

[0054] In an embodiment, an assembled sand screen structure can be made up of several joints of the wellbore tubular comprising the shunt tube assemblies 200 described herein. During the formation of the assembled sand screen structure, the shunt tubes 206 on the respective joints are fluidly connected to each other as the joints are coupled together to provide a continuous flowpath for the gravel slurry along the entire length of assembled sand screen structure during gravel packing operations.

[0055] In order to couple joints of wellbore tubulars, adjacent joints comprising screens may be connected by threading together adjacent joints using a threaded coupling (e.g., using timed threads) to substantially align the shunt tubes on the adjacent joints. As illustrated in Figure 4, the end of each shunt tube on the adjacent joints may then be individually coupled using a connector such as a jumper tube. A jumper tube may comprise a relatively short length of tubing which may be engaged to one or more shunt tubes on adjacent joints of wellbore tubulars to provide fluid communication along the length of the shunt tube system. The jumper tubes may comprise one or more tubular components that may be fixed in length or configured to provide a telescoping and extending tubular for engaging one or more shunt tubes. The various components of the jumper tube and jumper tubes connections may be configured to reduce and/or minimize the transitional flow affects through the connections, thus reducing and/or minimizing the associated pressure drops across the various components.

[0056] Typically, the jumper tube may be assembled onto the aligned shunt tubes after the adjacent joints of wellbore tubular are coupled together. In general, jumper tubes may comprise the same or similar shape to the shunt tubes to which they are coupled. However, the use of couplings with non-round cross-sectional shapes may result in a number of difficulties in forming a reliable seal. For example, the alignment of a shunt tube with a non-round cross-

section and a jumper tube with a corresponding non-round cross-section may need to be more precise than the alignment of the same or similar coupling with both parts having round cross-sectional shapes. In order to address this type of issue, the connection between a shunt tube and a jumper tube may comprise a coupling with a substantially round cross-section. The use of a coupling with a substantially round cross-section may allow for more reliable seals and/or seal back-ups to be used, potentially increasing the pressure rating of the resulting coupling.

[0057] Various configurations may be used to form a coupling between a shunt tube and a jumper tube comprising a round cross-section. In an embodiment, an end of the shunt tube and jumper tube may have substantially round cross-sections, allowing the shunt tube and jumper tube to form a coupling with a substantially round cross-section. In an embodiment, a coupling member, which may be separate from the shunt tube and jumper tube, may be used to coupling the shunt tube to the jumper tube. The coupling member may comprise a first end and a second end. The coupling member may be configured to provide a sealing engagement between an end of the shunt tube, which may have a non-round cross-section, and an end of the jumper tube, which may have a round cross-section. In this embodiment, the coupling member may be configured to adapt the non-round cross-section of the shunt tube to a round cross-sectional shape for engaging the jumper tube. In an embodiment, a coupling member may be configured to engage the jumper tube with a round cross-section and a plurality of shunt tubes, which may comprise non-round cross-sections. In this embodiment, the coupling member may serve to distribute flow to a plurality of shunt tubes such as a transport tube and a packing tube. In some embodiments, the coupling member may be the retaining ring 212, where the retaining ring is configured to provide the functions of the coupling member. In an embodiment, the coupling member may comprise a plurality of body portions that are rotatable about the wellbore tubular. This may allow each portion to be rotated and engaged with the jumper tube and/or the shunt tube(s). This may allow for a longitudinal misalignment of the shunt tubes on adjacent sections of wellbore tubular. Each of these configurations will be discussed below in more detail.

[0058] In an embodiment illustrated in Figure 5, the shunt tube 506 may transition from a non-round cross-section to a substantially round cross-section at the coupling 503 with the jumper tube 501. As described herein, the shunt tube 506 may generally comprise a tubular member aligned along the longitudinal axis of the wellbore tubular 120. The shunt tube 506 may have a non-round cross-section along the length of the wellbore tubular joint 120. In an

embodiment, a first end 502 of the shunt tube 506 may comprise a substantially round cross-section. The cross-section of the shunt tube 506 may transition from a non-round shape to a substantially round shape over a portion 505 of the shunt tube 506. Various processes may be used to form a shunt tube 506 comprising a non-round cross-section that transitions or otherwise changes to a round cross-section at the first end 502. For example, the shunt tube 506 may be rolled, cast, or otherwise formed into a tubular member comprising the different cross-sectional shapes along its length.

[0059] In an embodiment, a second shunt tube 526 may transition from a non-round cross-section to a substantially round cross-section at a second coupling 523 between the jumper tube 501 and the second shunt tube 526. The second shunt tube 526 may have a non-round cross-section along the length of a second wellbore tubular joint 520. In an embodiment, a first end 522 of the second shunt tube 526 may comprise a substantially round cross-section. The cross-section of the second shunt tube 526 may transition from a non-round shape to a substantially round shape over a portion 525 of the second shunt tube 526. Various processes may be used to form the second shunt tube 526 comprising a non-round cross-section that transitions or otherwise changes to a round cross-section at the first end 522. For example, the shunt tube 526 may be rolled, cast, or otherwise formed into a tubular member comprising the different cross-sectional shapes along its length. While it is understood that one or both ends 512, 532 of the jumper tube 501 and the corresponding ends 502, 522 of the shunt tubes 506, 526, respectively, may be formed as described herein, reference in the following discussion will be made to the first coupling 503 alone in the interest of clarity.

[0060] As noted above, the use of a round cross-section may provide for a more reliable coupling between the jumper tube 501 and a shunt tube 506. The coupling 503 between the jumper tube 501 and shunt tube 506 may also provide for a similar flow cross-sectional area as compared to the flow cross-sectional area through the shunt tube 506 upstream of the first end 502. In an embodiment, the flow cross-sectional area at the coupling between the jumper tube 501 and the shunt tube 506 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 506 upstream of the first end 502. Due to the differing cross-sectional shapes between the shunt tubes 506 upstream of the end 502 and at the coupling between the jumper tube 501 and the shunt tube 506, the concept of a similar flow capacity may be expressed in terms of a hydraulic

diameter. In an embodiment, the hydraulic diameter of the shunt tubes 506 upstream of the end 502 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the hydraulic diameter of the coupling between the jumper tube 501 and the shunt tube 506.

[0061] As can be seen in Figure 5, the coupling 503 formed by the engagement of the jumper tube 501 with the end 502 of the shunt tube 506 may comprise the jumper tube 501 engaged within the substantially round bore of the end 502 of the shunt tube 506. One or more seals 514 (e.g., o-ring) may be disposed between the outer diameter of the jumper tube 501 and the inner diameter of the shunt tube 506 to form a sealing engagement between the jumper tube 501 and the shunt tube 506 at the coupling 503. In an embodiment, the one or more seals 514 may comprise seal back-ups for providing a higher pressure rating for the coupling 503 than if seal back-ups were not used. The one or more seals 514 may be disposed in corresponding recesses disposed on the outer diameter of the jumper tube 501 and/or in the inner diameter of the shunt tube 506. In order to aid in forming the coupling 503, the end 502 of the shunt tube 506 and/or the end 512 of the jumper tube 501 may be beveled, angled, rounded, or otherwise formed to provide a non-squared shoulder at the end of the shunt tube 506 and/or the jumper tube 501.

[0062] While Figure 5 illustrates the end 512 of the jumper tube 501 sealingly engaged and disposed within the end 502 of the shunt tube 506, the end 512 of the jumper tube 501 may be configured to receive the end 502 of the shunt tube 506 within its bore. In this configuration, the one or more seals 514 may be disposed between the inner diameter of the jumper tube 501 and the outer diameter of the shunt tube 506 within the coupling 503. In an embodiment in which both ends of the jumper tube 501 comprise substantially round cross-sections, the engagement configuration of the jumper tube 501 and the shunt tubes 506, 526 may be the same at each end 512, 532 of the jumper tube 501. For example, the ends 512, 532 of the jumper tube 501 may be disposed within the ends 502, 522 of the shunt tubes 506, 526, respectively, or the ends 502, 522 of the shunt tubes 506, 526 may be disposed within the ends 512, 532 of the jumper tube 501. In an embodiment, the engagement configuration of the jumper tube 501 and the shunt tubes 506, 526 may be different at each end 512, 532 of the jumper tube 501. For example, the end 512 of the jumper tube 501 may be disposed within the end 502 of the shunt tube 506, and the end 522 of the shunt tube 526 may be disposed within the end 532 of the jumper tube 501, or vice-versa. In some embodiments, a coupling between the jumper tube 501 and a shunt tube 506, 526 may

be formed by abutting the end 502 of the shunt tube 506 to the end 512 of the jumper tube 501. The ends 502, 512 may be held in engagement using any suitable connection methods. For example, each component may be coupled with a connection mechanism (e.g., bolts, screws, adhesives, welds, corresponding threads, or the like).

[0063] In an embodiment as illustrated in Figure 5, the portions 505, 525 of the shunt tubes 506, 526 over which the shunt tubes 506, 526 transitions from a non-round cross-section to a substantially round cross-section may be configured to allow for a jumper tube 501 having a substantially fixed longitudinal length to be used to couple to both shunt tubes 506, 526. In this embodiment, the jumper tube 501 may be configured to be engaged with a shunt tube 526 over a sufficient distance so that the opposite end 512 of the jumper tube 501 can be aligned and engaged with the shunt tube 506. The longitudinal length 556 of the jumper tube 501 may allow both ends 512, 532 of the jumper tube 501 to engage (e.g., sealingly engage) the shunt tubes 506, 526, respectively, on adjacent joints of wellbore tubular.

[0064] As illustrated in Figure 5, the longitudinal length of the jumper tube 501 and the portions of the shunt tubes 506, 526 configured to engage the jumper tube 501 may be configured to allow the jumper tube 501 to engage both shunt tubes 506, 526. In an embodiment, the shunt tube 526 may have a substantially round cross-section configured to receive and/or be disposed within the jumper tube 501 over the distance 550, and the shunt tube 506 may have a substantially round cross-section configured to receive and/or be disposed within the jumper tube 501 over at least a distance 554. A distance 552 may exist between the ends 502, 522 of the shunt tubes 506, 526 on adjacent joints of wellbore tubulars 120, 520. In an embodiment, a jumper tube having a substantially fixed length may be used when the overall length 556 of the jumper tube 501 is less than the sum of the distance 552 between the ends 502, 522 of the shunt tubes 506, 526 and the distance 550. This may allow the jumper tube 501 to be inserted into the shunt tube 526 a distance 550, and then be aligned with the shunt tube 506. The jumper tube 501 may then be engaged with the shunt tube 506 a distance 554, which may be less than the distance 550 to provide for an engagement between the jumper tube 501 and the shunt tubes 506, 526.

[0065] Once engaged with the shunt tubes 506, 526, the jumper tube 501 may be held in place using a retaining mechanism 570 configured to engage the jumper tube 501 and/or one or more of the shunt tubes 506, 526 to maintain the jumper tube 501 in engagement with the shunt

tubes 506, 526. In an embodiment, the retaining mechanism may comprise a snap ring configured to engage the jumper tube 501 adjacent to one or both of the shunt tubes 506, 526, thereby preventing movement of the jumper tube 501 into the shunt tubes 506, 526. In some embodiments, the retaining mechanism may engage one or more of the shunt tubes 506, 526 to prevent movement of one or more of the shunt tubes 506, 526 into the jumper tube 501 (e.g., when the jumper tube 501 is configured to receive one or more of the shunt tubes 506, 526 within its bore). In some embodiments, the retaining mechanism 570 may comprise an indicator on the jumper tube 501 or the shunt tube 506, 526 with a corresponding snap fitting assembly (e.g., a snap ring, a collet lug, etc.) on the engaging surface. In some embodiments, the engagement between the jumper tube 501 and one or more of the shunt tubes 506, 526 may comprise a friction fit, compression fit, and/or the like that may be sufficient to maintain the engagement without the need for a retaining mechanism. In some embodiments, the engagement between the jumper tube 501 and one or more of the shunt tubes 506, 526 may comprise a threaded connection. For example, the engagement between the jumper tube 501 and the shunt tube 526 may comprise a sliding, sealing engagement, and the engagement with the shunt tube 506 may then be maintained using a threaded connection, thereby maintaining the engagement with the shunt tube 526 in position through the fixed engagement at the threaded interface on the shunt tube 506.

[0066] In an embodiment as illustrated in Figure 6A, one or more portions of the jumper tube 601 may comprise a non-round cross-section. One or more protrusions 562, 564 may be disposed about the wellbore tubulars 120, 520, respectively, at the ends of the wellbore tubulars 120, 520 to provide for various mechanical properties and/or handling procedures during the coupling of the adjacent wellbore tubulars 120, 520. For example, the protrusions 562, 564 may provide engagement locations for the tongs used during the coupling process of the wellbore tubular joints 120, 520 at the surface of the well. These protrusions 562, 564 may have increased outer diameters relative to the outer diameter of the wellbore tubulars 120, 520. In some embodiments, the protrusions 562, 564 may have outer diameters that would interfere with the jumper tube 501 if the jumper tube 501 comprised a straight tubular component having a substantially round cross-section along its length. The jumper tube 501 may be sized to avoid the protrusions 562, 564, for example by reducing the diameter of the jumper tube 501, but the flow area through the jumper tube 501 may also be reduced.

[0067] In order to avoid the protrusions and/or provide additional flow area through the jumper tube 501, one or more portions of the jumper tube 501 may be configured to comprise a non-round cross-section. As shown in Figure 6A, a portion 604 of the jumper tube 601 may have a non-round cross-section. The portion 604 of the jumper tube 601 having a non-round cross-section may be disposed adjacent to the protrusions 562, 564 forming the coupling between the wellbore tubulars 120, 520. This may allow the jumper tube to extend past the protrusions while maintaining a suitable flow area through the jumper tube 501. The non-round cross-section may comprise any suitable shape. Figures 6B-6E illustrate various suitable cross-sectional shapes including, but not limited to, rectangular, oval, kidney shaped (e.g., arced and/or oblong), trapezoidal, squared, and/or any other suitable non-round cross-sectional shape. In some embodiments, the jumper tube 601 may comprise a bend between the first end 612 and the second end 622 to allow the jumper tube 601 to be routed past the protrusions 562, 564 at the coupling between the wellbore tubular joints 120, 520. The bend may allow the jumper tube 601 to be disposed adjacent to the wellbore tubular 120, extend out to be disposed adjacent to the outer diameter of the protrusions 562, 564, and then be disposed adjacent to the wellbore tubular 520. This embodiment may limit the length of the portion 604 of the jumper tube 601 having an increased outer diameter.

[0068] The portion 604 of the jumper tube 601 having a non-round cross-section may have the same or similar cross-sectional area available for flow as compared to the flow cross-sectional area through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601. In an embodiment, the flow cross-sectional area of the portion 604 comprising the non-round cross-section may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601. Due to the differing cross-sectional shapes between the shunt tubes 506 upstream of the end 502, the end 612 of the jumper tube 601, and/or the portion 604 comprising the non-round cross-section, the concept of a similar flow capacity may be expressed in terms of a hydraulic diameter. In an embodiment, the hydraulic diameter of the portion 604 comprising the non-round cross-section may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the hydraulic diameter through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601.

[0069] Referring to Figures 4 and 5, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 502 of a first shunt tube 506 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 522 of a second shunt tube 526 on the second wellbore tubular joint 520. In an embodiment, the shunt tubes 506, 526 may be considered substantially aligned if they are aligned to within about 10 degrees, about 7 degrees, or about 5 degrees of each other.

[0070] Once the adjacent shunt tubes 506, 526 are substantially aligned, the jumper tube 501 may be used to provide a fluid coupling between the adjacent shunt tubes 506, 526. In an embodiment, the jumper tube 501 may be coupled to the adjacent ends of the adjacent shunt tubes 506, 526. For example, the jumper tube 501 may be engaged with one of the shunt tubes 506. The opposite end of the jumper tube 501 may then be extended (e.g., extended through a telescoping configuration) to engage the shunt tube 526 on the adjacent joint of wellbore tubular 520. In some embodiments, a jumper tube 501 having a fixed length may be used. In this embodiment, the jumper tube 501 may be engaged with the shunt tube 506 and displaced relative to the shunt tube 506 a sufficient distance to allow the opposite end of the jumper tube 501 to be aligned and engaged with the shunt tube 526. The jumper tube 501 may then be engaged with the shunt tube 526 a distance sufficient to form an engagement while maintaining the engagement with the first shunt tube 506. One or more seals (e.g., o-ring seals 514, etc.) may be used to provide a fluid tight connection between the jumper tube 501 and the end of the respective shunt tube 506, 526. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube 501 with the shunt tubes 506, 526.

[0071] Similar jumper tubes 501 may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes 506, 526 and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes 501. In an embodiment, the shroud may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section 540 to prevent

damage to the jumper tubes 501 and ends of the adjacent shunt tubes 506, 526 during conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[0072] In an embodiment illustrated in Figures 7A and 7B, a coupling member 705, which may be separate from the shunt tube 706 and jumper tube 701, may be used to coupling the shunt tube 706 to the jumper tube 701. The shunt tube 706 may comprise a first cross-sectional shape, which may be a non-round cross-sectional shape, and the jumper tube 701 may comprise a second cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the coupling member 705. The coupling member 705 may then be configured to provide a sealing engagement with the shunt tube 706 and the jumper tube 701, and the coupling member 705 may act as a converter between the cross-sectional shapes of the shunt tube 706 and the jumper tube 701. In an embodiment, one or more portions of the jumper tube 701 may comprise a non-round cross-section. Any of the jumper tube 701 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 701 coupled to the coupling member.

[0073] The coupling member 705 may generally comprise a tubular member comprising a first end 707 having a non-round cross-section and a second end 708 having a substantially round cross-section. A flowbore may be disposed through the coupling member 705 for providing fluid communication between the first end 707 and the second end 708. The coupling member 705 may be configured to provide a sealing engagement between an end 702 of the shunt tube 706, which may have a non-round cross-section, and an end 712 of the jumper tube 701, which may have a round cross-section. In this embodiment, the coupling member may be configured to adapt the non-round cross-section of the shunt tube 706 to a round cross-sectional shape for engaging the jumper tube 701. In order to adapt the cross-sections of the shunt tube 706 to the jumper tube 701, the cross-section of the flowbore and/or the outer diameter of the coupling member 705 may transition along the length of the coupling member 705. The relative inner diameter of the first end 707 and the second end 708 of the coupling member 705 may be selected to provide for the connections to the shunt tube 706 and the jumper tube 701.

[0074] As illustrated in Figure 7B, the first end 707 of the coupling member 705 may comprise a shoulder configured to engage the end 702 of the shunt tube 706. One or more seals (e.g., O-ring seals with or without seal backups) may be disposed between the end 702 of the shunt tube 706 and the coupling member 705 to provide for a sealing engagement between the shunt tube 706 and the coupling member 705. In an embodiment, the coupling member 705 may be fixedly coupled to the shunt tube 706 using, for example, a connector (e.g., bolts, screws, and the like), adhesives, welds, or any other suitable connections.

[0075] The coupling member 705 may also form a sealing engagement with the end 712 of the jumper tube 701. One or more seals 714 (e.g., o-ring) may be disposed between the outer diameter of the jumper tube 701 and the inner diameter of the coupling member 705 to form a sealing engagement between the jumper tube 701 and the coupling member 705. In an embodiment, the one or more seals 714 may comprise seal back-ups for providing a higher pressure rating for the sealing engagement than if seal back-ups were not used. The one or more seals 714 may be disposed in corresponding recesses disposed on the outer diameter of the jumper tube 701 and/or in the inner diameter of the coupling member 705. In order to aid in forming the engagement, the end 712 of the jumper tube 701 and/or the end 708 of the coupling member 705 may comprise a beveled, angled, rounded, or otherwise formed portion to provide a non-squared shoulder 750 at the end of the jumper tube 701 and/or the coupling member 705.

[0076] While Figures 7A and 7B illustrate the coupling member 705 receiving the shunt tube 706 and the jumper tube 701 within the flowbore, the coupling member 705 may also be received within the shunt tube 706 and/or the jumper tube 701. As illustrated in Figure 8, the coupling member 805 may be received within and engage an inner diameter of the shunt tube 706 and the jumper tube 701. In this configuration, the one or more seals 714 may be disposed between the inner diameter of the shunt tube 706 and/or the jumper tube 701 and the outer diameter of the coupling member 805. It will be appreciated that the coupling member may be received within, disposed about, or abut the end of the shunt tube 706 and/or the jumper tube 701. In an embodiment, the engagement configuration of the coupling member with jumper tube 701 and/or the shunt tubes 706, 726 may be the same or different so long as the coupling member engages the shunt tube and the jumper tube. The considerations of the orientations of each component discussed above with respect to Figure 5 may also apply to the orientations of the engagement of the coupling member with the shunt tube and/or the jumper tube.

[0077] As illustrated in Figure 8, one or more retaining mechanisms 870 may be used to maintain the coupling member 805 in engagement within the shunt tube 706 and/or the jumper tube 701. In an embodiment, the retaining mechanisms may comprise a snap ring configured to engage an inner diameter of the jumper tube 701 adjacent to the coupling member 805, thereby preventing movement of the coupling member 805 into the jumper tube 701 and/or the shunt tube 706. In an embodiment, the retaining mechanisms 870 may comprise any of those retaining mechanisms described above with respect to Figure 5.

[0078] In an embodiment illustrated in Figures 7A and 7B, a second shunt tube 726 disposed on the second joint of wellbore tubular 520 may comprise a non-round cross-section. The non-round cross-section of the shunt tube 706 may be the same as or different than the non-round cross-section of the second shunt tube 726. The non-round cross-section of the shunt tube 706 may extend into the jumper tube section 728 for coupling to the jumper tube 701 using the coupling member 705. In an embodiment, the non-round cross-section of the second shunt tube 726 may extend into the jumper tube section 702 for coupling to the jumper tube 701 using a second coupling member 725. The second coupling member 725 may be the same or similar to the coupling member 705, though the cross-sectional shape of the end having the non-round cross-sectional shape may be different than the non-round cross-sectional shape of the coupling member 705. While the coupling member 705 is discussed herein, it is understood that the description also applies to the second coupling member 725.

[0079] The coupling member 705 providing the engagement and fluid communication between the jumper tube 701 and shunt tube 706 may also provide for a similar flow cross-sectional area as compared to the flow cross-sectional area through the shunt tube 706 upstream of the first end 702. In an embodiment, the flow cross-sectional area through the coupling member 705 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 706 upstream of the first end 702. Due to the differing cross-sectional shapes along the length of the coupling member 705 to provide the coupling with the end 702 of the shunt tube 706 and at the end 712 of the jumper tube 701, the concept of a similar flow capacity may be expressed in terms of a hydraulic diameter. In an embodiment, the hydraulic diameter of the shunt tubes 706 upstream of the end 702 may be within about 10%, within about 20%, within about 30%, within about

40%, or within about 50% of the hydraulic diameter of the flow area through the end 708 of coupling member 705.

[0080] In an embodiment, the coupling member 705 may be configured to receive the jumper tube 701 over a length of the flowbore. This configuration may be configured to allow for a jumper tube 701 having a substantially fixed longitudinal length to be used to couple to the coupling member 705 and the second coupling member 725. In this embodiment, the jumper tube 701 may be configured to be engaged with at least one of the coupling members 705, 725 over a sufficient distance so that the opposite end of the jumper tube 701 can be aligned and engaged with the shunt tube. Any of the considerations and/or configurations described with respect to the lengths, distances, and portions of the shunt tubes configured to receive the jumper tube in Figure 5 may also apply to one or more of the coupling members 705, 725.

[0081] In an embodiment illustrated in Figure 9, the coupling member comprises the retaining ring 905 disposed about the wellbore tubular 120. The retaining ring 905 may be used to couple the shunt tube 906 to the jumper tube 901. The shunt tube 906 may comprise a first cross-sectional shape, which may be a non-round cross-sectional shape, and the jumper tube 901 may comprise a second cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the retaining ring 905. The retaining ring 905 may then be configured to provide a sealing engagement with the shunt tube 906 and the jumper tube 901, and the retaining ring 905 may act as a converter between the cross-sectional shapes of the shunt tube 906 and the jumper tube 901. In an embodiment, one or more portions of the jumper tube 901 may comprise a non-round cross-section. Any of the jumper tube 901 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 901 coupled to the retaining ring 905.

[0082] The retaining ring 905 may generally comprise a ring and/or clamp configured to engage and be disposed about the wellbore tubular 120. The retaining ring 905 may have one or more fluid passages disposed therethrough to provide fluid communication from a first side 907 to a second side 908 of the retaining ring 905. The openings of the fluid passages on the first side 907 may be configured to engage one or more shunt tubes 906 having a non-round cross-section, and the openings of the fluid passages on the second side 908 may be configured to engage one or more jumper tubes 901 having a substantially round cross-section at the coupling with the retaining ring 905. The retaining ring 905 may be configured to provide a sealing

engagement (e.g., using one or more o-ring seals with or without seal backups) between an end 902 of the shunt tube 906 and the retaining ring 905, and/or the retaining ring 905 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals 914 with or without seal backups) between an end 912 of the jumper tube 901 and the retaining ring 905. In this embodiment, the retaining ring and the fluid passages may be configured to adapt the non-round cross-section of the shunt tube 906 to a round cross-sectional shape for engaging the jumper tube 901. In order to adapt the cross-sections of the shunt tube 906 to the jumper tube 901, the cross-section of the fluid passages through the retaining ring 905 may transition along the length of the fluid passages through the retaining ring 905. The relative inner diameters of the first end 907 and the second side 908 of the retaining ring 905 may be selected to provide for the connections to the shunt tube 906 and the jumper tube 901. The retaining ring 905 may be coupled to the shunt tube 906 and/or the jumper tube 901 using any of the connector types and configurations described herein.

[0083] In an embodiment, a second retaining ring 925 may be similarly configured to the first retaining ring 905. In this embodiment, the second retaining ring 925 may engage the jumper tube 901 and a second shunt tube 926, which may comprise a non-round cross-section, on a second wellbore tubular 520. The non-round cross-section of the shunt tube 906 may be the same as or different than the non-round cross-section of the second shunt tube 926. The second retaining ring 925 may be the same as or different than the retaining ring 905. While the retaining ring 905 is discussed herein, it is understood that the description also applies to the second retaining ring 925.

[0084] When the coupling member is a retaining ring, any of the flow considerations with respect to flow area and/or hydraulic diameter as described herein may also apply. Further, any of the considerations and/or configurations described with respect to the lengths, distances, and portions of the shunt tubes configured to receive the jumper tube in Figure 5 may also apply to one or more of the retaining rings 905, 925, and the discussion of the relative distances is not repeated herein in the interest of clarity. Still further, any of the types of jumper tubes, including those comprising non-round cross-sections and/or bends, may be used in combination with the retaining rings 905, 925.

[0085] The use of a coupling member described with respect to Figures 7 and 8 and the retaining ring comprising one or more fluid passageways described with respect to Figure 9 may

be used in combination. For example, the retaining ring may comprise one or more fluid passageways comprising openings on the first and second sides with the same or similar cross-sectional shapes. One or more shunt tubes may be received at the first side of the retaining ring, and a separate coupling member may be engaged with the openings on the second side of the retaining ring. The coupling member may then act as the conversion between the opening in the retaining ring having a non-round cross-section and the substantially round cross-section of the jumper tube at the coupling with the coupling member.

[0086] Referring to Figures 4 and 7 to 9, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 702 of a first shunt tube 706 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 722 of a second shunt tube 726 on the second wellbore tubular joint 520.

[0087] Once the adjacent shunt tubes 706, 726 are substantially aligned, a coupling member 705 may be engaged with the shunt tube 706, and a second coupling member 725 may be coupled with the shunt tube 726. In some embodiments, the coupling members 705, 725 may be pre-coupled to the shunt tubes 706, 726. One or more seals (e.g., o-ring seals 714, etc.) may be used to provide a fluid tight connection between the shunt tubes 706, 726 and the respectively coupling members 705, 725. In an embodiment, the coupling member comprises the retaining ring 905 as shown in Figure 9. In this embodiment, the retaining ring 905 may be pre-installed as part of the screen assembly, and may have one or more openings for engaging the jumper tube 901. While described below in terms of the coupling members 705, 725 being separate from the retaining rings 905, 925, the same or similar formation process may be used to couple the jumper tube 901 to the retaining rings 905, 925.

[0088] The jumper tube 701 may then be coupled to the coupling members 705, 725. For example, the jumper tube 701 may be engaged with one of the coupling member 705. The opposite end of the jumper tube 701 may then be extended (e.g., extended through a telescoping configuration) to engage the coupling member 725 on the adjacent joint of wellbore tubular 520. In some embodiments, a jumper tube 701 having a fixed length may be used. In this

embodiment, the jumper tube 701 may be engaged with the coupling member 705 and displaced a sufficient distance to allow the opposite end of the jumper tube 701 to be aligned and engaged with the second coupling member 725. The jumper tube 701 may then be engaged with the coupling member 725 a distance sufficient to form an engagement while maintaining the engagement with the first coupling member 705. One or more seals (e.g., o-ring seals 714, etc.) may be used to provide a fluid tight connection between the jumper tube 701 and the coupling members 705, 725. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube 701 with the coupling members 705, 725.

[0089] Similar jumper tubes 701 and coupling members may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes 706, 726 and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes 701. In an embodiment, the shroud 403 may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section 728 to prevent damage to the jumper tubes 701, coupling members 705, 725 and ends of the adjacent shunt tubes 706, 726 during conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[0090] As described above, the shunt tubes may form a branched structure along the length of a screen assembly with the one or more transport tubes forming the trunk line and the one or more packing tubes forming the branch lines. The coupling between the transport tubes and the packing tubes may occur along the length of the screen assembly with a packing tube being directly connected to the transport tube. As described herein a coupling member may be configured to engage the jumper tube and a plurality of shunt tubes. In this embodiment, the coupling member may be coupled to and configured to distribute flow to a plurality of shunt tubes such as a transport tube and a packing tube, thereby eliminating or reducing the need for the packing tubes to be directly coupled to the transport tubes.

[0091] In an embodiment as illustrated in Figure 10, the coupling member may be similar to the coupling member described with respect to Figures 7 and 8 and the like components will not

be repeated in the interest of clarity. The coupling member 1002 may generally comprise a body portion 1003 comprising a first opening 1004 having a substantially round cross-section and a plurality of second openings 1006, 1008, which may comprise non-round cross-sections. A chamber 1014 may be disposed within the body portion 1003, and the chamber 1014 may be in fluid communication with the inlet opening 1004 and each of the plurality of outlet openings 1006, 1008. While only two second openings are depicted in Figure 10, the body portion 1003 may comprise more than two second openings, and the chamber 1014 may be in fluid communication with each of the plurality of second openings.

[0092] In an embodiment, the first opening 1004 may be configured to receive a jumper tube 1001, and the coupling between the jumper tube 1001 and the body portion 1003 may comprise a substantially round cross-section. The plurality of second openings 1006, 1008 may comprise non-round cross-sections, and each of the second openings 1006, 1008 may be configured to engage and couple to a shunt tube 1010, 1012. In an embodiment, the second opening 1006 may be coupled to a transport tube 1010, and the second opening 1008 may be coupled to a packing tube 1012. The plurality of second openings 1006, 1008 may generally be oriented in a parallel configuration to allow for the tubular members coupled thereto to extend parallel along the length of the wellbore tubular. In an embodiment, orientations other than parallel are possible. Fluid entering the first opening through the jumper tube 1001 may be distributed to the transport tube 1010 and the packing tube 1012 through the chamber 1014.

[0093] The coupling member 1002 may be configured to provide a sealing engagement between the jumper tube 1001 and the body portion 1003. For example, one or more seals may be disposed in corresponding seal recesses between the jumper tube 1001 and the body portion 1003. In an embodiment, the seals may comprise seal back-ups to provide for suitable pressure rating through the coupling member 1002. Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the coupling member, and/or the seal locations may also apply to the coupling member 1002.

[0094] In an embodiment, the coupling member 1002 may be configured to provide a sealing engagement between the body portion 1003 and one or more of the plurality of shunt tubes 1010, 1012. For example, one or more seals may be disposed in corresponding seal recesses between the body portion 1003 and one or more of the plurality of shunt tubes 1010, 1012. In an

embodiment, the seals may comprise seal back-ups to provide for suitable pressure rating through the coupling member 1002.

[0095] Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the coupling member, and/or the seal locations may also apply to the coupling member 1002. While described in terms of the jumper tube being coupled to a plurality of shunt tubes, the coupling member 1002 may also be used to couple a shunt tube to a plurality of jumper tubes. In this embodiment, the plurality of jumper tubes, which may comprise substantially round cross-sections at the coupling with the coupling member, may then be coupled to corresponding shunt tubes, which may comprise non-round cross-sections, on an adjacent section of wellbore tubular.

[0096] In an embodiment illustrated in Figures 11A to 11C, the coupling member comprises the retaining ring 1101. While illustrated as a half-view, it is understood that the retaining ring 1101 is configured to be disposed about a wellbore tubular. The retaining ring 1101 may be used to couple a jumper tube 1110 to a plurality of shunt tubes 1112, 1114. The jumper tube 1110 may comprise a cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the retaining ring 1101, and the plurality of shunt tubes 1112, 1114 may comprise a one or more second cross-sectional shapes, which may be non-round cross-sectional shapes. The retaining ring 1101 may then be configured to provide a sealing engagement with the jumper tube 1110 and the plurality of shunt tubes 1112, 1114, and the retaining ring 1101 may act as a converter between the cross-sectional shapes of the jumper tube 1110 and the plurality of shunt tubes 1112, 1114. In an embodiment, one or more portions of the jumper tube 1110 may comprise a non-round cross-section. Any of the jumper tube 1110 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 1110 coupled to the retaining ring 1101.

[0097] The retaining ring 1101 may have one or more fluid passages disposed therethrough. The openings 1102 of the fluid passages on a first side may be configured to engage one or more jumper tubes 1110 having a substantially round cross-section at the coupling with the retaining ring 1101, and the openings 1104, 1106 of the fluid passages on a second side may be configured to engage one or more shunt tubes 1112, 1114 having a non-round cross-section at the coupling with the retaining ring 1101. A chamber 1108 may be disposed within the retaining ring 1101 to provide fluid communication between each of the openings 1102, 1104, 1106. The plurality of

openings 1104, 1106 may generally be oriented in a parallel configuration to allow for the tubular members coupled thereto to extend parallel along the length of the wellbore tubular. In an embodiment, orientations other than parallel are possible.

[0098] The retaining ring 1101 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals with or without seal backups) between one or more of the plurality of shunt tubes 1112, 1114 and the retaining ring 1101, and/or the retaining ring 1101 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals with or without seal backups) between the jumper tube 1110 and the retaining ring 1101. In this embodiment, the retaining ring 1101 and the fluid passages may be configured to adapt a round cross-sectional shape for engaging the jumper tube 1110 to one or more non-round cross-sections of the shunt tubes 1112, 1114. In order to adapt the cross-sections of the plurality of shunt tubes 1112, 1114 to the jumper tube 1110, the cross-section of the fluid passages through the retaining ring 1101 may transition along the length of the fluid passages through the retaining ring 1101. The retaining ring 1101 may be coupled to the plurality of shunt tubes 1112, 1114 and/or the jumper tube 1110 using any of the connector types and configurations described herein. While illustrated as comprising two shunt tubes 1112, 1114, more than two shunt tubes may be engaged with the retaining ring 1101. Fluid entering the first opening 1102 through the jumper tube 1110 may be distributed to the transport tube 1112 and the packing tube 1114 through the chamber 1108.

[0099] The fluid communication provided by the retaining ring may be divided into two separate fluid communication pathways. As described herein, two or more separate fluid communication pathways may be used along the length of the well screen assembly to allow for redundancy in the shunt tube system. The separate fluid communication pathways may be retained by the inclusion of two openings 1102 to receive two jumper tubes 1110, and two pluralities of outlets to couple to separate pluralities of shunt tubes. For example, as shown in Figure 11B, the fluid communication provided between the opening 1102 and the plurality of openings 1104, 1106 through the chamber 1108 may be separate from a second set of openings 1103, 1105.

[00100] In an embodiment as illustrated in Figures 12A to 12D, the retaining ring 1101 may comprise a plurality of body portions. As shown in Figures 12A and 12B, the retaining ring 1101 may comprise a first body portion 1202 comprising the openings 1104, 1106. A seal recess

1204 may be disposed within a side of the first body portion 1202. A second body portion may be configured to engage the first body portion 1202, forming a chamber 1206 within the assembled retaining ring 1101. The second body portion may comprise the openings for receiving one or more jumper tubes. The second body portion may comprise a seal (e.g., a seal, gasket, etc.) configured to engage the seal recess 1204 and form a sealing engagement between the first body portion 1202 and the second body portion. The first body portion 1202 and second body portion may be engaged and coupled together using any suitable coupling mechanism (e.g., bolts, screws, pins, adhesives, clamps, etc.). While the retaining ring 1101 illustrated in Figures 12A and 12B show a single chamber 1206 being formed within the retaining ring 1101, a divider (not shown) may be disposed within the first body portion 1202 and/or the second body portion. The divider may be configured to divide the chamber 1206 into two portions, thereby maintaining independent and redundant fluid communication pathways along the length of the shunt tube assembly.

[00101] Another embodiment of a retaining ring 1101 comprising a plurality of body portions is illustrated in Figures 12C and 12D. In this embodiment, the first body portion 1208 may comprise the openings 1102 for coupling with one or more jumper tubes, which may have substantially round cross-sections at the coupling with the first body portion 1208. The second body portion 1210 may comprise the openings 1104, 1106 for coupling with one or more shunt tubes (e.g., transport tubes, packing tubes, etc.). The first body portion 1208 and the second body portion 1210 may be engaged and coupled using any suitable coupling mechanism. In an embodiment, the first body portion 1208 and the second body portion 1210 may be coupled using a welded coupling. One or more weldment surfaces 1212, 1214 may be disposed on the first body portion 1208 and/or the second body portion 1210 for receiving a weld. The use of the welded connection and the weldment surfaces 1212, 1214 disposed about the retaining ring 1101 surfaces may allow the orientation of the first body portion 1208 and the second body portion 1210 to be adjusted. For example, the first body portion 1208 may be somewhat misaligned with the second body portion 1210 while still allowing for the first body portion 1208 to be coupled to the second body portion 1210. Upon being coupled, one or both of the body portions 1208, 1210 may be fixedly attached to the wellbore tubular about which the retaining ring 1101 is disposed.

[00102] A partial isometric view of the retaining ring 1101 is illustrated in Figure 12D. A chamber 1206 may be formed by the engagement of the first body portion 1208 with the second

body portion 1210. The chamber may provide fluid communication between the openings 1102 and the openings 1104, 1106. When a single chamber is present, fluid communication may exist between each of the openings 1102 and each of the openings 1104, 1106. While the retaining ring 1101 illustrated in Figures 12C and 12D shows a single chamber 1206 being formed within the retaining ring 1101, a divider (not shown) may be disposed within the first body portion 1208 and/or the second body portion 1210. The divider may be configured to divide the chamber 1206 into two portions, thereby maintaining independent and redundant fluid communication pathways along the length of the shunt tube assembly.

[00103] Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the retaining member, and/or the seal locations may also apply to the retaining member 1101. While described in terms of the jumper tube being coupled to a plurality of shunt tubes, the retaining member 1101 may also be used to couple a shunt tube to a plurality of jumper tubes. In this embodiment, the plurality of jumper tubes, which may comprise substantially round cross-sections at the coupling with the retaining member 1101, may then be coupled to corresponding shunt tubes, which may comprise non-round cross-sections, on an adjacent section of wellbore tubular.

[00104] Referring to Figures 4, 10, 11A-11C, and 12A-12D, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 702 of a first shunt tube 706 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 722 of a second shunt tube 726 on the second wellbore tubular joint 520.

[00105] Once the adjacent shunt tubes are substantially aligned, a first coupling member may be engaged with the first shunt tube, and a second coupling member may be coupled with a second shunt tube. In an embodiment, one or more of the coupling members may comprise a coupling member engaged with a plurality of shunt tubes. In an embodiment, the first coupling member may be configured to engage a single jumper tube and a single shunt tube (e.g., a transport tube). In this embodiment, the second coupling member may be configured to engage the jumper tube and a plurality of shunt tubes (e.g., one or more transport tubes and/or packing

tubes), thereby forming the branched structure of the shunt tube assembly with the coupling member/retaining ring and the jumper tube. The coupling member comprising a plurality of openings for shunt tubes may then be used to distribute the sand or gravel slurry to the transport tubes and packing tubes.

[00106] The coupling member may comprise a separate component and/or a retaining ring as described herein. In this embodiment, the retaining ring may be pre-installed as part of the screen assembly, and may have one or more openings for engaging the jumper tube. In some embodiments, the coupling members may be pre-coupled to the shunt tubes. One or more seals (e.g., o-ring seals, etc.) may be used to provide a fluid tight connection between the shunt tubes and the respective coupling members. While described below in terms of the coupling members being separate from the retaining rings, the same or similar formation process may be used to couple the jumper tube to the retaining rings.

[00107] The jumper tube may then be coupled to the coupling members. For example, the jumper tube may be engaged with one of the coupling member. The opposite end of the jumper tube may then be extended (e.g., extended through a telescoping configuration) to engage the coupling member on the adjacent joint of wellbore tubular. In some embodiments, a jumper tube having a fixed length may be used. In this embodiment, the jumper tube may be engaged with the coupling member and displaced a sufficient distance to allow the opposite end of the jumper tube to be aligned and engaged with the second coupling member. The jumper tube may then be engaged with the coupling member a distance sufficient to form an engagement while maintaining the engagement with the first coupling member. One or more seals (e.g., o-ring seals, etc.) may be used to provide a fluid tight connection between the jumper tube and the coupling members. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube with the coupling members.

[00108] Similar jumper tubes and coupling members may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes. In an embodiment, the shroud 403 may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section to prevent damage to the jumper tubes, coupling members and ends of the adjacent shunt tubes during

conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[00109] In an embodiment, the coupling member may comprise a rotating and/or translating ring assembly. As shown in Figure 13, the coupling member 1300 comprises two rings 1304, 1306. The first ring 1304 may generally comprise a ring and/or clamp configured to engage and be disposed about the wellbore tubular 120. The first ring 1304 may engage the wellbore tubular 120 using any suitable coupling including any of those described with respect to the retaining ring 212, as described in more detail herein. The first ring 1304 may be configured to rotate about the wellbore tubular 120, and in some embodiments, axially translate over at least a portion of the length of the wellbore tubular 120. One or more seals 1308, 1310 may be used to form a sealing engagement between the first ring 1304 and the wellbore tubular 120 and a cover 1322. One or more ports 1312 may be disposed between an exterior side of the first ring 1304 and an interior side of the first ring 1304. Similarly, a second ring 1306 may engage the wellbore tubular 120. The second ring 1306 may be configured to rotate about the wellbore tubular 120, and in some embodiments, axially translate over at least a portion of the length of the wellbore tubular 120. One or more seals 1316, 1318 may be used to form a sealing engagement between the second ring 1306 and the wellbore tubular 120 and a cover 1322. One or more ports 1314 may be disposed between an exterior side of the second ring 1306 and an interior side of the second ring 1306.

[00110] The combination of the first ring 1304, the second ring 1306, and the cover 1322 may form a chamber 1320 through which fluid communication is established between one or more jumper tubes 1301 and one or more shunt tubes 1302. One or more stops may be disposed on and/or about the wellbore tubular to limit the axial translation of the first ring 1304 and/or the second ring 1306 along the length of the wellbore tubular. In an embodiment, the first ring 1304 and/or the second ring 1306 may be fixedly coupled to the wellbore tubular 120.

[00111] The first ring 1304 may be configured to be coupled to one or more jumper tubes 1301 and/or the second ring 1306 may be configured to be coupled to one or more shunt tubes 1302. The coupling with the one or more jumper tubes 1301 may comprise a substantially round cross-section, and/or the coupling with the one or more shunt tubes 1302 may comprise a non-

round cross-section. Thus, the combination of the first ring 1304 and the second ring 1306 may be used to adapt a non-round cross-section of one or more shunt tubes 1302 to a substantially round cross-section of the coupling portion of one or more jumper tubes 1301. Further the rotation and translation of the first ring 1304 and/or the second ring 1306 may allow for a misalignment of the shunt tubes on adjacent sections of wellbore tubular. For example, the first ring 1304 and/or the second ring 1306 may be rotated and/or axially translated into engagement with the one or more jumper tubes 1301 and one or more shunt tubes 1302, respectively.

[00112] In use, the first ring 1304 may be rotated about the wellbore tubular 120 and/or axially translated into engagement with the jumper tube 1301. The second ring 1306 may similarly be rotated about the wellbore tubular 120 and/or axially translated into engagement with the shunt tubes 1302. Upon being engaged with the respective tubes, the cover 1322 may be engaged with the first ring 1304 and the second ring 1306 to form the chamber 1320 and provide fluid communication between the tubes. The first ring 1304 and/or the second ring 1306 may then be optionally fixedly coupled to the wellbore tubular 120 to maintain the relative positions of the first ring 1304 and/or the second ring 1306.

[00113] Another embodiment of a coupling member comprising a rotating and/or translating ring assembly is illustrated in Figure 14. The embodiment of Figure 14 is similar to the embodiment illustrated in Figure 13 and like components will not be discussed in the interest of clarity. In this embodiment, a first ring 1404 and a second ring 1406 may be disposed about the wellbore tubular 120, and the first ring 1404 and second ring 1406 may be configured to directly engage each other, thereby forming the chamber 1320. A coupling mechanism 1420 may be used to engage and couple the first ring 1404 to the second ring 1406. The engagement of the first ring 1404 with the second ring 1406 may form a sealing engagement. In an embodiment, the coupling mechanism may be configured to couple the first ring 1404 and the second ring 1406 regardless of the axial alignment of the rings 1404, 1406 and/or the one or more jumper tubes 1301 or one or more shunt tube 1302. This may allow the first ring 1404 and/or the second ring 1406 to be rotated about the wellbore tubular 120 to provide the appropriate alignment with the one or more jumper tubes 1301 and/or the one or more shunt tubes 1302 before being coupled together.

[00114] In use, the first ring 1304 may be rotated about the wellbore tubular 120 and into engagement with the jumper tube 1301. The second ring 1306 may similarly be rotated about

the wellbore tubular 120 and into engagement with the shunt tubes 1302. Upon being engaged with the respective tubes, the coupling mechanism may be used to couple the first ring 1404 to the second ring 1406, which may form a sealing engagement between the rings 1404, 1406. The first ring 1404 and/or the second ring 1406 may then be optionally fixedly coupled to the wellbore tubular 120 to maintain the relative positions of the first ring 1404 and/or the second ring 1406.

[00115] In each of the embodiments of the couplings, coupling members, and/or retaining rings described herein may be used alone or in combination to provide an assembled shunt tube assembly. For example, a shunt tube assembly comprising a plurality of wellbore tubular joints may be coupled using any combination of the configurations described herein. Once assembled, any of the shunt tube assemblies described herein may be disposed within a wellbore for use in forming a sand screen. Referring again to Figure 1, after the assembled sand screen structure is installed in the wellbore 114, a packing sand/gel slurry can be forced downwardly into the annulus between the casing and the sand screen to form the pre-filtering sand pack around the screen structure. In the event that an annular sand bridge is created externally around the sand screen structure, the slurry is caused to bypass the sand bridge by flowing into the shunt tubes downwardly through the shunt tubes, and then outwardly into the casing/sand screen annulus beneath the sand bridge. When flowing through the shunt tubes, the packing sand/gel slurry may pass through one or more connections comprising jumper tubes coupled to one or more shunt tubes using the couplings, coupling members, and/or retaining rings described herein. Once the gravel pack has been formed as desired, a fluid may be allowed to flow through the gravel pack, through the slots in the outer body member, through the filter media, and into the throughbore of the wellbore tubular where it may be produced to the surface.

[00116] At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example,

whenever a numerical range with a lower limit, R_l, and an upper limit, R_u, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R=R_l+k*(R_u-R_l)$, wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ..., 50 percent, 51 percent, 52 percent, ..., 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention.

CLAIMS

What is claimed is:

1. A shunt tube assembly comprising:
   a shunt tube, wherein the shunt tube comprises a non-round cross section; and
   a jumper tube comprising a first end, wherein the first end of the jumper tube is coupled to the shunt tube at a coupling, wherein the first end of the jumper tube comprises a substantially round cross section at the coupling.
2. The shunt tube assembly of claim 1, further comprising a second shunt tube coupled to a second end of the jumper tube at a second coupling, wherein the second shunt tube comprises a non-round cross section, and wherein the second end of the jumper tube comprises a substantially round cross section at the second coupling.
3. The shunt tube assembly of claim 1, wherein the jumper tube comprises a non-round cross section.
4. The shunt tube assembly of claim 3, wherein the jumper tube maintains a substantially constant hydraulic diameter between the first end and a second end.
5. The shunt tube assembly of claim 3, wherein the non-round cross section of the jumper tube is disposed adjacent to a coupling between a first wellbore tubular and a second wellbore tubular.
6. The shunt tube assembly of claim 3, wherein the non-round cross section of the jumper tube comprises a rectangular, oval, kidney shaped, trapezoidal, or squared cross section.
7. The shunt tube assembly of claim 1, wherein the jumper tube comprises a bend between the first end and a second end.
8. The shunt tube assembly of claim 1, wherein the jumper tube comprises a first tubular body and a second tubular body, wherein the first tubular body is configured to sealingly slidingly engage the second tubular body.
9. A shunt tube assembly comprising:
   a shunt tube comprising a first cross-sectional shape;
   a jumper tube comprising a second cross-sectional shape; and
   a coupling member comprising a first end and a second end, wherein the coupling member is configured to provide a sealing engagement between the coupling member and the shunt tube at the first end, and wherein the coupling member is

configured to provide a sealing engagement between the coupling member and the jumper tube at the second end.

10. The shunt tube assembly of claim 9, wherein the second cross-sectional shape is a substantially round cross-sectional shape.

11. The shunt tube assembly of claim 9, wherein the first cross-sectional shape is a rectangular cross-sectional shape.

12. The shunt tube assembly of claim 9, further comprising one or more seals disposed between the coupling member and the shunt tube at the first end.

13. The shunt tube assembly of claim 12, further comprising one or more seal back-ups disposed adjacent to the one or more seals at the first end.

14. The shunt tube assembly of claim 9, further comprising one or more seals disposed between the coupling member and the jumper tube at the second end.

15. The shunt tube assembly of claim 14, further comprising one or more seal back-ups disposed adjacent to the one or more seals at the second end.

16. The shunt tube assembly of claim 9, further comprising:

a second shunt tube comprising a third cross-sectional shape; and

a second coupling member comprising a third end and a fourth end, wherein the second coupling member is configured to provide a sealing engagement between the second coupling member and the second shunt tube at the third end, and wherein the second coupling member is configured to provide a sealing engagement between the second coupling member and the jumper tube at the second end.

17. The shunt tube assembly of claim 16, wherein the first cross-sectional shape and the third cross-sectional shape are the same.

18. The shunt tube assembly of claim 9, wherein the coupling member comprises an alignment ring.

19. A method of forming a shunt tube coupling comprising:

aligning a first end of a jumper tube with a shunt tube, wherein the shunt tube comprises a non-round cross section; and

coupling the first end of the jumper tube to the shunt tube at a coupling, wherein the first end of the jumper tube comprises a substantially round cross section at the coupling.

20. The method of claim 19, further comprising: aligning a second end of the jumper tube with a second shunt tube, wherein the second shunt tube comprises a second non-round cross section; and coupling the second end of the jumper tube to the second shunt tube at a second coupling, wherein the second end of the jumper tube comprises a substantially round cross-section at the second coupling.

21. The method of claim 19, wherein the jumper tube comprises a non-round cross section, and wherein the non-round cross-section of the jumper tube comprises a rectangular, oval, kidney shaped, trapezoidal, or squared cross section.

22. The method of claim 19, wherein the jumper tube comprises a bend between the first end and a second end.

23. A method of gravel packing comprising:

passing a slurry through a first shunt tube, wherein the first shunt tube comprises a first cross-sectional shape;

passing the slurry through a coupling, wherein the coupling comprises a coupling between the first shunt tube and a jumper tube, wherein the jumper tube comprises a substantially round cross-section at the coupling; and

disposing the slurry about a well screen assembly below the coupling.

24. The method of claim 23, wherein the coupling further comprises a coupling member, wherein the coupling member is configured to adapt the first cross-sectional shape to a substantially round-cross sectional shape.

25. The method of claim 24, wherein the coupling member comprises a retaining ring disposed about a wellbore tubular.

26. The method of claim 23, wherein the coupling further comprises a chamber.

27. The method of claim 23, further comprising;

passing the slurry through a second coupling, wherein the second coupling comprises a coupling between the jumper tube and a plurality of second shunt tubes.

28. The method of claim 27, wherein the plurality of second shunt tubes comprises a packing tube and a transport tube.

29. The method of claim 28, wherein disposing the slurry comprises passing the slurry through one or more perforations in the packing tube.

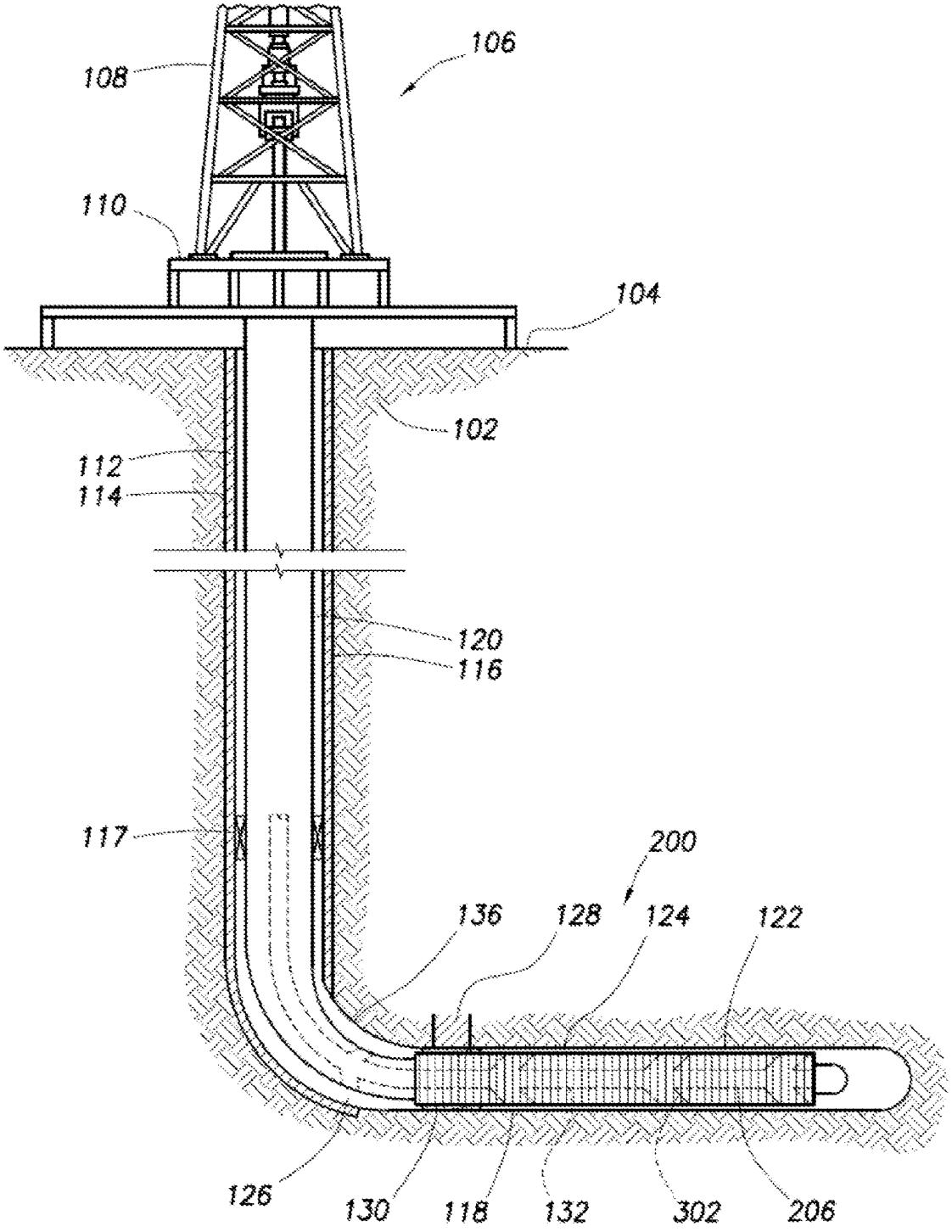
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FIG. 1

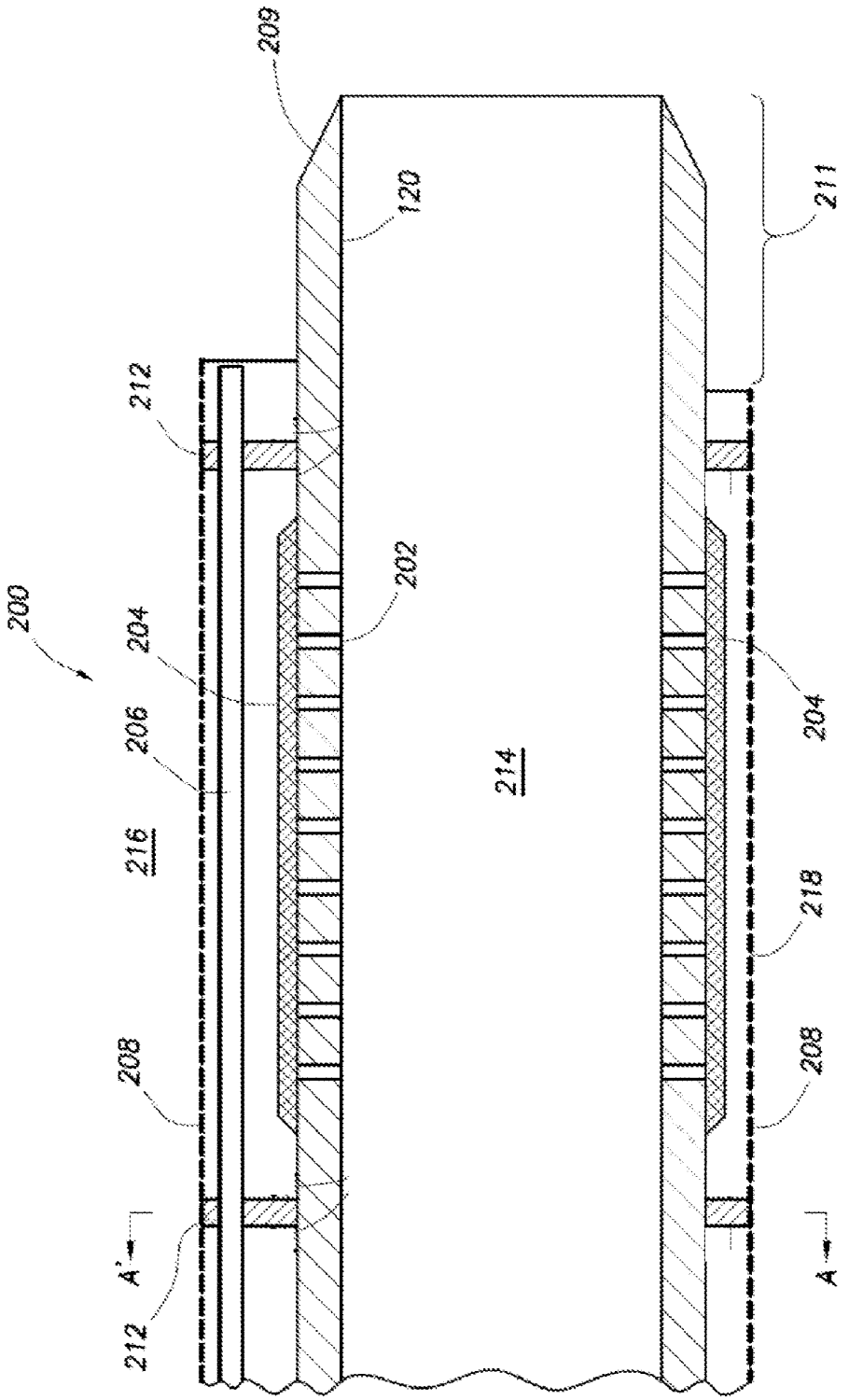

FIG.2

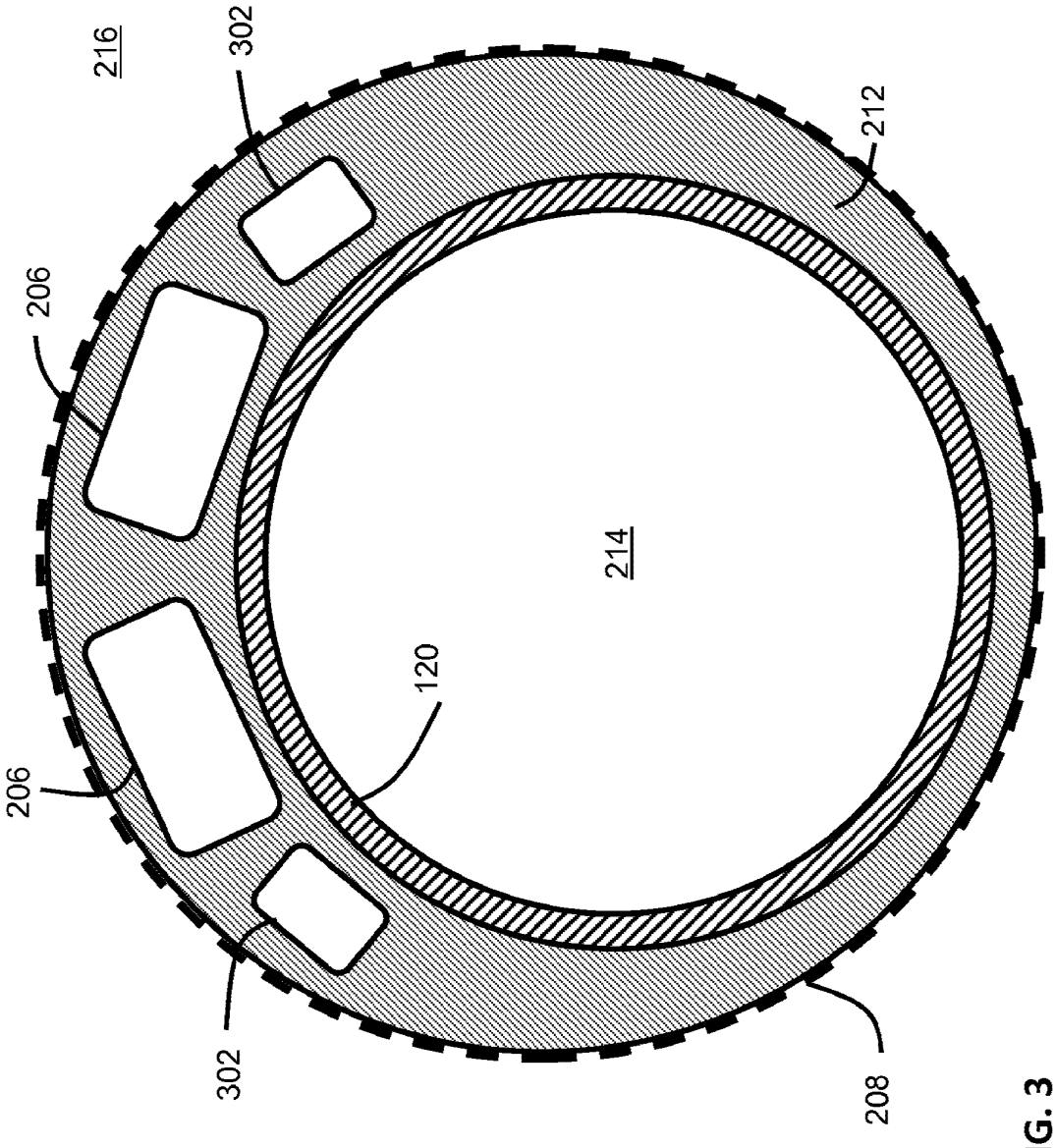

FIG. 3

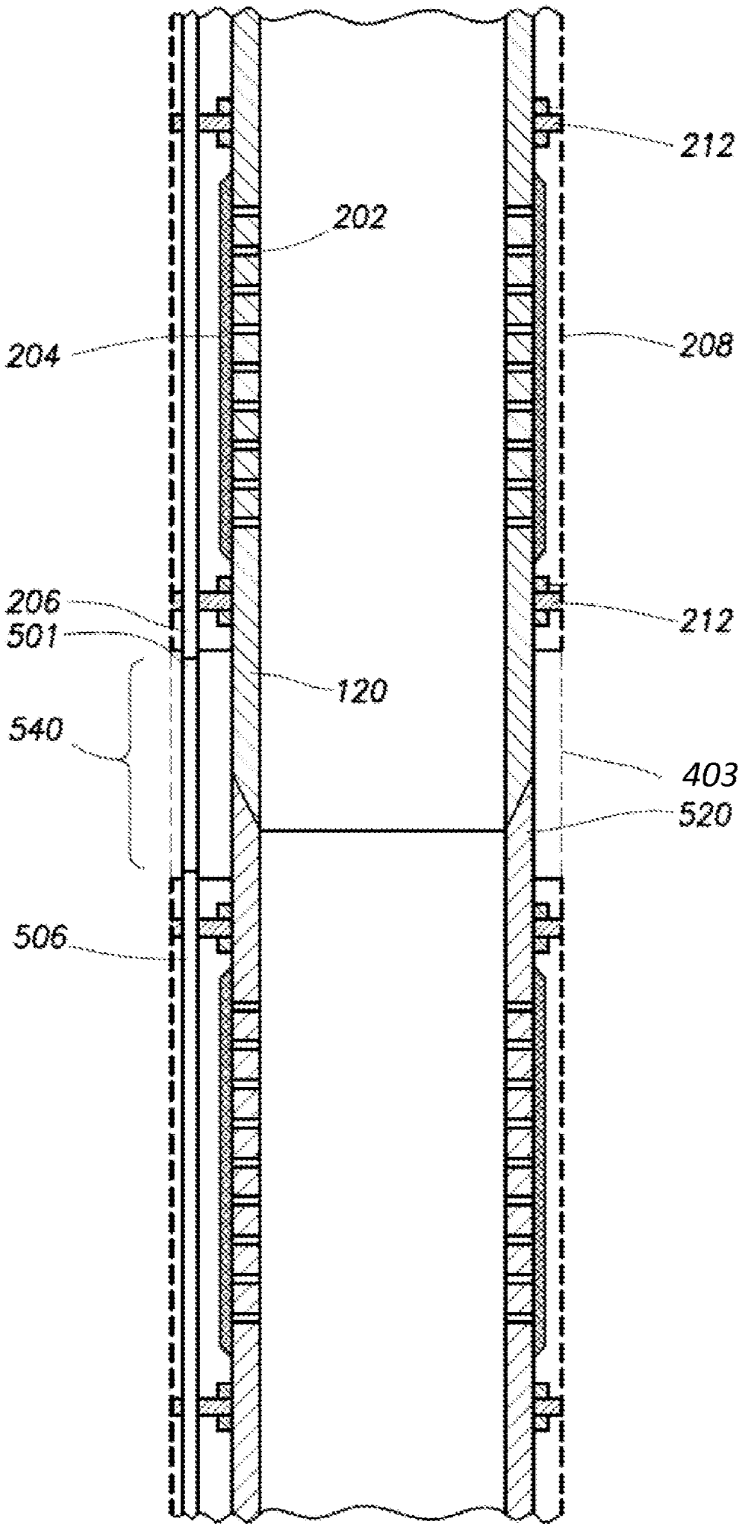

FIG. 4

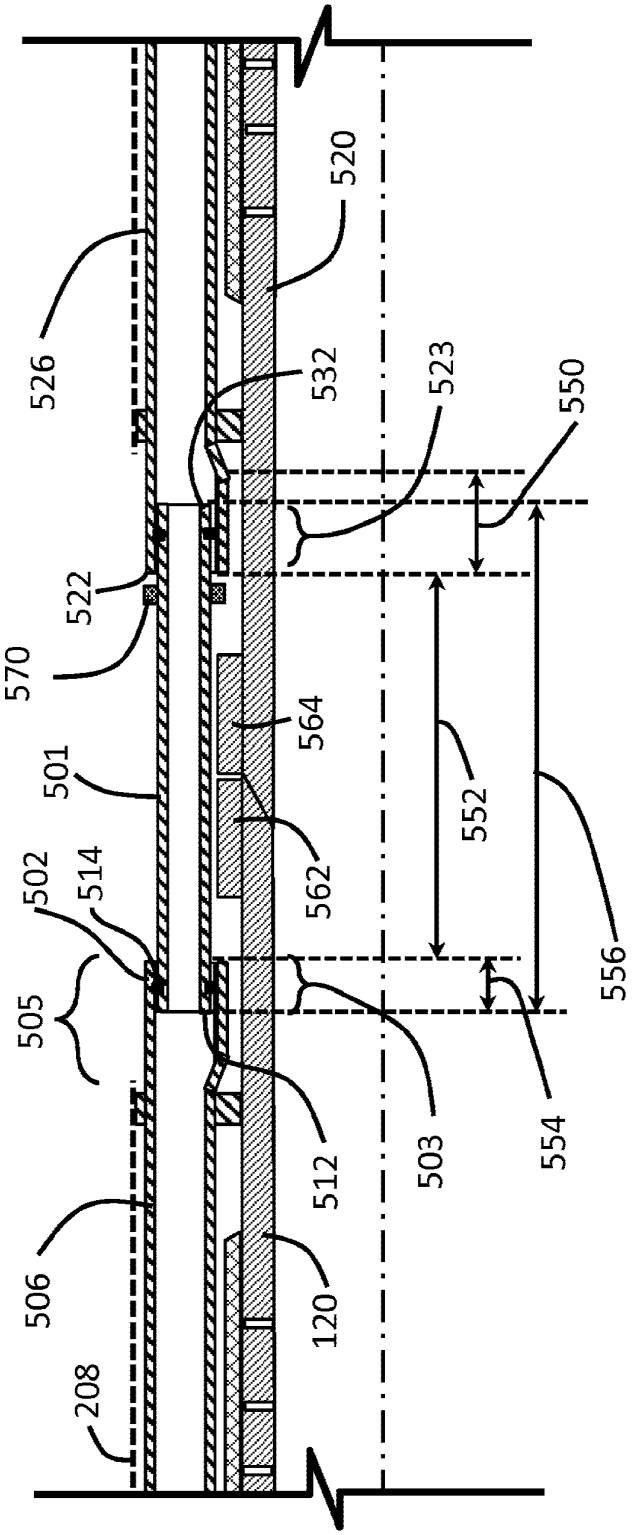
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FIG. 5

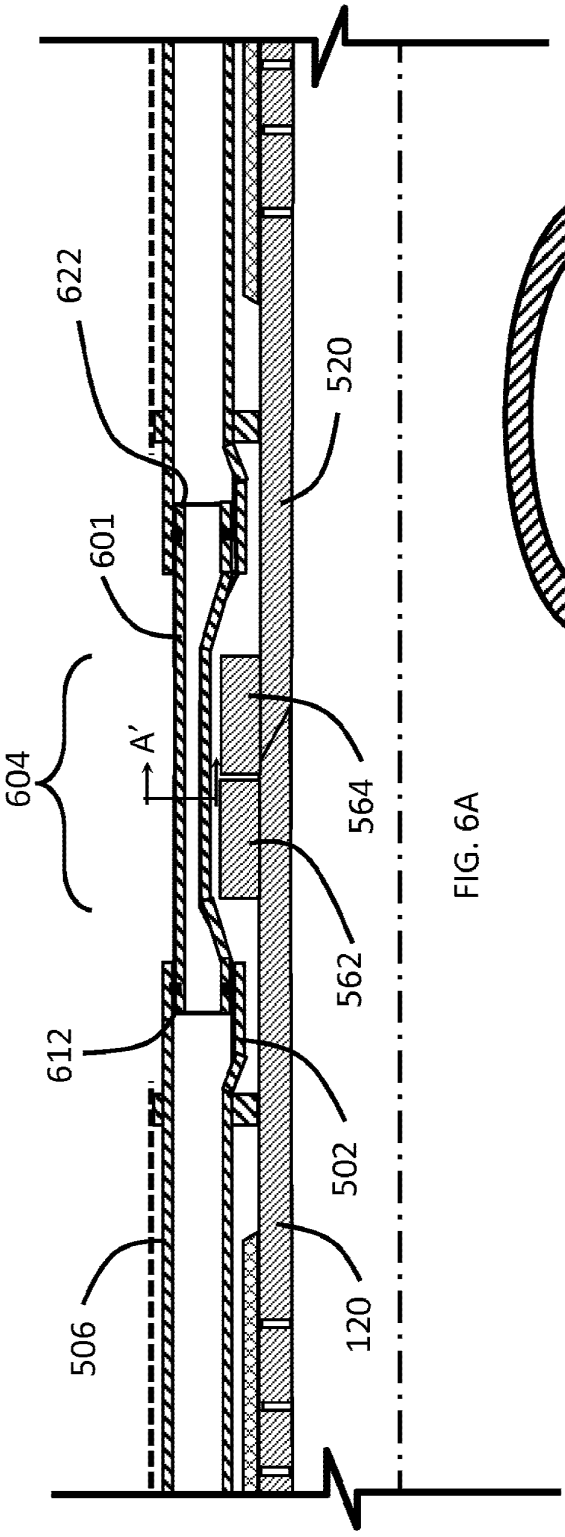

FIG. 6A

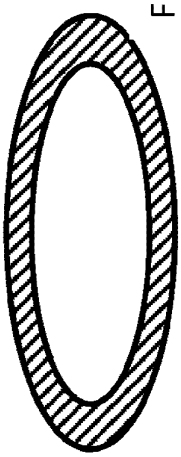

FIG. 6D

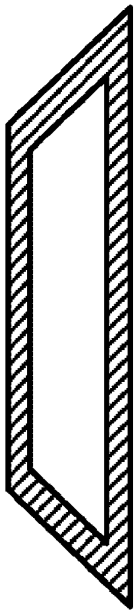

FIG. 6E

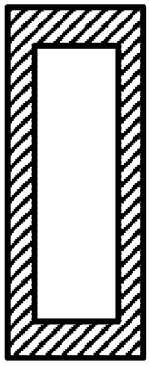

FIG. 6B

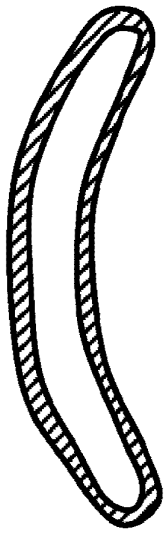

FIG. 6C

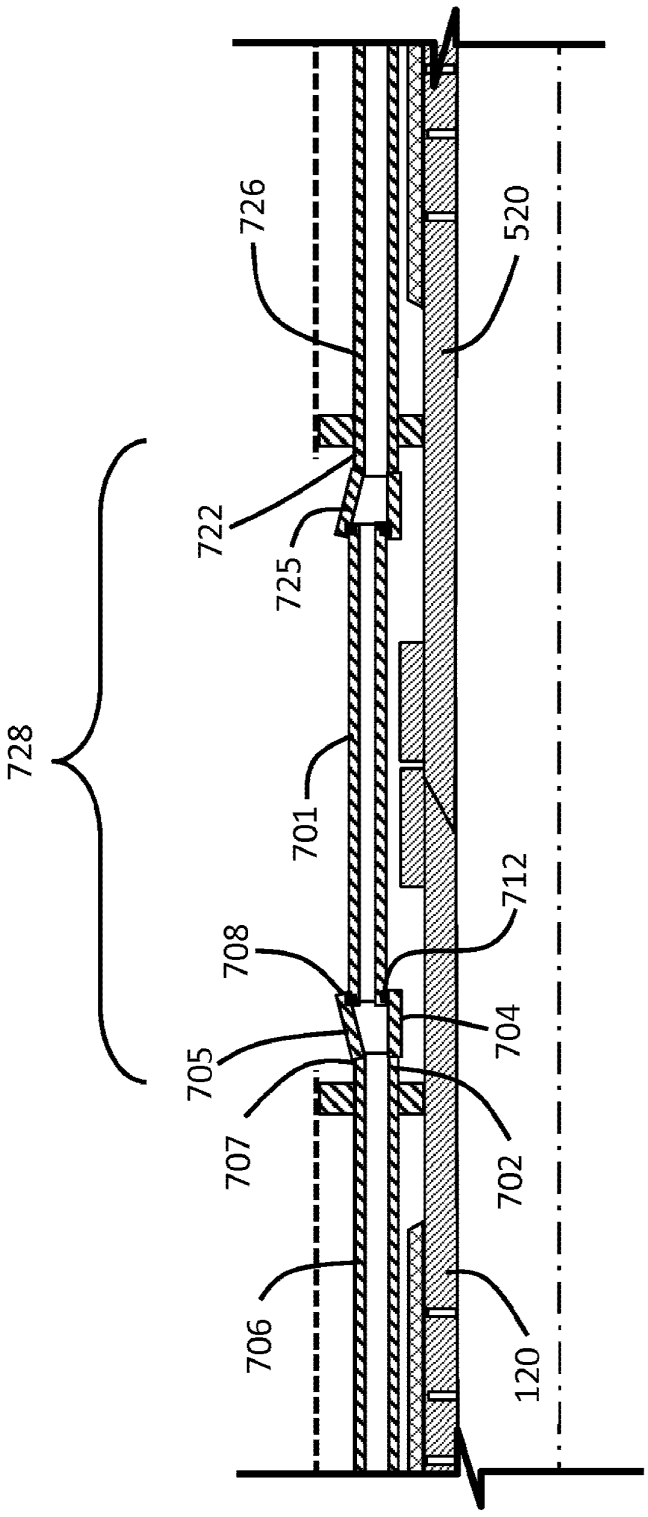

FIG. 7A

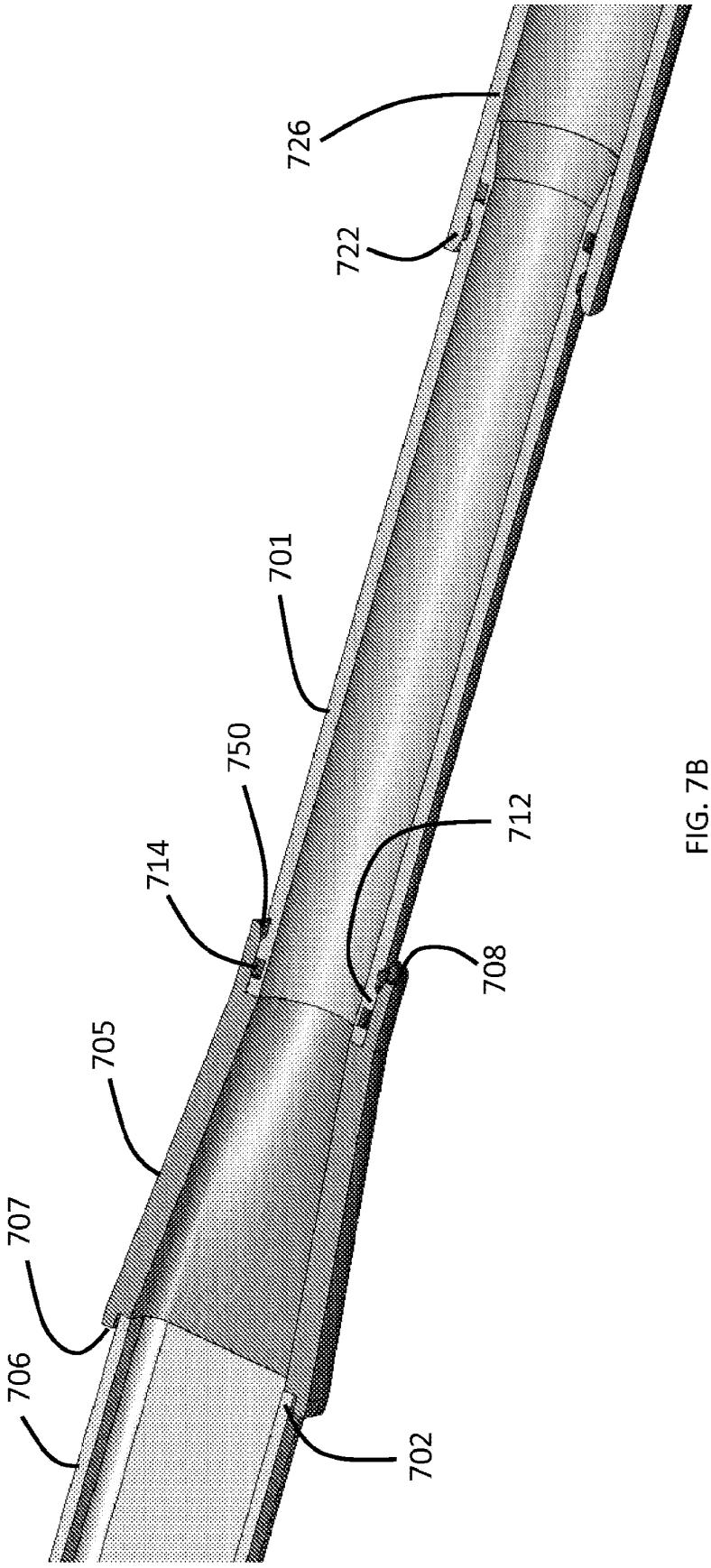

FIG. 7B

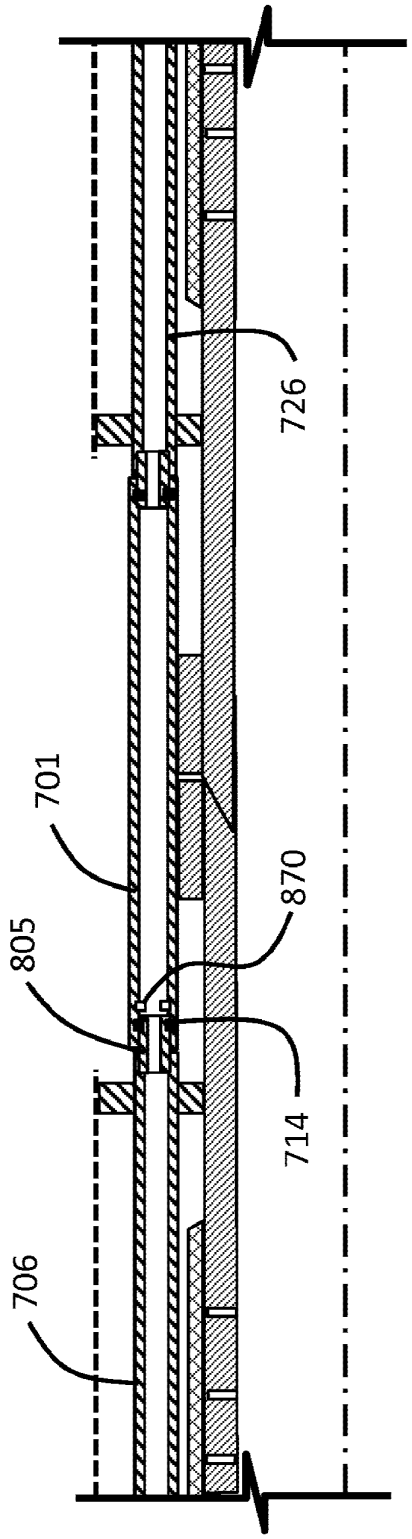
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FIG. 8

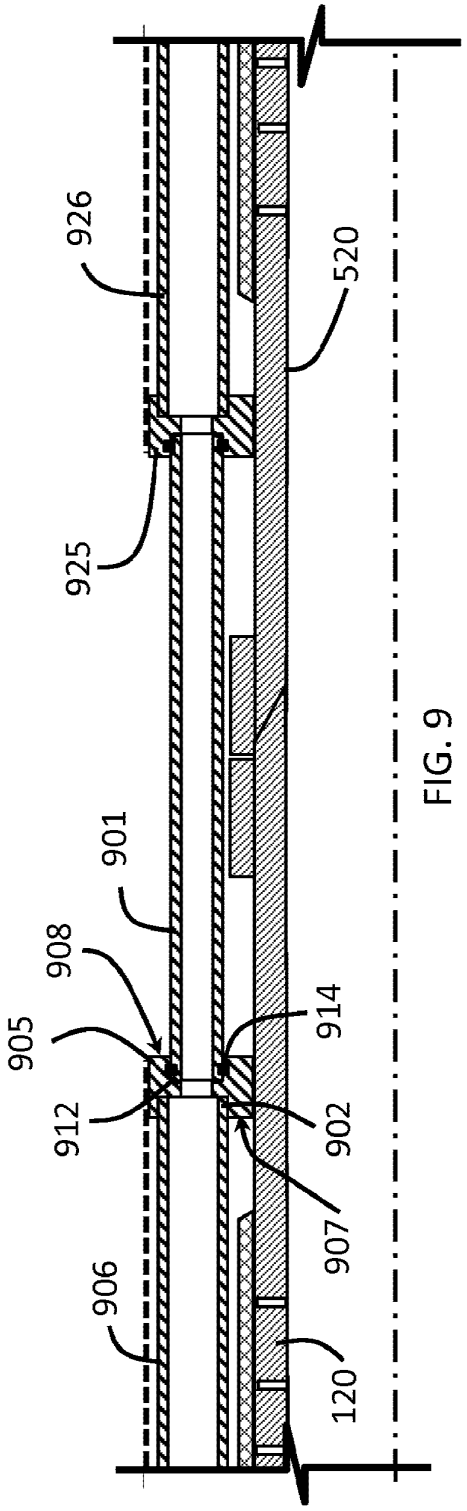
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FIG. 9

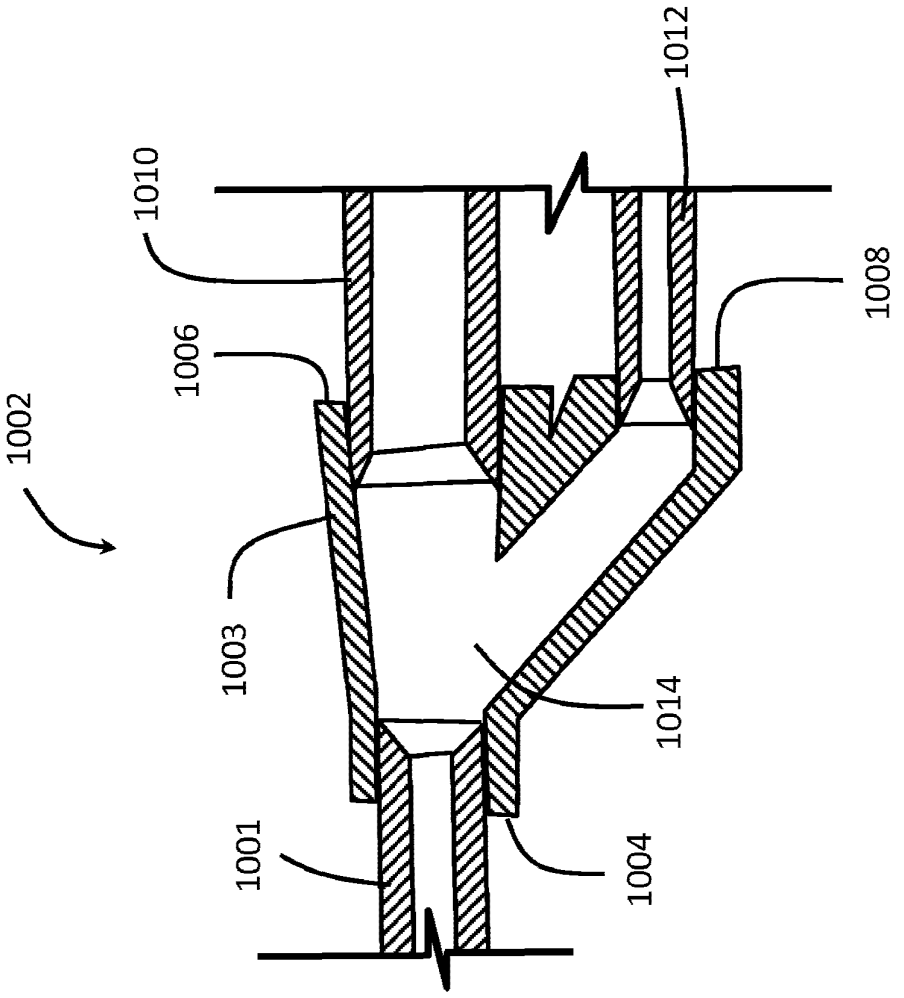

FIG. 10

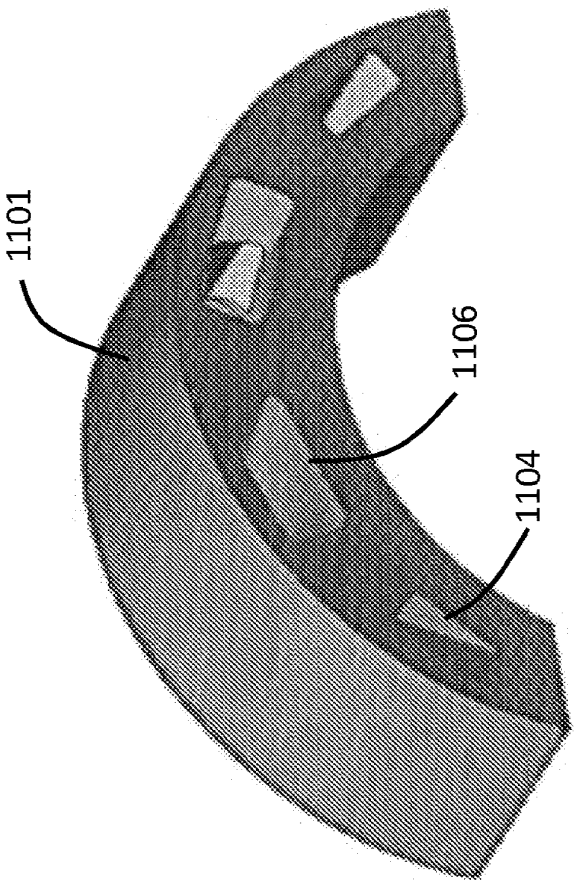

FIG. 11A

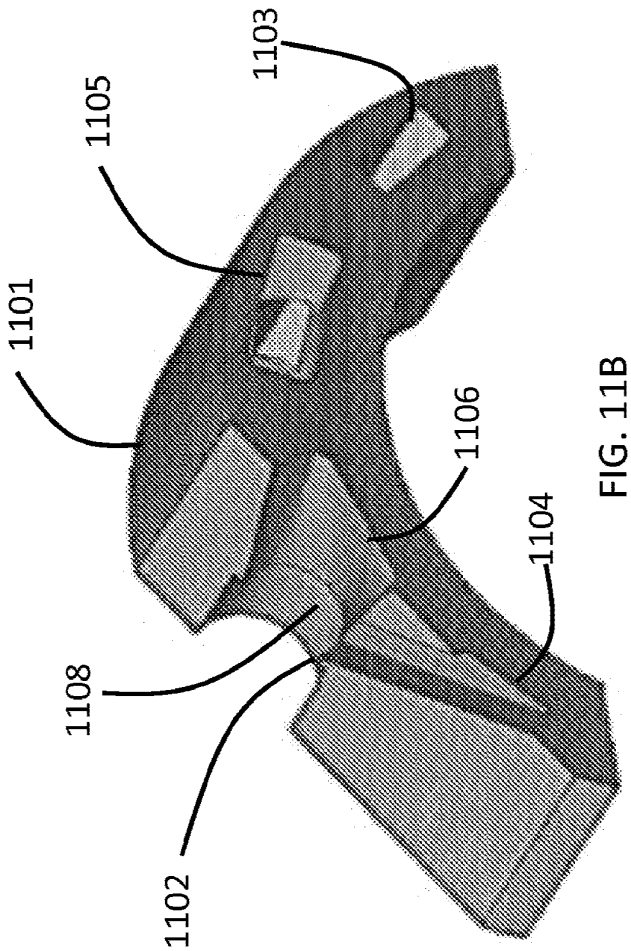

FIG. 11B

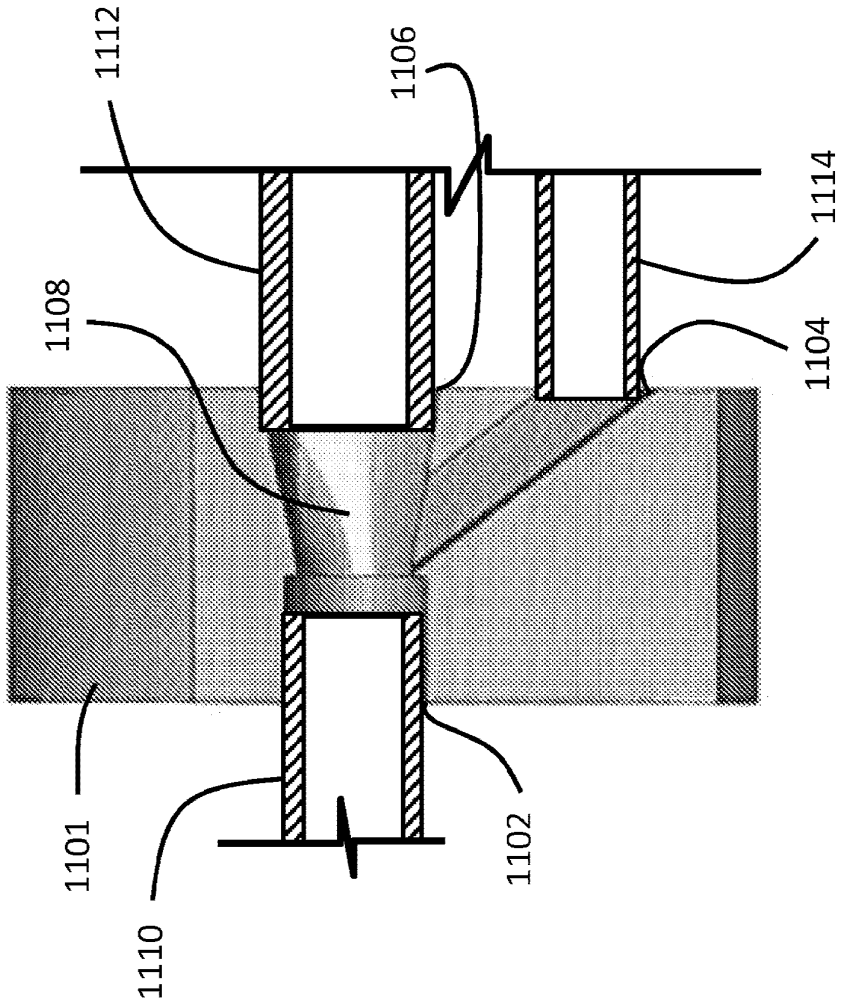

FIG. 11C

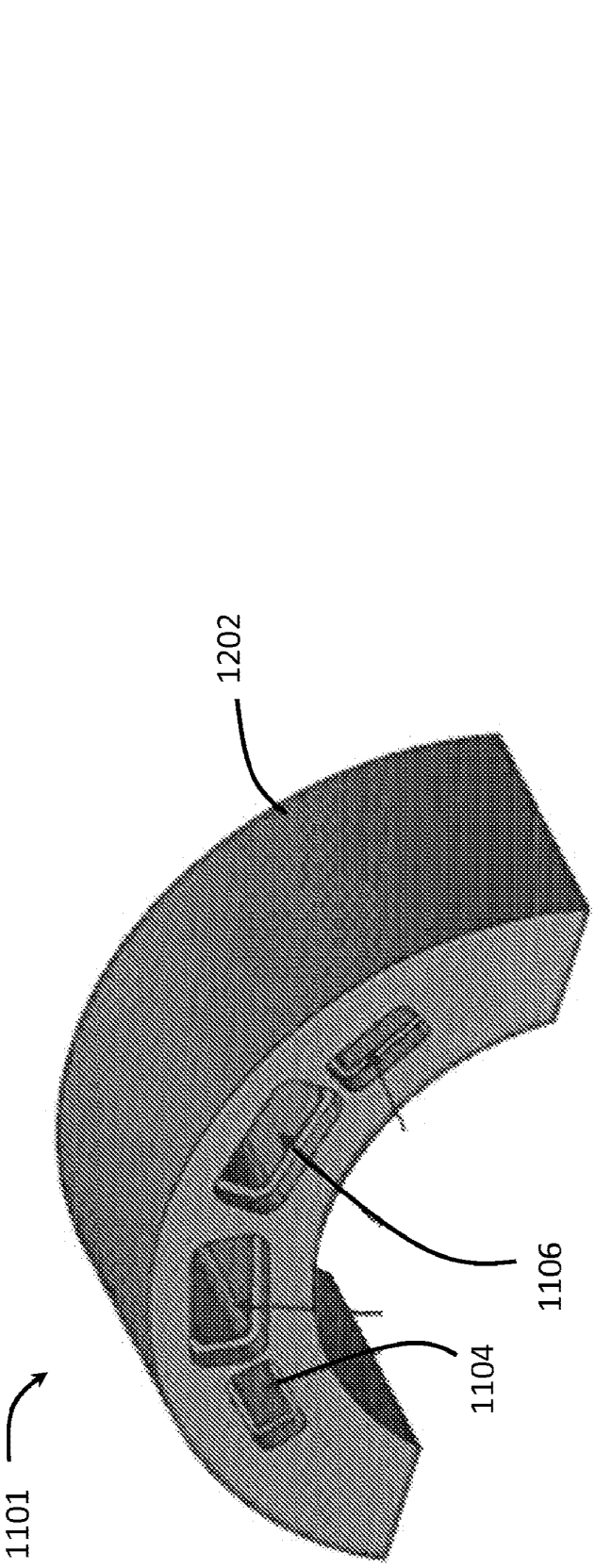

FIG. 12A

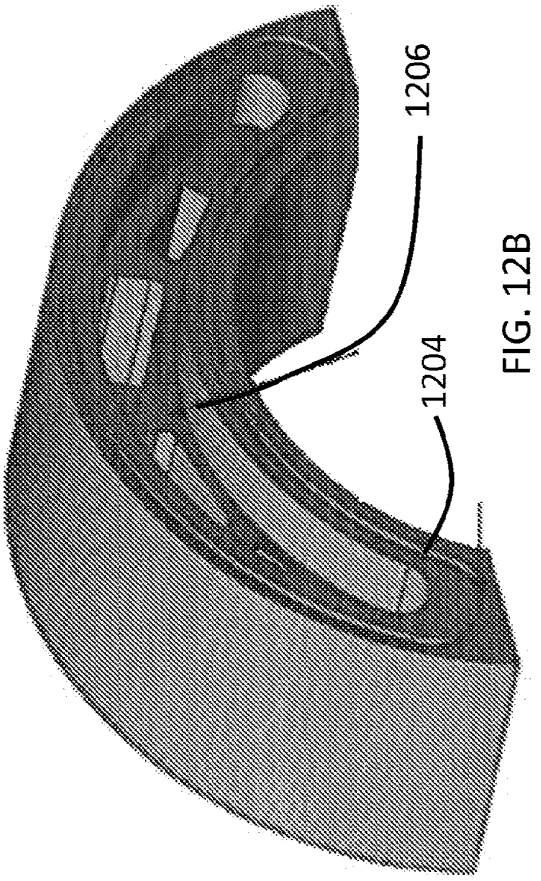

FIG. 12B

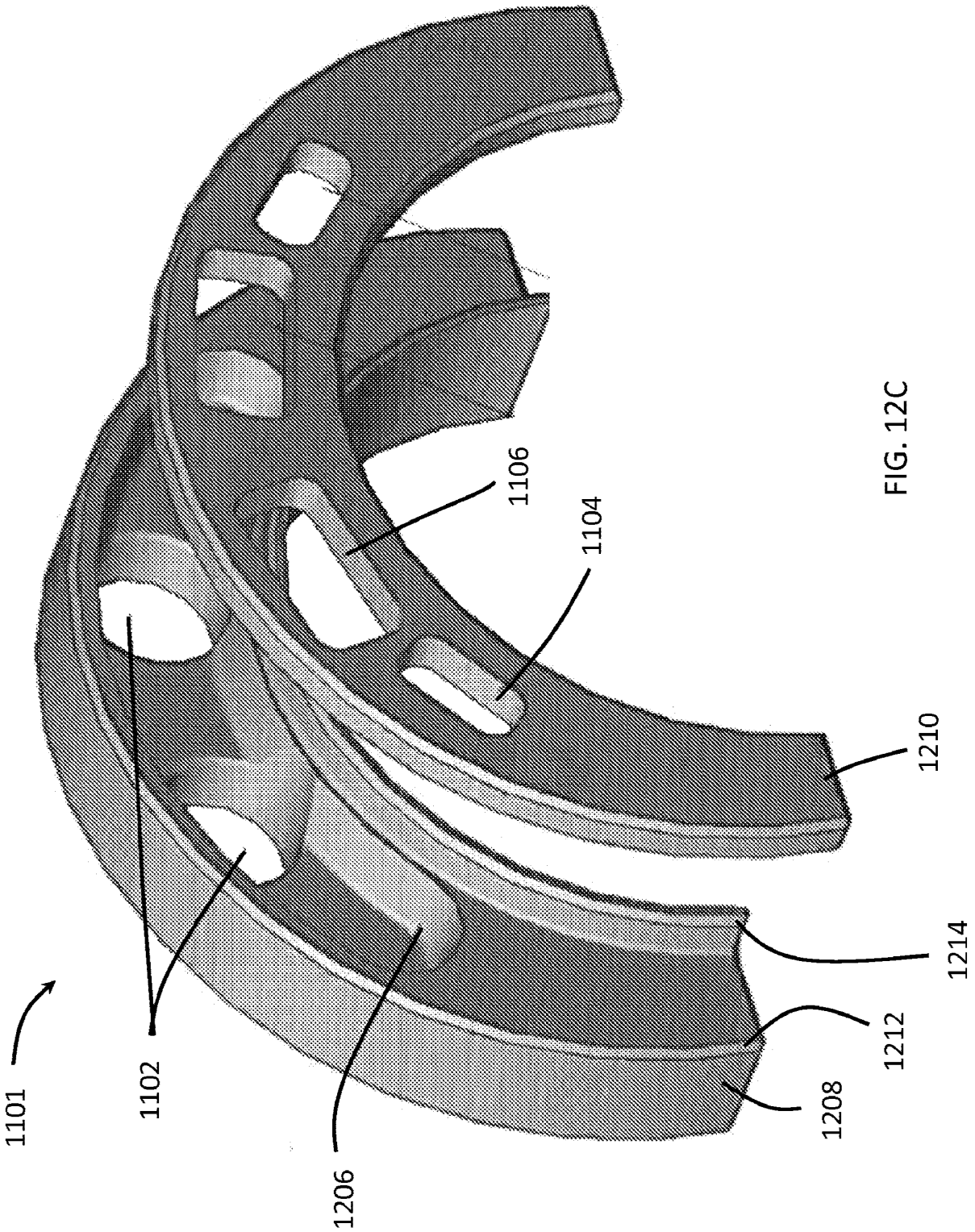

FIG. 12C

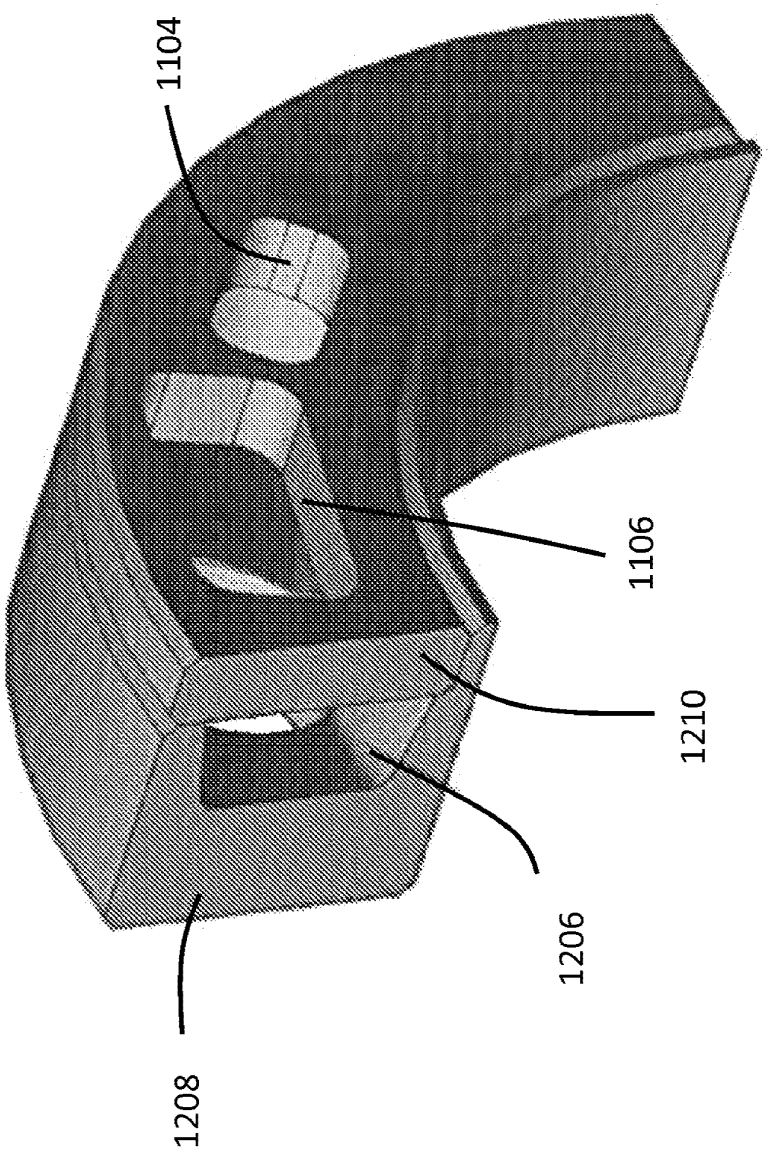

FIG. 12D

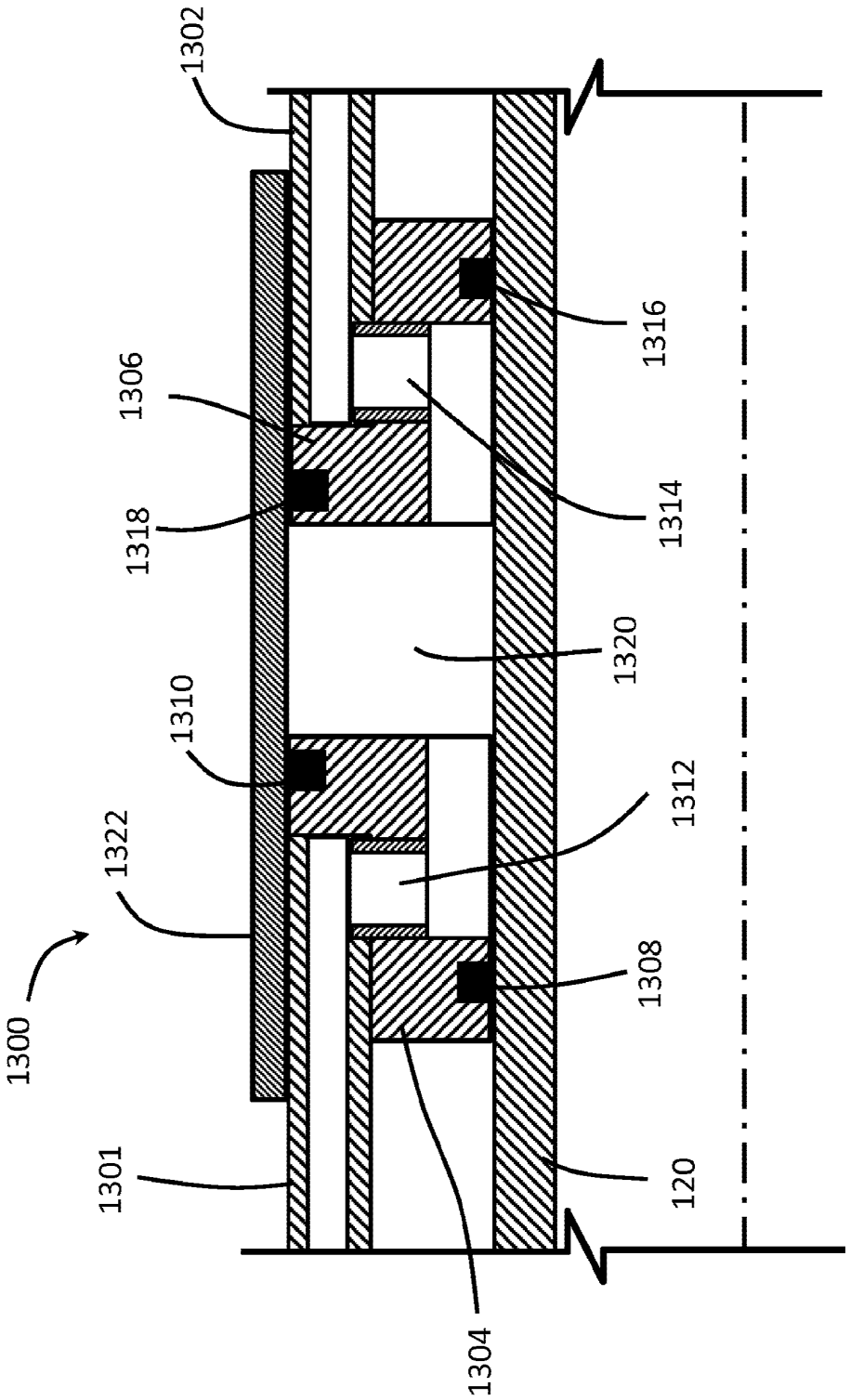
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FIG. 13

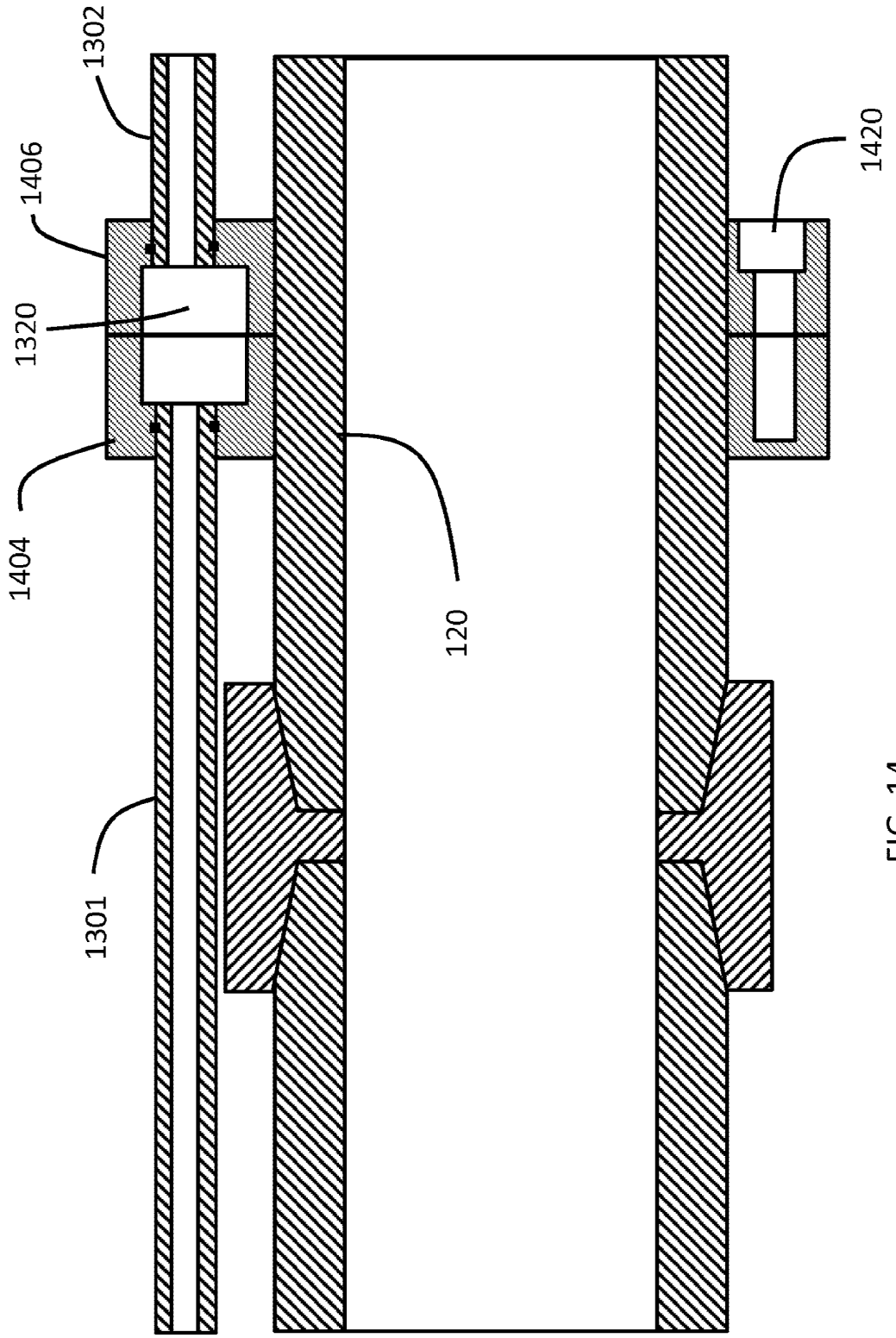

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/041970

A. CLASSIFICATION OF SUBJECT MATTER

E21B 19/16(2006.01)i, E21B 43/08(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)

IPC: E21B 19/16; E21B 43/00; E21B 43/08; E21B 43/04

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: gravel, slurry, shunt, bypass, screen, filter, cross section and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US20060283604 A1 (SETTERBERG JR., JOHN RICHARD et al.) 21 December 2006 See abstract, paragraph 19 and claim 1	1-29
A	US5515915 A (JONES, LLOYD G. et al.) 14 May 1996 See abstract, column 4 lines 9-20 and figure 1	1-29
A	US20100032158 A1 (DALE, BRUCE A. et al.) 11 February 2010 See abstract, paragraph 36 and figures 2a,2b	1-29
A	US5113935 A (JONES, LLOYD G. et al.) 19 May 1992 See abstract, column 3 line 56 - column 4 line 4 and figure 1	1-29

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

☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 FEBRUARY 2013 (18.02.2013)	**19 FEBRUARY 2013 (19.02.2013)**
Name and mailing address of the ISA/KR Facsimile No. 82-42-472-7140	Authorized officer Kim Sun Telephone No. 82-42-481-3578

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/041970

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US5113935 A	19.05.1992	None	

Weatherford Exhibit 1002
Weatherford v. Halliburton
Page 229

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
TIDWELL, Mark

Haynes and Boone, LLP 2323 Victory Avenue, Suite 700
Dallas, Texas 75219 USA

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing *(day/month/year)*	07 August 2019 (07.08.2019)
Applicant's or agent's file reference 75231981WO01	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2019/024626**	International filing date *(day/month/year)* **28 March 2019 (28.03.2019)**

Applicant

HALLIBURTON ENERGY SERVICES, INC.

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 . 9-011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Within **22 months** from the priority date, the applicant may request that a supplementary international search be carried out by a different International Searching Authority, that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

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	Authorized officer COMMISSIONER
Facsimile No. 82-42-481-8578	Telephone No. 82-42-481-8751

Form PCT/ISA/220 (July 2017)

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for six months(expire date : **2020.02.07**) from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT ISA Portal => PCT Status

ID : PCT international application number

PW : **NV5SW3BM(**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com

Email: ipkc@ipkcenter.com

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 75231981WO01	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. **PCT/US2019/024626**	International filing date *(day/month/year)* **28 March 2019 (28.03.2019)**	(Earliest) Priority Date *(day/month/year)* 22 June 2018 (22.06.2018)
Applicant **HALLIBURTON ENERGY SERVICES, INC.**		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 7 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out 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))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☐ the text is approved as submitted by the applicant.
   ☒ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 2
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

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Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies. A completion assembly for deployment in a wellbore, comprises a first sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, and a second sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, wherein the first and second sand screen assemblies are arranged end to end relative to one another. And the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/024626

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/04(2006.01)i, E21B 33/12(2006.01)i, E21B 34/06(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 19/16; E21B 43/08; E21B 33/12; E21B 34/06

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: completion, sand screen, shunt tube, transport tube, packing tube, wall thickness

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003-0029613 A1 (DANOS et al.) 13 February 2003 See paragraphs [0002]-[0046]; and figures 5-9.	1,5-23
A		2-4
Y	US 2010-0139919 A1 (YEH et al.) 10 June 2010 See paragraphs [0041]-[0092]; and figures 2A-3C, 5B, 11A-11B.	1,5-23
A	WO 2013-187878 A1 (HALLIBURTON ENERGY SERVICES, INC. et al.) 19 December 2013 See paragraphs [0036]-[0116]; and figures 1-14.	1-23
A	US 2014-0110131 A1 (HALLIBURTON ENERGY SERVICES, INC.) 24 April 2014 See paragraphs [0031]-[0047]; and figures 1-13.	1-23
A	US 2013-0008652 A1 (BROUSSARD et al.) 10 January 2013 See paragraphs [0051]-[0110]; and figures 2-12.	1-23

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 August 2019 (06.08.2019)	**07 August 2019 (07.08.2019)**

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

Authorized officer
PARK, Tae Wook
Telephone No. +82-42-481-3405

Form PCT/ISA/210 (second sheet) (January 2015)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2014-074485 A2	15/05/2014
		WO 2014-074485 A3	11/12/2014

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
TIDWELL, Mark

Haynes and Boone, LLP 2323 Victory Avenue, Suite 700
Dallas, Texas 75219 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)* **07 August 2019 (07.08.2019)**

Applicant's or agent's file reference
75231981WO01

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/024626	**28 March 2019 (28.03.2019)**	22 June 2018 (22.06.2018)

International Patent Classification (IPC) or both national classification and IPC
E21B 43/04(2006.01)i, E21B 33/12(2006.01)i, E21B 34/06(2006.01)i

Applicant
HALLIBURTON ENERGY SERVICES, INC.

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

- [x] 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
- [x] Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [x] 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	Date of completion of this opinion	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	06 August 2019 (06.08.2019)	PARK, Tae Wook Telephone No. +82-42-481-3405

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/024626

Box No. I 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*.1(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*.1(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*.1(a)).
      ☐ on paper or in the form of an image file (Rule 13*ter*.1(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:

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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	1-23	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	2-4	YES
	Claims	1,5-23	NO
Industrial applicability (IA)	Claims	1-23	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: US 2003-0029613 A1 (DANOS et al.) 13 February 2003
D2: US 2010-0139919 A1 (YEH et al.) 10 June 2010
D3: WO 2013-187878 A1 (HALLIBURTON ENERGY SERVICES, INC. et al.) 19 December 2013
D4: US 2014-0110131 A1 (HALLIBURTON ENERGY SERVICES, INC.) 24 April 2014
D5: US 2013-0008652 A1 (BROUSSARD et al.) 10 January 2013

I. Novelty and Inventive Step (PCT Article 33(2) and (3))

1. Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses an apparatus for a wellbore completion system comprising: a first sand screen assembly comprising a sand screen (28) and a second sand screen assembly comprising a sand screen (28); and a first fluid communication path which is capable of communicating fluid flow from the first sand screen assembly to the second sand screen assembly (see paragraphs [0010]-[0012], [0038]; and figure 5).

Claim 1 differs from D1 in that a completion assembly comprises: a shunt tube assembly disposed outwardly of a sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; and the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow

Continued on Supplemental Box

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Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

The units of pressure employed in claims 7-8, 12-13 and 18 are not additionally expressed in terms of the units stipulated by PCT Rule 10.1(a).

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Weatherford v. Halliburton
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Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of : Box No. V

area (hereinafter Difference 1-A), wherein the transport tube of the first sand screen assembly which has a first wall thickness and the transport tube of the second sand screen assembly which has a second wall thickness, the first wall thickness being greater than the second wall thickness (hereinafter Difference 1-B).

However, Difference 1-A would be easily conceived by a person skilled in the art from the disclosure of D2 considering that shunt tubes (208) include packing tubes (208a) or transport tubes (208b), wherein the packing tubes (208a) may have one or more valves or nozzles (212) (see paragraph [0041]; and figures 2A-2B). And Difference 1-B is merely a matter of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, it would be obvious to combine the disclosures of D1 and D2 to arrive at the completion assembly of claim 1. Therefore, claim 1 does not involve an inventive step.

2. Dependent Claims 2-4

The additional feature of claim 2, characterized by a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly which is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly, is not disclosed in any of the documents D1-D5, nor is it obvious to a person skilled in the art by the documents.

The additional feature of claim 3, characterized by the first sand screen assembly further comprising a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly, is not disclosed in any of the documents D1-D5, nor is it obvious to a person

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skilled in the art by the documents.

The additional feature of claim 4, characterized by the number of packing tube nozzles in the first sand screen assembly which is less than the number of packing tube nozzles in the second sand screen assembly, is not disclosed in any of the documents D1-D5, nor is it obvious to a person skilled in the art by the documents.

Therefore, claims 2-4 are novel and involve an inventive step.

3. Dependent Claims 5-10

The additional feature of claim 5 would be easily conceived by a person skilled in the art from the disclosure of D1 considering that the longitudinal passageway (64) is connected to the alternate path elements (50, 52) creating a second fluid communication path (see paragraph [0046]; and figure 6).

The additional feature of claim 6 would be easily conceived by a person skilled in the art from the disclosures of D1 considering that the couplings are provided for connecting two sand screen assemblies, the sand screen assemblies comprising screen elements and alternate path elements, the longitudinal bore providing fluid communication between the screen elements and the longitudinal passageway providing fluid communication between the alternate path elements; and after the sand screen sections have been joined, jumper tubes can be used to connect the lengths of conduit that are located adjacent the sand screens (see paragraphs [0008], [0013]).

The additional features of claims 7-10 are merely matters of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, claims 5-10 would have been obvious over D1 in view of D2. Therefore, claims 5-10 do not involve an inventive step.

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4. Independent Claim 11

D1, which is considered to be the closest prior art to the subject matter of claim 11, discloses an apparatus for a wellbore completion system comprising a first sand screen assembly connecting a second sand screen assembly (see paragraphs [0010], [0012]).

Claim 11 differs from D1 in a completion assembly comprising a first sand screen assembly which comprises a shunt tube assembly with a first burst pressure and a second sand screen assembly which comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

However, this feature is merely a matter of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, it would be obvious to combine the disclosures of D1 and D2 to arrive at the completion assembly of claim 11. Therefore, claim 11 does not involve an inventive step.

5. Dependent Claims 12-13

The additional feature of claim 12 is merely a matter of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

The additional feature of claim 13 would be easily conceived by a person skilled in the art from the disclosures of D1 considering a first sand screen assembly connecting a second sand screen assembly (see paragraph [0010]) and D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the

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transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, claims 12-13 would have been obvious over D1 in view of D2. Therefore, claims 12-13 do not involve an inventive step.

6. Independent Claim 14

D1, which is considered to be the closest prior art to the subject matter of claim 14, discloses a method for use in performing gravel pack operations, the method comprising the step of connecting a first sand screen assembly and a second sand screen assembly to the tubular housing (see paragraphs [0002], [0010]).

Claim 14 differs from D1 in a method comprising the step of providing a first sand screen assembly having a low pressure shunt tube system and a second sand screen assembly having a high pressure shunt tube system.

However, this feature is merely a matter of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, it would be obvious to combine the disclosures of D1 and D2 to arrive at the method of claim 14. Therefore, claim 14 does not involve an inventive step.

7. Dependent Claims 15-20

The additional feature of claim 15 would be easily conceived by a person skilled in the art from the disclosure of D1 considering that first and second ends provide for connecting a first sand screen assembly and a second sand screen assembly to the tubular housing (see paragraph [0010]).

The additional feature of claim 16 would be easily conceived by a person skilled in the art from the disclosures of D1 considering providing a wellbore (10) that has penetrated a

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subterranean zone (12) that includes a productive formation (14); and connecting a first sand screen assembly and a second sand screen assembly to the tubular housing (see paragraphs [0010], [0033]; and figure 5) and D2 considering performing a non-destructive pressure test (see paragraph [0075]).

The additional feature of claim 17 is merely a matter of design option from the disclosure of D2 considering that once the screen (1104) is covered with gravel pack (1160) and the shunt tubes (1106) of the joint assemblies (300) are full of sand, the drillpipe (1116) fluid pressure increases (see paragraph [0092]; and figures 11A-11B).

The additional features of claims 18-19 are merely matters of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

The additional feature of claim 20 is identical to the feature of D1 in that the final gravel filled annulus area is referred to as a gravel pack (see paragraph [0035]).

Accordingly, claims 15-20 would have been obvious over D1 in view of D2. Therefore, claims 15-20 do not involve an inventive step.

8. Independent Claim 21

D1, which is considered to be the closest prior art to the subject matter of claim 21, discloses an apparatus for a wellbore completion system comprising: a first sand screen assembly comprising a sand screen (28) and a second sand screen assembly comprising a sand screen (28); and a first fluid communication path which is capable of communicating fluid flow from the first sand screen assembly to the second sand screen assembly (see paragraphs [0010]-[0012], [0038]; and figure 5).

Claim 21 differs from D1 in that a completion assembly comprises: a shunt tube assembly disposed outwardly of a sand screen, the shunt tube assembly having a transport tube and a

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packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; and the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area (hereinafter Difference 21-A), wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material (hereinafter Difference 21-B).

However, Difference 21-A would be easily conceived by a person skilled in the art from the disclosure of D2 considering that shunt tubes (208) include packing tubes (208a) or transport tubes (208b), wherein the packing tubes (208a) may have one or more valves or nozzles (212) (see paragraph [0041]; and figures 2A-2B). And Difference 21-B is merely a matter of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, it would be obvious to combine the disclosures of D1 and D2 to arrive at the completion assembly of claim 21. Therefore, claim 21 does not involve an inventive step.

9. Dependent Claims 22-23

The additional features of claims 22-23 are merely matters of design option from the disclosure of D2 considering that the transport conduits (508a-508f) may also have a reduced entry pressure loss or smooth-profile design at their upstream opening to facilitate the fluid flow into the transport tubes (308a-308f), wherein the transport conduits (508a-508f) and the transport tubes (308a-308f) have different diameter respectively (see paragraph [0059]; and figures 3B-3C, 5B).

Accordingly, claims 22-23 would have been obvious over D1 in view of D2. Therefore, claims 22-23 do not involve an inventive step.

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II. Industrial Applicability (PCT Article 33(4))

Claims 1-23 are industrially applicable.

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Electronic Acknowledgement Receipt

EFS ID:	37458568
Application Number:	16347711
International Application Number:	
Confirmation Number:	5449
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Customer Number:	27683
Filer:	Harold Borland/Delaunda Lanford
Filer Authorized By:	Harold Borland
Attorney Docket Number:	7523.1981US01
Receipt Date:	15-OCT-2019
Filing Date:	
Time Stamp:	14:07:21
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	7523-1981US01_SupplDS.pdf	27774 eec6329374cdf1d8fa8be13acc91f8a4533122cb	no	2

Warnings:

Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	7523-1981US01_SuppSB08.pdf	25339 e32457036a4b7129d33283b25f9b2e42d14cb034	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Foreign Reference	WO2013187878A1.pdf	3477780 1244d0b15376266537132cc99d2ea1249f0c9935	no	60
Warnings:					
Information:					
4	Other Reference-Patent/App/Search documents	PCTUS2019024626_ISRWO.pdf	7532726 8f3d0c30496a5e2bf0f44da01be3fa2952a1b8a8	no	20
Warnings:					
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		Total Files Size (in bytes):	11063619		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Coffin et al.	§	
	§	Confirmation No.: 5449
Serial No.: 16/347711	§	
	§	Art Unit: TBD
Filing Date: May 6, 2019	§	
	§	Examiner: TBD
For: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	
	§	

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Commissioner:

In compliance with the duty of disclosure under 37 CFR §1.56, and in accordance with the practice under 37 CFR §1.97 and §1.98, the Examiner's attention is directed to the documents listed on the enclosed modified Form PTO-1449. No inference should be made that the documents are in fact material, are in fact prior art, or that no better art exists. The documents are listed in numerical order and are not in any order based on their pertinence.

Pursuant to 37 CFR § 1.98(a)(2)(i), copies of the U.S. patent documents listed on the enclosed modified Form PTO-1449 are not attached.

This Information Disclosure Statement is being filed within three months of the United States filing date or before the mailing date of a first Office Action on the merits. No certification or fee is required (37 CFR §1.97(b)).

An early action on the merits is respectfully requested.

Should additional fees be deemed necessary for any reason in connection with the present submission, the Commissioner is hereby authorized to deduct any necessary amounts from (or credit any overpayments to) Haynes and Boone, LLP's Deposit Account No. 08-1394, Order No. 7523.1981US01.

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It is respectfully requested that the above information be considered by the Examiner and that a copy of the enclosed modified Form PTO-1449 be returned indicating that such information has been considered.

Respectfully submitted,

/Harold A. Borland/

Harold A. Borland
Registration No. 57,854

Date: October 15, 2019

HAYNES AND BOONE, LLP
2323 Victory Ave., Suite 700
Dallas, Texas 75219
Telephone: 713-547-2881
Facsimile: 214-200-0853
File: 7523.1981US01

Certificate of Transmission

I hereby certify that this correspondence is being transmitted via EFS-Web to the United States Patent and Trademark Office, on October 15, 2019.

/Delaunda N. Lanford/
Delaunda N. Lanford

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UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/347,711	05/06/2019		2340	7523.1981US01	23	4

CONFIRMATION NO. 5449

FILING RECEIPT

27683
HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

OC000000125979241

Date Mailed: 06/02/2021

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Maxime Philippe Coffin, Frisco, TX;
Thomas Jules Frosell, Dallas, TX;

Applicant(s)

Halliburton Energy Services, Inc.##, Houston, TX;

Power of Attorney: The patent practitioners associated with Customer Number 27683

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/US2019/024626 03/28/2019
which claims benefit of 62/688,813 06/22/2018

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

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If Required, Foreign Filing License Granted: 05/29/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/347,711**

Projected Publication Date: 09/09/2021

Non-Publication Request: No

Early Publication Request: No
Title

MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/347,711

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	320
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	540
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	800
TOTAL CLAIMS (37 CFR 1.16(i))	23 minus 20 =	* 3			OR	x 100 =	300
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1				x 480 =	480
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	2440

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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U.S. APPLICATION NO.	FIRST NAMED INVENTOR	ATTY. DOCKET NO.
16/347,711	Maxime Philippe Coffin	7523.1981US01

27683
HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

INTERNATIONAL APPLICATION NO.	
PCT/US2019/024626	
I.A. FILING DATE	PRIORITY DATE
03/28/2019	06/22/2018

CONFIRMATION NO. 5449
371 ACCEPTANCE LETTER

OC000000125979242

Date Mailed: 06/02/2021

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office, in its capacity as a Designated / Elected Office (37 CFR 1.495), has ACCEPTED the above identified international application for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above. A Filing Receipt will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE or 371(c) DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1) and (c)(2) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN BELOW.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363)

05/06/2019
DATE OF RECEIPT OF 35 U.S.C.
371(c)(1) and (c)(2) REQUIREMENTS

The following items have been received:

- Copy of the International Application filed on 05/06/2019
- Copy of the International Search Report filed on 05/06/2019
- Preliminary Amendments filed on 05/06/2019
- Information Disclosure Statements filed on 10/15/2019
- Inventor's Oath or Declaration filed on 05/06/2019
- U.S. Basic National Fees filed on 05/06/2019
- Assignment filed on 05/06/2019
- Authorize Access to Search Results filed on 05/06/2019
- Priority Documents filed on 05/06/2019
- Power of Attorney filed on 05/23/2019
- Authorization to Permit Access filed on 05/06/2019
- Application Data Sheet (37 CFR 1.76) filed on 05/06/2019

Weatherford Exhibit 1002
Weatherford v. Halliburton
Page 258

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

ANTHONY L WILLIAMS

Telephone: (703) 756-1557

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Page 259

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

Substitute for Form PTO-1360
(For use with Form PTO/SB/06)

Application Number	Filing Date
16347711	

Applicant(s) Maxime Coffin

* May be used for additional claims or amendments

CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT	
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

27683 7590 07/06/2021

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

EXAMINER	
GAY, JENNIFER HAWKINS	

ART UNIT	PAPER NUMBER
3619	

NOTIFICATION DATE	DELIVERY MODE
07/06/2021	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocketing@haynesboone.com

Office Action Summary	Application No. 16/347,711	Applicant(s) Coffin et al.	
	Examiner JENNIFER H GAY	Art Unit 3619	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-23 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-23 is/are rejected.

8) ☐ Claim(s) _____ is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☑ The drawing(s) filed on 06 May 2019 is/are: a)☑ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Drawings

2. The drawings were received on May 6, 2021. These drawings are accepted.

Claim Objections

3. Claim **6** is objected to because of the following informalities: **in line 3, "an coupling" should be changed --a coupling--**. Appropriate correction is required.

Claim Rejections - 35 USC § 112

4. The following is a quotation of the first paragraph of 35 U.S.C. 112(a):

> (a) IN GENERAL.—The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor or joint inventor of carrying out the invention.

The following is a quotation of the first paragraph of pre-AIA 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

5. **Claims 1-23 are rejected under 35 U.S.C. 112(a) or 35 U.S.C. 112 (pre-AIA), first paragraph, as failing to comply with the enablement requirement.** The claim(s) contains

subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

Claims 1, 11, 14, and 21 include limitations that, when taken in light of the specification, require that the operating pressure of the shunt tube assemblies lower in the well be less than that of shunt tube assemblies higher up in the well. These limitations are the wall thickness of the transport tubes (claim 1), the burst pressure of the assemblies (claim 11), the tensile strength of the material of the transport tubes (claim 21), and specifically requiring that one shunt tube system be a high pressure system and the other a low pressure system (claim 14). Page 10, line 21 through page 12, line 11 indicates that these parameters are chosen to accommodate for the pressure of the gravel slurry decreasing as the slurry flows from the upstream portion to the downstream portion **11:3-5**.

The pressure of the gravel slurry decreasing as the slurry flows from the upstream portion to the downstream portion is considered to not be enabled by the original disclosure. It is a well-known and established principle that fluids in a wellbore increase in pressure as the depth of the well increases, i.e. the frictional or hydrostatic pressure. This is evidenced by Langlais et al. (US 2021/0123327) where it is taught in paragraph [0003] that the frictional pressure of the gravel slurry increases at a rate of 1 psi/foot. Applicant has failed to establish how the gravel slurry can decrease in pressure as the depth of the wellbore increases. Even with the distribution of slurry into the annulus at various stages along the well and the leak off of fluid from the slurry, the pressure of the

gravel slurry in the completion and shunt tubes would be increase from the uphole portion to the downhole portion of the wellbore. Such an increase is both naturally occurring as the pressure on the tubes from the surrounding wellbore and wellbore fluid increases, i.e. hydrostatic head or pressure, and necessary in order for the gravel slurry to be able to overcome the pressure of the wellbore fluid and displace it in order to place the gravel in the annulus, i.e. pump pressure of the slurry. A decrease in pressure of the gravel slurry would result in the gravel slurry being unable to leave the shunt tubes at the various stages or even being pushed back up the tubes.

Beyond the statement on page 11, Applicant has failed to provide any teaching or evidence that such a decrease in pressure in gravel slurry pressure can and does occur. Without such a teaching or evidence one of ordinary skill in the art would not understand how such a phenomenon would occur as it goes against well-known and established principles. Without such a teaching or evidence one of ordinary skill in the art would not be able to make or use a gravel packing completion assembly where such a phenomenon happened. One of ordinary skill in the art would not know how to make or use a system where the hydrostatic pressure on a fluid in the well did not decrease as the depth of the well decreased. How does one prevent the force of the fluids in the wellbore and the pressure of the earth from acting on and increasing the pressure of the gravel slurry as it travels deeper into the wellbore?

As Applicant has failed to provide any teaching or evidence to support the pressure of the gravel slurry decreasing as the as the slurry flows from the upstream portion to the downstream portion and configuring the shunt tube assemblies along the completion assembly so that the lower shunt tube assemblies had a lower pressure rating

or burst pressure as a result, the limitations of the wall thickness of the transport tubes (claim 1), the burst pressure of the assemblies (claim 11), the tensile strength of the material of the transport tubes (claim 21), and specifically requiring that one shunt tube system be a high pressure system and the other a low pressure system (claim 14) are not enabled.

6. The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

7. Claims 5, 7-10, 12, 13, and 15 are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor (or for applications subject to pre-AIA 35 U.S.C. 112, the applicant), regards as the invention.

Regarding claim 5: The term "**substantially**" in claim 5 is a relative term which renders the claim indefinite. The term "substantially" is not defined by the claim, the specification does not provide a standard for ascertaining the requisite degree, and one of ordinary skill in the art would not be reasonably apprised of the scope of the invention. It is unclear how close to or far from the same the cross-sectional flow areas of the passageways of the first and second transport tubes needs to be or can be to be considered "substantially the same". See MPEP 2173.05(b)(III)(D) provided below.

2173.05(b) Relative Terminology [R-08.2017]

The use of relative terminology in claim language, including terms of degree, does not automatically render the claim indefinite under **35 U.S.C. 112(b)** or **pre-AIA 35 U.S.C. 112**, second paragraph. *Seattle Box Co., Inc. v. Industrial Crating & Packing, Inc.,* 731 F.2d 818, 221 USPQ 568 (Fed. Cir. 1984). Acceptability of the claim language depends on whether one of ordinary skill in the art would understand what is claimed, in light of the specification.

III. APPROXIMATIONS

D. *"Substantially"*

The term "substantially" is often used in conjunction with another term to describe a particular characteristic of the claimed invention. It is a broad term. *In re Nehrenberg,* 280 F.2d 161, 126 USPQ 383 (CCPA 1960). The court held that the limitation "to substantially increase the efficiency of the compound as a copper extractant" was definite in view of the general guidelines contained in the specification. *In re Mattison,* 509 F.2d 563, 184 USPQ 484 (CCPA 1975). The court held that the limitation "which produces substantially equal E and H plane illumination patterns" was definite because one of ordinary skill in the art would know what was meant by "substantially equal." *Andrew Corp. v. Gabriel Electronics,* 847 F.2d 819, 6 USPQ2d 2010 (Fed. Cir. 1988).

Regarding claim 7: Claim 7 recites "**a pressure rating over 5000 psi**". This is a range with an unbounded upper limit, and therefore encompasses a pressure rating so inconceivable high that it cannot reasonably be possible in the present invention. To make a point through hyperbole, the present application does not provide full enablement for a pressure rating of 100,000 psi (increasable *ad nauseam*), even though these amounts are encompassed in the claimed range. See MPEP 2173.05(c)(II), reproduced below.

Regarding claim 8: Claim 8 recites "**a pressure rating of less than 4000 psi**". This is a range with an unbounded lower limit, and therefore encompasses a pressure rating so inconceivable low that it cannot reasonably be possible in the present invention. To make a point through hyperbole, the present application does not provide full

enablement for a pressure rating of 10 psi (increasable *ad nauseam*), even though these amounts are encompassed in the claimed range. See MPEP 2173.05(c)(II), reproduced below.

II. OPEN-ENDED NUMERICAL RANGES

Open-ended numerical ranges should be carefully analyzed for definiteness. For example, when an independent claim recites a composition comprising "at least 20% sodium" and a dependent claim sets forth specific amounts of nonsodium ingredients which add up to 100%, apparently to the exclusion of sodium, an ambiguity is created with regard to the "at least" limitation (unless the percentages of the nonsodium ingredients are based on the weight of the nonsodium ingredients). On the other hand, the court held that a composition claimed to have a theoretical content greater than 100% (i.e., 20-80% of A, 20-80% of B and 1-25% of C) was not indefinite simply because the claims may be read in theory to include compositions that are impossible in fact to formulate. It was observed that subject matter which cannot exist in fact can neither anticipate nor infringe a claim. *In re Kroekel,* 504 F.2d 1143, 183 USPQ 610 (CCPA 1974).

In a claim directed to a chemical reaction process, a limitation required that the amount of one ingredient in the reaction mixture should "be maintained at less than 7 mole percent" based on the amount of another ingredient. The examiner argued that the claim was indefinite because the limitation sets only a maximum amount and is inclusive of substantially no ingredient resulting in termination of any reaction. The court did not agree, holding that the claim was clearly directed to a reaction process, and explaining that "[t]he imposition of a maximum limit on the quantity of one of the reactants without specifying a minimum does not warrant distorting the overall meaning of the claim to preclude performing the claimed process."*In re Kirsch,* 498 F.2d 1389, 1394, 182 USPQ 286, 290 (CCPA 1974).

Some terms have been determined to have the following meanings in the factual situations of the reported cases: the term "up to" includes zero as a lower limit, *In re Mochel,* 470 F.2d 638, 176 USPQ 194 (CCPA 1974); and "a moisture content of not more than 70% by weight" reads on dry material, *Ex parte Khusid,* 174 USPQ 59 (Bd. App. 1971).

Regarding claims 7-10: Claims 7-10 recites "**a shunt tube assembly**" in lines 1 and 2. It is unclear if these recitations are the same shunt tube assemblies required in claim 1 or separate assemblies. For the purposes of examination they are being treated as the same with the recitation in line 1 being treated as the shunt tube assembly of the first screen assembly and the recitation in line 2 being the shunt tube assembly of the second screen assembly.

Regarding claim 12: Claim 12 recites "**operating at pressures over 5000 psi**". This is a range with an unbounded upper limit, and therefore encompasses an operating pressure so inconceivable high that it cannot reasonably be possible in the present invention. To make a point through hyperbole, the present application does not provide full enablement for an operating pressure of 100,000 psi (increasable *ad nauseam*), even though these amounts are encompassed in the claimed range. See MPEP 2173.05(c)(II), reproduced above.

Regarding claim 13: Claim 13 recites "**an operating pressure rating over 5000 psi**". This is a range with an unbounded upper limit, and therefore encompasses a pressure rating so inconceivable high that it cannot reasonably be possible in the present invention. To make a point through hyperbole, the present application does not provide full enablement for a pressure rating of 100,000 psi (increasable *ad nauseam*), even though these amounts are encompassed in the claimed range. See MPEP 2173.05(c)(II), reproduced above.

Regarding claim 15: There is insufficient antecedent basis for "the uppermost first sand screen assembly".

Claim Rejections - 35 USC § 103

8. In the event the determination of the status of the application as subject to AIA 35 U.S.C. 102 and 103 (or as subject to pre-AIA 35 U.S.C. 102 and 103) is incorrect, any correction of the

statutory basis for the rejection will not be considered a new ground of rejection if the prior art relied upon, and the rationale supporting the rejection, would be the same under either status.

9. This application currently names joint inventors. In considering patentability of the claims the examiner presumes that the subject matter of the various claims was commonly owned as of the effective filing date of the claimed invention(s) absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and effective filing dates of each claim that was not commonly owned as of the effective filing date of the later invention in order for the examiner to consider the applicability of 35 U.S.C. 102(b)(2)(C) for any potential 35 U.S.C. 102(a)(2) prior art against the later invention.

10. The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

11. Claims 1, 5-15, and 18-23 is/are rejected under 35 U.S.C. 103 as being unpatentable over Sessa et al. (US 2019/01452321, Sessa) in view of Langlais et al. (US 2021/0123327, Lang).

Regarding claim 1: Sessa discloses a completion assembly **Fig 3** for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly **50** comprising a base pipe **110** having perforations **114** therein and extending between a first end **Fig 3** and a second ends **Fig 3**, a sand

screen **120** disposed around a portion of the base pipe **Fig 3**, and a shunt tube assembly **200** disposed outwardly of the sand screen **Fig 3**, the shunt tube assembly having a transport tube **202** and a packing tube **204**, where each of the tubes has a passageway defined therein **Fig 4A, 4B**, the packing tube further including a plurality of nozzles **207 – [0074]** spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area **Fig 4A, 4B, 11A, 11B**;

a second sand screen assembly **50U – all of the screens in the completion assembly have the same components and arrangement, [0048]** comprising a base pipe **110** having perforations **114** therein and extending between a first end **Fig 3** and a second ends **Fig 3**, a sand screen **120** disposed around a portion of the base pipe **Fig 3**, and a shunt tube assembly **200** disposed outwardly of the sand screen **Fig 3**, the shunt tube assembly having a transport tube **202** and a packing tube **204**, the packing tube further including a plurality of nozzles **207 – [0074]** spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area **Fig 4A, 4B, 11A, 11B**;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another **Fig 3**.

Sessa discloses all of the limitations of the above claim(s) except for the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness. Sessa does disclose that gravel pack slurry is pumped through at elevated pressures which implies that the components of the

completion assembly, especially the transport tubes would need to be designed to account for this pressure.

Lang discloses a completion assembly similar to that of Sessa **Fig 7**. Lang also teaches that gravel slurry moving through the transport tubes are designed to operate at the pressures needed to overcome the frictional pressure of the slurry in the tubes which is approximately 1 psi/ft **[0003]**. In other words, transport tubes that extend to 3,000 feet must have an operating pressure rating of at least 3,000 psi and transport tubes that extend to 5,000 feet must have an operating pressure rating of at least 5,000 psi **[0003]**. Lang goes on to say that the tubes can have various sizes, shapes, and configurations to achieve the needed operating pressure ratings **[0028]**.

It would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have modified the transport tubes of the completion assembly of Sessa so that the size, shape, or configuration accounted for the varying operating pressures along the length of the assembly as suggested by Lang. This would have achieved the predictable result of ensuring that the transport tubes didn't burst or buckle at the high operating pressures.

Further, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have accounted for the varying operating pressures along the length of the assembly by modified the transport tubes of the completion assembly of Sessa so that the transport tubes of the first sand screen assembly had a greater wall thickness that the transport tubes of second sand screen assembly. It is well known by one of ordinary skill in the art that one of the means by which the operating pressure of a tube is increased is to increase its wall thickness. As

such, the Examiner takes **OFFICAL NOTICE** that it would have been obvious that the pressure rating, and thus the thickness, of the transport tubes of the lower, or first, sand screen assembly was higher than that of the upper, or second, sand screen assembly. There are finite number of choices of how to change the pressure rating of a tube available to a person of ordinary skill in the art for gravel pack assemblies. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try might show that it was obvious under 103" *KSR Int'l Co. v. Teleflex, Inc.,* 550 U.S. __, 82 USPQ2d 1385 (2007)

Regarding claim 5: Wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same **Fig 3 of Sessa**.

Regarding claim 6: Wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint **52 – Fig 3 of Sessa** therebetween, the completion assembly further comprising an coupling **162 of Sessa** interconnecting one end of a jumper tube **160 of Sessa** to the transport tube of the first sand screen assembly **Fig 3 of Sessa**, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies **Fig 3 of Sessa**.

Regarding claim 7: Wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of over 5000 psi **[0028] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than 5000 psi. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was no more than 5000 psi.

Regarding claim 8: Wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of between 5000 and 10000 psi **[0003] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of less than 4000 psi. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was less than 4000 psi.

Further, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have modified the shunt tube assemblies to have any needed and/or desired pressure rating since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. *In re Boesch*, 617 F.2d 272, 205 USPQ 215 (CCPA 1980).

Regarding claim 9: Wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of over a selected threshold **[0028] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than the select threshold. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was no more than threshold pressure rating of the first sand screen assembly.

Regarding claim 10: Wherein the shunt tube assembly of the first sand screen assembly has a first burst pressure **[0028] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a burst pressure less than the first burst pressure. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure

[0003] of Lang and thus need a burst pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the burst pressure of the shunt tube assembly of the second sand screen assembly was no more than the burst pressure of the first sand screen assembly.

Regarding claims 11 and 14: Sessa discloses a completion assembly **Fig 3** for deployment in a wellbore and the method of its installation, the completion assembly comprising: a first sand screen assembly **50** attached to a second sand screen assembly **50U**, wherein the first sand screen assembly comprises a shunt tube assembly **200** with a first burst pressure **all tubes have a burst pressure** and the second sand screen assembly comprises a shunt tube assembly **200 – the screens of Sessa all have the same features, [0048]** with a second burst pressure **all tubes have a burst pressure**.

Sessa discloses all of the limitations of the above claim(s) except for the burst pressure of the second shunt tube assembly less than the burst pressure of the first shunt tube assembly.

Lang discloses a completion assembly similar to that of Sessa **Fig 7**. Lang also teaches that gravel slurry moving through the transport tubes are designed to operate at the pressures needed to overcome the frictional pressure of the slurry in the tubes which is approximately 1 psi/ft **[0003]**. In other words, transport tubes that extend to 3,000 feet must have an operating pressure rating of at least 3,000 psi and transport tubes that extend to 5,000 feet must have an operating pressure rating of at least 5,000 psi **[0003]**.

Lang goes on to say that the tubes can have various sizes, shapes, and configurations to achieve the needed operating pressure ratings **[0028]**.

It would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have modified the shunt tube assemblies of the completion assembly of Sessa so that the size, shape, or configuration accounted for the varying operating pressures along the length of the assembly as suggested by Lang. This would have achieved the predictable result of ensuring that the burst pressures of the transport tubes was such that the tubes didn't burst or buckle at the high operating pressures.

Further, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have accounted for the varying operating pressures along the length of the assembly by modified the shunt tube assemblies of the completion assembly of Sessa so that the shunt tube assembly of the first sand screen assembly had a burst pressure and the shunt tube assembly of the second sand screen assembly had a burst pressure less than that of the first as the frictional pressure from the gravel slurry experienced by the second or upper sand screen assembly would be less than that of the first sand screen assembly.

Regarding claim 12: Wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of over 5000 psi **[0028] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than 5000 psi. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less

frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was no more than 5000 psi.

Regarding claim 13: The completion assembly further comprising: a plurality of first sand screen assemblies **50, 50D of Sessa** forming a lower portion of the completion assembly **Fig 3 of Sessa** and attached to a plurality of second sand screen assemblies **50U – [0047] of Sessa** forming an upper portion of the completion assembly **Fig 3 of Sessa**, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi **[0003] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than 5000 psi. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was no more than 5000 psi.

Regarding claim 15: The method further comprising: installing a plurality of interconnected first sand screen assemblies **50, 50D** in a wellbore adjacent the production

zone; and attaching a plurality of second sand screen assemblies **50U – [0047]** to the uppermost first sand screen assembly upstream of the first sand screen assemblies.

Regarding claim 18: Wherein the high pressure shunt tube assembly has a pressure rating of over 5000 psi **[0028] of Lang**. Sessa, as modified, fails to disclose that the lower pressure shunt tube assembly has a pressure rating of no more than 5000 psi. However, as the low pressure shunt tube assembly is located above the high pressure shunt tube assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the low pressure shunt tube assembly was no more than 5000 psi.

Regarding claim 19: Wherein the high pressure shunt tube assembly has a pressure rating of over a selected threshold **[0028] of Lang**. Sessa, as modified, fails to disclose that the low pressure shunt tube assembly has a pressure rating of no more than the select threshold. However, as the low pressure shunt tube assembly is located above the high pressure shunt tube assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the low pressure shunt tube assembly was no more than threshold pressure rating of the high pressure shunt tube assembly.

Regarding claim 19: The method further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus **[0046] of Sessa**.

Regarding claim 1: Sessa discloses a completion assembly **Fig 3** for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly **50** comprising a base pipe **110** having perforations **114** therein and extending between a first end **Fig 3** and a second ends **Fig 3**, a sand screen **120** disposed around a portion of the base pipe **Fig 3**, and a shunt tube assembly **200** disposed outwardly of the sand screen **Fig 3**, the shunt tube assembly having a transport tube **202** and a packing tube **204**, where each of the tubes has a passageway defined therein **Fig 4A, 4B**, the packing tube further including a plurality of nozzles **207 – [0074]** spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area **Fig 4A, 4B, 11A, 11B**;

a second sand screen assembly **50U – all of the screens in the completion assembly have the same components and arrangement, [0048]** comprising a base pipe **110** having perforations **114** therein and extending between a first end **Fig 3** and a second ends **Fig 3**, a sand screen **120** disposed around a portion of the base pipe **Fig 3**, and a shunt tube assembly **200** disposed outwardly of the sand screen **Fig 3**, the shunt tube assembly having a transport tube **202** and a packing tube **204**, the packing tube further including a plurality of nozzles **207 – [0074]** spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area **Fig 4A, 4B, 11A, 11B**;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another **Fig 3**.

Sessa discloses all of the limitations of the above claim(s) except for the transport tube of the first sand screen assembly being formed from a first material and the transport tube of the second sand screen assembly being formed from a second material, the first material having a greater tensile strength than that of the second material. Sessa does disclose that gravel pack slurry is pumped through at elevated pressures which implies that the components of the completion assembly, especially the transport tubes would need to be designed to account for this pressure.

Lang discloses a completion assembly similar to that of Sessa **Fig 7**. Lang also teaches that gravel slurry moving through the transport tubes are designed to operate at the pressures needed to overcome the frictional pressure of the slurry in the tubes which is approximately 1 psi/ft **[0003]**. In other words, transport tubes that extend to 3,000 feet must have an operating pressure rating of at least 3,000 psi and transport tubes that extend to 5,000 feet must have an operating pressure rating of at least 5,000 psi **[0003]**. Lang goes on to say that the tubes can have various sizes, shapes, and configurations to achieve the needed operating pressure ratings **[0028]**.

It would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have modified the transport tubes of the completion assembly of Sessa so that the size, shape, or configuration accounted for the varying operating pressures along the length of the assembly as suggested by Lang.

This would have achieved the predictable result of ensuring that the transport tubes didn't burst or buckle at the high operating pressures.

Further, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have accounted for the varying operating pressures along the length of the assembly by modified the transport tubes of the completion assembly of Sessa so that the transport tubes of the first sand screen assembly was formed a material with a greater tensile strength than that the material of the transport tubes of second sand screen assembly. It is well known by one of ordinary skill in the art that one of the means by which the operating pressure of a tube is increased is to increase tensile strength of the tube which is done by choosing a material with an increased tensile strength. As such, the Examiner takes **OFFICAL NOTICE** that it would have been obvious that the pressure rating, and thus the tensile strength, of the transport tubes of the lower, or first, sand screen assembly was higher than that of the upper, or second, sand screen assembly. There are finite number of choices of how to change the pressure rating of a tube available to a person of ordinary skill in the art for gravel pack assemblies. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try might show that it was obvious under 103" *KSR Int'l Co. v. Teleflex, Inc.,* 550 U.S. __, 82 USPQ2d 1385 (2007)

Regarding claim 22: Sessa, as modified, discloses all of the limitations of the above claim(s) except for the transport tube of the first sand screen assembly having a first wall thickness and the transport tube of the second sand screen assembly having a second wall thickness, the first wall thickness being greater than the second wall thickness.

It would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, to have accounted for the varying operating pressures along the length of the assembly by further modifying the transport tubes of the completion assembly of Sessa so that the transport tubes of the first sand screen assembly had a greater wall thickness that the transport tubes of second sand screen assembly. It is well known by one of ordinary skill in the art that one of the means by which the operating pressure of a tube is increased is to increase its wall thickness. As such, the Examiner takes **OFFICAL NOTICE** that it would have been obvious that the pressure rating, and thus the thickness, of the transport tubes of the lower, or first, sand screen assembly was higher than that of the upper, or second, sand screen assembly. There are finite number of choices of how to change the pressure rating of a tube available to a person of ordinary skill in the art for gravel pack assemblies. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try might show that it was obvious under 103" *KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. __, 82 USPQ2d 1385 (2007)

Regarding claim 23: Wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of over a selected threshold **[0028] of Lang**. Sessa, as modified, fails to disclose that the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than the select threshold. However, as the second sand screen assembly is located above the first sand screen assembly it would naturally experience less frictional pressure **[0003] of Lang** and thus need an operating pressure rating than that of the first sand screen assembly. As such, it would have been considered obvious to one of ordinary skill in the art, before the effective filing date of the claimed invention, that the pressure rating of the shunt tube assembly of the second sand screen assembly was no more than threshold pressure rating of the first sand screen assembly.

Claim Rejections – Art Rejection

12. While claims 2-4, 16, and 17 are not disclosed or suggested by the prior art of record, due to the above 35 USC 112(a) rejection they cannot be considered as allowable.

Conclusion

13. Any inquiry concerning this communication or earlier communications from the examiner should be directed to JENNIFER H GAY whose telephone number is (571)272-7029. The examiner can normally be reached on Monday through Thursday, 6-3:30 and every other Friday 6-11.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Anna M Momper can be reached on 571-270-5788. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/JENNIFER H GAY/
Primary Examiner, Art Unit 3619

JHG
6/29/2021

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CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

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Search Notes		
Search Notes	Date	Examiner
E21B 17/02, 43/04,08,086,10 - text search only	06/29/2021	JHG
PE2E Search	06/29/2021	JHG
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Interference Search			
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PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	6	("0000110" OR "0000213" OR "0000424" OR "0000610" OR "0000708" OR "0000722").pn.	(US-PGPUB; USPAT)	OR	ON	ON	2021/06/28 03:11 PM
L2	63	"6588506" "20040140089"	(US-PGPUB; USPAT)	OR	ON	ON	2021/06/28 03:11 PM
L3	14	("20030029613" "20100139919" "20130008652" "20140110131").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:16 PM
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L7	24186	(E21B43/04 OR E21B43/08 OR E21B17/02 OR E21B43/086).cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR,	OR	ON	ON	2021/06/28 03:20 PM

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			GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
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L9	1567	8 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:24 PM
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		20130327542-A1 OR US-20210002987-A1).did. AND PGPB.dbnm.) OR ((WO-2014088594-A1 OR WO-2013187877-A1 OR WO-2014062180-A1 OR FR-3091309-A1 OR WO-2020142076-A1).did. AND FTDB.dbnm.)					
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L22	2073	7 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:54 AM
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		AND lower) (first AND second)))	GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L26	423	25 NOT 24	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 06:54 AM
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L34	390	33 AND ((((shunt	(US-PGPUB; USPAT;	OR	ON	ON	2021/06/29

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		transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (thickness cross tensile rating material strength)))	USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				09:40 AM
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(71) Applicant *(for all designated States except US)*: **HAL¬ LIBURTON ENERGY SERVICES, INC.** [US/US]; 10200 Bellaire Boulevard, Houston, Texas 77072 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **CUNNINGHAM, Gregory Scott** [US/US]; 532 Chasewood Drive, Grapevine, Texas 7605 1 (US). **LEAST, Brandon Thomas** [US/US]; 3218 Jubilee Trail, Dallas, Texas 75229 (US). **GRECI, Stephen Michael** [US/US]; 4416 San Mateo Lane, McKinney, Texas 75070 (US). **LOPEZ, Jean Marc** [FR/US]; 7308 Stoddard Lane, Piano, Texas 75025 (US). **VEIT, Jan** [CZ/US]; 3201 Dover Drive, Piano, Texas 75075 (US).

(74) Agents: **CONLEY ROSE, P.C.** et al; 5601 Granite Parkway, Suite 750, Piano, TX 75024 (US).

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(54) Title: SHUNT TUBE CONNECTION AND DISTRIBUTION ASSEMBLY AND METHOD

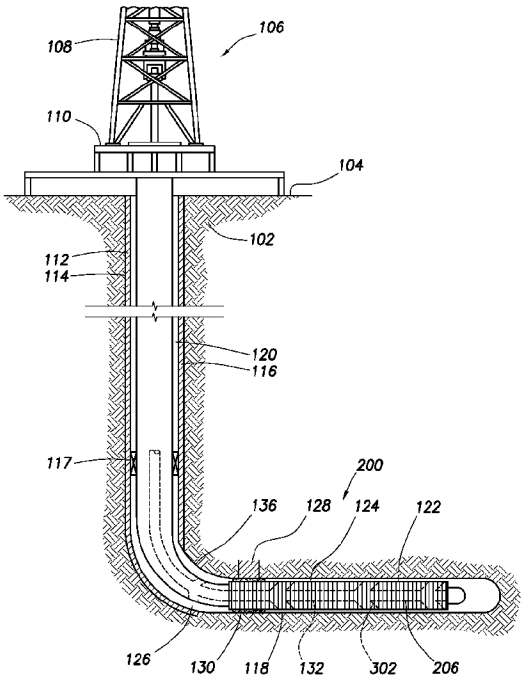

FIG. 1

(57) Abstract: A shunt tube assembly comprises a plurality of shunt tubes, a jumper tube, and a coupling member configured to provide fluid communication between the jumper tube and the plurality of shunt tubes. The coupling member can comprise a first end and a second end. The coupling member may be configured to provide a sealing engagement between the coupling member and the jumper tube at the first end, and the coupling member may be configured to provide a sealing engagement between the coupling member and the plurality of jumper tubes at the second end.

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SHUNT TUBE CONNECTION AND DISTRIBUTION ASSEMBLY AND METHOD

BACKGROUND

[0001] In the course of completing an oil and/or gas well, a string of protective casing can be run into the wellbore followed by production tubing inside the casing. The casing can be perforated across one or more production zones to allow production fluids to enter the casing bore. During production of the formation fluid, formation sand may be swept into the flow path. The formation sand tends to be relatively fine sand that can erode production components in the flow path. In some completions, the wellbore is uncased, and an open face is established across the oil or gas bearing zone. Such open bore hole (uncased) arrangements are typically utilized, for example, in water wells, test wells, and horizontal well completions.

[0002] When formation sand is expected to be encountered, one or more sand screens can be installed in the flow path between the production tubing and the perforated casing (cased) and/or the open well bore face (uncased). A packer is customarily set above the sand screen to seal off the annulus in the zone where production fluids flow into the production tubing. The annulus around the screen can then be packed with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of water and/or gel and fills the annulus between the sand screen and the well casing. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation.

[0003] During the sand packing process, annular sand "bridges" can form around the sand screen that may prevent the complete circumscribing of the screen structure with packing sand in the completed well. This incomplete screen structure coverage by the packing sand may leave an axial portion of the sand screen exposed to the fine formation sand, thereby undesirably lowering the overall filtering efficiency of the sand screen structure.

[0004] One conventional approach to overcoming this packing sand bridging problem has been to provide each generally tubular filter section with a series of shunt tubes that longitudinally extend through the filter section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the filter section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen structure. The shunt path operates to permit the inflowing packing sand/gel

slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

SUMMARY

[0005] In an embodiment, a shunt tube assembly comprises a shunt tube and a jumper tube comprising a first end. The shunt tube comprises a non-round cross section, and the first end of the jumper tube is coupled to the shunt tube at a coupling. The first end of the jumper tube comprises a substantially round cross section at the coupling.

[0006] In an embodiment, a shunt tube assembly comprises a shunt tube comprising a first cross-sectional shape, a jumper tube comprising a second cross-sectional shape, and a coupling member comprising a first end and a second end. The coupling member is configured to provide a sealing engagement between the coupling member and the shunt tube at the first end, and the coupling member is configured to provide a sealing engagement between the coupling member and the jumper tube at the second end.

[0007] In an embodiment, a shunt tube assembly comprises a plurality of shunt tubes, a jumper tube, and a coupling member configured to provide fluid communication between the jumper tube and the plurality of shunt tubes.

[0008] In an embodiment, a coupling member for use with a shunt tube assembly comprises a body member comprising a first side and a second side, a first opening disposed through the first side, and a second opening disposed through the second side. The body member is configured to be disposed about a wellbore tubular, the first opening is configured to engage a shunt tube, and the second opening is configured to engage a jumper tube. The first opening is in fluid communication with the second opening.

[0009] In an embodiment, a coupling member for use with a shunt tube assembly comprises a first body member, a second body member, and a chamber defined between the first body member and the second body member. The first body member is configured to be rotatably disposed about a wellbore tubular, and the first body member comprises a first opening configured to receive a jumper tube. The second body member is configured to be disposed about a wellbore tubular, and the second body member comprises one or more second openings configured to receive one or more shunt tubes. The first opening is in fluid communication with the one or more second openings through the chamber.

[0010] In an embodiment, a method of forming a shunt tube coupling comprises aligning a first end of a jumper tube with a shunt tube, where the shunt tube comprises a non-round cross section, and coupling the first end of the jumper tube to the shunt tube at a coupling, where the first end of the jumper tube comprises a substantially round cross section at the coupling.

[0011] In an embodiment, a method of gravel packing comprises passing a slurry through a first shunt tube, where the first shunt tube comprises a first cross-sectional shape, passing the slurry through a coupling, where the coupling comprises a coupling between the first shunt tube and a jumper tube, and where the jumper tube comprises a substantially round cross-section at the coupling, and disposing the slurry about a well screen assembly below the coupling.

[0012] In an embodiment, a method of forming a shunt tube coupling comprises rotating a first ring about a wellbore tubular, engaging a jumper tube with the first ring, rotating a second ring about the wellbore tubular, engaging one or more shunt tubes with the second ring, and forming a sealing engagement between the first ring and the second ring.

[0013] These and other features will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

[0015] Figure 1 is a cut-away view of an embodiment of a wellbore servicing system according to an embodiment.

[0016] Figure 2 is a cross-sectional view of an embodiment of a shunt tube assembly.

[0017] Figure 3 is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A' of Figure 2.

[0018] Figure 4 is a partial cross-sectional view of an embodiment of a shunt tube assembly.

[0019] Figure 5 is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0020] Figure 6A is still another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0021] Figures 6B-6E are schematic cross-sectional views of an embodiment of a jumper tube.

[0022] Figure 7A is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0023] Figure 7B is a schematic isometric view of an embodiment of a coupling member.

[0024] Figure 8 is another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0025] Figure 9 is yet another partial cross-sectional view of an embodiment of a shunt tube assembly.

[0026] Figure 10 is a partial cross-sectional view of an embodiment of a coupling member.

[0027] Figures 11A and 11B are schematic isometric views of an embodiment of a retaining ring.

[0028] Figure 11C is a partial cross-sectional view of an embodiment of a retaining ring.

[0029] Figures 12A-12D are isometric views of various embodiments of a retaining ring.

[0030] Figure 13 is a schematic cross-sectional view of an embodiment of a coupling member.

[0031] Figure 14 is another schematic cross-sectional view of an embodiment of a coupling member.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0032] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawing figures are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness.

[0033] Unless otherwise specified, any use of any form of the terms "connect," "engage," "couple," "attach," or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to ...". Reference to up or down will be made for purposes of description with "up," "upper," "upward," "upstream," or "above" meaning toward the surface of the wellbore and with "down," "lower," "downward," "downstream," or "below" meaning toward the terminal end of the well, regardless of the wellbore orientation. Reference to inner or outer will be made for purposes of description with "in," "inner," or "inward"

meaning towards the central longitudinal axis of the wellbore and/or wellbore tubular, and "out," "outer," or "outward" meaning towards the wellbore wall. As used herein, the term "longitudinal" or "longitudinally" refers to an axis substantially aligned with the central axis of the wellbore tubular, and "radial" or "radially" refer to a direction perpendicular to the longitudinal axis. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0034] Shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple shunt tubes on adjacent wellbore tubular joints are generally of the same non-round cross section as the shunt tubes to allow for a flow path having a continuous cross-sectional shape along the length of the shunt tube system. However, the use of couplings having non-round cross sections may lead to unreliable connections and the need to closely align the ends of the shunt tubes on adjacent joints of wellbore tubulars. Further, the use of couplings having non-round cross sections may result in a limit to the pressure rating of the coupling.

[0035] Rather than use couplings having non-round cross sections matching those of the shunt tubes, the system disclosed herein utilizes couplings having substantially round cross-sections. The use of couplings with substantially round cross-sections may allow for an improved seal at the couplings, thereby improving the pressure ratings of the couplings. These benefits may provide for more reliable couplings to be formed and improve the assembly time for forming the shunt tube system.

[0036] Referring to Figure 1, an example of a wellbore operating environment in which a well screen assembly may be used is shown. As depicted, the operating environment comprises a workover and/or drilling rig 106 that is positioned on the earth's surface 104 and extends over and around a wellbore 114 that penetrates a subterranean formation 102 for the purpose of recovering hydrocarbons. The wellbore 114 may be drilled into the subterranean formation 102 using any suitable drilling technique. The wellbore 114 extends substantially vertically away from the earth's surface 104 over a vertical wellbore portion 116, deviates from vertical relative

to the earth's surface 104 over a deviated wellbore portion 136, and transitions to a horizontal wellbore portion 118. In alternative operating environments, all or portions of a wellbore may be vertical, deviated at any suitable angle, horizontal, and/or curved. The wellbore 114 may be a new wellbore, an existing wellbore, a straight wellbore, an extended reach wellbore, a sidetracked wellbore, a multi-lateral wellbore, and other types of wellbores for drilling and completing one or more production zones. Further, the wellbore may be used for both producing wells and injection wells. The wellbore 114 may also be used for purposes other than hydrocarbon production such as geothermal recovery and the like.

[0037] A wellbore tubular 120 may be lowered into the subterranean formation 102 for a variety of drilling, completion, workover, treatment, and/or production processes throughout the life of the wellbore. The embodiment shown in Figure 1 illustrates the wellbore tubular 120 in the form of a completion assembly string comprising a well screen assembly 122, which in turn comprises a shunt tube assembly, disposed in the wellbore 114. It should be understood that the wellbore tubular 120 is equally applicable to any type of wellbore tubulars being inserted into a wellbore including as non-limiting examples drill pipe, casing, liners, jointed tubing, and/or coiled tubing. Further, the wellbore tubular 120 may operate in any of the wellbore orientations (e.g., vertical, deviated, horizontal, and/or curved) and/or types described herein. In an embodiment, the wellbore may comprise wellbore casing 112, which may be cemented into place in at least a portion of the wellbore 114.

[0038] In an embodiment, the wellbore tubular 120 may comprise a completion assembly string comprising one or more downhole tools (e.g., zonal isolation devices 117, screen assemblies 122, valves, etc.). The one or more downhole tools may take various forms. For example, a zonal isolation device 117 may be used to isolate the various zones within a wellbore 114 and may include, but is not limited to, a packer (e.g., production packer, gravel pack packer, frac-pac packer, etc.). While Figure 1 illustrates a single screen assembly 122, the wellbore tubular 120 may comprise a plurality of screen assemblies 122. The zonal isolation devices 117 may be used between various ones of the screen assemblies 122, for example, to isolate different gravel pack zones or intervals along the wellbore 114 from each other.

[0039] The workover and/or drilling rig 106 may comprise a derrick 108 with a rig floor 110 through which the wellbore tubular 120 extends downward from the drilling rig 106 into the wellbore 114. The workover and/or drilling rig 106 may comprise a motor driven winch and

other associated equipment for conveying the wellbore tubular 120 into the wellbore 114 to position the wellbore tubular 120 at a selected depth. While the operating environment depicted in Figure 1 refers to a stationary workover and/or drilling rig 106 for conveying the wellbore tubular 120 within a land-based wellbore 114, in alternative embodiments, mobile workover rigs, wellbore servicing units (such as coiled tubing units), and the like may be used to convey the wellbore tubular 120 within the wellbore 114. It should be understood that a wellbore tubular 120 may alternatively be used in other operational environments, such as within an offshore wellbore operational environment.

[0040] In use, the screen assembly 122 can be positioned in the wellbore 114 as part of the wellbore tubular string adjacent a hydrocarbon bearing formation. An annulus 124 is formed between the screen assembly 122 and the wellbore 114. A gravel slurry 126 may travel through the annulus 124 between the well screen assembly 122 and the wellbore 114 wall as it is pumped down the wellbore 114 around the screen assembly 122. Upon encountering a section of the subterranean formation 102 including an area 128 of highly permeable material, the highly permeable area 128 can draw liquid from the slurry, thereby dehydrating the slurry. As the slurry dehydrates in the permeable area 128, the remaining solid particles form a sand bridge 130 and prevent further filling of the annulus 124 with gravel. One or more shunt tubes 132 may be used to create an alternative path for gravel around the sand bridge 130. The shunt tube 132 allows a slurry of sand to enter an apparatus and travel in the shunt tube 132 past the sand bridge 130 to reenter the annulus 124 downstream. The shunt tube 132 may be placed on the outside of the wellbore tubular 120 or run along the interior thereof.

[0041] The screen assembly 122 comprises one or more interconnected joints of threaded wellbore tubulars having shunt tube assemblies disposed about each joint of the wellbore tubulars. Adjacent sections may generally be substantially longitudinally aligned to allow the ends of adjacent shunt tubes on adjacent sections to be coupled with jumper tubes. The present disclosure teaches the use of various jumper tube and coupling mechanism configurations to improve the coupling between the various shunt tubes on adjacent sections. In an embodiment, the shunt tube and the jumper tube may comprise substantially round (e.g., circular) ends, thereby allowing for a coupling between the two components comprising a substantially round cross-section. In an embodiment, a coupling member may be used to couple to a shunt tube having an end with a non-round (e.g., non-circular) cross-section and a jumper tube having an

end with a substantially round cross-section. The coupling member may be configured to provide fluid communication between a jumper tube and one or more shunt tubes, for example, a transport tube and a packing tube. In an embodiment, the jumper tube may comprise a non-uniform cross-sectional shape along its length. For example, one or more of the ends of the jumper tube may have a substantially round cross-section, and one or more portions between the ends of the jumper tube may have non-round cross-sections. Such an embodiment may be useful in reducing the outer diameter of the jumper tubes while maintaining the available flow area for fluid transport.

[0042] A cross-sectional view of an embodiment of an individual joint of wellbore tubular comprising a shunt tube assembly 200 disposed thereabout is shown in Figure 2. The wellbore tubular 120 generally comprises a series of perforations 202 disposed therethrough. A filter media 204 is disposed about the wellbore tubular 120 and the series of perforations 202 to screen the incoming fluids from the formation. The shunt tube assembly 200 comprises one or more retaining rings 212 and one or more shunt tubes 206 disposed along and generally parallel to the wellbore tubular 120. An outer body member 208 may be disposed about the wellbore tubular 120, one or more shunt tubes 206, and filter media 204. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 206 and/or outer body member 208 in position relative to the wellbore tubular 120.

[0043] The wellbore tubular 120 comprises the series of perforations 202 through the wall thereof. The wellbore tubular 120 may comprise any of those types of wellbore tubular described above with respect to Figure 1. While the wellbore tubular 120 is illustrated as being perforated in Figure 2, the wellbore tubular 120 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 214 and an exterior 216 of the shunt tube assembly 200.

[0044] The wellbore tubular 120 may generally comprise a pin end 209 and a box end to allow the wellbore tubular 120 to be coupled to other wellbore tubulars having corresponding connections. As can be seen in Figure 2, the wellbore tubular 120 may have a coupling section that extends beyond the shunt tube assembly 200. The exposed portion 211 of the wellbore tubular 120 may be used during the coupling process to allow one or more tools to engage the exposed portion 211 and thread the joint to an adjacent joint of wellbore tubular. In an embodiment, the exposed portion may be about 1 to about 5 feet, or alternatively about 2 feet to

about 4 feet, though any distance suitable for allowing the wellbore tubular 120 to be coupled to an adjacent joint of wellbore tubular may be used.

[0045] The filter media 204 may be disposed about the wellbore tubular 120 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the wellbore tubular 120. In an embodiment, the filter media 204 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a wellbore tubular 120, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 204 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 204 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

[0046] The one or more shunt tubes 206 generally comprise tubular members disposed outside of and generally parallel to the wellbore tubular 120, though other positions and alignment may be possible. While described as tubular members (e.g., having substantially circular cross-sections), the one or more shunt tubes 206 may have shapes other than cylindrical and may generally be rectangular, elliptical, kidney shaped, and/or trapezoidal in cross-section. The retaining rings 212 may retain the shunt tubes 206 in position relative to the wellbore tubular 120. The one or more shunt tubes 206 may be eccentrically aligned with respect to the wellbore tubular 120 as best seen in Figure 3. In this embodiment, four shunt tubes 206, 302 are arranged to one side of the wellbore tubular 120 within the outer body member 208. While illustrated in Figures 2 and 3 as having an eccentric alignment, other alignments of the one or more shunt tubes about the wellbore tubular 120 may also be possible.

[0047] Various configurations for providing fluid communication between the interior of the one or more shunt tubes 206 and the exterior 216 of the outer body member 208 are possible. In an embodiment, the one or more shunt tubes 206 may comprise a series of perforations (e.g., openings and/or nozzles). Upon the formation of a sand bridge, a back pressure generated by the blockage may cause the slurry carrying the sand to be diverted through the one or more shunt

tubes 206 until bypassing the sand bridge. The slurry may then pass out of the one or more shunt tubes 206 through the perforations in both the shunt tubes 206 and outer body member 208 and into the annular space between the wellbore tubular and casing/wellbore wall to form a gravel pack.

[0048] In an embodiment, the shunt tubes 206 may comprise transport tubes and/or packing tubes 302. The one or more packing tubes 302 may be disposed in fluid communication with the one or more transport tubes. As illustrated in Figures 1 and 3, the packing tubes 302 may generally comprise tubular members disposed outside of and generally parallel to the wellbore tubular 120. The transport tubes and packing tubes 302 may be disposed generally parallel to the wellbore tubular 120 and may be retained in position relative to the wellbore tubular 120 by the retaining rings 212. A first end of the packing tubes 302 may be coupled to the one or more transport tubes at various points along the length of the transport tubes, and the packing tubes may comprise a series of perforations providing fluid communication within and/or through the outer body member 208 at a second end. As shown schematically in Figure 1, the shunt tubes may form a branched structure along the length of a screen assembly 122 with the one or more transport tubes forming the trunk line and the one or more packing tubes 302 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the screen assembly 122. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended.

[0049] In use, the branched configuration of the transport tubes and packing tubes 302 may provide the fluid pathway for a slurry to be diverted around a sand bridge. Upon the formation of a sand bridge, a back pressure generated by the blockage may cause the slurry carrying the sand to be diverted through the one or more transport tubes 206 until bypassing the sand bridge. The slurry may then pass out of the one or more transport tubes 206 into the one or more packing tubes 302. While flowing through the one or more packing tubes 302, the slurry may pass through the perforations in the packing tubes 302 and into the annular space about the wellbore tubular 120 to form a gravel pack.

[0050] To protect the shunt tubes 206 and/or filter media 204 from damage during installation of the screen assembly comprising the shunt tube assembly 200 within the wellbore, the outer body member 208 may be positioned about a portion of the shunt tube assembly 200.

The outer body member 208 comprises a generally cylindrical member formed from a suitable material (e.g. steel) that can be secured at one or more points, for example to the retaining rings 212, which in turn, are secured to wellbore tubular 120. The outer body member 208 may have a plurality of openings 218 (only one of which is numbered in Figure 2) through the wall thereof to provide an exit for fluid (e.g., gravel slurry) to pass through the outer body member 208 as it flows out of one or more openings in the shunt tubes 206 (e.g., through openings in the packing tubes 302), and/or an entrance for fluids into the outer body member 208 and through the permeable section of the filter media 204 during production. By positioning the outer body member 208 over the shunt tube assembly 200, the shunt tubes 206 and/or filter media 204 may be protected from any accidental impacts during the assembly and installation of the screen assembly in the wellbore that might otherwise damage or destroy one or more components of the screen assembly or the shunt tube assembly 200.

[0051] As illustrated in Figures 2 and 3, the shunt tubes 206, outer body member 208, and/or in some embodiments, the filter media 204 can be retained in position relative to the wellbore tubular 120 using the retaining rings 212. The retaining rings 212 generally comprise rings and/or clamps configured to engage and be disposed about the wellbore tubular 120. The retaining ring 212 may engage the wellbore tubular using any suitable coupling including, but not limited to, corresponding surface features, adhesives, curable components, spot welds, any other suitable retaining mechanisms, and any combination thereof. For example, the inner surface of the retaining ring 212 may comprise corrugations, castellations, scallops, and/or other surface features, which in an embodiment, may be aligned generally parallel to the longitudinal axis of the wellbore tubular 120. The corresponding outer surface of the wellbore tubular 120 may comprise corresponding surface features that, when engaged, couples the retaining rings 212 to the wellbore tubular 120.

[0052] Figure 3 illustrates a cross-sectional view along line A-A' of Figure 2 that shows the cross-section of a retaining ring 212. In the embodiment shown in Figure 3, the retaining ring extends around the wellbore tubular 120. A plurality of through passages are provided in the retaining ring 212 to allow the one or more shunt tubes 206, 302 to pass through a portion of the retaining ring 212. The retaining ring 212 may also be configured to engage and retain the outer body member 208 in position about the wellbore tubular 120. The retaining ring 212 may also

be used to couple the shunt tubes 206, 302 to the jumper tubes, as described in more detail herein.

[0053] While the joints of wellbore tubular described herein are generally described as comprising a series of perforations 202 and filter media 204, one or more joints of wellbore tubular 120 may only have the shunt tube assemblies disposed thereabout. Such a configuration may be used between joints of wellbore tubular 120 comprising production sections to act as spacers or blank sections while still allowing for a continuous fluid path through the shunt tubes 206 along the length of the interval being completed.

[0054] In an embodiment, an assembled sand screen structure can be made up of several joints of the wellbore tubular comprising the shunt tube assemblies 200 described herein. During the formation of the assembled sand screen structure, the shunt tubes 206 on the respective joints are fluidly connected to each other as the joints are coupled together to provide a continuous flowpath for the gravel slurry along the entire length of assembled sand screen structure during gravel packing operations.

[0055] In order to couple joints of wellbore tubulars, adjacent joints comprising screens may be connected by threading together adjacent joints using a threaded coupling (e.g., using timed threads) to substantially align the shunt tubes on the adjacent joints. As illustrated in Figure 4, the end of each shunt tube on the adjacent joints may then be individually coupled using a connector such as a jumper tube. A jumper tube may comprise a relatively short length of tubing which may be engaged to one or more shunt tubes on adjacent joints of wellbore tubulars to provide fluid communication along the length of the shunt tube system. The jumper tubes may comprise one or more tubular components that may be fixed in length or configured to provide a telescoping and extending tubular for engaging one or more shunt tubes. The various components of the jumper tube and jumper tubes connections may be configured to reduce and/or minimize the transitional flow affects through the connections, thus reducing and/or minimizing the associated pressure drops across the various components.

[0056] Typically, the jumper tube may be assembled onto the aligned shunt tubes after the adjacent joints of wellbore tubular are coupled together. In general, jumper tubes may comprise the same or similar shape to the shunt tubes to which they are coupled. However, the use of couplings with non-round cross-sectional shapes may result in a number of difficulties in forming a reliable seal. For example, the alignment of a shunt tube with a non-round cross-

section and a jumper tube with a corresponding non-round cross-section may need to be more precise than the alignment of the same or similar coupling with both parts having round cross-sectional shapes. In order to address this type of issue, the connection between a shunt tube and a jumper tube may comprise a coupling with a substantially round cross-section. The use of a coupling with a substantially round cross-section may allow for more reliable seals and/or seal back-ups to be used, potentially increasing the pressure rating of the resulting coupling.

[0057] Various configurations may be used to form a coupling between a shunt tube and a jumper tube comprising a round cross-section. In an embodiment, an end of the shunt tube and jumper tube may have substantially round cross-sections, allowing the shunt tube and jumper tube to form a coupling with a substantially round cross-section. In an embodiment, a coupling member, which may be separate from the shunt tube and jumper tube, may be used to coupling the shunt tube to the jumper tube. The coupling member may comprise a first end and a second end. The coupling member may be configured to provide a sealing engagement between an end of the shunt tube, which may have a non-round cross-section, and an end of the jumper tube, which may have a round cross-section. In this embodiment, the coupling member may be configured to adapt the non-round cross-section of the shunt tube to a round cross-sectional shape for engaging the jumper tube. In an embodiment, a coupling member may be configured to engage the jumper tube with a round cross-section and a plurality of shunt tubes, which may comprise non-round cross-sections. In this embodiment, the coupling member may serve to distribute flow to a plurality of shunt tubes such as a transport tube and a packing tube. In some embodiments, the coupling member may be the retaining ring 212, where the retaining ring is configured to provide the functions of the coupling member. In an embodiment, the coupling member may comprise a plurality of body portions that are rotatable about the wellbore tubular. This may allow each portion to be rotated and engaged with the jumper tube and/or the shunt tube(s). This may allow for a longitudinal misalignment of the shunt tubes on adjacent sections of wellbore tubular. Each of these configurations will be discussed below in more detail.

[0058] In an embodiment illustrated in Figure 5, the shunt tube 506 may transition from a non-round cross-section to a substantially round cross-section at the coupling 503 with the jumper tube 501. As described herein, the shunt tube 506 may generally comprise a tubular member aligned along the longitudinal axis of the wellbore tubular 120. The shunt tube 506 may have a non-round cross-section along the length of the wellbore tubular joint 120. In an

embodiment, a first end 502 of the shunt tube 506 may comprise a substantially round cross-section. The cross-section of the shunt tube 506 may transition from a non-round shape to a substantially round shape over a portion 505 of the shunt tube 506. Various processes may be used to form a shunt tube 506 comprising a non-round cross-section that transitions or otherwise changes to a round cross-section at the first end 502. For example, the shunt tube 506 may be rolled, cast, or otherwise formed into a tubular member comprising the different cross-sectional shapes along its length.

[0059] In an embodiment, a second shunt tube 526 may transition from a non-round cross-section to a substantially round cross-section at a second coupling 523 between the jumper tube 501 and the second shunt tube 526. The second shunt tube 526 may have a non-round cross-section along the length of a second wellbore tubular joint 520. In an embodiment, a first end 522 of the second shunt tube 526 may comprise a substantially round cross-section. The cross-section of the second shunt tube 526 may transition from a non-round shape to a substantially round shape over a portion 525 of the second shunt tube 526. Various processes may be used to form the second shunt tube 526 comprising a non-round cross-section that transitions or otherwise changes to a round cross-section at the first end 522. For example, the shunt tube 526 may be rolled, cast, or otherwise formed into a tubular member comprising the different cross-sectional shapes along its length. While it is understood that one or both ends 512, 532 of the jumper tube 501 and the corresponding ends 502, 522 of the shunt tubes 506, 526, respectively, may be formed as described herein, reference in the following discussion will be made to the first coupling 503 alone in the interest of clarity.

[0060] As noted above, the use of a round cross-section may provide for a more reliable coupling between the jumper tube 501 and a shunt tube 506. The coupling 503 between the jumper tube 501 and shunt tube 506 may also provide for a similar flow cross-sectional area as compared to the flow cross-sectional area through the shunt tube 506 upstream of the first end 502. In an embodiment, the flow cross-sectional area at the coupling between the jumper tube 501 and the shunt tube 506 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 506 upstream of the first end 502. Due to the differing cross-sectional shapes between the shunt tubes 506 upstream of the end 502 and at the coupling between the jumper tube 501 and the shunt tube 506, the concept of a similar flow capacity may be expressed in terms of a hydraulic

diameter. In an embodiment, the hydraulic diameter of the shunt tubes 506 upstream of the end 502 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the hydraulic diameter of the coupling between the jumper tube 501 and the shunt tube 506.

[0061] As can be seen in Figure 5, the coupling 503 formed by the engagement of the jumper tube 501 with the end 502 of the shunt tube 506 may comprise the jumper tube 501 engaged within the substantially round bore of the end 502 of the shunt tube 506. One or more seals 514 (e.g., o-ring) may be disposed between the outer diameter of the jumper tube 501 and the inner diameter of the shunt tube 506 to form a sealing engagement between the jumper tube 501 and the shunt tube 506 at the coupling 503. In an embodiment, the one or more seals 514 may comprise seal back-ups for providing a higher pressure rating for the coupling 503 than if seal back-ups were not used. The one or more seals 514 may be disposed in corresponding recesses disposed on the outer diameter of the jumper tube 501 and/or in the inner diameter of the shunt tube 506. In order to aid in forming the coupling 503, the end 502 of the shunt tube 506 and/or the end 512 of the jumper tube 501 may be beveled, angled, rounded, or otherwise formed to provide a non-squared shoulder at the end of the shunt tube 506 and/or the jumper tube 501.

[0062] While Figure 5 illustrates the end 512 of the jumper tube 501 sealingly engaged and disposed within the end 502 of the shunt tube 506, the end 512 of the jumper tube 501 may be configured to receive the end 502 of the shunt tube 506 within its bore. In this configuration, the one or more seals 514 may be disposed between the inner diameter of the jumper tube 501 and the outer diameter of the shunt tube 506 within the coupling 503. In an embodiment in which both ends of the jumper tube 501 comprise substantially round cross-sections, the engagement configuration of the jumper tube 501 and the shunt tubes 506, 526 may be the same at each end 512, 532 of the jumper tube 501. For example, the ends 512, 532 of the jumper tube 501 may be disposed within the ends 502, 522 of the shunt tubes 506, 526, respectively, or the ends 502, 522 of the shunt tubes 506, 526 may be disposed within the ends 512, 532 of the jumper tube 501. In an embodiment, the engagement configuration of the jumper tube 501 and the shunt tubes 506, 526 may be different at each end 512, 532 of the jumper tube 501. For example, the end 512 of the jumper tube 501 may be disposed within the end 502 of the shunt tube 506, and the end 522 of the shunt tube 526 may be disposed within the end 532 of the jumper tube 501, or vice-versa. In some embodiments, a coupling between the jumper tube 501 and a shunt tube 506, 526 may

be formed by abutting the end 502 of the shunt tube 506 to the end 512 of the jumper tube 501. The ends 502, 512 may be held in engagement using any suitable connection methods. For example, each component may be coupled with a connection mechanism (e.g., bolts, screws, adhesives, welds, corresponding threads, or the like).

[0063] In an embodiment as illustrated in Figure 5, the portions 505, 525 of the shunt tubes 506, 526 over which the shunt tubes 506, 526 transitions from a non-round cross-section to a substantially round cross-section may be configured to allow for a jumper tube 501 having a substantially fixed longitudinal length to be used to couple to both shunt tubes 506, 526. In this embodiment, the jumper tube 501 may be configured to be engaged with a shunt tube 526 over a sufficient distance so that the opposite end 512 of the jumper tube 501 can be aligned and engaged with the shunt tube 506. The longitudinal length 556 of the jumper tube 501 may allow both ends 512, 532 of the jumper tube 501 to engage (e.g., sealingly engage) the shunt tubes 506, 526, respectively, on adjacent joints of wellbore tubular.

[0064] As illustrated in Figure 5, the longitudinal length of the jumper tube 501 and the portions of the shunt tubes 506, 526 configured to engage the jumper tube 501 may be configured to allow the jumper tube 501 to engage both shunt tubes 506, 526. In an embodiment, the shunt tube 526 may have a substantially round cross-section configured to receive and/or be disposed within the jumper tube 501 over the distance 550, and the shunt tube 506 may have a substantially round cross-section configured to receive and/or be disposed within the jumper tube 501 over at least a distance 554. A distance 552 may exist between the ends 502, 522 of the shunt tubes 506, 526 on adjacent joints of wellbore tubulars 120, 520. In an embodiment, a jumper tube having a substantially fixed length may be used when the overall length 556 of the jumper tube 501 is less than the sum of the distance 552 between the ends 502, 522 of the shunt tubes 506, 526 and the distance 550. This may allow the jumper tube 501 to be inserted into the shunt tube 526 a distance 550, and then be aligned with the shunt tube 506. The jumper tube 501 may then be engaged with the shunt tube 506 a distance 554, which may be less than the distance 550 to provide for an engagement between the jumper tube 501 and the shunt tubes 506, 526.

[0065] Once engaged with the shunt tubes 506, 526, the jumper tube 501 may be held in place using a retaining mechanism 570 configured to engage the jumper tube 501 and/or one or more of the shunt tubes 506, 526 to maintain the jumper tube 501 in engagement with the shunt

tubes 506, 526. In an embodiment, the retaining mechanism may comprise a snap ring configured to engage the jumper tube 501 adjacent to one or both of the shunt tubes 506, 526, thereby preventing movement of the jumper tube 501 into the shunt tubes 506, 526. In some embodiments, the retaining mechanism may engage one or more of the shunt tubes 506, 526 to prevent movement of one or more of the shunt tubes 506, 526 into the jumper tube 501 (e.g., when the jumper tube 501 is configured to receive one or more of the shunt tubes 506, 526 within its bore). In some embodiments, the retaining mechanism 570 may comprise an indicator on the jumper tube 501 or the shunt tube 506, 526 with a corresponding snap fitting assembly (e.g., a snap ring, a collet lug, etc.) on the engaging surface. In some embodiments, the engagement between the jumper tube 501 and one or more of the shunt tubes 506, 526 may comprise a friction fit, compression fit, and/or the like that may be sufficient to maintain the engagement without the need for a retaining mechanism. In some embodiments, the engagement between the jumper tube 501 and one or more of the shunt tubes 506, 526 may comprise a threaded connection. For example, the engagement between the jumper tube 501 and the shunt tube 526 may comprise a sliding, sealing engagement, and the engagement with the shunt tube 506 may then be maintained using a threaded connection, thereby maintaining the engagement with the shunt tube 526 in position through the fixed engagement at the threaded interface on the shunt tube 506.

[0066] In an embodiment as illustrated in Figure 6A, one or more portions of the jumper tube 601 may comprise a non-round cross-section. One or more protrusions 562, 564 may be disposed about the wellbore tubulars 120, 520, respectively, at the ends of the wellbore tubulars 120, 520 to provide for various mechanical properties and/or handling procedures during the coupling of the adjacent wellbore tubulars 120, 520. For example, the protrusions 562, 564 may provide engagement locations for the tongs used during the coupling process of the wellbore tubular joints 120, 520 at the surface of the well. These protrusions 562, 564 may have increased outer diameters relative to the outer diameter of the wellbore tubulars 120, 520. In some embodiments, the protrusions 562, 564 may have outer diameters that would interfere with the jumper tube 501 if the jumper tube 501 comprised a straight tubular component having a substantially round cross-section along its length. The jumper tube 501 may be sized to avoid the protrusions 562, 564, for example by reducing the diameter of the jumper tube 501, but the flow area through the jumper tube 501 may also be reduced.

[0067] In order to avoid the protrusions and/or provide additional flow area through the jumper tube 501, one or more portions of the jumper tube 501 may be configured to comprise a non-round cross-section. As shown in Figure 6A, a portion 604 of the jumper tube 601 may have a non-round cross-section. The portion 604 of the jumper tube 601 having a non-round cross-section may be disposed adjacent to the protrusions 562, 564 forming the coupling between the wellbore tubulars 120, 520. This may allow the jumper tube to extend past the protrusions while maintaining a suitable flow area through the jumper tube 501. The non-round cross-section may comprise any suitable shape. Figures 6B-6E illustrate various suitable cross-sectional shapes including, but not limited to, rectangular, oval, kidney shaped (e.g., arced and/or oblong), trapezoidal, squared, and/or any other suitable non-round cross-sectional shape. In some embodiments, the jumper tube 601 may comprise a bend between the first end 612 and the second end 622 to allow the jumper tube 601 to be routed past the protrusions 562, 564 at the coupling between the wellbore tubular joints 120, 520. The bend may allow the jumper tube 601 to be disposed adjacent to the wellbore tubular 120, extend out to be disposed adjacent to the outer diameter of the protrusions 562, 564, and then be disposed adjacent to the wellbore tubular 520. This embodiment may limit the length of the portion 604 of the jumper tube 601 having an increased outer diameter.

[0068] The portion 604 of the jumper tube 601 having a non-round cross-section may have the same or similar cross-sectional area available for flow as compared to the flow cross-sectional area through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601. In an embodiment, the flow cross-sectional area of the portion 604 comprising the non-round cross-section may be within about 10%, within about 20%>, within about 30%>, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601. Due to the differing cross-sectional shapes between the shunt tubes 506 upstream of the end 502, the end 612 of the jumper tube 601, and/or the portion 604 comprising the non-round cross-section, the concept of a similar flow capacity may be expressed in terms of a hydraulic diameter. In an embodiment, the hydraulic diameter of the portion 604 comprising the non-round cross-section may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the hydraulic diameter through the shunt tube 506 upstream of the first end 502 and/or the end 612 of the jumper tube 601.

[0069] Referring to Figures 4 and 5, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 502 of a first shunt tube 506 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 522 of a second shunt tube 526 on the second wellbore tubular joint 520. In an embodiment, the shunt tubes 506, 526 may be considered substantially aligned if they are aligned to within about 10 degrees, about 7 degrees, or about 5 degrees of each other.

[0070] Once the adjacent shunt tubes 506, 526 are substantially aligned, the jumper tube 501 may be used to provide a fluid coupling between the adjacent shunt tubes 506, 526. In an embodiment, the jumper tube 501 may be coupled to the adjacent ends of the adjacent shunt tubes 506, 526. For example, the jumper tube 501 may be engaged with one of the shunt tubes 506. The opposite end of the jumper tube 501 may then be extended (e.g., extended through a telescoping configuration) to engage the shunt tube 526 on the adjacent joint of wellbore tubular 520. In some embodiments, a jumper tube 501 having a fixed length may be used. In this embodiment, the jumper tube 501 may be engaged with the shunt tube 506 and displaced relative to the shunt tube 506 a sufficient distance to allow the opposite end of the jumper tube 501 to be aligned and engaged with the shunt tube 526. The jumper tube 501 may then be engaged with the shunt tube 526 a distance sufficient to form an engagement while maintaining the engagement with the first shunt tube 506. One or more seals (e.g., o-ring seals 514, etc.) may be used to provide a fluid tight connection between the jumper tube 501 and the end of the respective shunt tube 506, 526. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube 501 with the shunt tubes 506, 526.

[0071] Similar jumper tubes 501 may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes 506, 526 and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes 501. In an embodiment, the shroud may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section 540 to prevent

damage to the jumper tubes 501 and ends of the adjacent shunt tubes 506, 526 during conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[0072] In an embodiment illustrated in Figures 7A and 7B, a coupling member 705, which may be separate from the shunt tube 706 and jumper tube 701, may be used to coupling the shunt tube 706 to the jumper tube 701. The shunt tube 706 may comprise a first cross-sectional shape, which may be a non-round cross-sectional shape, and the jumper tube 701 may comprise a second cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the coupling member 705. The coupling member 705 may then be configured to provide a sealing engagement with the shunt tube 706 and the jumper tube 701, and the coupling member 705 may act as a converter between the cross-sectional shapes of the shunt tube 706 and the jumper tube 701. In an embodiment, one or more portions of the jumper tube 701 may comprise a non-round cross-section. Any of the jumper tube 701 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 701 coupled to the coupling member.

[0073] The coupling member 705 may generally comprise a tubular member comprising a first end 707 having a non-round cross-section and a second end 708 having a substantially round cross-section. A flowbore may be disposed through the coupling member 705 for providing fluid communication between the first end 707 and the second end 708. The coupling member 705 may be configured to provide a sealing engagement between an end 702 of the shunt tube 706, which may have a non-round cross-section, and an end 712 of the jumper tube 701, which may have a round cross-section. In this embodiment, the coupling member may be configured to adapt the non-round cross-section of the shunt tube 706 to a round cross-sectional shape for engaging the jumper tube 701. In order to adapt the cross-sections of the shunt tube 706 to the jumper tube 701, the cross-section of the flowbore and/or the outer diameter of the coupling member 705 may transition along the length of the coupling member 705. The relative inner diameter of the first end 707 and the second end 708 of the coupling member 705 may be selected to provide for the connections to the shunt tube 706 and the jumper tube 701 .

[0074] As illustrated in Figure 7B, the first end 707 of the coupling member 705 may comprise a shoulder configured to engage the end 702 of the shunt tube 706. One or more seals (e.g., O-ring seals with or without seal backups) may be disposed between the end 702 of the shunt tube 706 and the coupling member 705 to provide for a sealing engagement between the shunt tube 706 and the coupling member 705. In an embodiment, the coupling member 705 may be fixedly coupled to the shunt tube 706 using, for example, a connector (e.g., bolts, screws, and the like), adhesives, welds, or any other suitable connections.

[0075] The coupling member 705 may also form a sealing engagement with the end 712 of the jumper tube 701. One or more seals 714 (e.g., o-ring) may be disposed between the outer diameter of the jumper tube 701 and the inner diameter of the coupling member 705 to form a sealing engagement between the jumper tube 701 and the coupling member 705. In an embodiment, the one or more seals 714 may comprise seal back-ups for providing a higher pressure rating for the sealing engagement than if seal back-ups were not used. The one or more seals 714 may be disposed in corresponding recesses disposed on the outer diameter of the jumper tube 701 and/or in the inner diameter of the coupling member 705. In order to aid in forming the engagement, the end 712 of the jumper tube 701 and/or the end 708 of the coupling member 705 may comprise a beveled, angled, rounded, or otherwise formed portion to provide a non-squared shoulder 750 at the end of the jumper tube 701 and/or the coupling member 705.

[0076] While Figures 7A and 7B illustrate the coupling member 705 receiving the shunt tube 706 and the jumper tube 701 within the flowbore, the coupling member 705 may also be received within the shunt tube 706 and/or the jumper tube 701. As illustrated in Figure 8, the coupling member 805 may be received within and engage an inner diameter of the shunt tube 706 and the jumper tube 701. In this configuration, the one or more seals 714 may be disposed between the inner diameter of the shunt tube 706 and/or the jumper tube 701 and the outer diameter of the coupling member 805. It will be appreciated that the coupling member may be received within, disposed about, or abut the end of the shunt tube 706 and/or the jumper tube 701. In an embodiment, the engagement configuration of the coupling member with jumper tube 701 and/or the shunt tubes 706, 726 may be the same or different so long as the coupling member engages the shunt tube and the jumper tube. The considerations of the orientations of each component discussed above with respect to Figure 5 may also apply to the orientations of the engagement of the coupling member with the shunt tube and/or the jumper tube.

[0077] As illustrated in Figure 8, one or more retaining mechanisms 870 may be used to maintain the coupling member 805 in engagement within the shunt tube 706 and/or the jumper tube 701. In an embodiment, the retaining mechanisms may comprise a snap ring configured to engage an inner diameter of the jumper tube 701 adjacent to the coupling member 805, thereby preventing movement of the coupling member 805 into the jumper tube 701 and/or the shunt tube 706. In an embodiment, the retaining mechanisms 870 may comprise any of those retaining mechanisms described above with respect to Figure 5.

[0078] In an embodiment illustrated in Figures 7A and 7B, a second shunt tube 726 disposed on the second joint of wellbore tubular 520 may comprise a non-round cross-section. The non-round cross-section of the shunt tube 706 may be the same as or different than the non-round cross-section of the second shunt tube 726. The non-round cross-section of the shunt tube 706 may extend into the jumper tube section 728 for coupling to the jumper tube 701 using the coupling member 705. In an embodiment, the non-round cross-section of the second shunt tube 726 may extend into the jumper tube section 702 for coupling to the jumper tube 701 using a second coupling member 725. The second coupling member 725 may be the same or similar to the coupling member 705, though the cross-sectional shape of the end having the non-round cross-sectional shape may be different than the non-round cross-sectional shape of the coupling member 705. While the coupling member 705 is discussed herein, it is understood that the description also applies to the second coupling member 725.

[0079] The coupling member 705 providing the engagement and fluid communication between the jumper tube 701 and shunt tube 706 may also provide for a similar flow cross-sectional area as compared to the flow cross-sectional area through the shunt tube 706 upstream of the first end 702. In an embodiment, the flow cross-sectional area through the coupling member 705 may be within about 10%, within about 20%, within about 30%, within about 40%, or within about 50% of the flow cross-sectional area through the shunt tube 706 upstream of the first end 702. Due to the differing cross-sectional shapes along the length of the coupling member 705 to provide the coupling with the end 702 of the shunt tube 706 and at the end 712 of the jumper tube 701, the concept of a similar flow capacity may be expressed in terms of a hydraulic diameter. In an embodiment, the hydraulic diameter of the shunt tubes 706 upstream of the end 702 may be within about 10%, within about 20%, within about 30%, within about

40%, or within about 50% of the hydraulic diameter of the flow area through the end 708 of coupling member 705.

[0080] In an embodiment, the coupling member 705 may be configured to receive the jumper tube 701 over a length of the flowbore. This configuration may be configured to allow for a jumper tube 701 having a substantially fixed longitudinal length to be used to couple to the coupling member 705 and the second coupling member 725. In this embodiment, the jumper tube 701 may be configured to be engaged with at least one of the coupling members 705, 725 over a sufficient distance so that the opposite end of the jumper tube 701 can be aligned and engaged with the shunt tube. Any of the considerations and/or configurations described with respect to the lengths, distances, and portions of the shunt tubes configured to receive the jumper tube in Figure 5 may also apply to one or more of the coupling members 705, 725.

[0081] In an embodiment illustrated in Figure 9, the coupling member comprises the retaining ring 905 disposed about the wellbore tubular 120. The retaining ring 905 may be used to couple the shunt tube 906 to the jumper tube 901. The shunt tube 906 may comprise a first cross-sectional shape, which may be a non-round cross-sectional shape, and the jumper tube 901 may comprise a second cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the retaining ring 905. The retaining ring 905 may then be configured to provide a sealing engagement with the shunt tube 906 and the jumper tube 901, and the retaining ring 905 may act as a converter between the cross-sectional shapes of the shunt tube 906 and the jumper tube 901. In an embodiment, one or more portions of the jumper tube 901 may comprise a non-round cross-section. Any of the jumper tube 901 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 901 coupled to the retaining ring 905.

[0082] The retaining ring 905 may generally comprise a ring and/or clamp configured to engage and be disposed about the wellbore tubular 120. The retaining ring 905 may have one or more fluid passages disposed therethrough to provide fluid communication from a first side 907 to a second side 908 of the retaining ring 905. The openings of the fluid passages on the first side 907 may be configured to engage one or more shunt tubes 906 having a non-round cross-section, and the openings of the fluid passages on the second side 908 may be configured to engage one or more jumper tubes 901 having a substantially round cross-section at the coupling with the retaining ring 905. The retaining ring 905 may be configured to provide a sealing

engagement (e.g., using one or more o-ring seals with or without seal backups) between an end 902 of the shunt tube 906 and the retaining ring 905, and/or the retaining ring 905 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals 914 with or without seal backups) between an end 912 of the jumper tube 901 and the retaining ring 905. In this embodiment, the retaining ring and the fluid passages may be configured to adapt the non-round cross-section of the shunt tube 906 to a round cross-sectional shape for engaging the jumper tube 901. In order to adapt the cross-sections of the shunt tube 906 to the jumper tube 901, the cross-section of the fluid passages through the retaining ring 905 may transition along the length of the fluid passages through the retaining ring 905. The relative inner diameters of the first end 907 and the second side 908 of the retaining ring 905 may be selected to provide for the connections to the shunt tube 906 and the jumper tube 901. The retaining ring 905 may be coupled to the shunt tube 906 and/or the jumper tube 901 using any of the connector types and configurations described herein.

[0083] In an embodiment, a second retaining ring 925 may be similarly configured to the first retaining ring 905. In this embodiment, the second retaining ring 925 may engage the jumper tube 901 and a second shunt tube 926, which may comprise a non-round cross-section, on a second wellbore tubular 520. The non-round cross-section of the shunt tube 906 may be the same as or different than the non-round cross-section of the second shunt tube 926. The second retaining ring 925 may be the same as or different than the retaining ring 905. While the retaining ring 905 is discussed herein, it is understood that the description also applies to the second retaining ring 925.

[0084] When the coupling member is a retaining ring, any of the flow considerations with respect to flow area and/or hydraulic diameter as described herein may also apply. Further, any of the considerations and/or configurations described with respect to the lengths, distances, and portions of the shunt tubes configured to receive the jumper tube in Figure 5 may also apply to one or more of the retaining rings 905, 925, and the discussion of the relative distances is not repeated herein in the interest of clarity. Still further, any of the types of jumper tubes, including those comprising non-round cross-sections and/or bends, may be used in combination with the retaining rings 905, 925.

[0085] The use of a coupling member described with respect to Figures 7 and 8 and the retaining ring comprising one or more fluid passageways described with respect to Figure 9 may

be used in combination. For example, the retaining ring may comprise one or more fluid passageways comprising openings on the first and second sides with the same or similar cross-sectional shapes. One or more shunt tubes may be received at the first side of the retaining ring, and a separate coupling member may be engaged with the openings on the second side of the retaining ring. The coupling member may then act as the conversion between the opening in the retaining ring having a non-round cross-section and the substantially round cross-section of the jumper tube at the coupling with the coupling member.

[0086] Referring to Figures 4 and 7 to 9, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 702 of a first shunt tube 706 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 722 of a second shunt tube 726 on the second wellbore tubular joint 520.

[0087] Once the adjacent shunt tubes 706, 726 are substantially aligned, a coupling member 705 may be engaged with the shunt tube 706, and a second coupling member 725 may be coupled with the shunt tube 726. In some embodiments, the coupling members 705, 725 may be pre-coupled to the shunt tubes 706, 726. One or more seals (e.g., o-ring seals 714, etc.) may be used to provide a fluid tight connection between the shunt tubes 706, 726 and the respectively coupling members 705, 725. In an embodiment, the coupling member comprises the retaining ring 905 as shown in Figure 9. In this embodiment, the retaining ring 905 may be pre-installed as part of the screen assembly, and may have one or more openings for engaging the jumper tube 901. While described below in terms of the coupling members 705, 725 being separate from the retaining rings 905, 925, the same or similar formation process may be used to couple the jumper tube 901 to the retaining rings 905, 925.

[0088] The jumper tube 701 may then be coupled to the coupling members 705, 725. For example, the jumper tube 701 may be engaged with one of the coupling member 705. The opposite end of the jumper tube 701 may then be extended (e.g., extended through a telescoping configuration) to engage the coupling member 725 on the adjacent joint of wellbore tubular 520. In some embodiments, a jumper tube 701 having a fixed length may be used. In this

embodiment, the jumper tube 701 may be engaged with the coupling member 705 and displaced a sufficient distance to allow the opposite end of the jumper tube 701 to be aligned and engaged with the second coupling member 725. The jumper tube 701 may then be engaged with the coupling member 725 a distance sufficient to form an engagement while maintaining the engagement with the first coupling member 705. One or more seals (e.g., o-ring seals 714, etc.) may be used to provide a fluid tight connection between the jumper tube 701 and the coupling members 705, 725. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube 701 with the coupling members 705, 725.

[0089] Similar jumper tubes 701 and coupling members may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes 706, 726 and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes 701 . In an embodiment, the shroud 403 may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section 728 to prevent damage to the jumper tubes 701, coupling members 705, 725 and ends of the adjacent shunt tubes 706, 726 during conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[0090] As described above, the shunt tubes may form a branched structure along the length of a screen assembly with the one or more transport tubes forming the trunk line and the one or more packing tubes forming the branch lines. The coupling between the transport tubes and the packing tubes may occur along the length of the screen assembly with a packing tube being directly connected to the transport tube. As described herein a coupling member may be configured to engage the jumper tube and a plurality of shunt tubes. In this embodiment, the coupling member may be coupled to and configured to distribute flow to a plurality of shunt tubes such as a transport tube and a packing tube, thereby eliminating or reducing the need for the packing tubes to be directly coupled to the transport tubes.

[0091] In an embodiment as illustrated in Figure 10, the coupling member may be similar to the coupling member described with respect to Figures 7 and 8 and the like components will not

be repeated in the interest of clarity. The coupling member 1002 may generally comprise a body portion 1003 comprising a first opening 1004 having a substantially round cross-section and a plurality of second openings 1006, 1008, which may comprise non-round cross-sections. A chamber 1014 may be disposed within the body portion 1003, and the chamber 1014 may be in fluid communication with the inlet opening 1004 and each of the plurality of outlet openings 1006, 1008. While only two second openings are depicted in Figure 10, the body portion 1003 may comprise more than two second openings, and the chamber 1014 may be in fluid communication with each of the plurality of second openings.

[0092] In an embodiment, the first opening 1004 may be configured to receive a jumper tube 1001, and the coupling between the jumper tube 1001 and the body portion 1003 may comprise a substantially round cross-section. The plurality of second openings 1006, 1008 may comprise non-round cross-sections, and each of the second openings 1006, 1008 may be configured to engage and couple to a shunt tube 1010, 1012. In an embodiment, the second opening 1006 may be coupled to a transport tube 1010, and the second opening 1008 may be coupled to a packing tube 1012. The plurality of second openings 1006, 1008 may generally be oriented in a parallel configuration to allow for the tubular members coupled thereto to extend parallel along the length of the wellbore tubular. In an embodiment, orientations other than parallel are possible. Fluid entering the first opening through the jumper tube 1001 may be distributed to the transport tube 1010 and the packing tube 1012 through the chamber 1014.

[0093] The coupling member 1002 may be configured to provide a sealing engagement between the jumper tube 1001 and the body portion 1003. For example, one or more seals may be disposed in corresponding seal recesses between the jumper tube 1001 and the body portion 1003. In an embodiment, the seals may comprise seal back-ups to provide for suitable pressure rating through the coupling member 1002. Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the coupling member, and/or the seal locations may also apply to the coupling member 1002.

[0094] In an embodiment, the coupling member 1002 may be configured to provide a sealing engagement between the body portion 1003 and one or more of the plurality of shunt tubes 1010, 1012. For example, one or more seals may be disposed in corresponding seal recesses between the body portion 1003 and one or more of the plurality of shunt tubes 1010, 1012. In an

embodiment, the seals may comprise seal back-ups to provide for suitable pressure rating through the coupling member 1002.

[0095] Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the coupling member, and/or the seal locations may also apply to the coupling member 1002. While described in terms of the jumper tube being coupled to a plurality of shunt tubes, the coupling member 1002 may also be used to couple a shunt tube to a plurality of jumper tubes. In this embodiment, the plurality of jumper tubes, which may comprise substantially round cross-sections at the coupling with the coupling member, may then be coupled to corresponding shunt tubes, which may comprise non-round cross-sections, on an adjacent section of wellbore tubular.

[0096] In an embodiment illustrated in Figures 11A to 11C, the coupling member comprises the retaining ring 1101. While illustrated as a half-view, it is understood that the retaining ring 1101 is configured to be disposed about a wellbore tubular. The retaining ring 1101 may be used to couple a jumper tube 1110 to a plurality of shunt tubes 1112, 1114. The jumper tube 1110 may comprise a cross-sectional shape, which may be a substantially round cross-sectional shape at the engagement with the retaining ring 1101, and the plurality of shunt tubes 1112, 1114 may comprise a one or more second cross-sectional shapes, which may be non-round cross-sectional shapes. The retaining ring 1101 may then be configured to provide a sealing engagement with the jumper tube 1110 and the plurality of shunt tubes 1112, 1114, and the retaining ring 1101 may act as a converter between the cross-sectional shapes of the jumper tube 1110 and the plurality of shunt tubes 1112, 1114. In an embodiment, one or more portions of the jumper tube 1110 may comprise a non-round cross-section. Any of the jumper tube 1110 configurations comprising non-round cross-sections discussed with respect to Figures 5 and 6A-6E may be used with the jumper tube 1110 coupled to the retaining ring 1101.

[0097] The retaining ring 1101 may have one or more fluid passages disposed therethrough. The openings 1102 of the fluid passages on a first side may be configured to engage one or more jumper tubes 1110 having a substantially round cross-section at the coupling with the retaining ring 1101, and the openings 1104, 1106 of the fluid passages on a second side may be configured to engage one or more shunt tubes 1112, 1114 having a non-round cross-section at the coupling with the retaining ring 1101. A chamber 1108 may be disposed within the retaining ring 1101 to provide fluid communication between each of the openings 1102, 1104, 1106. The plurality of

openings 1104, 1106 may generally be oriented in a parallel configuration to allow for the tubular members coupled thereto to extend parallel along the length of the wellbore tubular. In an embodiment, orientations other than parallel are possible.

[0098] The retaining ring 1101 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals with or without seal backups) between one or more of the plurality of shunt tubes 1112, 1114 and the retaining ring 1101, and/or the retaining ring 1101 may be configured to provide a sealing engagement (e.g., using one or more o-ring seals with or without seal backups) between the jumper tube 1110 and the retaining ring 1101. In this embodiment, the retaining ring 1101 and the fluid passages may be configured to adapt a round cross-sectional shape for engaging the jumper tube 1110 to one or more non-round cross-sections of the shunt tubes 1112, 1114. In order to adapt the cross-sections of the plurality of shunt tubes 1112, 1114 to the jumper tube 1110, the cross-section of the fluid passages through the retaining ring 1101 may transition along the length of the fluid passages through the retaining ring 1101. The retaining ring 1101 may be coupled to the plurality of shunt tubes 1112, 1114 and/or the jumper tube 1110 using any of the connector types and configurations described herein. While illustrated as comprising two shunt tubes 1112, 1114, more than two shunt tubes may be engaged with the retaining ring 1101. Fluid entering the first opening 1102 through the jumper tube 1110 may be distributed to the transport tube 1112 and the packing tube 1114 through the chamber 1108.

[0099] The fluid communication provided by the retaining ring may be divided into two separate fluid communication pathways. As described herein, two or more separate fluid communication pathways may be used along the length of the well screen assembly to allow for redundancy in the shunt tube system. The separate fluid communication pathways may be retained by the inclusion of two openings 1102 to receive two jumper tubes 1110, and two pluralities of outlets to couple to separate pluralities of shunt tubes. For example, as shown in Figure 11B, the fluid communication provided between the opening 1102 and the plurality of openings 1104, 1106 through the chamber 1108 may be separate from a second set of openings 1103, 1105.

[00100] In an embodiment as illustrated in Figures 12A to 12D, the retaining ring 1101 may comprise a plurality of body portions. As shown in Figures 12A and 12B, the retaining ring 1101 may comprise a first body portion 1202 comprising the openings 1104, 1106. A seal recess

1204 may be disposed within a side of the first body portion 1202. A second body portion may be configured to engage the first body portion 1202, forming a chamber 1206 within the assembled retaining ring 1101. The second body portion may comprise the openings for receiving one or more jumper tubes. The second body portion may comprise a seal (e.g., a seal, gasket, etc.) configured to engage the seal recess 1204 and form a sealing engagement between the first body portion 1202 and the second body portion. The first body portion 1202 and second body portion may be engaged and coupled together using any suitable coupling mechanism (e.g., bolts, screws, pins, adhesives, clamps, etc.). While the retaining ring 1101 illustrated in Figures 12A and 12B show a single chamber 1206 being formed within the retaining ring 1101, a divider (not shown) may be disposed within the first body portion 1202 and/or the second body portion. The divider may be configured to divide the chamber 1206 into two portions, thereby maintaining independent and redundant fluid communication pathways along the length of the shunt tube assembly.

[00101] Another embodiment of a retaining ring 1101 comprising a plurality of body portions is illustrated in Figures 12C and 12D. In this embodiment, the first body portion 1208 may comprise the openings 1102 for coupling with one or more jumper tubes, which may have substantially round cross-sections at the coupling with the first body portion 1208. The second body portion 1210 may comprise the openings 1104, 1106 for coupling with one or more shunt tubes (e.g., transport tubes, packing tubes, etc.). The first body portion 1208 and the second body portion 1210 may be engaged and coupled using any suitable coupling mechanism. In an embodiment, the first body portion 1208 and the second body portion 1210 may be coupled using a welded coupling. One or more weldment surfaces 1212, 1214 may be disposed on the first body portion 1208 and/or the second body portion 1210 for receiving a weld. The use of the welded connection and the weldment surfaces 1212, 1214 disposed about the retaining ring 1101 surfaces may allow the orientation of the first body portion 1208 and the second body portion 1210 to be adjusted. For example, the first body portion 1208 may be somewhat misaligned with the second body portion 1210 while still allowing for the first body portion 1208 to be coupled to the second body portion 1210. Upon being coupled, one or both of the body portions 1208, 1210 may be fixedly attached to the wellbore tubular about which the retaining ring 1101 is disposed.

[00102] A partial isometric view of the retaining ring 1101 is illustrated in Figure 12D. A chamber 1206 may be formed by the engagement of the first body portion 1208 with the second

body portion 1210. The chamber may provide fluid communication between the openings 1102 and the openings 1104, 1106. When a single chamber is present, fluid communication may exist between each of the openings 1102 and each of the openings 1104, 1106. While the retaining ring 1101 illustrated in Figures 12C and 12D shows a single chamber 1206 being formed within the retaining ring 1101, a divider (not shown) may be disposed within the first body portion 1208 and/or the second body portion 1210. The divider may be configured to divide the chamber 1206 into two portions, thereby maintaining independent and redundant fluid communication pathways along the length of the shunt tube assembly.

[00103] Any of the configurations described herein with respect to the type and/or orientation of the jumper tubes, the retaining member, and/or the seal locations may also apply to the retaining member 1101. While described in terms of the jumper tube being coupled to a plurality of shunt tubes, the retaining member 1101 may also be used to couple a shunt tube to a plurality of jumper tubes. In this embodiment, the plurality of jumper tubes, which may comprise substantially round cross-sections at the coupling with the retaining member 1101, may then be coupled to corresponding shunt tubes, which may comprise non-round cross-sections, on an adjacent section of wellbore tubular.

[00104] Referring to Figures 4, 10, 11A-1 1C, and 12A-12D, the coupling process between the adjacent wellbore tubular joints 120, 520 may begin with coupling a first joint of wellbore tubular 120 comprising a shunt tube assembly to a second joint of wellbore tubular 520 comprising a shunt tube assembly. The wellbore tubular sections 120, 520 may generally comprise a pin and box type connection that can be threaded together and torqued according to standard connection techniques. Once coupled, the end 702 of a first shunt tube 706 on the first wellbore tubular joint 120 may be substantially aligned with the adjacent end 722 of a second shunt tube 726 on the second wellbore tubular joint 520.

[00105] Once the adjacent shunt tubes are substantially aligned, a first coupling member may be engaged with the first shunt tube, and a second coupling member may be coupled with a second shunt tube. In an embodiment, one or more of the coupling members may comprise a coupling member engaged with a plurality of shunt tubes. In an embodiment, the first coupling member may be configured to engage a single jumper tube and a single shunt tube (e.g., a transport tube). In this embodiment, the second coupling member may be configured to engage the jumper tube and a plurality of shunt tubes (e.g., one or more transport tubes and/or packing

tubes), thereby forming the branched structure of the shunt tube assembly with the coupling member/retaining ring and the jumper tube. The coupling member comprising a plurality of openings for shunt tubes may then be used to distribute the sand or gravel slurry to the transport tubes and packing tubes.

[00106] The coupling member may comprise a separate component and/or a retaining ring as described herein. In this embodiment, the retaining ring may be pre-installed as part of the screen assembly, and may have one or more openings for engaging the jumper tube. In some embodiments, the coupling members may be pre-coupled to the shunt tubes. One or more seals (e.g., o-ring seals, etc.) may be used to provide a fluid tight connection between the shunt tubes and the respective coupling members. While described below in terms of the coupling members being separate from the retaining rings, the same or similar formation process may be used to couple the jumper tube to the retaining rings.

[00107] The jumper tube may then be coupled to the coupling members. For example, the jumper tube may be engaged with one of the coupling member. The opposite end of the jumper tube may then be extended (e.g., extended through a telescoping configuration) to engage the coupling member on the adjacent joint of wellbore tubular. In some embodiments, a jumper tube having a fixed length may be used. In this embodiment, the jumper tube may be engaged with the coupling member and displaced a sufficient distance to allow the opposite end of the jumper tube to be aligned and engaged with the second coupling member. The jumper tube may then be engaged with the coupling member a distance sufficient to form an engagement while maintaining the engagement with the first coupling member. One or more seals (e.g., o-ring seals, etc.) may be used to provide a fluid tight connection between the jumper tube and the coupling members. In some embodiments, one or more retaining mechanisms may be used to maintain the engagement of the jumper tube with the coupling members.

[00108] Similar jumper tubes and coupling members may be used to couple any additional shunt tubes (e.g., transport tubes, packing tubes, etc.) being fluidly coupled between the adjacent joints of wellbore tubulars 120, 520. Having fluidly coupled the shunt tubes and any additional tubes on the adjacent joints of wellbore tubulars 120, 520, an additional shroud 403 may be used to protect the jumper tubes. In an embodiment, the shroud 403 may be similar to the outer body member 208, and may be configured to be disposed about the jumper tube section to prevent damage to the jumper tubes, coupling members and ends of the adjacent shunt tubes during

conveyance within the wellbore. Once the adjacent wellbore tubulars 120, 520 are coupled and the shroud 403 has been engaged, additional joints of wellbore tubulars may be similarly coupled to the existing joints and/or additional wellbore tubulars may be used to complete the assembled sand screen structure for use in the wellbore.

[00109] In an embodiment, the coupling member may comprise a rotating and/or translating ring assembly. As shown in Figure 13, the coupling member 1300 comprises two rings 1304, 1306. The first ring 1304 may generally comprise a ring and/or clamp configured to engage and be disposed about the wellbore tubular 120. The first ring 1304 may engage the wellbore tubular 120 using any suitable coupling including any of those described with respect to the retaining ring 212, as described in more detail herein. The first ring 1304 may be configured to rotate about the wellbore tubular 120, and in some embodiments, axially translate over at least a portion of the length of the wellbore tubular 120. One or more seals 1308, 1310 may be used to form a sealing engagement between the first ring 1304 and the wellbore tubular 120 and a cover 1322. One or more ports 1312 may be disposed between an exterior side of the first ring 1304 and an interior side of the first ring 1304. Similarly, a second ring 1306 may engage the wellbore tubular 120. The second ring 1306 may be configured to rotate about the wellbore tubular 120, and in some embodiments, axially translate over at least a portion of the length of the wellbore tubular 120. One or more seals 1316, 1318 may be used to form a sealing engagement between the second ring 1306 and the wellbore tubular 120 and a cover 1322. One or more ports 1314 may be disposed between an exterior side of the second ring 1306 and an interior side of the second ring 1306.

[00110] The combination of the first ring 1304, the second ring 1306, and the cover 1322 may form a chamber 1320 through which fluid communication is established between one or more jumper tubes 1301 and one or more shunt tubes 1302. One or more stops may be disposed on and/or about the wellbore tubular to limit the axial translation of the first ring 1304 and/or the second ring 1306 along the length of the wellbore tubular. In an embodiment, the first ring 1304 and/or the second ring 1306 may be fixedly coupled to the wellbore tubular 120.

[00111] The first ring 1304 may be configured to be coupled to one or more jumper tubes 1301 and/or the second ring 1306 may be configured to be coupled to one or more shunt tubes 1302. The coupling with the one or more jumper tubes 1301 may comprise a substantially round cross-section, and/or the coupling with the one or more shunt tubes 1302 may comprise a non-

round cross-section. Thus, the combination of the first ring 1304 and the second ring 1306 may be used to adapt a non-round cross-section of one or more shunt tubes 1302 to a substantially round cross-section of the coupling portion of one or more jumper tubes 1301. Further the rotation and translation of the first ring 1304 and/or the second ring 1306 may allow for a misalignment of the shunt tubes on adjacent sections of wellbore tubular. For example, the first ring 1304 and/or the second ring 1306 may be rotated and/or axially translated into engagement with the one or more jumper tubes 1301 and one or more shunt tubes 1302, respectively.

[00112] In use, the first ring 1304 may be rotated about the wellbore tubular 120 and/or axially translated into engagement with the jumper tube 1301. The second ring 1306 may similarly be rotated about the wellbore tubular 120 and/or axially translated into engagement with the shunt tubes 1302. Upon being engaged with the respective tubes, the cover 1322 may be engaged with the first ring 1304 and the second ring 1306 to form the chamber 1320 and provide fluid communication between the tubes. The first ring 1304 and/or the second ring 1306 may then be optionally fixedly coupled to the wellbore tubular 120 to maintain the relative positions of the first ring 1304 and/or the second ring 1306.

[00113] Another embodiment of a coupling member comprising a rotating and/or translating ring assembly is illustrated in Figure 14. The embodiment of Figure 14 is similar to the embodiment illustrated in Figure 13 and like components will not be discussed in the interest of clarity. In this embodiment, a first ring 1404 and a second ring 1406 may be disposed about the wellbore tubular 120, and the first ring 1404 and second ring 1406 may be configured to directly engage each other, thereby forming the chamber 1320. A coupling mechanism 1420 may be used to engage and couple the first ring 1404 to the second ring 1406. The engagement of the first ring 1404 with the second ring 1406 may form a sealing engagement. In an embodiment, the coupling mechanism may be configured to couple the first ring 1404 and the second ring 1406 regardless of the axial alignment of the rings 1404, 1406 and/or the one or more jumper tubes 1301 or one or more shunt tube 1302. This may allow the first ring 1404 and/or the second ring 1406 to be rotated about the wellbore tubular 120 to provide the appropriate alignment with the one or more jumper tubes 1301 and/or the one or more shunt tubes 1302 before being coupled together.

[00114] In use, the first ring 1304 may be rotated about the wellbore tubular 120 and into engagement with the jumper tube 1301. The second ring 1306 may similarly be rotated about

the wellbore tubular 120 and into engagement with the shunt tubes 1302. Upon being engaged with the respective tubes, the coupling mechanism may be used to couple the first ring 1404 to the second ring 1406, which may form a sealing engagement between the rings 1404, 1406. The first ring 1404 and/or the second ring 1406 may then be optionally fixedly coupled to the wellbore tubular 120 to maintain the relative positions of the first ring 1404 and/or the second ring 1406.

[00115] In each of the embodiments of the couplings, coupling members, and/or retaining rings described herein may be used alone or in combination to provide an assembled shunt tube assembly. For example, a shunt tube assembly comprising a plurality of wellbore tubular joints may be coupled using any combination of the configurations described herein. Once assembled, any of the shunt tube assemblies described herein may be disposed within a wellbore for use in forming a sand screen. Referring again to Figure 1, after the assembled sand screen structure is installed in the wellbore 114, a packing sand/gel slurry can be forced downwardly into the annulus between the casing and the sand screen to form the pre-filtering sand pack around the screen structure. In the event that an annular sand bridge is created externally around the sand screen structure, the slurry is caused to bypass the sand bridge by flowing into the shunt tubes downwardly through the shunt tubes, and then outwardly into the casing/sand screen annulus beneath the sand bridge. When flowing through the shunt tubes, the packing sand/gel slurry may pass through one or more connections comprising jumper tubes coupled to one or more shunt tubes using the couplings, coupling members, and/or retaining rings described herein. Once the gravel pack has been formed as desired, a fluid may be allowed to flow through the gravel pack, through the slots in the outer body member, through the filter media, and into the throughbore of the wellbore tubular where it may be produced to the surface.

[00116] At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example,

whenever a numerical range with a lower limit, R_l, and an upper limit, R_u, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R=Ri+k*(R_u-Ri)$, wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ..., 50 percent, 51 percent, 52 percent, ..., 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention.

CLAIMS

What is claimed is:

1. A shunt tube assembly comprising:
   a plurality of shunt tubes;
   a jumper tube; and
   a coupling member configured to provide fluid communication between the jumper tube and the plurality of shunt tubes.
2. The shunt tube assembly of claim 1, wherein the coupling member comprises a first end and a second end, wherein the coupling member is configured to provide a sealing engagement between the coupling member and the jumper tube at the first end, and wherein the coupling member is configured to provide a sealing engagement between the coupling member and the plurality of jumper tubes at the second end.
3. The shunt tube assembly of claim 1, wherein the coupling member comprises at least one chamber, wherein the chamber is in fluid communication with the jumper tube and the plurality of shunt tubes.
4. The shunt tube assembly of claim 1, wherein the plurality of shunt tubes comprises a transport tube.
5. The shunt tube assembly of claim 4, wherein the plurality of shunt tubes comprises a packing tube.
6. The shunt tube assembly of claim 1, further comprising a second shunt tube coupled to the jumper tube, wherein the second shunt tube is in fluid communication with the plurality of shunt tubes through the jumper tube and the coupling member.
7. The shunt tube assembly of claim 1, wherein the plurality of shunt tubes comprises a first cross-sectional shape, and wherein the jumper tubes comprise a second cross-sectional shape.
8. The shunt tube assembly of claim 7, wherein the coupling member is further configured to sealingly engage the first cross-sectional shape and the second cross-sectional shape.
9. The shunt tube assembly of claim 1, wherein the coupling member comprises an alignment ring.
10. A coupling member for use with a shunt tube assembly comprising:
    a body member comprising a first side and a second side, wherein the body member is

configured to be disposed about a wellbore tubular;

a first opening disposed through the first side, wherein the first opening is configured to engage a shunt tube; and

a second opening disposed through the second side, wherein the second opening is configured to engage a jumper tube, wherein the first opening is in fluid communication with the second opening.

11. The coupling member of claim 10, further comprising a chamber disposed within the body member, wherein the chamber is in fluid communication with the first opening and the second opening.

12. The coupling member of claim 11, further comprising a third opening disposed through the first side, wherein the third opening is configured to engage a second shunt tube.

13. The coupling member of claim 12, wherein the third opening is in fluid communication with the chamber.

14. The coupling member of claim 12, further comprising a divider disposed within the chamber, wherein the divider is configured to separate the chamber into a first portion and a second portion, and wherein the first portion is in fluid communication with the first opening and the second opening, and wherein the second portion is in fluid communication with the third opening.

15. The coupling member of claim 10, wherein the body member is further configured to retain the shunt tube in position relative to the wellbore tubular.

16. A coupling member for use with a shunt tube assembly comprising:

a first body member, wherein the first body member is configured to be rotatably disposed about a wellbore tubular, and wherein the first body member comprises a first opening configured to receive a jumper tube;

a second body member, wherein the second body member is configured to be disposed about a wellbore tubular, and wherein the second body member comprises one or more second openings configured to receive one or more shunt tubes; and

a chamber defined between the first body member and the second body member, wherein the first opening is in fluid communication with the one or more second openings through the chamber.

17. The coupling member of claim 16, wherein the second body member is configured to be rotatably disposed about the wellbore tubular.

18. The coupling member of claim 16, further comprising a cover sealingly engaged with the first body member and the second body member, wherein the chamber is further defined by the cover.

19. The coupling member of claim 16, wherein the first body member sealingly engages the second body member.

20. The coupling member of claim 16, wherein the one or more shunt tubes comprise a transport tube and a packing tube.

21. The coupling member of claim 16, wherein the first opening is axially misaligned relative to the one or more second openings.

22. The coupling member of claim 16, wherein the first body member is configured to be axially translatable about the wellbore tubular.

23. A method of forming a shunt tube coupling comprising:
rotating a first ring about a wellbore tubular;
engaging a jumper tube with the first ring;
rotating a second ring about the wellbore tubular;
engaging one or more shunt tubes with the second ring; and
forming a sealing engagement between the first ring and the second ring.

24. The method of claim 23, wherein forming the sealing engagement comprises forming a chamber between the first ring and the second ring.

25. The method of claim 23, wherein forming the sealing engagement comprises: engaging a cover with the first ring and the second ring.

26. The method of claim 23, wherein the jumper tube and the one or more shunt tubes are radially misaligned.

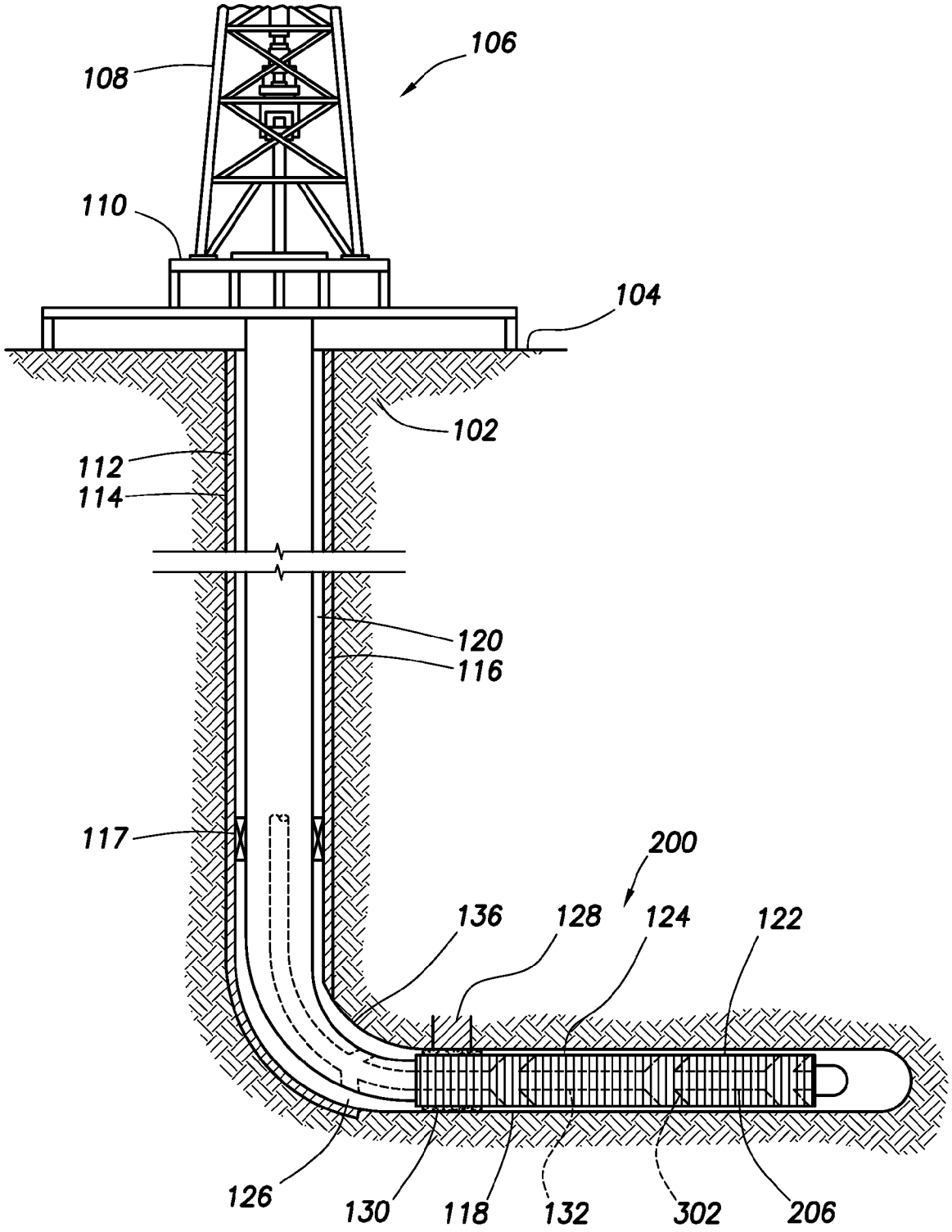
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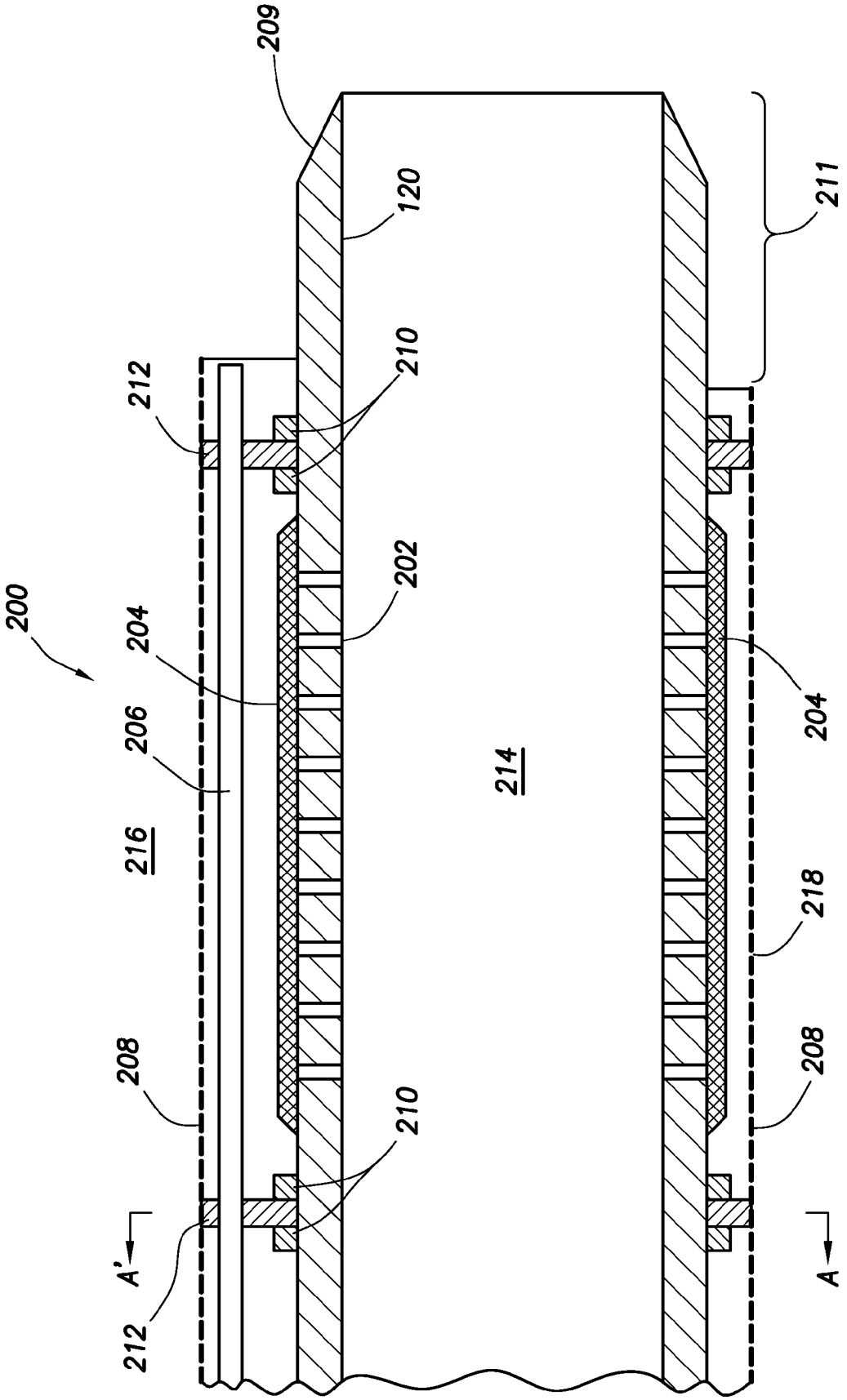
FIG. 1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A'
A
204

FIG.2

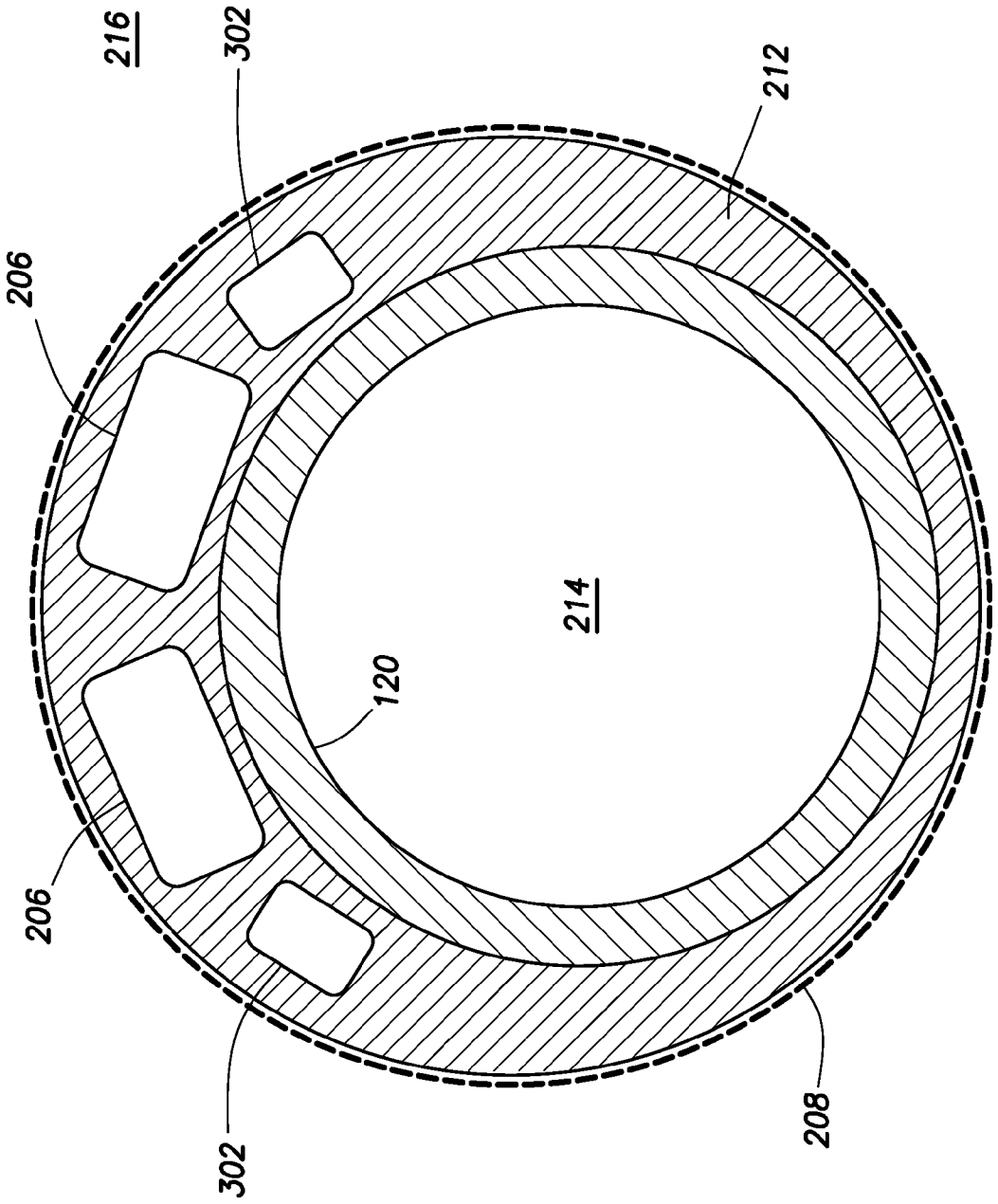


FIG.3

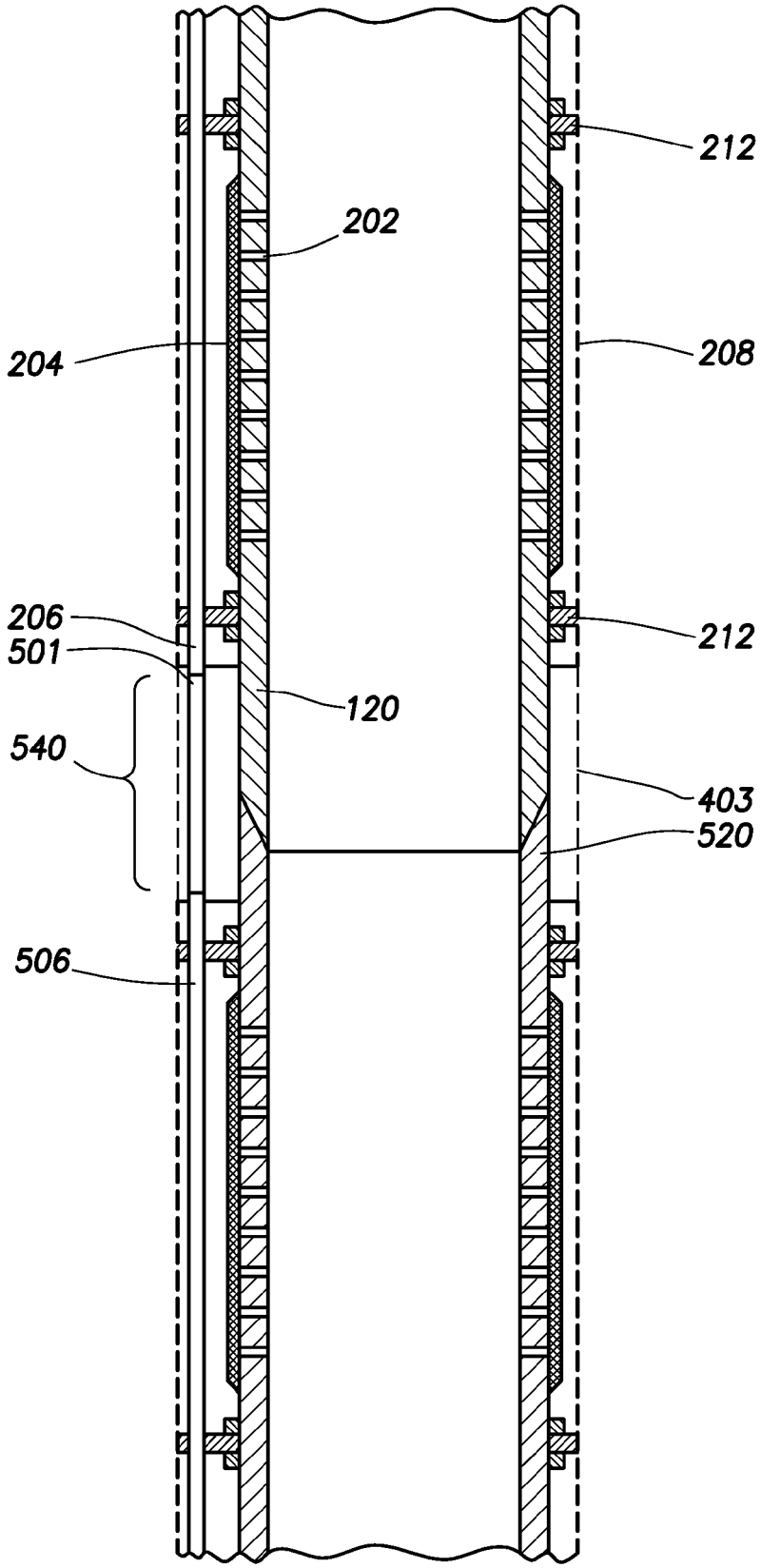
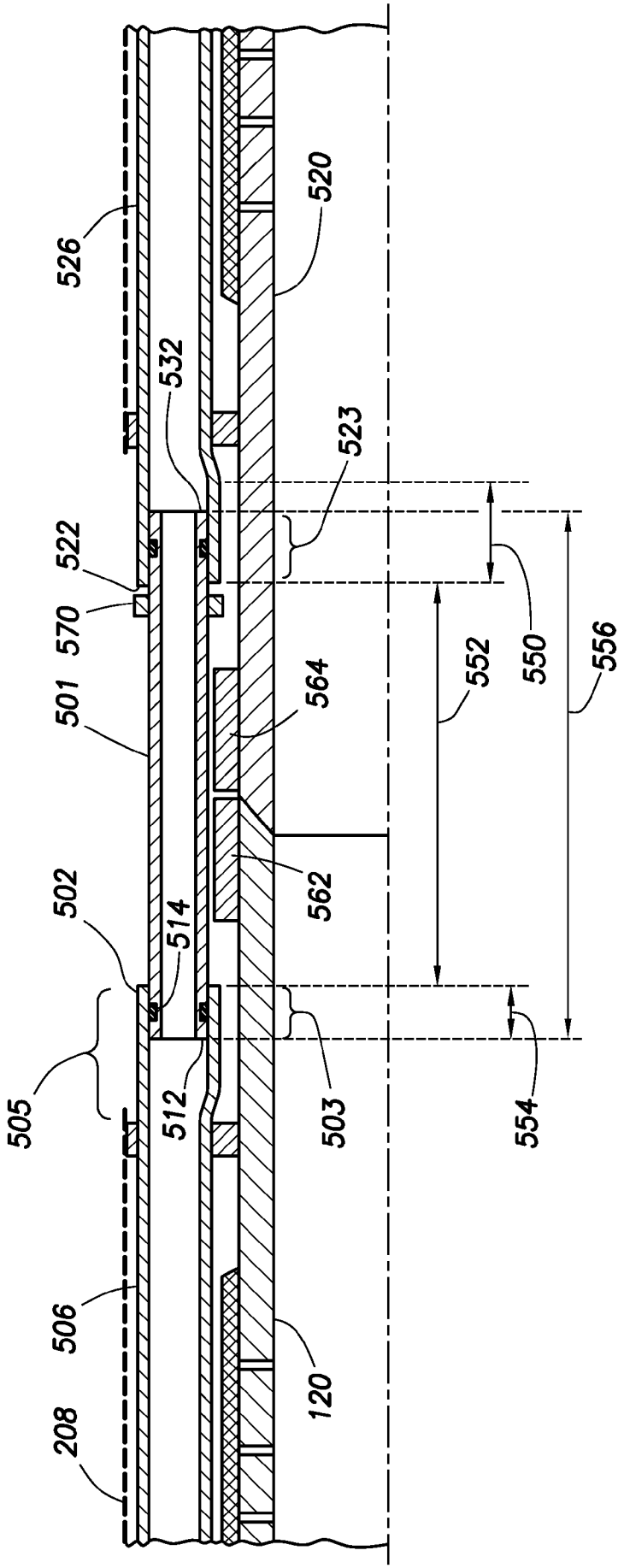


FIG.4


526
520
532
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564
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556
502
514
562
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512
503
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120
208

FIG.5

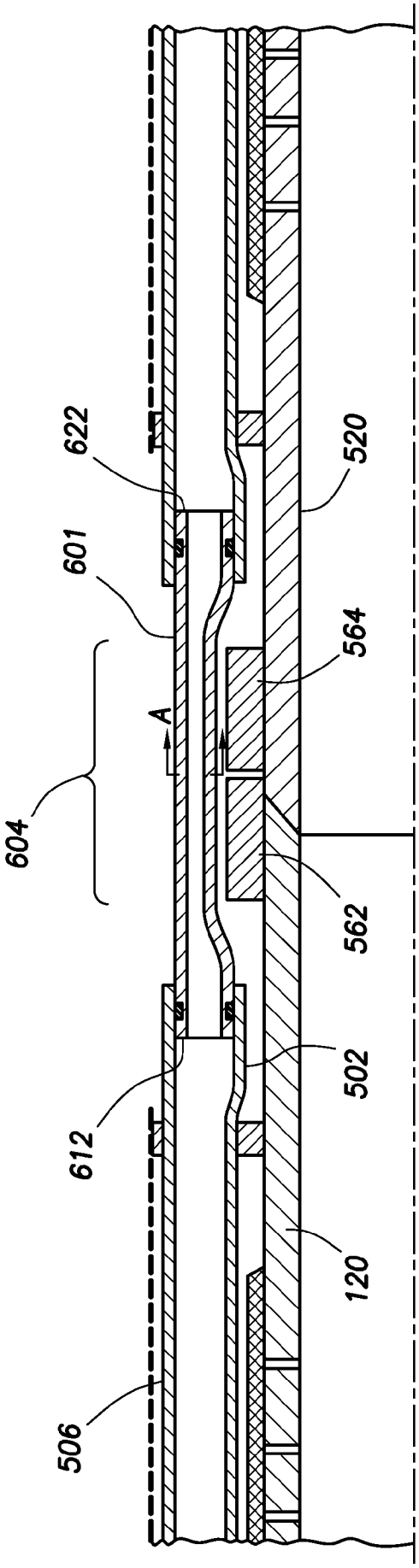


FIG.6A

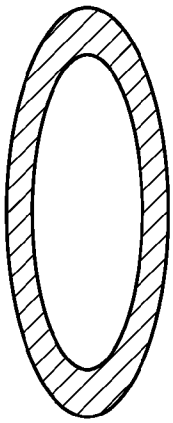


FIG.6D

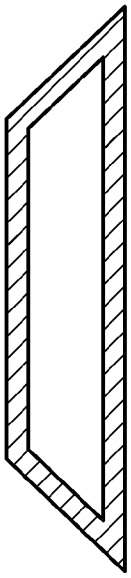


FIG.6E

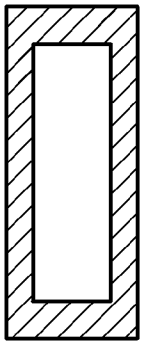


FIG.6B

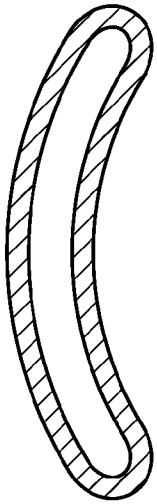


FIG.6C

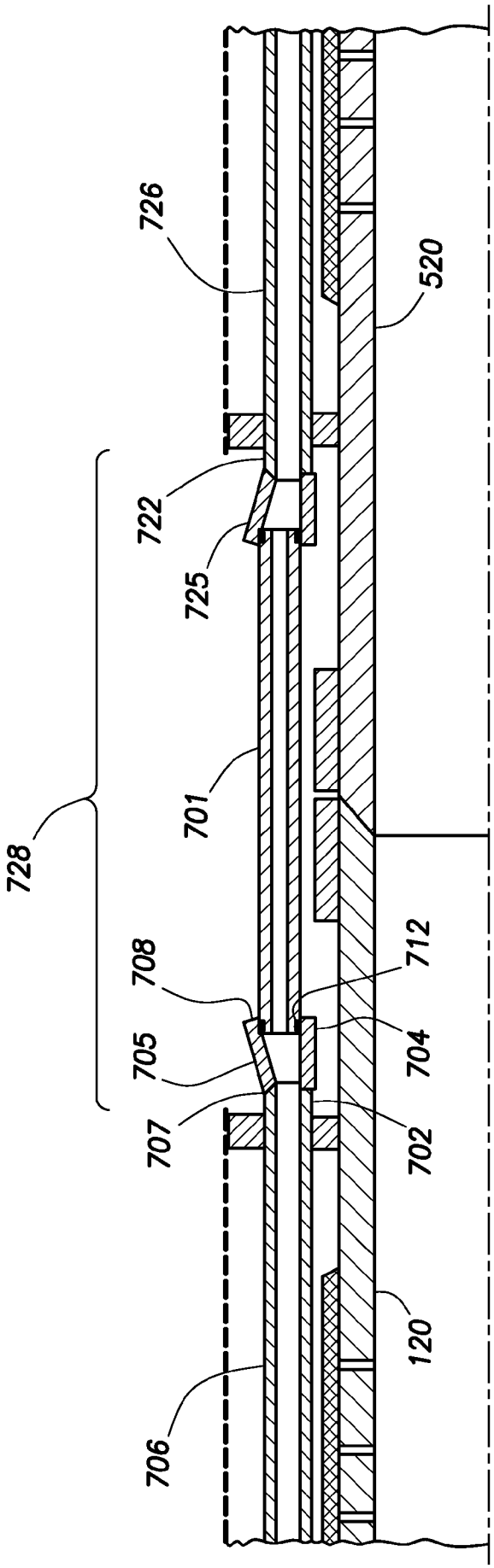


FIG.7A

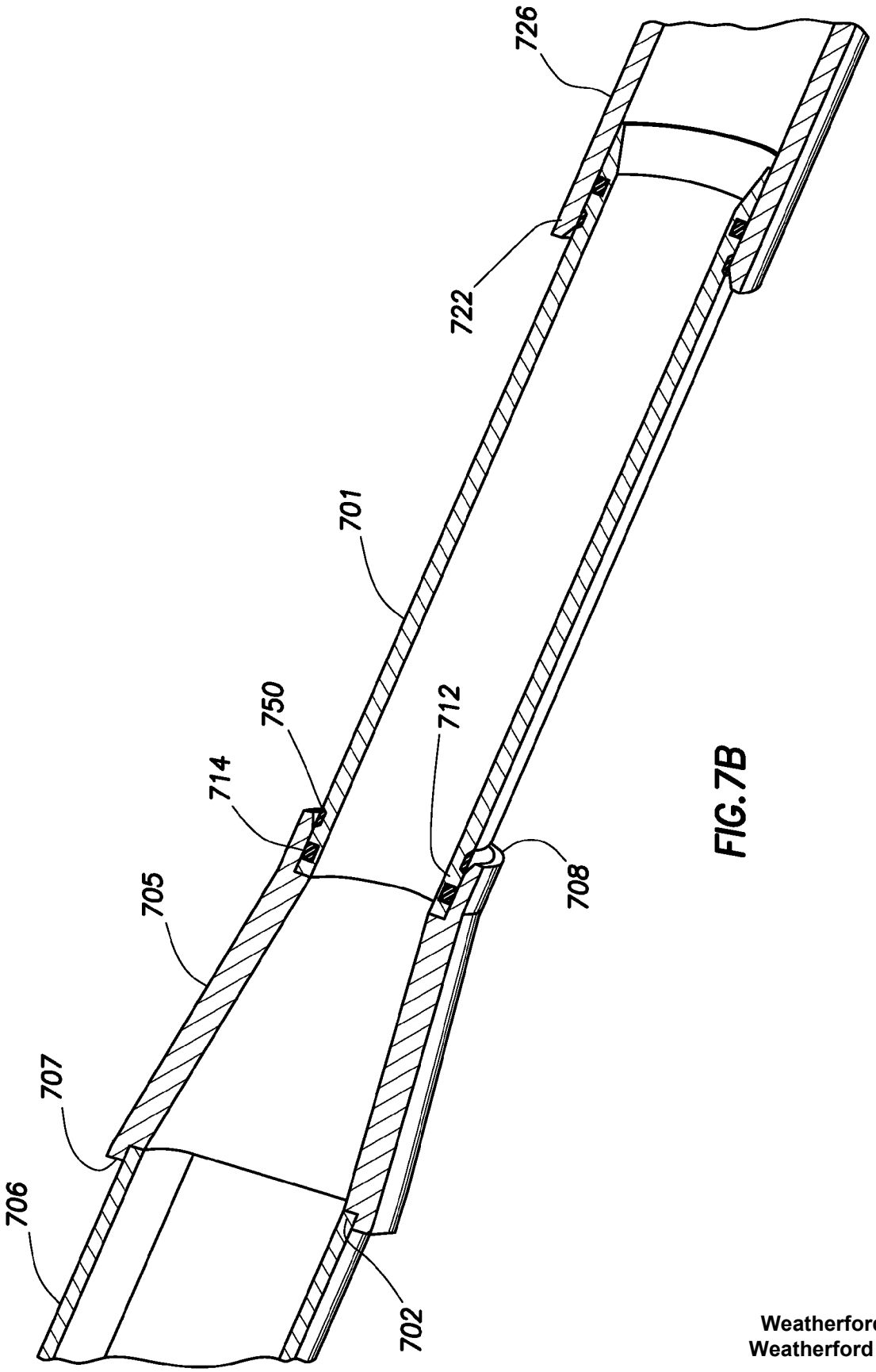
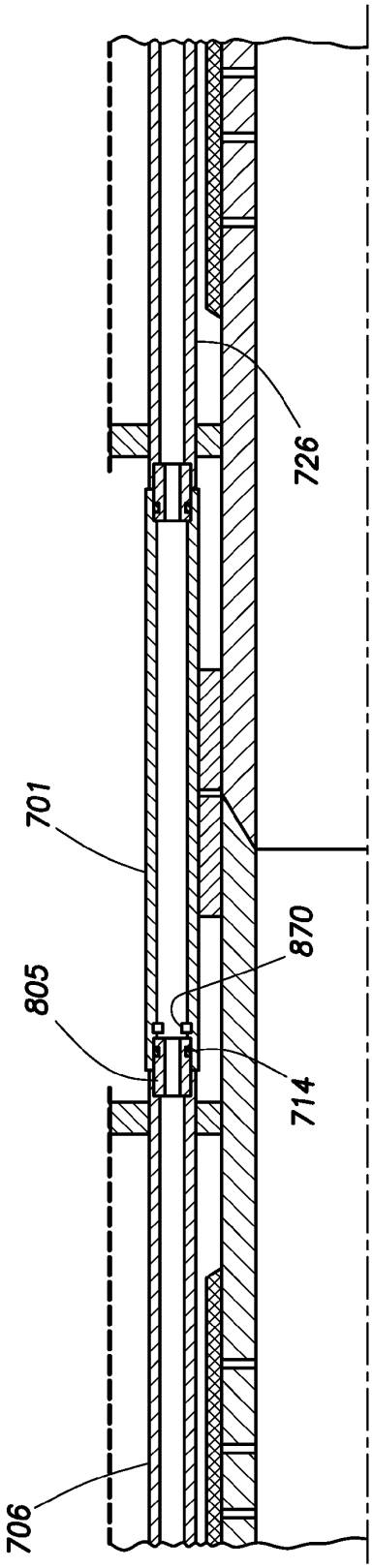


FIG.7B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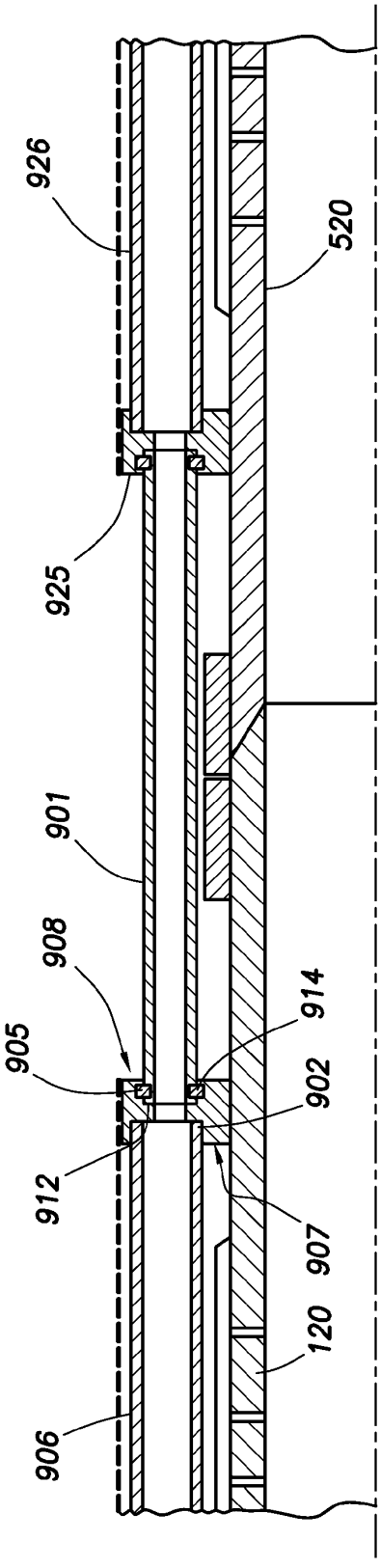
706

FIG.8


926
520
925
901
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914
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912
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120
906

FIG.9

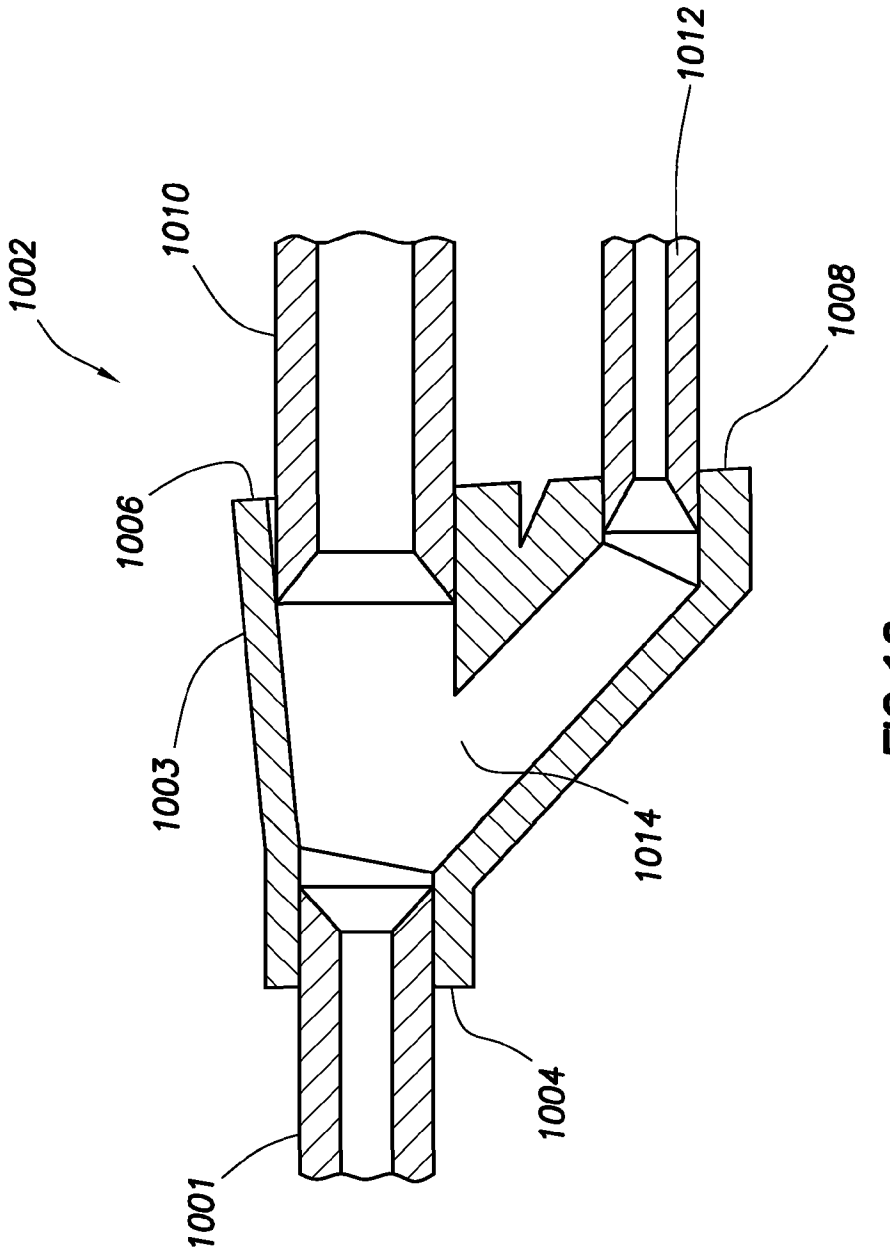

FIG. 10

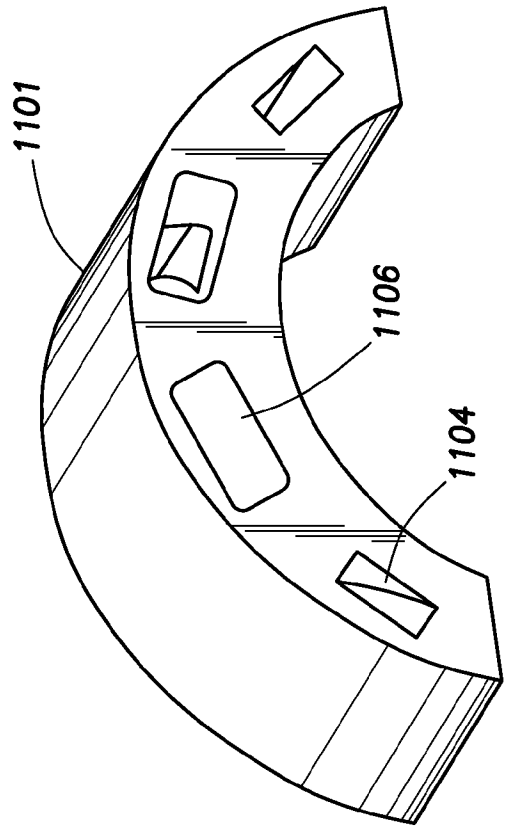

FIG.11A

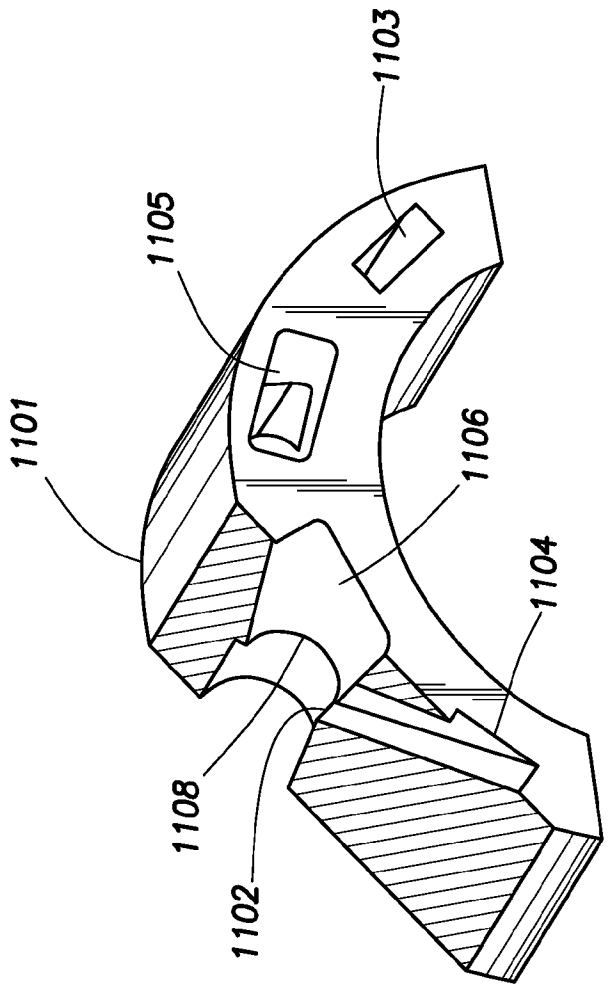

FIG.11B

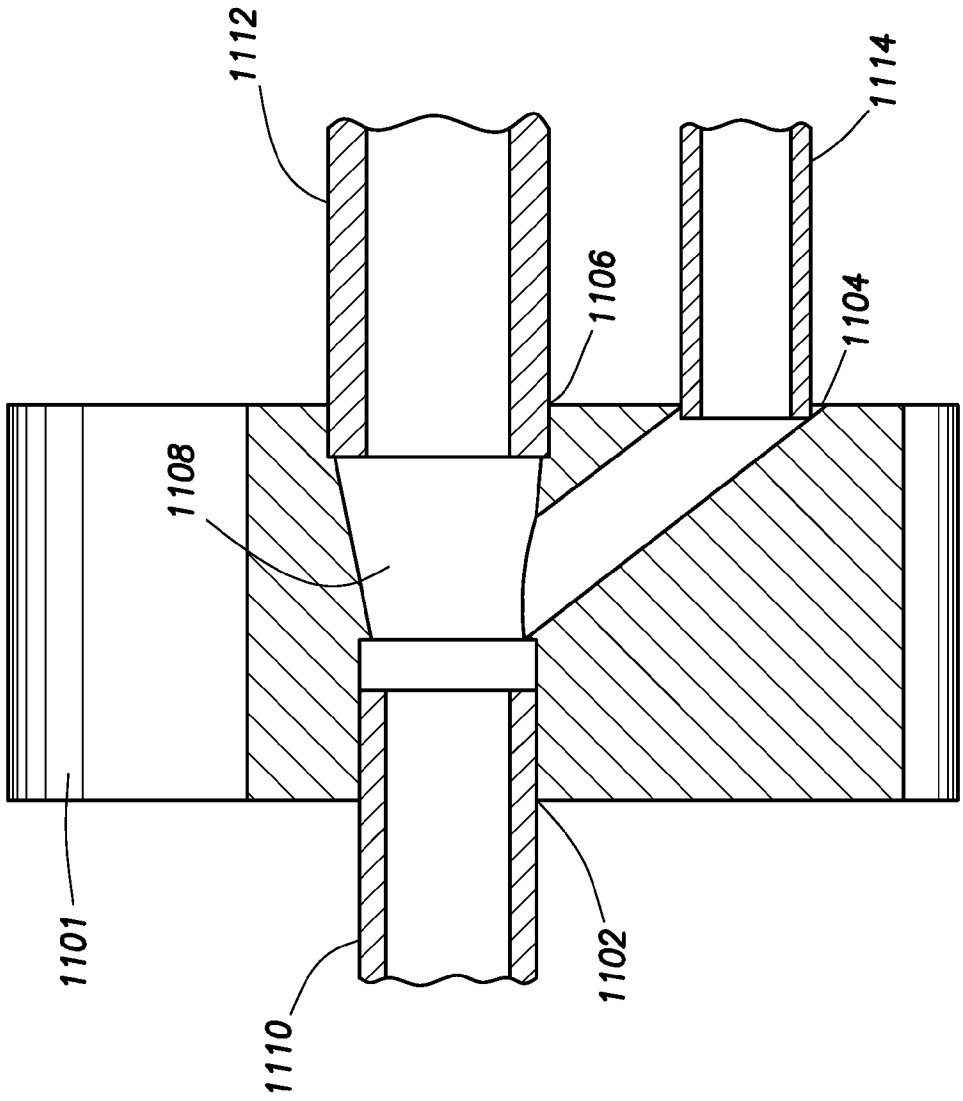

FIG.11C

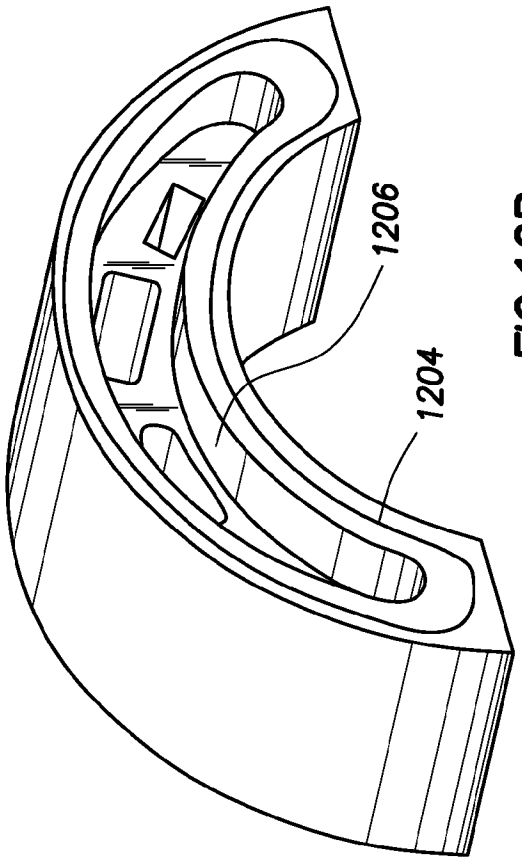

FIG.12B

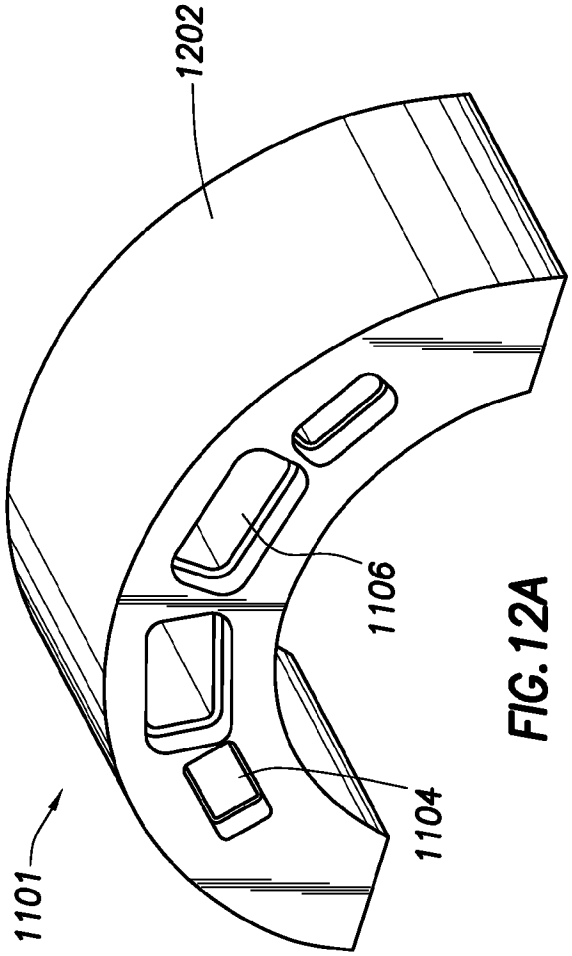

FIG.12A

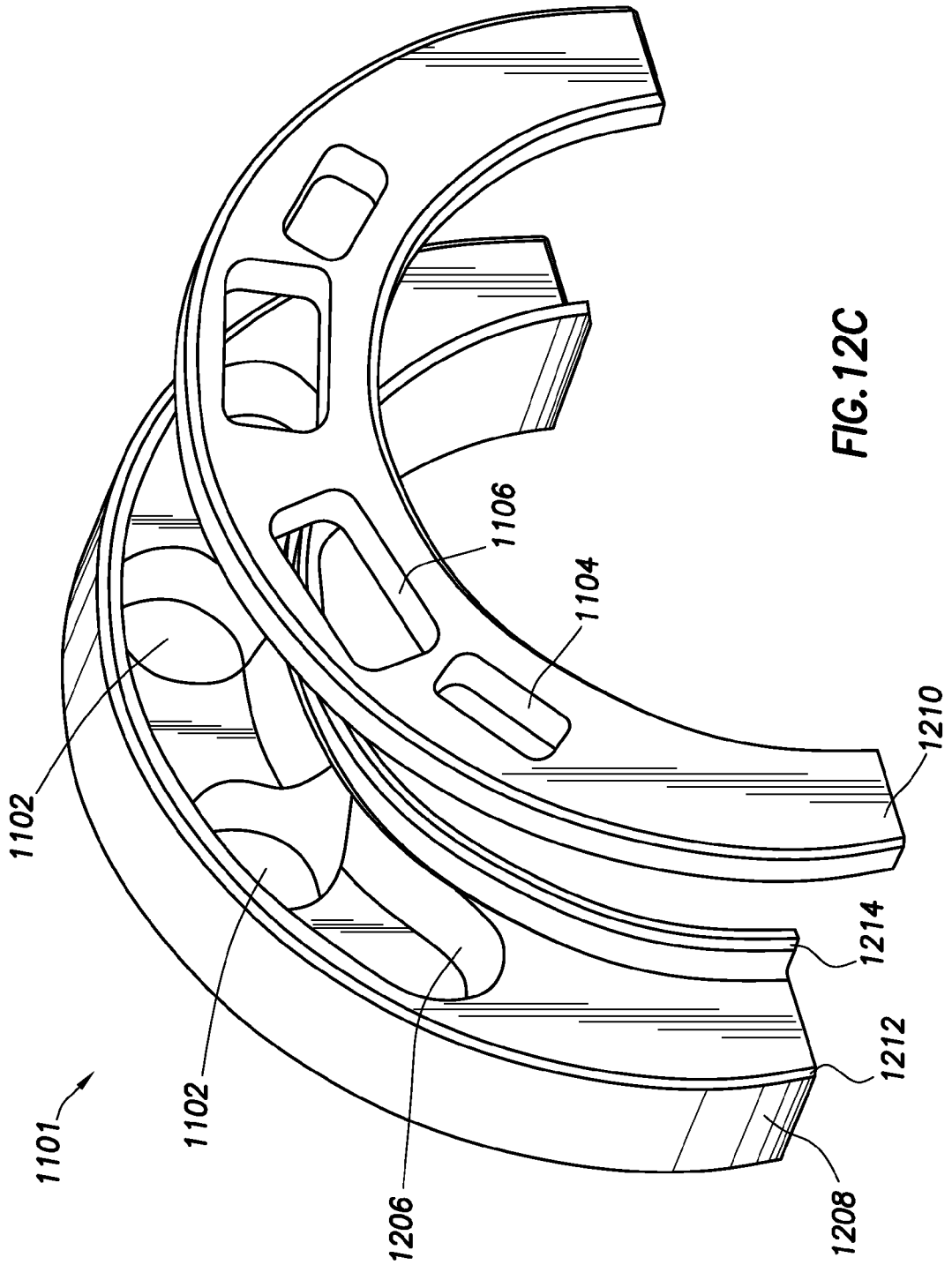

FIG.12C

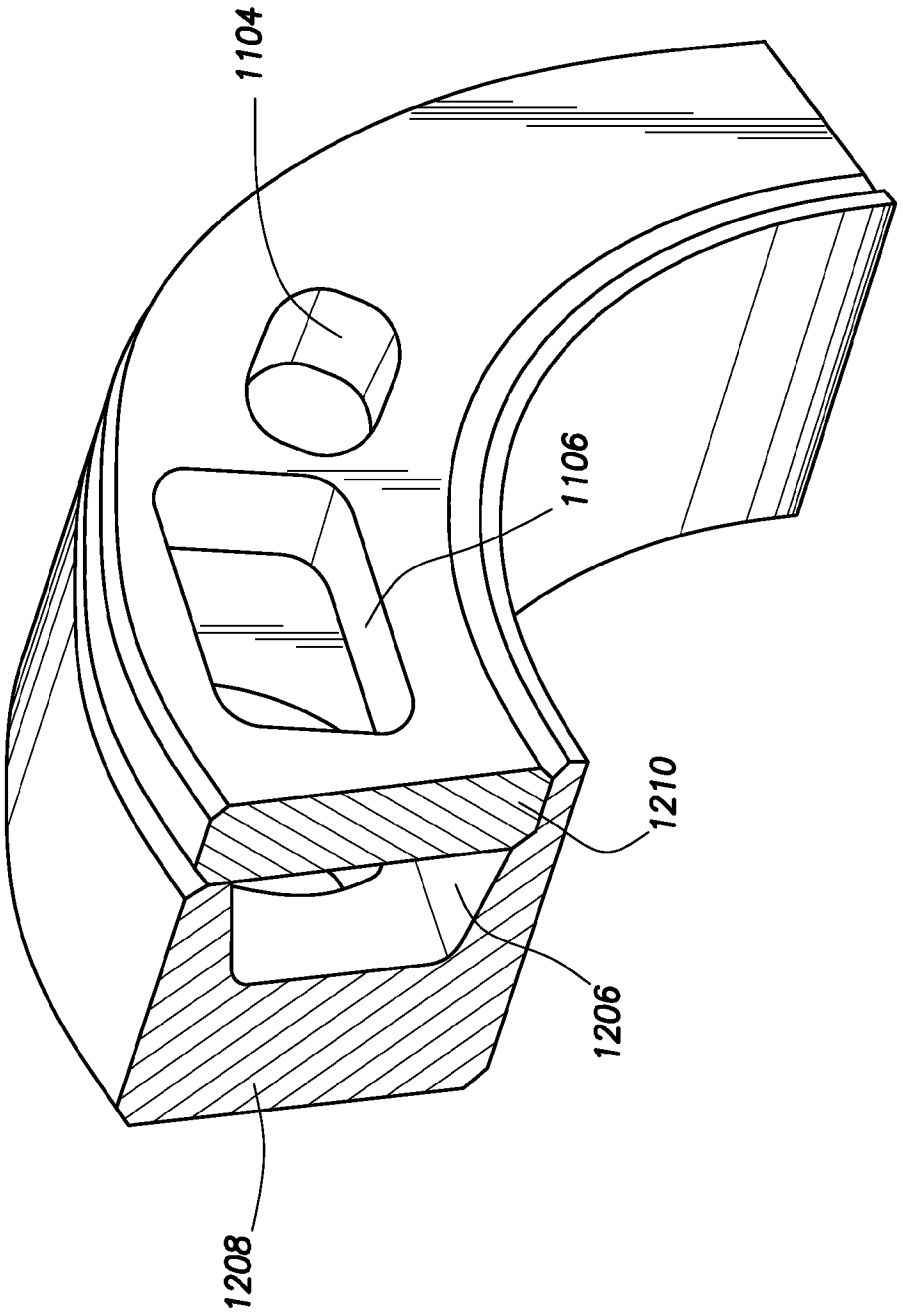

FIG. 12D

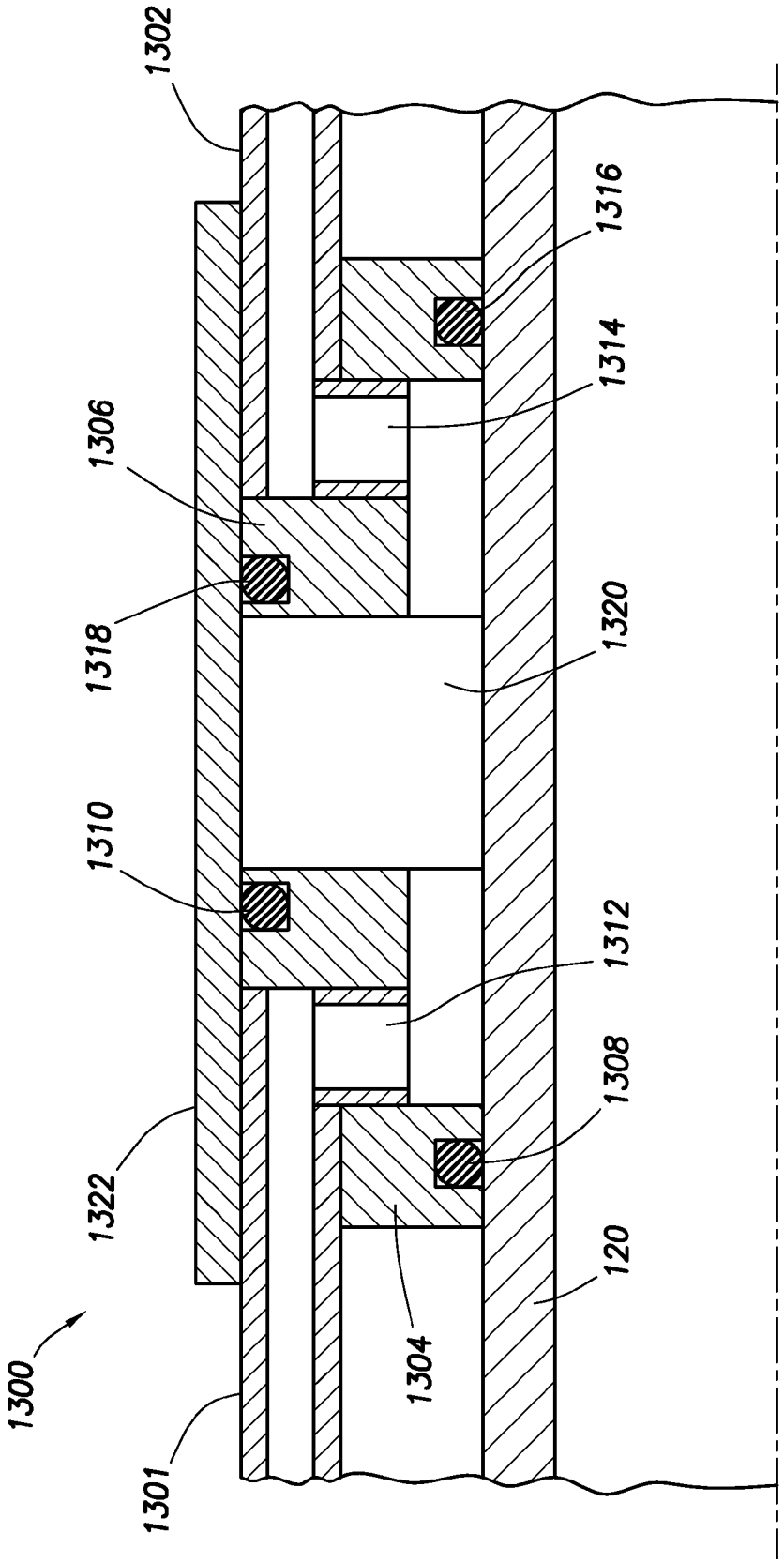
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FIG.13

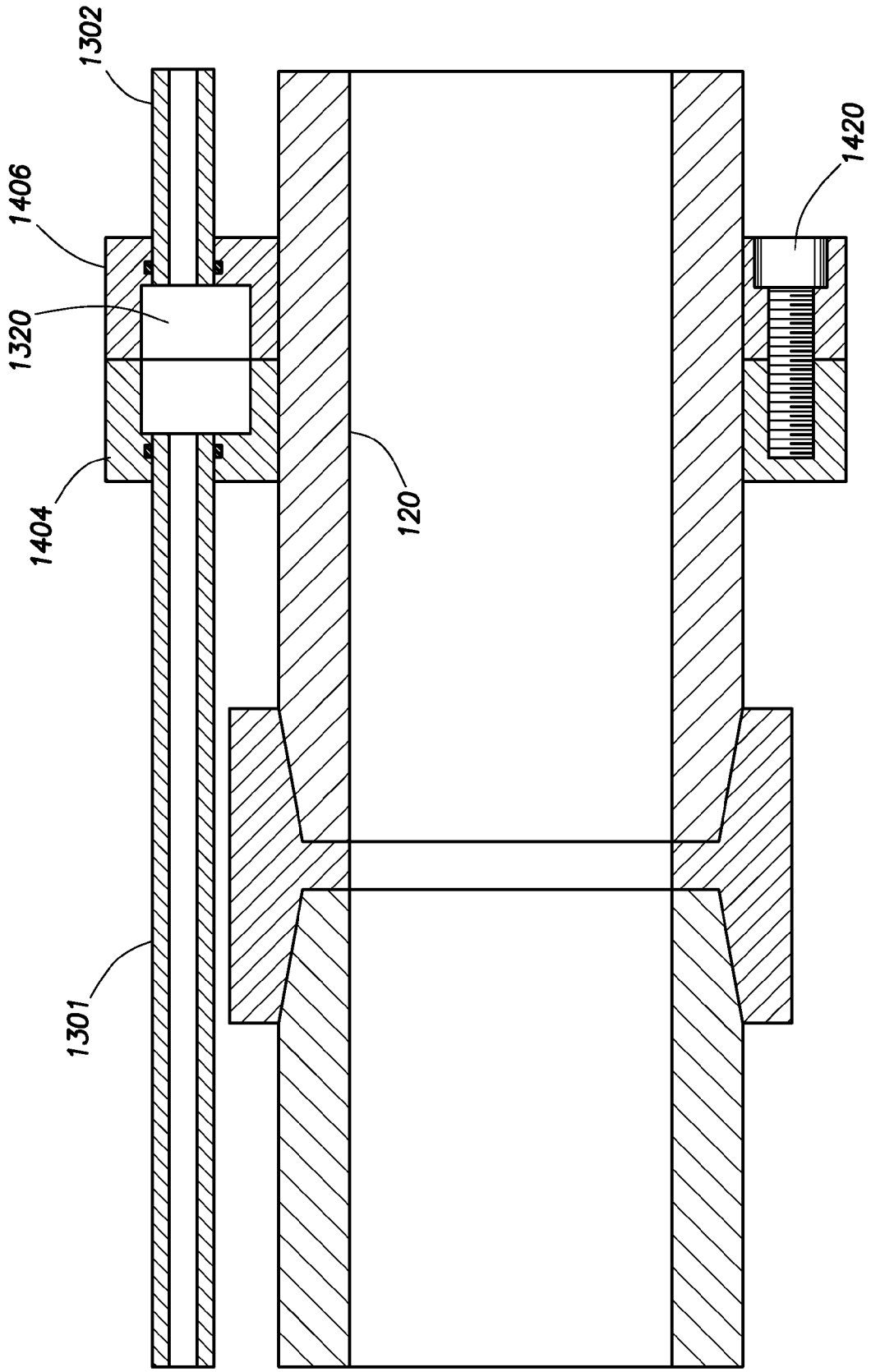

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/041968

A. CLASSIFICATION OF SUBJECT MATTER

E21B 33/124(2006.01)i, E21B 33/12(2006.01)1

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 33/124; E21B 43/04; F25B 41/00; E21B 43/08; B21D 53/04

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: shunt, jumper, tube, coupling member

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0032158 A1 (DALE, BRUCE A. et al.) 11 February 2010	23
Y	See paragraphs [0036],[0041],[0042], and figure 3B	1-11,15,24-26
A		12-14,16-22
Y	US 7363974 B2 (WANG, DAVID WEI et al.) 29 April 2008	1-11,15,24-26
A	See column 6 line 48-column 7 line 13, and figure 9.	12-14,16-23
A	US 2009-0159270 A1 (SETTERBERG, JR. JOHN RICHARD et al.) 25 June 2009	1-26
	See abstract, paragraphs [0018],[0020],[0021], and figures 1-3.	
A	JP 2001-133078 A (ISOBE, RENTARO) 18 May 2001	1-26
	See abstract, paragraphs [0022],[0024], and figures 5,6.	

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

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(use as many sheets as necessary)*		Application Number	Unassigned
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(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 10200 Bellaire Boulevard, Houston, TX 77072 (US).

(72) Inventors: **LEAST, Brandon, Thomas;** 3218 Jubilee Trail, Dallas, TX 75229 (US). **CUNNINGHAM, Gregory, Scott;** 532 Chasewood Drive, Grapevine, TX 7605 1 (US).

(74) Agent: **YOUST, Lawrence, R.;** Lawrence Youst PLLC, One Waterway Court, Suite 3b, The Woodlands, TX 77380 (US).

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(54) Title: GRAVEL PACKING APPARATUS HAVING A JUMPER TUBE PROTECTION ASSEMBLY

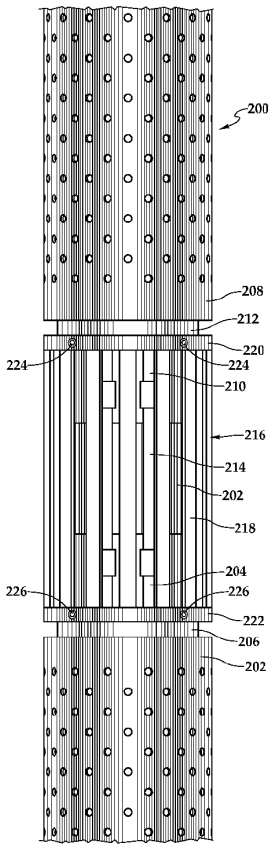

Fig.7D

(57) Abstract: A gravel packing assembly has first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly. The slurry delivery sub-assembly includes at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly. At least one jumper tube is coupled to and extends between the at least one transport tube of the first joint and the at least one transport tube of the second joint. A jumper tube protection assembly extends between the first and second joints and is positioned exteriorly about the at least one jumper tube.

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GRAVEL PACKING APPARATUS HAVING A JUMPER TUBE PROTECTION ASSEMBLY

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to equipment utilized in conjunction with operations performed in relation to subterranean wells and, in particular, to a gravel packing apparatus having a jumper tube protection assembly and a method for assembling the gravel packing apparatus on the rig floor.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background is described with reference to a sand control completion in a wellbore traversing an unconsolidated or loosely consolidated subterranean formation, as an example.

[0003] It is well known in the subterranean well drilling and completion art that particulate materials such as sand may be produced during the production of hydrocarbons from a well traversing an unconsolidated or loosely consolidated subterranean formation. Numerous problems may occur as a result of the production of such particulate. For example, the particulate causes abrasive wear to components within the well, such as the tubing, pumps and valves. In addition, the particulate may partially or fully clog the well creating the need for an expensive workover. Also, if the particulate matter is produced to the surface, it must be removed from the hydrocarbon fluids by processing equipment at the surface.

[0004] One method for preventing the production of such particulate material to the surface is gravel packing the well adjacent the unconsolidated or loosely consolidated production interval. In a typical gravel pack completion, a sand control screen is lowered into the wellbore on a work string to a position proximate the desired production interval. A fluid slurry including a liquid carrier and a particulate material known as gravel is then pumped down the work string and into the well annulus formed between the sand control screen and the perforated well casing or open hole production zone.

[0005] The liquid carrier either flows into the formation or returns to the surface by flowing through the sand control screen or both. In either case, the gravel is deposited around the sand control screen to form a gravel pack, which is highly permeable to the flow of hydrocarbon fluids but blocks the flow of the particulate carried in the hydrocarbon fluids.

As such, gravel packs can successfully prevent the problems associated with the production of particulate materials from the formation.

[0006] It has been found, however, that a complete gravel pack of the desired production interval is difficult to achieve particularly in long or inclined/horizontal production intervals. These incomplete packs are commonly a result of the liquid carrier entering a permeable portion of the production interval causing the gravel to form a sand bridge in the annulus. Thereafter, the sand bridge prevents the slurry from flowing to the remainder of the annulus which, in turn, prevents the placement of sufficient gravel in the remainder of the annulus.

[0007] Prior art devices and methods have been developed which attempt to overcome this sand bridge problem. For example, attempts have been made to use tubing positioned exteriorly along the length of the sand control screens to provide an alternate path for the fluid slurry around the sand bridge. It has been found, however, that this exterior tubing is susceptible to damage during installation in the wellbore, particularly in the region between adjacent joints of the sand control screens. Therefore, a need has arisen for an apparatus for gravel packing a production interval that overcomes the problems created by sand bridges. A need has also arisen for such an apparatus that is not susceptible to damage during installation.

SUMMARY OF THE INVENTION

[0008] The present invention disclosed herein is directed to a gravel packing apparatus having a jumper tube protection assembly. The gravel packing apparatus of the present invention is operable to overcome the problems created by sand bridges. In addition, the gravel packing apparatus of the present invention is not susceptible to damage during installation.

[0009] In one aspect, the present invention is directed to a gravel packing apparatus that includes a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly. The slurry delivery subassembly includes at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly. At least one jumper tube is coupled to and extends between the at least one transport tube of the first joint and the at least one transport tube of the second joint. A jumper tube protection assembly extends between the first and second joints and is positioned exteriorly of the at least one jumper tube.

[0010] In some embodiments, the jumper tube protection assembly is in the form of a cage assembly. In these embodiments, the cage assembly may include a plurality of circumferentially distributed plate members having gaps therebetween. Alternatively, in these embodiments, the cage assembly may include a plurality of circumferentially distributed ribs having a wrap wire positioned therearound. As another alternative, the cage assembly may have a plurality of circumferentially distributed ribs having a sheet member helically positioned therearound. In a further alternative, the cage assembly may have a plurality of circumferentially distributed bowsprings having gaps therebetween, wherein the bowsprings have an outer diameter greater than an outer diameter of the first and second joints. In certain embodiments, the jumper tube protection assembly may be formed from a plurality of circumferentially distributed plate members. In still other embodiments, the jumper tube protection assembly may be formed from a housing assembly having a plurality of circumferentially distributed blades, wherein the blades have an outer diameter greater than an outer diameter of the first and second joints.

[0011] In another aspect, the present invention is directed to a gravel packing apparatus that includes a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly. The slurry delivery subassembly includes at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly. At least one jumper tube is coupled to and extends between the at least one transport tube of the first joint and the at least one transport tube of the second joint. A jumper tube protection assembly extends between the first and second joints and is positioned exteriorly of the at least one jumper tube, wherein the jumper tube protection assembly has an outer diameter greater than an outer diameter of the first and second joints.

[0012] In one embodiment, the jumper tube protection assembly may include a cage assembly having a plurality of circumferentially distributed bowsprings having gaps therebetween, wherein the bowsprings have an outer diameter greater than an outer diameter of the first and second joints. In another embodiment, the jumper tube protection assembly may include a housing assembly having a plurality of circumferentially distributed blades, wherein the blades have an outer diameter greater than an outer diameter of the first and second joints. In certain embodiments, the jumper tube protection assembly may have a pair of hinged collars.

[0013] In a further aspect, the present invention is directed to a method for assembling a gravel packing apparatus. The method includes providing first and second joints each

including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly; threadably coupling the sand control screen assembly of the first joint to the sand control screen assembly of the second joint; coupling at least one jumper tube between the at least one transport tube of the first joint and the at least one transport tube of the second joint; and positioning a jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube.

[0014] The method may also include forming a cage assembly by circumferentially distributing a plurality of plate members having gaps therebetween exteriorly around the at least one jumper tube, circumferentially distributing a plurality of plate members exteriorly around the at least one jumper tube, bolting the plate members to the sand control screen assemblies of the first and second joints, forming a cage assembly by circumferentially distributing a plurality of bowsprings having gaps therebetween exteriorly around the at least one jumper tube, wherein the bowsprings have an outer diameter greater than an outer diameter of the first and second joints and/or positioning a housing assembly having a plurality of circumferentially distributed blades exteriorly around the at least one jumper tube, wherein the blades have an outer diameter greater than an outer diameter of the first and second joints.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0016] Figure 1 is a schematic illustration of an offshore platform operating a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0017] Figure 2 is a side view partially in cut away of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0018] Figure 3 is a cross sectional view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0019] Figure 4 is a cross sectional view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0020] Figure 5 is a cross sectional view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0021] Figure 6 is a cross sectional view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0022] Figures 7A-7D are schematic illustration of the process of coupling two joints of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0023] Figure 8 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0024] Figure 9 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0025] Figure 10 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0026] Figure 11 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention;

[0027] Figure 12 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention; and

[0028] Figure 13 is a side view of a gravel packing apparatus having a jumper tube protection assembly according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0029] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the present invention.

[0030] Referring initially to figure 1, a gravel packing apparatus positioned in an interval of a wellbore and operating from an offshore oil and gas platform is schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22 including blowout preventers 24.

Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as work string 30.

[0031] A wellbore 32 extends through the various earth strata including formation 14. A casing 34 is secured within wellbore 32 by cement 36. Work string 30 includes various tools including joints 38, 40, 42 that form the gravel packing apparatus of the present invention that is positioned in an interval of wellbore 32 adjacent to formation 14 between packers 44, 46. When it is desired to gravel pack annular region 48 surrounding joints 38, 40, 42, a fluid slurry including a liquid carrier and a particulate material such as sand, gravel or proppants is pumped down work string 30.

[0032] Some or all of the fluid slurry is typically injected directly into annular region 48 in a known manner, such as through a crossover tool (not pictured), which allows the slurry to travel from the interior of work string 30 to the exterior of work string 30. Once the fluid slurry is in annular region 48, a portion of the gravel in the fluid slurry is deposited in annular region 48. Some of the liquid carrier may enter formation 14 through perforation 50 while the remainder of the fluid carrier along with some of the gravel enters certain sections of joints 38, 40, 42 filling those sections with gravel. The sand control screens within joints 38, 40, 42 disallows further migration of the gravel but allows the liquid carrier to travel therethrough into work string 30 and up to the surface via annulus 52. If sand bridges form in annular region 48, some or all of the fluid slurry is injected or diverted into the slurry delivery subassemblies within joints 38, 40, 42 to bypass the sand bridge such that a complete pack can be achieved.

[0033] Even though figure 1 depicts the gravel packing apparatus of the present invention in a vertical wellbore, it should be understood by those skilled in the art that the gravel packing apparatus of the present invention is equally well suited for use in wellbores having other directional configurations including horizontal wellbores, deviated wellbores, slanted wells, lateral wells and the like. Accordingly, it should be understood by those skilled in the art that the use of directional terms such as above, below, upper, lower, upward, downward, uphole, downhole and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the well and the downhole direction being toward the toe of the well. Also, even though figure 1 depicts an offshore operation, it should be noted by one skilled in the art that the gravel packing apparatus of the present invention is equally well-suited for use in onshore operations.

Further, even though figure 1 depicts the gravel packing apparatus of the present invention as having a particular number of joints, it should be understood by those skilled in the art that a gravel packing apparatus of the present invention may have any number of joints both less than or greater than the number shown.

[0034] Referring next to figure 2, therein is depicted a cut away view of a gravel packing apparatus of the present invention that is generally designated 100. Apparatus 100 has an outer tubular or shroud 102 that includes a plurality of openings 104 that are substantially evenly distributed around and along the length of outer tubular 102, which allow the flow of production fluids therethrough. Disposed within outer tubular 102 is a sand control screen assembly 106. Sand control screen assembly 106 includes a base pipe 108 that has a plurality of openings 110 which allow the flow of production fiuids into the production tubing. The exact number, size and shape of openings 110 are not critical to the present invention, so long as sufficient area is provided for fluid production and the integrity of base pipe 108 is maintained.

[0035] Positioned around base pipe 108 is a filter medium depicted as a fluid-porous, particulate restricting wire mesh screen 112. Screen 112 is designed to allow fluid flow therethrough but prevent the flow of particulate materials of a predetermined size from passing therethrough. Screen 112 preferably has a plurality of layers of wire mesh including one or more drainage layers and one or more filter layers wherein the drainage layers that have a mesh size that is larger than the mesh size of the filter layers. For example, a drainage layer may preferably be positioned as the outermost layer and the innermost layer of wire mesh screen 112 with the filter layer or layers positioned therebetween. Positioned around screen 112 is a screen wrapper 114 that has a plurality of openings 116 which allow the flow of production fluids therethrough. The exact number, size and shape of openings 116 is not critical to the present invention, so long as sufficient area is provided for fluid production and the integrity of screen wrapper 114 is maintained. Typically, various sections of screen 112 and screen wrapper 114 are manufactured together as a unit by, for example, diffusion bonding or sintering the layers of wire mesh that form screen 112 together with screen wrapper 114, then rolling the unit into a tubular configuration. The two ends of the tubular unit are then seam welded together. Several tubular units of the screen and screen wrapper combination may be placed over each joint of base pipe 108 and secured thereto by welding or other suitable technique. It should be understood by those skilled in the art that even though figure 2 has described a particular filter medium, other types of filter media could

alternatively be used in conjunction with the apparatus of the present invention, including, but not limited to, a wire wrapped sand control screen.

[0036] Disposed between outer tubular 102 and sand control screen assembly 106 is a slurry delivery subassembly 118. In the illustrated embodiment, slurry delivery subassembly 118 includes a pair of transport tubes 120, 122, a pair of packing tubes 124, 126 and a manifold 128 that provides fluid communication between transport tubes 120, 122 and packing tubes 124, 126. As illustrated, transport tubes 120, 122 extend longitudinally past outer tubular 102 such that the transport tubes 120, 122 of one joint can be fluidically coupled to the transport tubes 120, 122 of another joint as explained in greater detail below. Packing tubes 124, 126 each include a plurality of nozzles, such as nozzle 130 of packing tube 124 and nozzle 132 of packing tube 126. In the event of sand bridge formation or as part of a planned gravel packing process, some or all of the fluid slurry is injected into the slurry delivery subassembly 118 of the uppermost joint. The fluid slurry is able to travel from one joint to the next via the transport tubes 120, 122. As the fluid slurry travels from joint to joint, portions of the fluid slurry enter packing tubes 124, 126 via manifold 128. From packing tubes 124, 126, the fluid slurry is able to enter the annular region surrounding gravel packing apparatus 100 by exiting slurry delivery subassembly 118 via nozzles 130, 132. In this manner, a complete gravel pack may be achieved even if sand bridges form in the annular region surrounding gravel packing apparatus 100.

[0037] In the illustrated embodiment, transport tubes 120, 122 extend through a ring assembly 134 that is preferably welded to base pipe 108. Likewise, outer tubular 102 may be welded to ring assembly 134. Ring assembly 134 may be eccentric in design such that it has suitable thickness to receive and support transport tubes 120, 122 on one side but may be thinner on the opposite side. Ring assembly 134 may be a single solid ring or may be formed from ring sections that substantially form a solid ring or may form a circumferentially segmented ring having gaps between the ring sections. Ring assembly 134 may include multiple components that receive and support transport tubes 120, 122 and may have notches, slots or openings that receive and support transport tubes 120, 122. It should be understood by those skilled in the art that even though transport tubes 120, 122 are depicted as extending through ring assembly 134, transport tubes may cooperate with a ring assembly in alternate ways, including, but not limited to, extending only partially into openings of a ring assembly or otherwise being fluidically coupled to one side of a ring assembly wherein the openings of the ring assembly become part of a fluid path for the fluid slurry. In such an embodiment, the jumper tubes that fluidically couple the transport tubes of one joint with the transport tubes of

the adjacent joint are similarly partially inserted into the openings of the ring assembly or otherwise fluidically coupled to the other side of the ring assembly.

[0038] As best seen in figure 3, sand control screen assembly 106 may be eccentrically positioned within outer tubular 102 to enable slurry delivery subassembly 118 to be positioned therebetween while maintaining a desired outer diameter of gravel packing apparatus 100. It should be understood by those skilled in the art, however, that even though figures 2 and 3 have described a particular slurry delivery subassembly, other slurry delivery subassembly having other configurations could alternatively be used in conjunction with the apparatus of the present invention. For example, as best seen in figure 4, a gravel packing apparatus 150 is depicted having a slurry delivery subassembly 152 including a single transport tube 154 and a pair of packing tubes 156, 158 each having a plurality of nozzles 160, 162 in an eccentric design. In another example, as best seen in figure 5, a gravel packing apparatus 170 is depicted having a slurry delivery subassembly 172 including a pair of slurry delivery tubes 174, 176 that serve as both transport tubes, as they extend from joint to joint, as well as packing tubes, as each has a plurality of nozzles 178, 180. Gravel packing apparatus 170 also has an eccentric design. In a further example, as best seen in figure 6, a gravel packing apparatus 190 is depicted having a slurry delivery subassembly 192 including three slurry delivery tubes 194, 196, 198 that serve as both transport tubes, as they extend from joint to joint, as well as packing tubes, as each has a plurality of nozzles 200, 202, 204. Unlike the previously described gravel packing apparatuses, gravel packing apparatus 190 has a concentric design wherein sand control screen assembly 106 is concentrically positioned within the outer tubular 102 with slurry delivery tubes 194, 196, 198 circumferentially distributed therebetween.

[0039] The operation of the assembling a gravel packing apparatus 200 of the present invention will now be described with reference to figures 7A-7D. A lower joint of gravel packing apparatus 200 is depicted as joint 202 having a pair of transport tubes 204 supported by a ring assembly 206. Joint 202 is supported by the well platform in, for example, a screen table assembly attached to the rotary table generally located on the well floor of the platform (not pictured). An upper joint of gravel packing apparatus 200 is depicted as joint 208 having a pair of transport tubes 210 supported by a ring assembly 212. Upper joint 208 has been maneuvered into position above joint 202 using the hoisting apparatus of the well platform (not pictured). Joints 202 and 208 are now threadably connected to one another to form coupled joint, as best seen in figure 7B, which may be supported by the hoisting apparatus of the well platform (not pictured). Once in this position, jumper tubes 214 may be coupled

between transport tubes 210 of joint 208 and transport tubes 204 of joint 202 which establishes fluid communication therebetween and preferably a fluid tight seal therebetween, as best seen in figure 7C.

[0040] After jumper tubes 214 have been connected, a jumper tube protection assembly 216 is installed, as best seen in figure 7D. In the illustrated embodiment, jumper tube protection assembly 216 extends between joints 202, 208 and is positioned to the exterior and around the coupled joint including jumper tubes 214. Jumper tube protection assembly 216 is depicted as a cage assembly having a plurality of circumferentially distributed plate members 218 having gaps therebetween that extend between a pair of oppositely disposed collars 220, 222. As illustrated, collar 220 is connected to ring assembly 212 by set screws 224. Likewise, collar 222 is connected to ring assembly 206 by set screws 226. Jumper tube protection assembly 216 may be prefabricated in sections such that two or more sections form the cage assembly with each section being independently connected to ring assemblies 206, 212. Alternatively, the cage assembly may have hinged collars 220, 222 that enable jumper tube protection assembly 216 to be installed in a clamshell type operation. As another alternative, the entire jumper tube protection assembly 216 may be constructed on the rig floor by installing each of the individual plate member 218 into the opposing collars 220, 222 as gravel packing apparatus 200 is being connected and deployed. As yet another alternative, the jumper tube protection assembly 216 may be prefabricated as part of the upper portion of joint 202 or as part of the lower portion of joint 208 then slid into place around the coupled joint including jumper tubes 214. As such, jumper tube protection assemblies 216 of the present invention provide protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore.

[0041] Referring now to figure 8, another embodiment of a jumper tube protection assembly 230 is depicted in place on gravel packing apparatus 200. Jumper tube protection assembly 230 is depicted as a cage assembly having a plurality of circumferentially distributed ribs 232 that extend between a pair of oppositely disposed collars 234, 236 having a screen wire 238 wrapped thereabout. As illustrated, collar 234 is connected to ring assembly 206 by set screws 240. Likewise, collar 236 is connected to ring assembly 212 by set screws 242. Jumper tube protection assembly 230 may be prefabricated in multiple sections that are independently connected to ring assemblies 206, 212, it may have hinged collars 234, 236 for clam shell type installation, it may be prefabricated as part of the upper portion of joint 202 or as part of the lower portion of joint 208 then slid into place around the coupled joint including jumper tubes 214 or installed in another suitable manner. As such,

jumper tube protection assemblies 230 of the present invention provide protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore.

[0042] Referring now to figure 9, another embodiment of a jumper tube protection assembly 250 is depicted in place on gravel packing apparatus 200. Jumper tube protection assembly 250 is depicted as a cage assembly having a plurality of circumferentially distributed ribs 252 that extend between a pair of oppositely disposed collars 254, 256 having a sheet metal wrapper 258 positioned therearound. As illustrated, collar 254 is connected to ring assembly 206 by set screws 260. Likewise, collar 256 is connected to ring assembly 212 by set screws 262. Jumper tube protection assembly 250 may be prefabricated in multiple sections that are independently connected to ring assemblies 206, 212, it may have hinged collars 254, 254 for clam shell type installation, it may be prefabricated as part of the upper portion of joint 202 or as part of the lower portion of joint 208 then slid into place around the coupled joint including jumper tubes 214, or installed in another suitable manner. Sheet metal wrapper 258 may be prefabricated on ribs 252 or installed on the rig floor as gravel packing apparatus 200 is being connected and deployed. As such, jumper tube protection assemblies 250 of the present invention provide protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore.

[0043] Referring now to figure 10, another embodiment of a jumper tube protection assembly 270 is depicted in place on gravel packing apparatus 200. Jumper tube protection assembly 270 is depicted as a plurality of circumferentially distributed plate members 272 that extend between ring assemblies 206, 212 and are attached thereto by set screws 274, 276. In the illustrated embodiment, each of the plate members has substantially the same construction and extends circumferentially approximately ninety degrees around the coupled joint. As such, jumper tube protection assemblies 270 of the present invention provide protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore.

[0044] Referring now to figure 11, another embodiment of a jumper tube protection assembly 280 is depicted in place on gravel packing apparatus 200. Jumper tube protection assembly 280 is depicted as a plurality of circumferentially distributed plate members including a pair of side plate members 282 and a central plate member 284 that extend between ring assemblies 206, 212 and are attached thereto by set screws 286, 288. In the illustrated embodiment, central plate member 284 extends circumferentially approximately sixty degrees around the coupled joint and is designed to cooperate with jumper tubes 214.

Side plate members 282 each extend circumferentially approximately one hundred and fifty degrees around the coupled joint. As such, jumper tube protection assemblies 280 of the present invention provide protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore.

[0045] Referring now to figure 12, another embodiment of a jumper tube protection assembly 300 is depicted in place on gravel packing apparatus 200. In the illustrated embodiment, jumper tube protection assembly 300 is depicted as a cage assembly having a plurality of circumferentially distributed bowsprings 302 having gaps therebetween that extend between a pair of oppositely disposed collars 304, 306. As illustrated, jumper tube protection assembly 300 is prefabricated in two sections that are bolted, clamped or otherwise secured together at tabs 308, 310. Importantly, bowsprings 302 have an outer diameter that is greater than the outer diameter of joints 202, 208 such that jumper tube protection assembly 300 not only provides protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore, but also, provides a centralization function to gravel packing apparatus 200.

[0046] Referring now to figure 13, another embodiment of a jumper tube protection assembly 320 is depicted in place on gravel packing apparatus 200. In the illustrated embodiment, jumper tube protection assembly 320 includes a housing 322 with a plurality of circumferentially distributed blades 324 radially extending therefrom. Housing 322 extends between a pair of oppositely disposed collars 326, 328. As illustrated, jumper tube protection assembly 320 is prefabricated in two sections that rotatably coupled together at hinges 330, 332 enabling installation in a clam shell manner. Thereafter, the two sections are bolted, clamped or otherwise secured together at tabs 334, 336. Blades 324 may be solid members or may be spring members. Importantly, blades 324 have an outer diameter that is greater than the outer diameter of joints 202, 208 such that jumper tube protection assembly 320 not only provides protection against damage to jumper tubes 214 during installation and deployment of gravel packing apparatus 200 into the wellbore, but also, provides a centralization function to gravel packing apparatus 200.

[0047] While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A gravel packing apparatus comprising:

first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly;

at least one jumper tube coupled to and extending between the at least one transport tube of the first joint and the at least one transport tube of the second joint; and

a jumper tube protection assembly extending between the first and second joints and positioned exteriorly of the at least one jumper tube.

2. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a cage assembly.

3. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a cage assembly having a plurality of circumferentially distributed plate members having gaps therebetween.

4. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a cage assembly having a plurality of circumferentially distributed ribs having a wrap wire positioned therearound.

5. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a cage assembly having a plurality of circumferentially distributed ribs having a sheet member helically positioned therearound.

6. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a plurality of circumferentially distributed plate members.

7. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a cage assembly having a plurality of circumferentially distributed bowsprings having gaps therebetween, the bowsprings having an outer diameter greater than an outer diameter of the first and second joints.

8. The apparatus as recited in claim 1 wherein the jumper tube protection assembly further comprises a housing assembly having a plurality of circumferentially distributed blades, the blades having an outer diameter greater than an outer diameter of the first and second joints.

9. The apparatus as recited in claim 1 wherein each joint further comprises an outer shroud positioned around the slurry delivery subassembly and the sand control screen assembly.

10. The apparatus as recited in claim 1 wherein the slurry delivery subassembly of each joint further comprises at least one packing tube having nozzles.

11. A gravel packing apparatus comprising:

first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly;

at least one jumper tube coupled to and extending between the at least one transport tube of the first joint and the at least one transport tube of the second joint; and

a jumper tube protection assembly extending between the first and second joints and positioned exteriorly of the at least one jumper tube, jumper tube protection assembly having an outer diameter greater than an outer diameter of the first and second joints.

12. The apparatus as recited in claim 11 wherein the jumper tube protection assembly further comprises a cage assembly having a plurality of circumferentially distributed bowsprings having gaps therebetween, the bowsprings having an outer diameter greater than an outer diameter of the first and second joints.

13. The apparatus as recited in claim 11 wherein the jumper tube protection assembly further comprises a housing assembly having a plurality of circumferentially distributed blades, the blades having an outer diameter greater than an outer diameter of the first and second joints.

14. The apparatus as recited in claim 11 wherein the jumper tube protection assembly further comprises a pair of hinged collars.

15. A method for assembling a gravel packing apparatus, the method comprising:

providing first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly;

threadably coupling the sand control screen assembly of the first joint to the sand control screen assembly of the second joint;

coupling at least one jumper tube between the at least one transport tube of the first joint and the at least one transport tube of the second joint; and

positioning a jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube.

16. The method as recited in claim 15 wherein positioning the jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube further comprises forming a cage assembly by circumferentially distributing a plurality of plate members having gaps therebetween exteriorly around the at least one jumper tube.

17. The method as recited in claim 15 wherein positioning the jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube further comprises circumferentially distributing a plurality of plate members exteriorly around the at least one jumper tube.

18. The method as recited in claim 17 wherein circumferentially distributing the plurality of plate members exteriorly around the at least one jumper tube further comprises bolting the plate members to the sand control screen assemblies of the first and second joints.

19. The method as recited in claim 15 wherein positioning the jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube further comprises forming a cage assembly by circumferentially distributing a plurality of bowsprings having gaps therebetween exteriorly around the at least one jumper tube, the bowsprings having an outer diameter greater than an outer diameter of the first and second joints.

20. The method as recited in claim 15 wherein positioning the jumper tube protection assembly exteriorly around adjacent end portions of the first and second joints and the at least one jumper tube further comprises positioning a housing assembly having a plurality of circumferentially distributed blades exteriorly around the at least one jumper tube, the blades having an outer diameter greater than an outer diameter of the first and second joints.

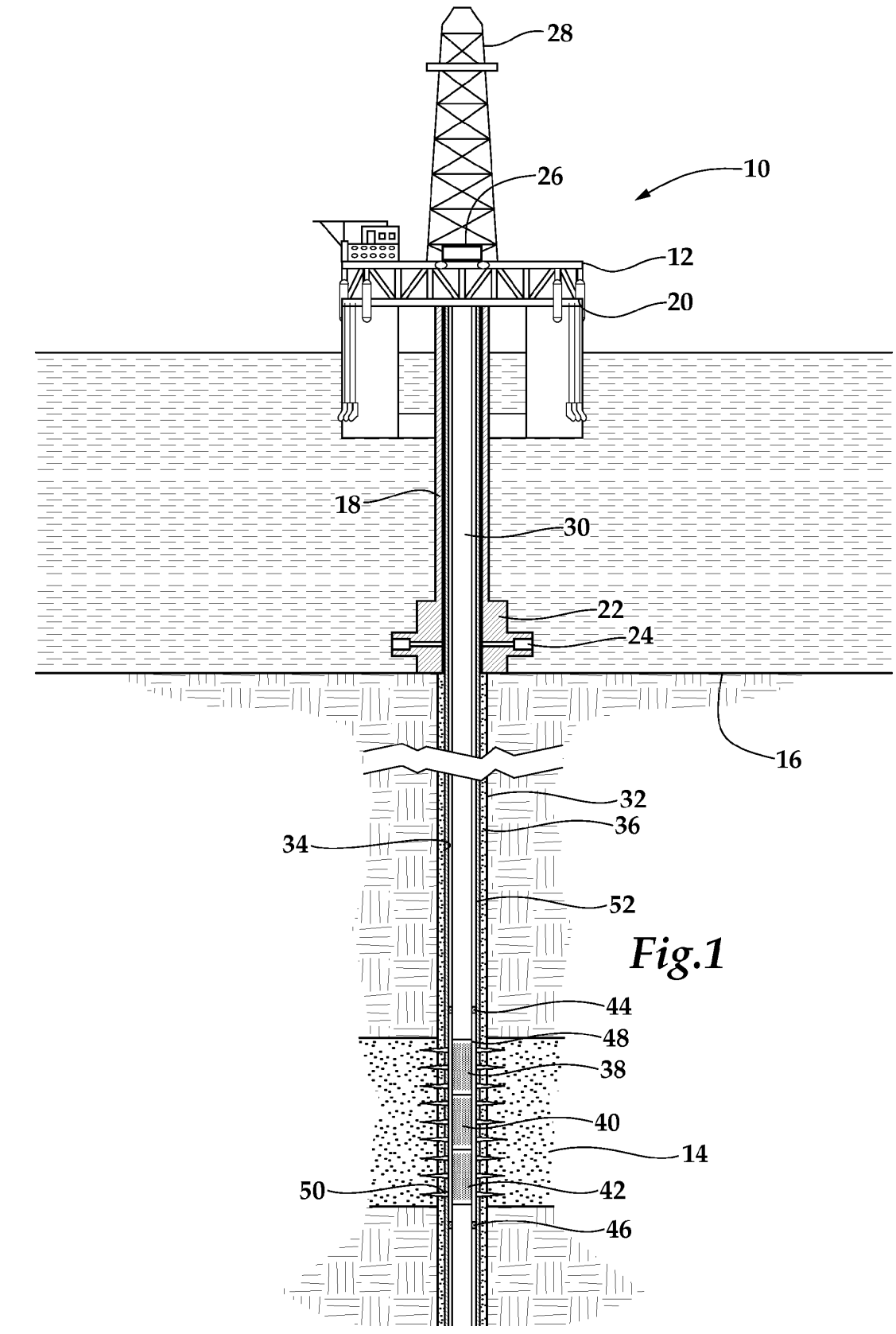

Fig.1

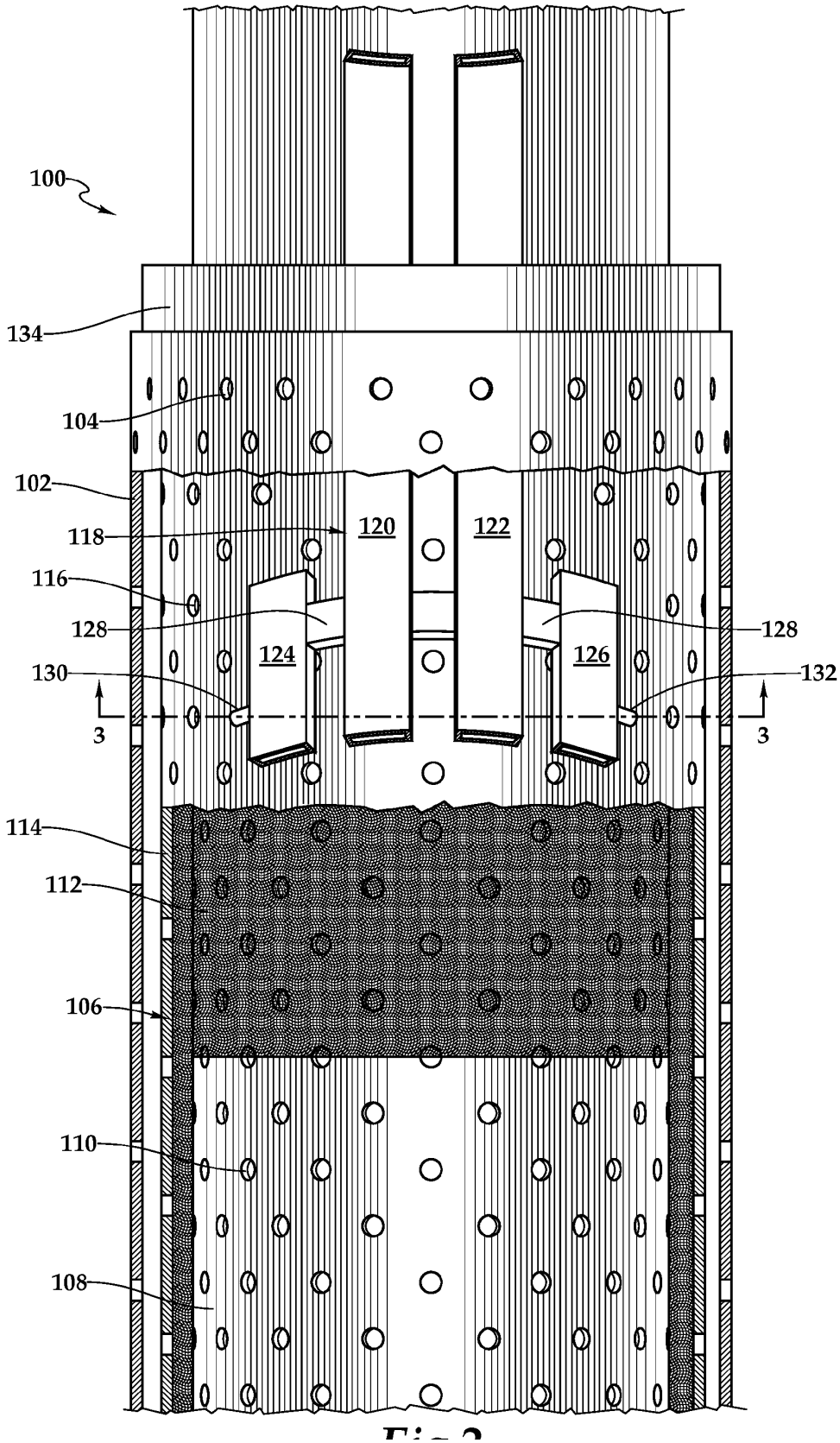
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Fig 2

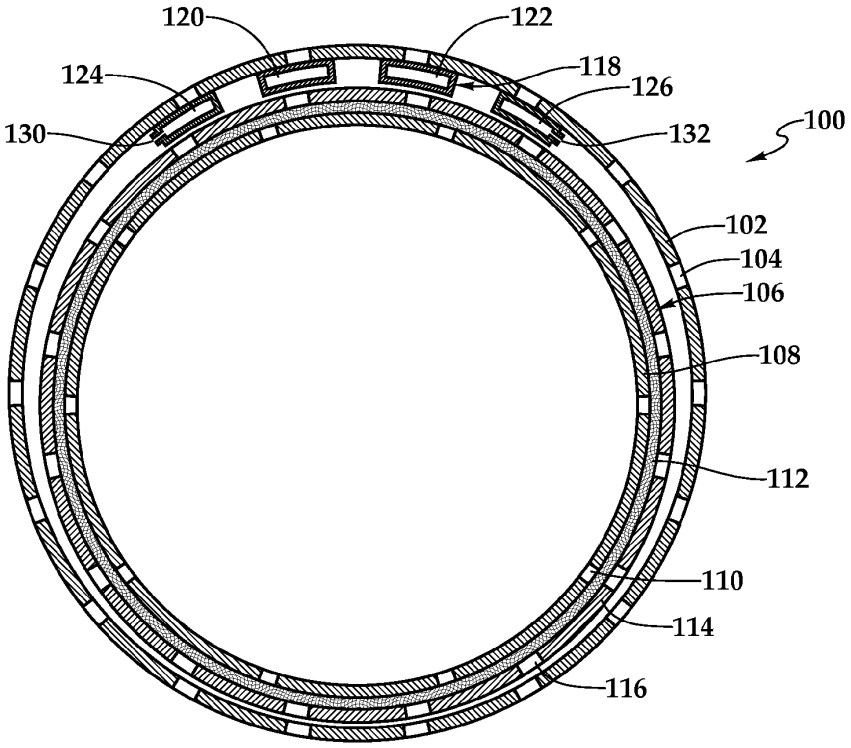
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Fig.3

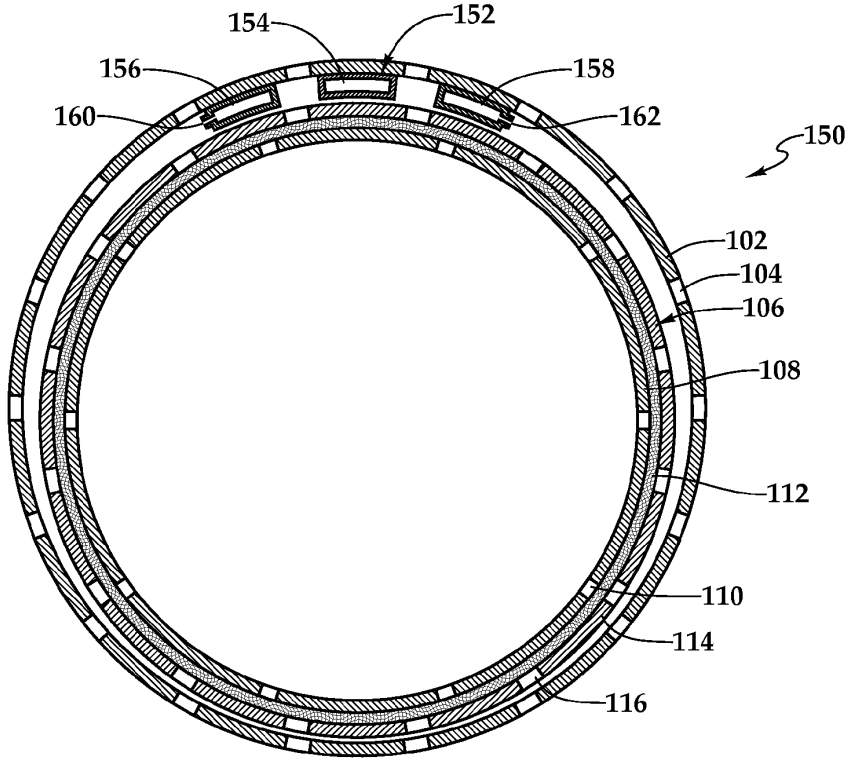
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Fig.4

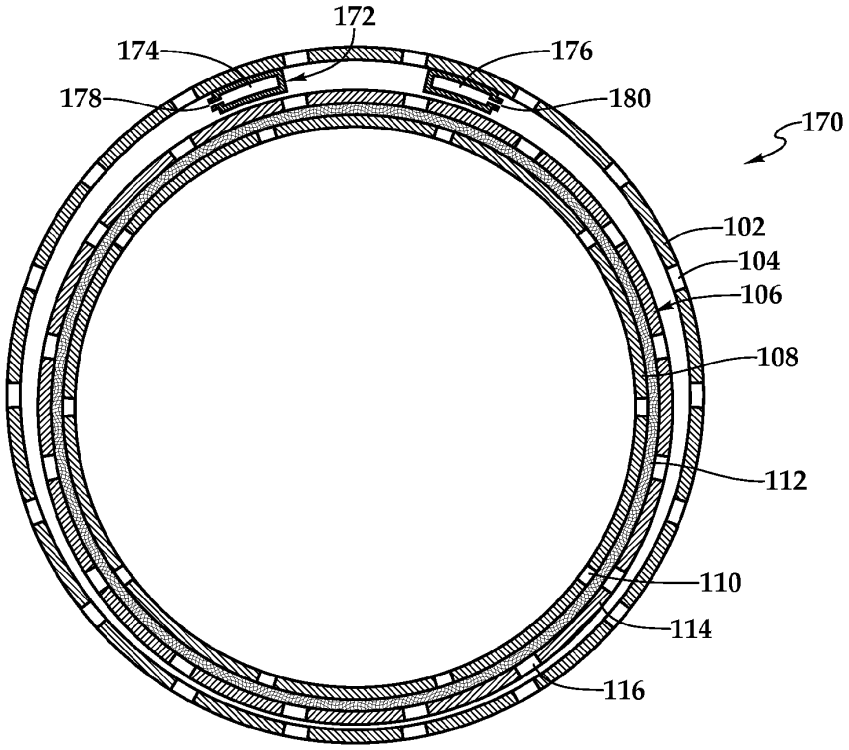
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Fig.5

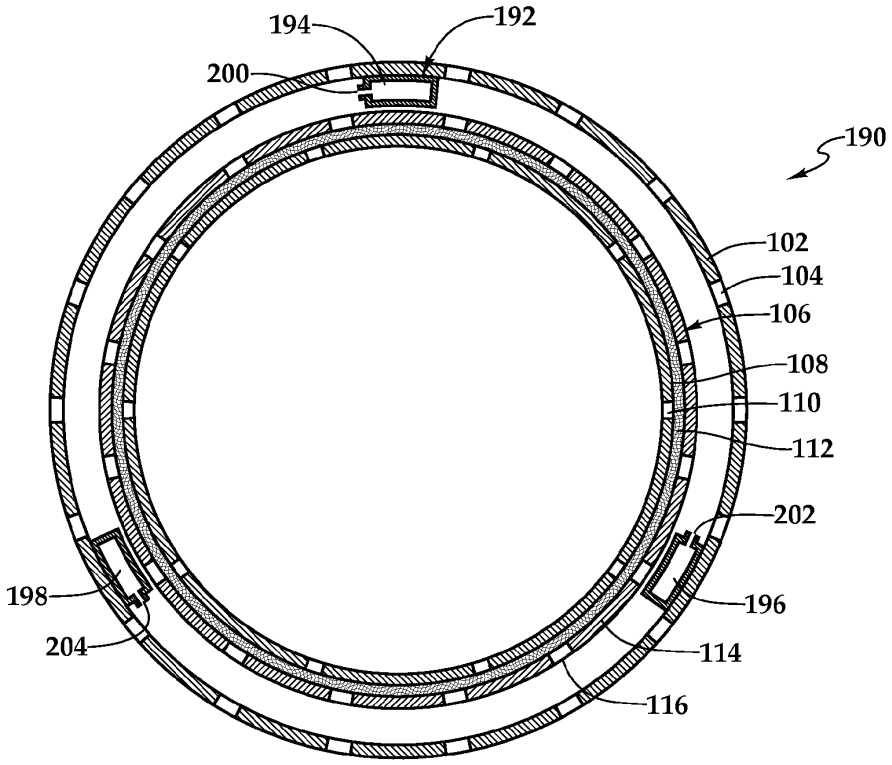
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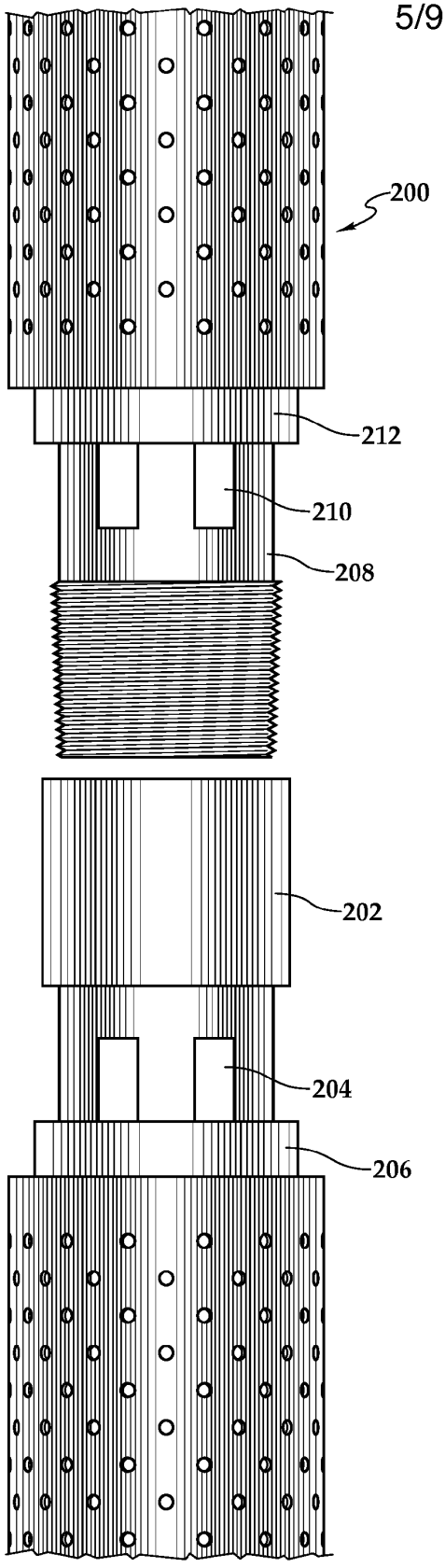
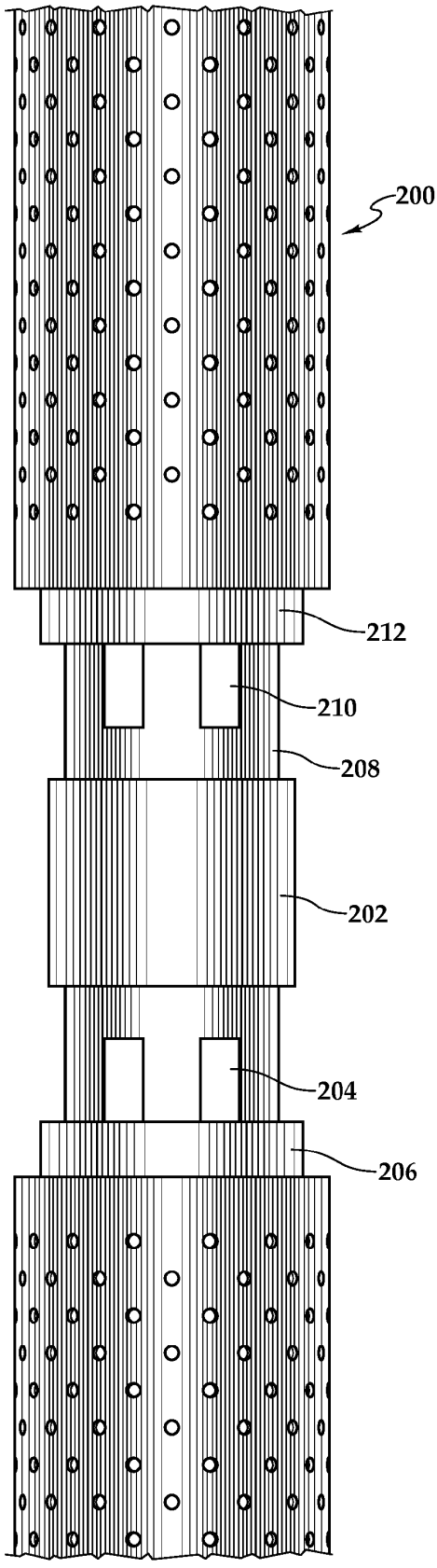
Fig.6





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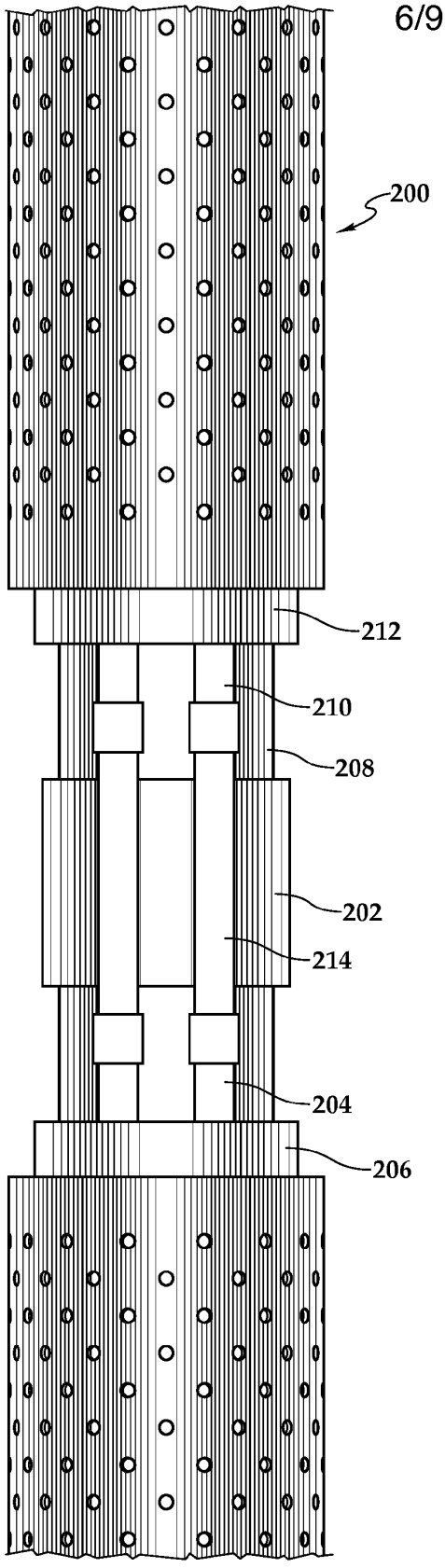

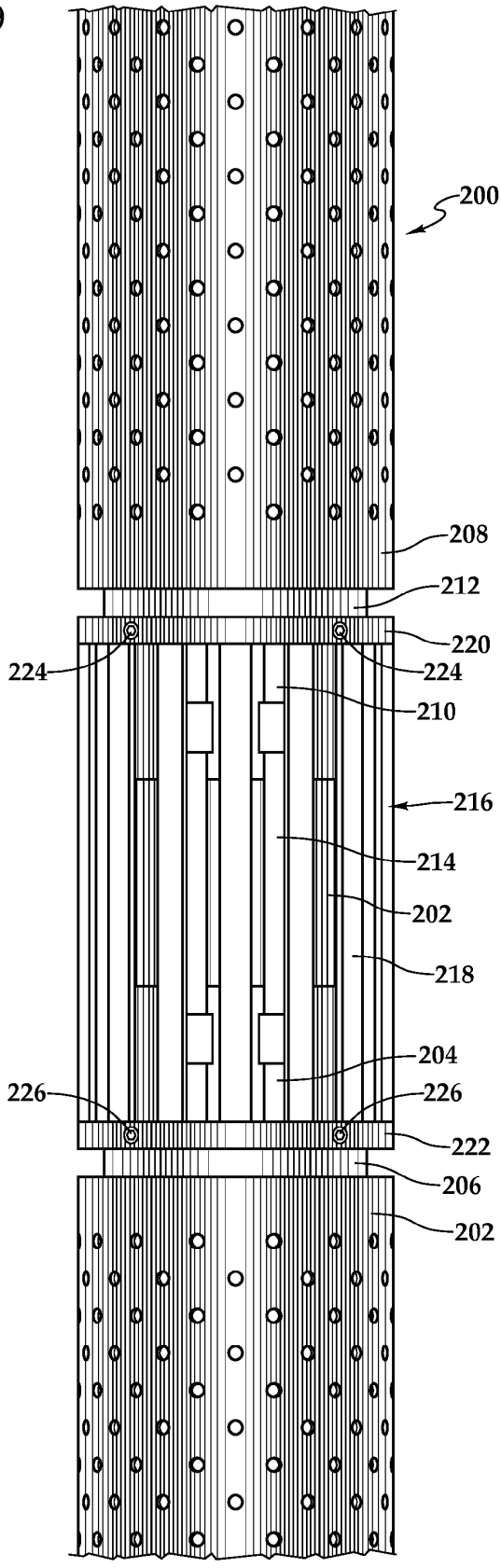

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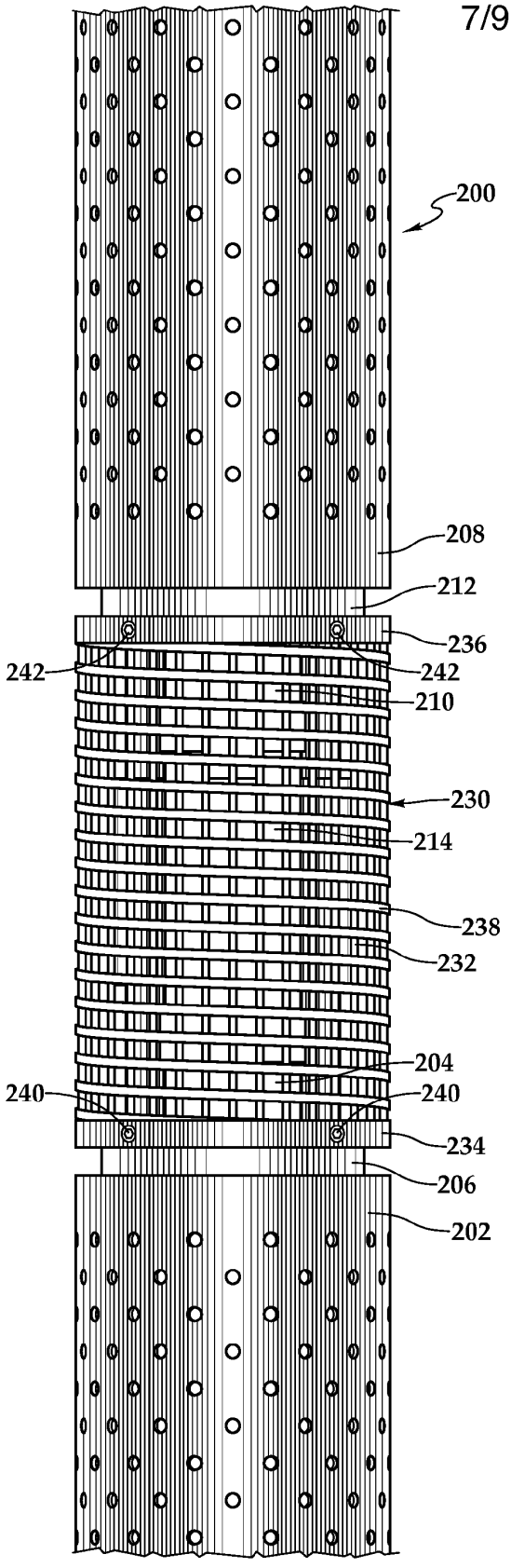

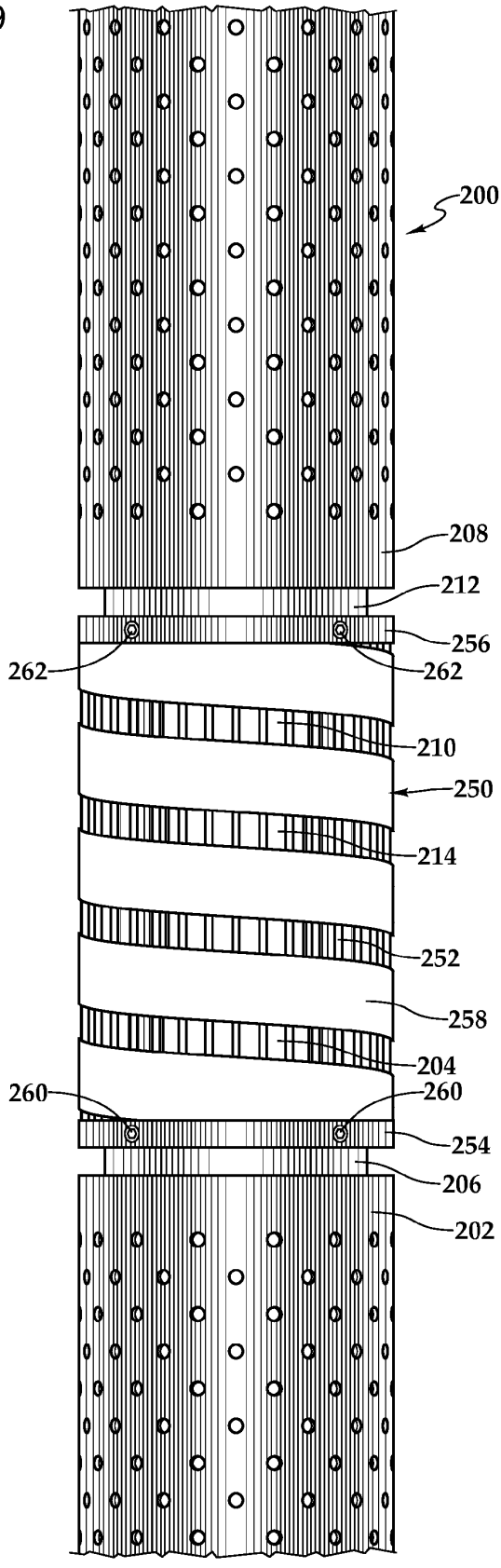

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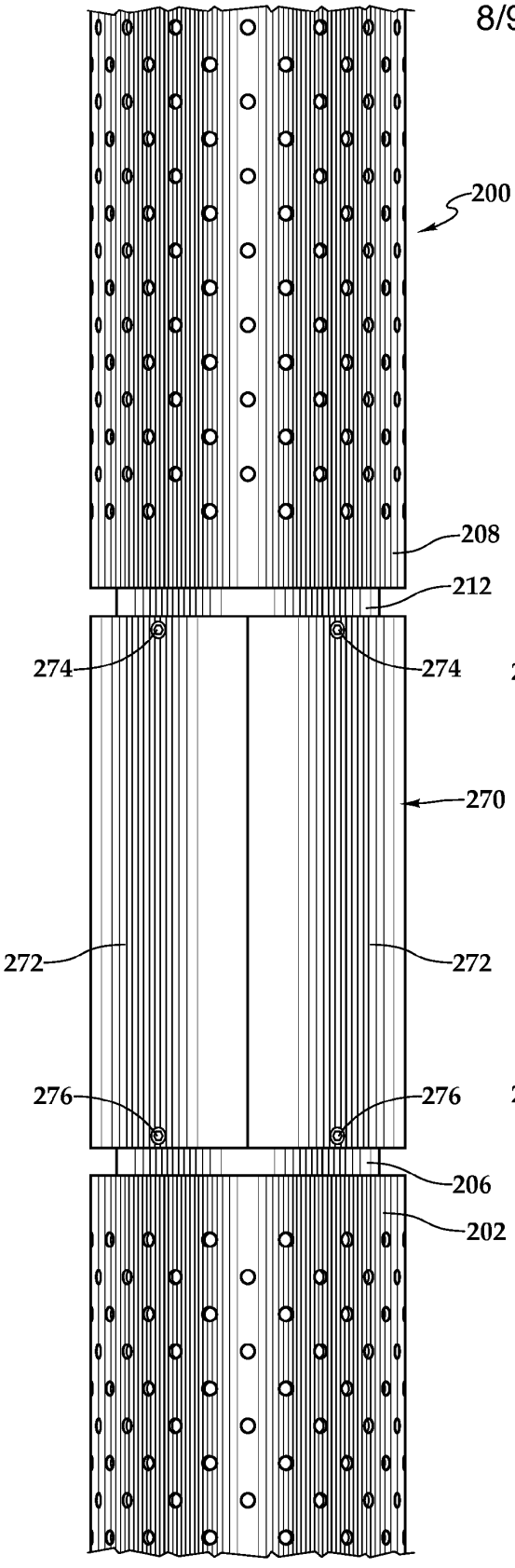
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Fig 10

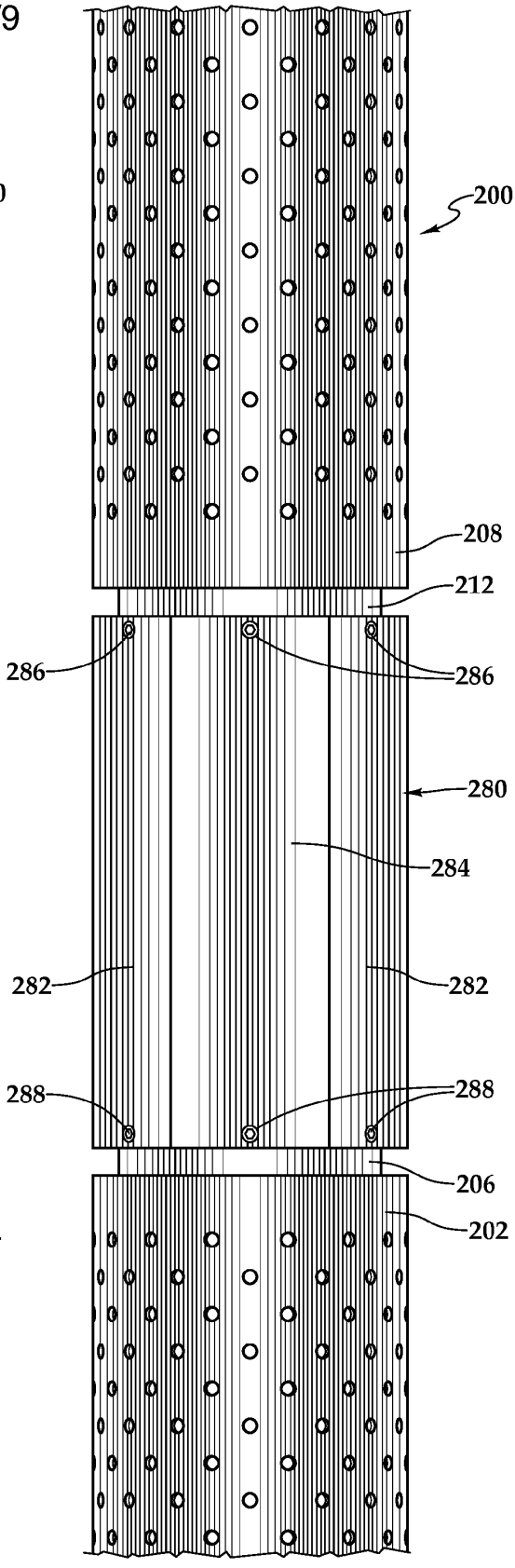
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Fig 11

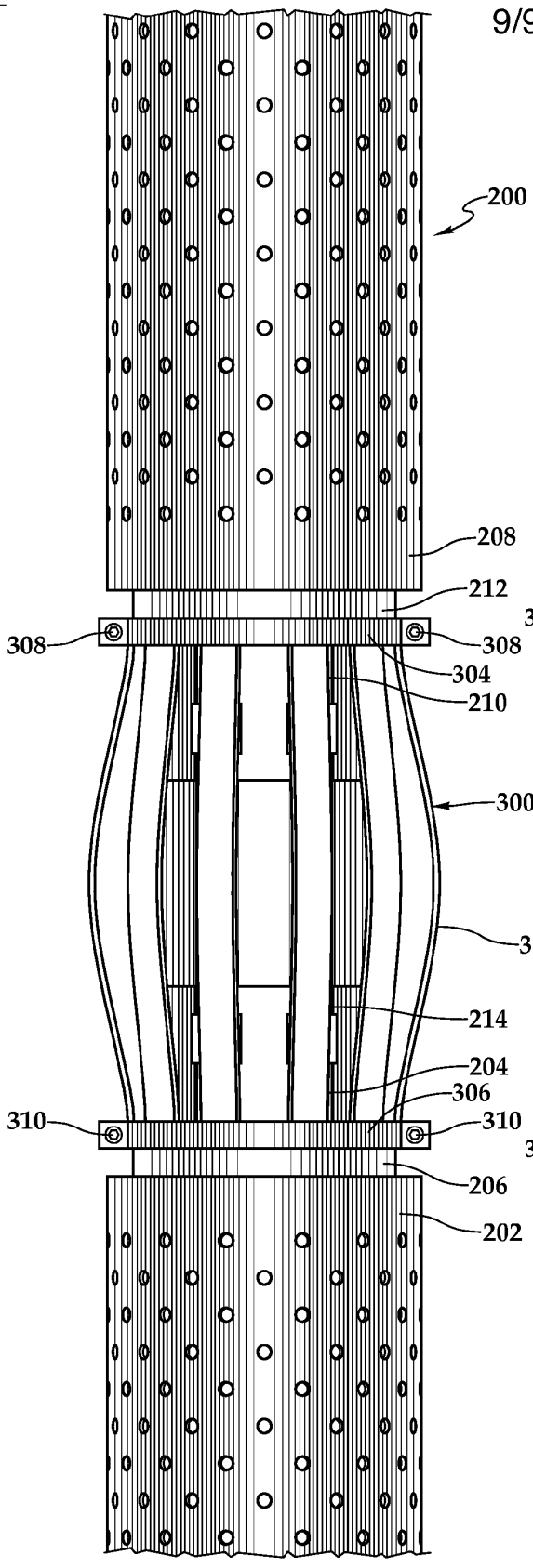
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Fig 12

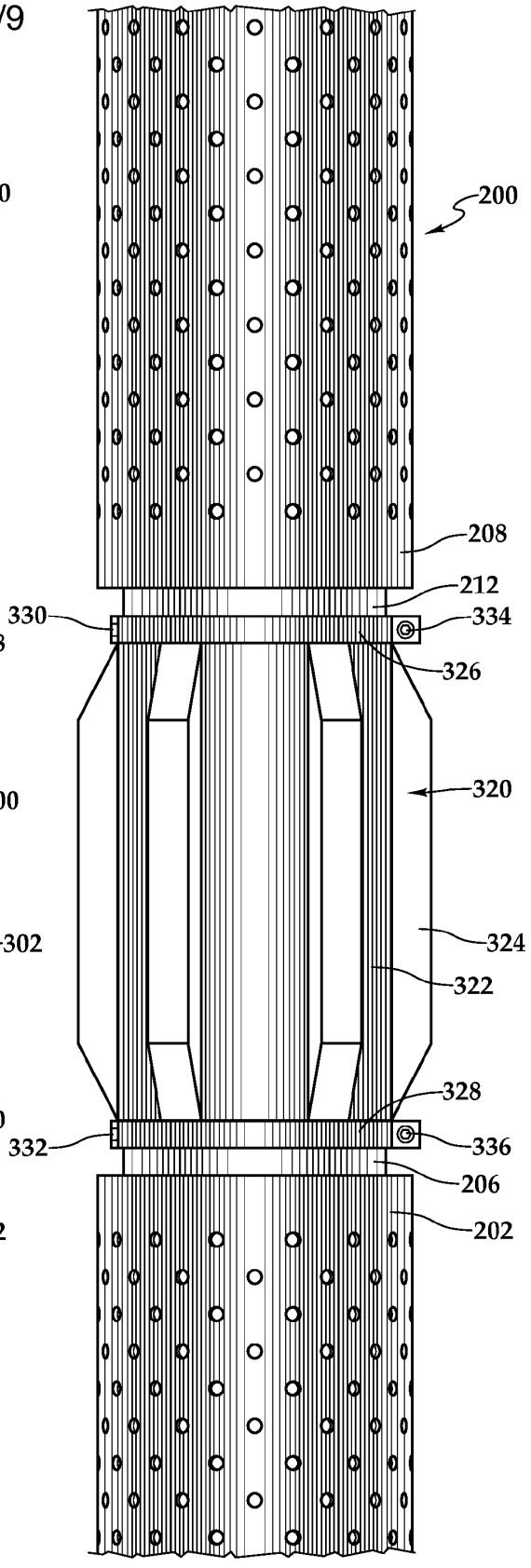
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Fig 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/060705

A. CLASSIFICATION OF SUBJECT MATTER

E21B 29/12(2006.01)i, E21B 43/08(2006.01)1, E21B 43/04(2006.01)1

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 29/12; E21B 43/04; E03B 3/18; F16C 17/00; E21B 33/122; E21B 43/16; E21B 33/13; E21B 33/047

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: gravel packing, transport tube, joint, jumper tube, protect, and cage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2010-0236779 Al (NUTLEY et al.) 23 September 2010 See abstract , paragraphs [0005] -[0006] , [0024] -[0025] , and figures 2A, 2B, 4.	1,9,11,14-15 6,8,10,13,17-18 ,20 2-5 ,7,12,16,19
Y	US 3894780 A (BROUSSARD, DALLAS N.) 15 July 1975 See column 6, lines 12-28 and figure 1.	6,8,13,17-18 ,20
Y	US 2009-0294128 Al (DALE et al.) 03 December 2009 See paragraphs [0043] , [0046] and figures 2A-3A.	10
A	US 2010-0155064 Al (NUTLEY et al.) 24 June 2010 See paragraph [0082] and figure 13A.	1-20
A	US 2012-0168159 Al (EDWARDS et al.) 05 July 2012 See paragraphs [0013] , [0016] and figure 2.	1-20

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

☒ See patent family annex.

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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
24 April 2013 (24.04.2013)	**25 April 2013 (25.04.2013)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-70 1, Republic of Korea Facsimile No. 82-42-472-7140	LEE, Jong Kyung Telephone No. 82-42-481-3360

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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(71) Applicant *(for all designated States except US)*: **EXXONMOBIL UPSTREAM RESEARCH COMPNAY** [US/US]; CORP-URC-SW-359, P.O.Box 2189, Houston, TX 77252-2189 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **YEH, Charles, S.** [US/US]; 9511 Merlins Oaks Court, Spring, TX 77379 (US). **BARRY, Michael, D.** [US/US]; 251 North Maple Glade Circle, The Woodlands, TX 77382 (US). **HECKER, Michael, T.** [US/US]; 16211 Castle Grove Court, Tomball, TX 77377 (US). **HAEBERLE, David, C.** [US/US]; 14215 Spyglen Lane, Cypress, TX 77429 (US).

(74) Agents: **McARTHUR, Douglas, W.** et al.; Exxonmobil Upstream Research Company, Corp-Urc-Sw-359, P.O.Box 2189, Houston, TX 77252-2189 (US).

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(54) **Title**: SYSTEMS AND METHODS FOR PROVIDING ZONAL ISOLATION IN WELLS

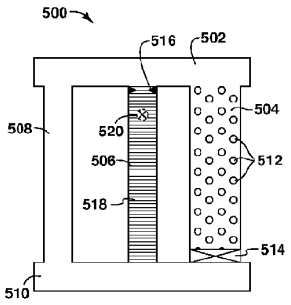

FIG. 7A

(57) **Abstract**: Systems and methods for providing zonal isolation in a hydrocarbon well include or utilize a tubular assembly having an upstream manifold, a gravel packing conduit, a transport conduit, a leak-off conduit, and a downstream flow path. The tubular assembly is adapted to receive a gravel-laden slurry and to direct at least a portion of the same to the gravel packing conduit. The gravel-laden slurry exiting the gravel packing conduit packs the annulus between the tubular assembly and the wellbore by dehydrating at least in part through the leak-off conduit. The leak-off conduit is further gravel-packed by the gravel- laden slurry received by the tubular assembly. The leak-off conduit is dehydrated through a flow control valve. Together, the gravel packed annulus and the gravel packed leak-off conduit provide a gravel-based zonal isolation system.

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SYSTEMS AND METHODS FOR PROVIDING ZONAL ISOLATION IN WELLS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/169,160, filed April 14, 2009, which is incorporated herein in its entirety for all purposes.

FIELD

[0002] The present disclosure relates generally to zonal isolation systems used in wells. More particularly, the present disclosure relates to systems and methods for providing gravel-based zonal isolation in a well.

BACKGROUND

[0003] This section is intended to introduce the reader to various aspects of art, which may be associated with embodiments of the present invention. This discussion is believed to be helpful in providing the reader with information to facilitate a better understanding of particular techniques of the present invention. Accordingly, it should be understood that these statements are to be read in this light, and not necessarily as admissions of prior art.

[0004] Producing oil and gas from subterranean formations has become increasingly challenging over the years, requiring continuing innovation in nearly every aspect of oil and gas operations. The continuing innovation enables current and future wells to reach reserves in reservoirs that were previously uneconomical. For example, multi-zone wells increase the efficiency of a single well, ultra-deep water wells access previously unreachable reservoirs, wells of greater depth and/or of extended reach wells may enable access to new and/or different reserves from new and/or existing wells, drilling and completion advances allows production from high pressure/temperature reservoirs, reservoirs having long intervals, reservoirs having high production rates, and reservoirs in remote locations. However, the technologies utilized to overcome the challenges increase the individual well cost dramatically and demands fewer wells for an economical field development. Consequently, the well productivity, reliability, and longevity become vital to avoid undesired production loss and expensive intervention or workovers.

[0005] As described above, many wells include multiple zones in one more intervals that may be of extended lengths. During operation of wells having multiple zones, it is important to control and manage fluids flowing to and from different zones. For example, in production operations, proper control of the fluid production rates in various zones can result in delaying water/gas coning and in maximizing reserve recovery. Various techniques are known to determine whether zonal isolation will be effective or desirable and where in a well to position the zonal isolation. Exemplary implementations of zonal isolations and inflow control devices installed in wells have been documented in various publications, including M. W. HELMY et al., "Application of New Technology in the Completion of ERD Wells,

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Sakhalin-1 Development," SPE 103587, October 2006; and David C. HAEBERLE et al., "Application of Flow-Control Devices for Water Injection in the Erha Field", SPE 112726, March 2008.

[0006] Exemplary operating conditions known to benefit from the use of zonal isolation technologies include the untimely production of water, gas, or other undesirable formation fluids. Water can be produced together with hydrocarbonds during well production for a number of reasons, including the presence of native water zones, coning (rise of near-well hydrocarbon-water contact), high permeability streaks, natural fractures, and fingering from injection wells. Depending on the mechanism or cause of the water production, the water may be produced at different locations and times during a well's lifetime. Careful installation of zonal isolation in the initial completion allows an operator to shut-off the production from one or more zones during the well lifetime to limit the production of water or other desirable fluids.

[0007] Zonal isolation in open-hole completions is becoming increasingly more important for establishing and maintaining optimized long-term performance of both injection and production wells. In cases where gravel pack is needed for sand (particle) control, multi-zone gravel packing with zonal isolation in openhole completions had been challenging until the internal shunt alternate path technology was introduced. The internal shunt alternate path technology is described at least in PCT Publication No. WO 2008/060479, which is incorporated herein by reference in its entirety for all purposes, and M. D. BARRY et al., "Openhole Gravel Packing with Zonal Isolation," SPE 110460, November 2007. Zonal isolation in a open-hole, gravel-packed completion could be provided by a conventional packer element and secondary flow paths to enable both zonal isolation and alternate path gravel packing, such as described in PCT Publication Nos. WO 2007/092082 and WO 2007/092083, which are each incorporated herein by reference in their entirety for all purposes. For example, enlarged and/or irregular boreholes, high pressure differentials, increasing number of zones per well, high temperatures, and temperature fluctuations each can challenge, and sometimes compromise, the effectiveness of the alternate path systems. In addition to these challenging environmental conditions, the operating conditions further complicate the efforts to provide a reliable, robust solution. For example, the longevity of the zonal isolation equipment is increasingly important as wells are required to produce for longer periods of time between workovers and treatment operations. Moreover, the risk or likelihood of water and/or gas production increases over the life of the well (due to increasing drawdown and depletion) requiring zonal isolation equipment that can endure the conditions of the well for extended periods.

[0008] For one or more of these reasons, there is a continuing need for improved zonal isolation technologies. Improved zonal isolation technologies would preferably provide one

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or more improvement such as being less sensitive to downhole conditions, being more forgiving of operational variables, being more flexible in its use and capabilities, being operationally easy to run into the well, position, and set, and/or being mechanically simple to improve tolerance to well conditions over time.

[0009] Prior efforts to improve upon mechanical packers for zonal isolation have provided improvements such as swellable packers. Still additional developments include the use of an annular gravel pack between a blank basepipe segment and a wellbore wall having very low permeability, such as a shale section of the well. The annular gravel pack forms an axial zonal isolation and provides substantial flow resistance. However, it is not possible for such gravel pack barrier to form without introducing a proper fluid leakoff path to dehydrate the gravel slurry. Due to the low permeability of the formation, the fluid leak-off in such implementations is through the basepipe to return to surface. One example of such a system is seen in U.S. Patent No. 6,520,254 to Hurst et al. However, if any leak-off path exists, water or gas production will follow the same path and render the isolation functionality of the gravel pack ineffective. Accordingly, there is a continuing need for zonal isolation systems and methods.

[0010] Other related material may be found in at least U.S. Patent Publication No. 2006/0124304; PCT Publication No. WO 2005/059304; and U.S. Patent No. 6,318,465; 6,619,397; and 7,108,060.

SUMMARY

[0011] In some implementations of the present invention, a tubular assembly adapted for downhole use in wells includes an upstream manifold, a gravel packing conduit, a transport conduit, and a leak-off conduit. The upstream manifold is adapted to receive a gravel-laden slurry. The gravel packing conduit is in fluid communication with the upstream manifold and extends longitudinally away from the upstream manifold. The gravel packing conduit is adapted to receive at least a portion of the gravel-laden slurry from the upstream manifold and is adapted to be in fluid communication with an annulus between a wellbore wall and the tubular assembly when the tubular assembly is disposed downhole in a well. The gravel packing conduit is adapted to communicate gravel-laden slurry into the annulus during isolation forming operations. Moreover, the gravel packing conduit is at least substantially isolated from direct fluid communication with a downstream flow path. The transport conduit is in fluid communication with the upstream manifold and in fluid communication with the downstream flow path. The leak-off conduit is in at least partially restricted fluid communication with the upstream manifold and is in fluid communication with the downstream flow path in a region longitudinally spaced from the upstream manifold. The leak-off conduit is in fluid communication with the annulus through permeable media adapted

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to retain particles while communicating fluids, thereby providing fluid leak-off from the annulus during the isolation forming operations.

[0012] Numerous variations on the tubular assembly are possible, at least some of which are described in this Summary and others are described herein. The gravel packing conduit may include at least one flow path adapted to gravel pack an interval of the wellbore. Additionally or alternatively, the at least partially restricted fluid communication between the upstream manifold and the leak-off conduit and the fluid communication between the leak-off conduit and the downstream flow path may be configured to maintain the fluid pressure in the leak-off conduit below a pressure in the annulus and a pressure in the gravel packing conduit during at least a portion of the isolation forming operations. In such implementations, the fluid pressure in the leak-off conduit may increase as isolation forming operations progress, as downstream portions of a well are gravel packed, for example. As the further downstream portions are gravel packed, the back pressure from downhole may cause gravel-laden slurry to enter the leak-off conduit from at least one of the downstream flow path and the transport conduit as isolation forming operations progress. As gravel-laden slurry enters the leak-off conduit, the fluid in the gravel-laden slurry in the leak-off conduit may exit the leak-off conduit into at least one of the annulus and a basepipe associated with the tubular assembly thereby gravel packing the leak-off conduit. The fluid may exit the leak-off conduit through at least one flow control valve, such as a nozzle, a one-way valve, etc. When the leak-off conduit is gravel packed, the gravel packed leak-off conduit and the gravel-packed annulus together provide a zonal isolation assembly in the wellbore.

[0013] In some implementations, the leak-off conduit and the gravel packing conduit may be adapted to provide a zonal isolation assembly in the wellbore in a region adjacent the tubular assembly. The zonal isolation assembly is adapted to at least substantially isolate annular intervals on either side of the tubular assembly. In some implementations, the zonal isolation assembly may be formed during gravel packing operations. Additionally or alternatively, the zonal isolation assembly may be formed in association with an imperfect isolation device to provide enhanced zonal isolation.

[0014] Additionally or alternatively, some implementations of the tubular assemblies described herein may be configured such that at least one of the gravel packing conduit, the transport conduit, and the leak-off conduit is operatively associated with a base pipe. In some implementations, at least one of the upstream manifold, the transport conduit, the leak-off conduit, and the gravel packing conduit may be adapted to promote fluid flow from the upstream manifold into the gravel packing conduit. Still further, some tubular assemblies may be configured to provide the fluid communication between the leak-off conduit and the downstream flow path through a double-U assembly.

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[0015] The present disclosure further describes methods for providing a gravel-based zonal isolation system in a hydrocarbon-related well. In some implementations, the methods include providing a tubular assembly, which may be according to the description above. The methods may further include positioning the tubular assembly at a predetermined position within a well. The methods further include pumping gravel-laden slurry to the upstream manifold and flowing at least a portion of the gravel-laden slurry to the gravel packing conduit of the tubular assembly to gravel pack an annulus between the tubular assembly and a wellbore wall. The gravel pack in the annulus is then dehydrated through at least the permeable media of the leak-off conduit. The filtrate through the permeable media flows through the leak-off conduit to the downstream flow path. The methods further include gravel packing the leak-off conduit with gravel-laden slurry from at least one of the upstream manifold, the downstream flow path, and the transport conduit. The leak-off conduit gravel pack is dehydrated to at least one of the annulus and a basepipe associated with the tubular assembly. The leak-off conduit gravel pack and the annular gravel pack are adapted to provide a zonal isolation system.

[0016] The methods and equipment used therein may be varied in any suitable manner. For example, the tubular assembly may be varied according to any of the descriptions provided above or elsewhere herein. Additional examples of variations on the methods are described in this Summary and elsewhere herein. In some implementations of the present methods, the tubular assembly may be coupled to downhole equipment when positioned at a predetermined position within the well, such as one or more of annular coiled tubing, production tubing basepipe, sand control equipment, and gravel pack equipment. In some implementations, the methods include flowing at least a majority of the gravel-laden slurry in the upstream manifold to the gravel-packing conduit. Additionally or alternatively, some implementations may include dehydrating the gravel pack in the annulus through the wellbore wall to a formation.

[0017] Some implementations of the present methods may include gravel packing distal regions of the well with gravel-laden slurry of which at least a portion flowed through the transport conduit. The gravel packing of the distal regions may utilize at least one of conventional gravel packing technology and alternate path gravel packing technology. In some implementations, the gravel packing of distal regions may include providing at least one additional gravel-based zonal isolation assembly.

[0018] Exemplary variations on the equipment that may be used with the present methods include a tubular assembly having at least two gravel packing conduits in fluid communication with the upstream manifold and the annulus. Additionally or alternatively, the gravel packing conduit(s) may be in direct fluid communication with only the upstream

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manifold and the annulus. The permeable media of the leak-off conduit may comprise a plurality of openings, such as may be provided by a slotted tube and/or a sand screen.

[0019] The present disclosure further discloses methods of operating a hydrocarbon-related well. Exemplary methods may include conducting gravel packing operations in a wellbore utilizing at least one sand screen; forming a gravel-based zonal isolation system in the wellbore while conducting gravel packing operations; and conducting at least one additional operation in the wellbore utilizing the gravel-based zonal isolation device.

[0020] In such methods, forming a gravel-based zonal isolation system may utilize a tubular assembly comprising: an upstream manifold; a gravel packing conduit in fluid communication with the upstream manifold and extending longitudinally away from the upstream manifold; wherein the gravel packing conduit is adapted to receive a gravel-laden slurry from the upstream manifold; wherein the gravel packing conduit is adapted to be in fluid communication with an annulus between a wellbore wall and the tubular assembly when the tubular assembly is disposed downhole in a well; wherein the gravel packing conduit is adapted to communicate the gravel-laden slurry into the annulus during isolation forming operations; and wherein the gravel packing conduit is at least substantially isolated from direct fluid communication with a downstream flow path; a transport conduit in fluid communication with the upstream manifold and in fluid communication with the downstream flow path; and a leak-off conduit; wherein the leak-off conduit is in at least partially restricted fluid communication with the upstream manifold; wherein the leak-off conduit is in fluid communication with the downstream flow path in a region longitudinally spaced from the upstream manifold; and wherein the leak-off conduit is in fluid communication with the annulus through permeable media adapted to retain particles while communicating fluids providing fluid leak-off from the annulus during the isolation forming operations. In some implementations, the gravel packing conduit comprises at least two gravel packing conduits in fluid communication with the upstream manifold and the annulus. Still further, in some implementations, the gravel packing conduit is in direct fluid communication with only the upstream manifold and the annulus.

[0021] The methods described herein include forming a gravel-based zonal isolation system, which may include a steps such as: positioning the tubular assembly at a predetermined position within a well; pumping gravel-laden slurry to the upstream manifold; flowing at least a portion of the gravel-laden slurry to the gravel packing conduit to gravel pack an annulus between the tubular assembly and a wellbore wall; dehydrating the gravel pack in the annulus through at least the permeable media of the leak-off conduit; wherein filtrate through the permeable media flows through the leak-off conduit to the downstream flow path; and gravel packing the leak-off conduit with gravel laden slurry from at least one of the downstream flow path and the transport conduit; wherein the leak-off conduit gravel pack

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is dehydrated to at least one of the annulus and a basepipe associated with the tubular assembly; and wherein the leak-off conduit gravel pack and the annular gravel pack are adapted to provide a zonal isolation zonal.

[0022] The methods of forming a gravel-based zonal isolation system may similarly include a number of variations. For example, flowing at least a portion of the gravel-laden slurry to the gravel packing conduit may comprise flow at least a majority of the gravel-laden slurry in the upstream manifold to the gravel-packing conduit. Additionally or alternatively, dehydrating the gravel pack in the annulus may include dehydrating fluids through the wellbore wall to a formation. The methods may include further steps such as gravel packing distal regions of the well with gravel-laden slurry, at least a portion of which flowed through the transport conduit. In such methods, gravel packing distal regions of the well may utilize conventional gravel packing technology. Additionally or alternatively, gravel packing distal regions may include providing at least one additional gravel-based zonal isolation assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The foregoing and other advantages of the present technique may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0024] Fig. 1 is a schematic view of a conventional well including zonal isolation systems and gravel-packed zones;

[0025] Fig. 2 is an enlarged schematic view of a conventional open-hole well including zonal isolation systems and gravel-packed zones;

[0026] Fig. 3 is a schematic view of a well provided with a gravel-based zonal isolation system of the present disclosure;

[0027] Fig. 4 is a schematic view of a gravel-based zonal isolation system of the present disclosure;

[0028] Fig. 5 is a flow chart of exemplary methods within the scope of the present disclosure;

[0029] Fig. 6 is a flow chart of exemplary methods for providing gravel-based zonal isolation systems;

[0030] Fig. 7A is a schematic illustration of a tubular assembly adapted for use in providing a gravel-based zonal isolation system;

[0031] Fig. 7B is a schematic illustration of a tubular assembly adapted for use in providing a gravel-based zonal isolation system;

[0032] Fig. 7C is a schematic illustration of a tubular assembly adapted for use in providing a gravel-based zonal isolation system;

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[0033] Fig. 8 is a schematic cross-sectional view of a tubular assembly operatively associated with a basepipe and adapted for use in providing a gravel-based zonal isolation system;

[0034] Fig. 9 is a schematic cross-section view of a tubular assembly operatively associated with a basepipe for use in providing a gravel-based zonal isolation system;

[0035] Fig. 10 is a schematic view of tubular assembly operatively associated with a basepipe and disposed in a well;

[0036] Fig. 11 is a schematic view of the tubular assembly of Fig. 10 illustrating a stage in the formation of a gravel-based zonal isolation system;

[0037] Fig. 12 is a schematic view similar to Fig. 11 and illustrating a further stage in the formation of a gravel-based zonal isolation system; and

[0038] Fig. 13 is a schematic view similar to Fig. 12 and illustrating a further stage in the formation of a gravel-based zonal isolation system.

[0039] While the technologies of the present disclosure are susceptible to various modifications and alternative forms, specific exemplary embodiments thereof are shown in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific exemplary embodiments is not intended to limit the disclosure to the particular forms disclosed herein, but on the contrary, this disclosure is to cover all modifications and equivalents of the technologies defined by the appended claims. It should also be understood that the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating principles of exemplary embodiments of the present invention. Moreover, certain dimensions may be exaggerated to help visually convey such principles. For the purposes of clarity, not every component is labeled in every figure, nor is every component of each embodiment of the invention shown where illustration is not necessary to allow those of ordinary skill in the art to understand the invention.

DETAILED DESCRIPTION

TERMS AND TERMINOLOGY

[0040] The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, i.e., a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, i.e., a meaning other than the broadest meaning understood by skilled artisans, such a special or clarifying definition will be expressly set forth in the specification in a definitional manner that provides the special or clarifying definition for the term or phrase.

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[0041] For example, the following discussion contains a non-exhaustive list of definitions of several specific terms used in this disclosure (other terms may be defined or clarified in a definitional manner elsewhere herein). These definitions are intended to clarify the meanings of the terms used herein. It is believed that the terms are used in a manner consistent with their ordinary meaning, but the definitions are nonetheless specified here for clarity.

[0042] A/an: The indefinite articles "a" and "an" as used herein mean one or more when applied to any feature in embodiments and implementations of the present invention described in the specification and claims. The use of "a" and "an" does not limit the meaning to a single feature unless such a limit is specifically stated. The term "a" or "an" entity refers to one or more of that entity. As such, the terms "a" (or "an"), "one or more" and "at least one" can be used interchangeably herein.

[0043] About: As used herein, "about" refers to a degree of deviation based on experimental error typical for the particular property identified. The latitude provided the term "about" will depend on the specific context and particular property and can be readily discerned by those skilled in the art. The term "about" is not intended to either expand or limit the degree of equivalents which may otherwise be afforded a particular value. Further, unless otherwise stated, the term "about" shall expressly include "exactly," consistent with the discussion below regarding ranges and numerical data.

[0044] Above/below: In the following description of the representative embodiments of the invention, directional terms, such as "above", "below", "upper", "lower", etc., are used for convenience in referring to the accompanying drawings. In general, "above", "upper", "upward" and similar terms refer to a direction toward the earth's surface along a wellbore, and "below", "lower", "downward" and similar terms refer to a direction away from the earth's surface along the wellbore. Continuing with the example of relative directions in a wellbore, "upper" and "lower" may also refer to relative positions along the longitudinal dimension of a wellbore rather than relative to the surface, such as in describing both vertical and horizontal wells.

[0045] And/or: The term "and/or" placed between a first entity and a second entity means one of (1) the first entity, (2) the second entity, and (3) the first entity and the second entity. Multiple elements listed with "and/or" should be construed in the same fashion, i.e., "one or more" of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the "and/or" clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to "A and/or B", when used in conjunction with open-ended language such as "comprising" can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another

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embodiment, to both A and B (optionally including other elements). As used herein in the specification and in the claims, "or" should be understood to have the same meaning as "and/or" as defined above. For example, when separating items in a list, "or" or "and/or" shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as "only one of" or "exactly one of," or, when used in the claims, "consisting of," will refer to the inclusion of exactly one element of a number or list of elements. In general, the term "or" as used herein shall only be interpreted as indicating exclusive alternatives (i.e. "one or the other but not both") when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of."

[0046] Any: The adjective "any" means one, some, or all indiscriminately of whatever quantity.

[0047] At least: As used herein in the specification and in the claims, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements). The phrases "at least one", "one or more", and "and/or" are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions "at least one of A, B and C", "at least one of A, B, or C", "one or more of A, B, and C", "one or more of A, B, or C" and "A, B, and/or C" means A alone, B alone, C alone, A and B together, A and C together, B and C together, or A, B and C together.

[0048] Based on: "Based on" does not mean "based only on", unless expressly specified otherwise. In other words, the phrase "based on" describes both "based only on," "based at least on," and "based at least in part on," which may be used interchangeably herein.

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[0049] Comprising: In the claims, as well as in the specification, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of" shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

[0050] Couple: Any use of any form of the terms "connect", "engage", "couple", "attach", or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described.

[0051] Embodiments: Reference throughout the specification to "one embodiment," "an embodiment," "some embodiments," "one aspect," "an aspect," "some aspects," "some implementations," "one implementation," or "an implementation" means that a particular component, feature, structure, method, or characteristic described in connection with the embodiment, aspect, or implementation is included in at least one embodiment and/or implementation of the claimed subject matter. Thus, the appearance of the phrases "in one embodiment" or "in an embodiment" or "in some embodiments" (or "aspects" or "implementations") in various places throughout the specification are not necessarily all referring to the same embodiment and/or implementation. Furthermore, the particular features, structures, methods, or characteristics of any one or more embodiments or implementations may be combined in any suitable manner in one or more additional or different embodiments or implementations.

[0052] Exemplary: "Exemplary" is used exclusively herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments.

[0053] Flow diagram: Exemplary methods may be better appreciated with reference to flow diagrams or flow charts. While for purposes of simplicity of explanation, the illustrated methods are shown and described as a series of blocks, it is to be appreciated that the methods are not limited by the order of the blocks, as in different embodiments some blocks may occur in different orders and/or concurrently with other blocks from that shown and described. Moreover, less than all the illustrated blocks may be required to implement an exemplary method. In some examples, blocks may be combined, may be separated into multiple components, may employ additional blocks, and so on. In some examples, one or more of the blocks may be performed by a combination of equipment and operators. Additionally or alternatively, one or more blocks may be performed by equipment alone and/or by computer systems. In some examples utilizing computerized systems, blocks may be implemented in logic or processing blocks may represent functions and/or actions

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performed by functionally equivalent circuits (e.g., an analog circuit, a digital signal processor circuit, an application specific integrated circuit (ASIC)), or other logic device. Blocks may represent executable instructions that cause a computer, processor, and/or logic device to respond, to perform an action(s), to change states, and/or to make decisions. While the figures illustrate various actions occurring in serial, it is to be appreciated that in some examples various actions could occur concurrently, substantially in parallel, and/or at substantially different points in time.

[0054] Operatively connected and/or coupled: Operatively connected and/or coupled means directly or indirectly connected for transmitting or conducting information, force, energy, or matter.

[0055] Operatively associated: Operatively associated means the recited components or elements are disposed relative to each other in a manner to accomplish the recited operation. Depending on the components described as being operatively associated, the association may be by way of coupling or other connection, by way of disposition near or adjacent to each other, or by way of other relationships. For example, an optical sensor may be operatively associated with another component by being in a line of sight with the other component. Other relationships may be require greater proximity, fluid tight connection, thermal relationships, electrical relationships, etc. Operatively associated refers to all suitable relationships identifiable to one of skill in the art for accomplishing the recited operative functionality.

[0056] Order of steps: It should also be understood that, unless clearly indicated to the contrary, in any methods claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

[0057] Preferred: "preferred" and "preferably" refer to embodiments of the invention that afford certain benefits, under certain circumstances. However, other embodiments may also be preferred, under the same or other circumstances. Furthermore, the recitation of one or more preferred embodiments does not imply that other embodiments are not useful, and is not intended to exclude other embodiments from the scope of the invention.

[0058] Ranges: Concentrations, dimensions, amounts, and other numerical data may be presented herein in a range format. It is to be understood that such range format is used merely for convenience and brevity and should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. For example, a range of about 1 to about 200 should be interpreted to include not only the explicitly recited limits of 1 and about 200, but also to include individual sizes such as 2, 3, 4, etc. and sub-ranges such as 10 to 50, 20

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to 100, etc. Similarly, it should be understood that when numerical ranges are provided, such ranges are to be construed as providing literal support for claim limitations that only recite the lower value of the range as well as claims limitation that only recite the upper value of the range. For example, a disclosed numerical range of 10 to 100 provides literal support for a claim reciting "greater than 10" (with no upper bounds) and a claim reciting "less than 100" (with no lower bounds).

DESCRIPTION

[0059] Reference will now be made to exemplary embodiments and implementations. Alterations and further modifications of the inventive features described herein and additional applications of the principles of the invention as described herein, such as would occur to one skilled in the relevant art having possession of this disclosure, are to be considered within the scope of the invention. Further, before particular embodiments of the present invention are disclosed and described, it is to be understood that this invention is not limited to the particular process and materials disclosed herein as such may vary to some degree. Moreover, in the event that a particular aspect or feature is described in connection with a particular embodiment, such aspects and features may be found and/or implemented with other embodiments of the present invention where appropriate. Specific language may be used herein to describe the exemplary embodiments and implementations. It will nevertheless be understood that such descriptions, which may be specific to one or more embodiments or implementations, are intended to be illustrative only and for the purpose of describing one or more exemplary embodiments. Accordingly, no limitation of the scope of the invention is thereby intended, as the scope of the present invention will be defined only by the appended claims and equivalents thereof.

[0060] In the interest of clarity, not all features of an actual implementation or operation are described in this disclosure. For example, some well-known features, principles, or concepts, are not described in detail to avoid obscuring the invention. It will be appreciated that in the development of any actual embodiment or in the operation of any actual implementation, numerous implementation-specific decisions may be made to achieve specific goals, such as compliance with system-related, process-related, and business-related constraints, which will vary from one implementation to another. For example, the specific details of an appropriate gravel-packing fluid, basepipe materials, connections, etc. for implementing methods of the present invention may vary from one implementation to another. Moreover, it will be appreciated that decision-making efforts required to finalize these details for an actual implementation may be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of the present disclosure.

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[0061] Fig. 1 illustrates a schematic view of a conventional multi-zone gravel packing operation. For purposes of discussion, the primary, somewhat generic components of a hydrocarbon-related well are identified here and may be referred to throughout the remaining discussion. For example, Fig. 1 illustrates that the well 110 is drilled through the surface 112 and extends away from the surface. As illustrated, the well 110 is a directional well including vertical and horizontal segments. The technologies of the present invention are not limited in implementation to directional wells and may be implemented in any well. Fig. 1 further illustrates schematically that the well 110 is associated with surface equipment 114, which is illustrated as a simple block representative of the multitude of equipment configurations that may be associated with a well, such as for drilling, treatments, workovers, production, etc. Still additionally, Fig. 1 illustrates that well 110 includes cased-hole segments enclosed or supported by casing 116 and other open-hole segments without casing. While this overview illustration of a well illustrates the gravel-packed zones in an open-hole segment, which is most conventional, the technologies of the present invention are not limited to implementations in an open-hole segment. Fig. 1 further illustrates a tubing string 118 extending from the surface equipment 114 into the well 110. It should be noted that the dimensions and the relative dimensions of the various components in Fig. 1 are not to scale but are sized for the purpose of illustrating key principles. Moreover, it should be noted that the Figures are schematic and do not show all of the details of the various components. For example, the tubing string 118 is comprised of multiple tubing joints and other components not illustrated.

[0062] As indicated, Fig. 1 illustrates a conventional multi-zone gravel packed well. The production string 118 includes multiple components used in created and providing the multi-zone gravel packed well, several of which are illustrated in Fig. 1. For example, the production string 118 includes a cross-over 120, such as may be used to exchange fluids between the interior of the production string and the annulus (e.g., during gravel packing operations). Additionally, Fig. 1 illustrates a plurality of packers 122 providing the zonal isolation of the well 110. As described above, the packers 122 may include internal shunts adapted to coordinate with other alternate path gravel packing equipment that may be used in gravel packing the well. Exemplary descriptions of internal shunt packers to enable multi-zone gravel packing in open-hole wells can be found at least in PCT Publication Nos. WO 2007/092082 and WO 2007/092083, each of which was previously incorporated. Fig. 1, being schematic, does not show all of the gravel packing equipment that may be used in creating or using the gravel pack, such as sand screens, shunt tubes, etc. Exemplary descriptions of alternate path gravel packing technologies are abundant. A non-exhaustive listing of such technologies includes U. S. Patent Nos. 4,945,991; 5,082,052; 5,113,395; 5,161,613; 5,161,618; 5,333,688; 5,333,689; 5,417,284; 5,419,394; 5,435,391; 5,515,915;

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5,588,487; 5,560,427; 5,690,175; 5,848,645; 5,842,516; 5,868,200; 5,890,533; 6,464,007; 6,644,406; 7,108,060; and 6,588,506; 6,059,032; 6,227,303; 6,220,345; 6,814,144; U. S. Patent Publication Nos. 2008/0128129 and 2008/0142227; and PCT Publication Nos. WO 2008/060479; WO 2007/092082; and WO 2007/092083; each of which is incorporated herein by reference for the purpose of describing various gravel packing equipment and methods that may be used together with the present systems and methods and/or that may be improved or augmented by the present systems and methods. As illustrated in Fig. 1, the packers 122 and other gravel packing equipment work together to provide the isolated gravel packed zones 124. Specifically, packer 122b is positioned to provide zonal isolation between gravel pack zone 124a and gravel pack zone 124b. Such zonal isolation may be desired for a variety of reasons understood by those in the art, including fluid flow control during production and/or treatment operations.

[**0063**] Fig. 2 provides an enlarged view of the schematic gravel-packed zones 124 and packers 122. Fig. 2 illustrates at least one of the problems encountered when utilizing a mechanical packer in an open-hole completion. The wellbore walls 126 of an open-hole completion are rarely perfectly circular and are even more rarely smooth and continuous over any measurable length as seen in Fig. 2. Accordingly, even the most perfectly sized mechanical packer will rarely provide perfect isolation between zones. Certain expandable mechanical packers provide better results but are generally unable to accommodate the changing shape of the wellbore wall as it evolves during the course of production and treatment operations. As illustrated in Fig. 2, this inability to conform to the shape of the wellbore wall 126 results in gaps 128 between the packer 122 and the wellbore wall 126, some of which are illustrated as being at least partially filled with gravel and others illustrated as being void space. The gaps 128 between the packer 122 and the wellbore wall 126, whether a void space or partially filled with gravel, provides a flow path for fluids between adjacent zones, defeating the attempted zonal isolation.

[**0064**] Fig. 3 provides an overview illustration of a gravel-based zonal isolation system according to the present technologies. Similar to the multi-zone gravel-packed well of Figs. 1 and 2, the well 210 of Fig. 3 includes a tubing string 218 and a crossover 220, such as may be used in gravel packing operations. Additionally, the well 210 of Fig. 3 includes a plurality of gravel-packed zones 224. However, in contrast to Figs. 1 and 2, the gravel-packed well 210 of Fig. 3 includes isolated gravel-packed zones without the use of mechanical packers or other mechanical isolation systems. Fig. 3 illustrates gravel-based zonal isolation systems 232 providing the zonal isolation between the three gravel-packed zones 224a-c. As will be described more fully below, the gravel-based zonal isolation systems 232 may be provided in the well using any of the tubular assemblies 234 described below and using any of the methods described herein.

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[0065] It should be noted the relative positions, sizes, etc. of the gravel-packed zones 224 and the gravel-based zonal isolation systems 232 in Fig. 3 are representative only. The number of zones, the length of the zones, the position of the gravel-based zonal isolation systems 232, the length of the gravel-based zonal isolation systems, etc. may all be varied to accommodate the conditions of the particular well and formation in which the present technologies are implemented. In some implementations, for example, the gravel-based zonal isolation systems 232 may be disposed adjacent a low permeability formation and sufficient zonal isolation may be provided by a gravel-based zonal isolation system of relatively short length, such as between about 1 feet and about 40 feet.

[0066] In other implementations, the zonal isolation may be desired at a position where the formation is more permeable. As described above, when the wellbore wall 226 adjacent a zonal isolator is poorly consolidated, permeable, or otherwise susceptible to fluid flow therethrough to flow around the zonal isolator. However, the gravel-based zonal isolation system 232 of the present technologies overcomes these challenges with conventional zonal isolators in a plurality of manners. For example, the gravel-pack of the gravel-based zonal isolation system 232 supports the wellbore wall 226, even those that are more poorly consolidated. Additionally, because the gravel-based zonal isolation systems can be formed of any desired length, the length of a given gravel-based zonal isolation system 232 may be selected such that the distance fluid would travel through the gravel and/or permeable formation is sufficiently long to effectively isolate the adjacent zones. Depending on the characteristics of the formation and the gravel-pack obtained through the present technologies, gravel-based zonal isolation systems 232 may extend from about 1 feet in length to about 40 feet in length (e.g., the length of a conventional tubing joint) to over about 100 feet. As can be understood, the length of the gravel-based zonal isolation system is limited only the practicalities of the materials costs and the characteristics of the well and formation. In some implementations where a long gravel-based zonal isolation system is desired, it may be preferred to utilize multiple tubular assemblies in series rather than a single, long tubular assembly.

[0067] As illustrated in Fig. 3, the gravel-packed zonal isolation systems 232 are provided between gravel-packed zones 224. As will be better understood from the remainder of this description, the adjacent gravel-packed zones 224 cooperate with the tubular assemblies 234 to pack the gravel into the gravel-based zonal isolation systems 232. Fig. 4 illustrates that gravel-based zonal isolation systems 232 may be provided in a well without an adjacent gravel pack. In the schematic illustration of Fig. 4, it can be seen that a gravel-based zonal isolation system may be formed adjacent to a mechanical packer 236 or, as illustrated, between mechanical packers. While mechanical packers 236 continue to suffer from the challenges described above, the mechanical packers 236 together with the

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gravel-based zonal isolation system 234 of the present disclosure provides more effective zonal isolation. In implementations such as those illustrated in Fig. 4, the mechanical packer 236 may be as simple as a cup-type packer, a swell packer, or may be any other form of packer. It is worth noting that the mechanical packers 236 of Fig. 4 are not intended to create long-term zonal isolation or even complete zonal isolation on their own. Accordingly, the mechanical packers 236 can be of simpler configuration, cheaper construction, and easier operation. The mechanical packers 236 may be provided by any enlarged portion or appendage to the tubing string 218 that, together with the wellbore wall 226, sufficiently restricts the flow of gravel in the annulus past the packer 236 resulting in gravel accumulation in the region, which accumulation becomes a gravel-based zonal isolation system. While Figs. 3 and 4 illustrate gravel-based zonal isolation assemblies 234 formed with gravel packs 224 on both sides or with mechanical packers 236 on both sides, it will be understood that the gravel-based zonal isolation systems 234 may be formed with any combination or variation of mechanical packers and gravel packs. In some implementations, the gravel-based zonal isolation systems 234 may be effectively formed with a packer and/or a gravel pack on the upstream side, on the downstream side, or both sides of the gravel-based zonal isolation system.

[**0068**] The formation of the gravel-based zonal isolation systems 234 of Figs. 3 and 4 will be better understood in connection with Figs. 5 and 6 illustrating exemplary methods of forming gravel-based zonal isolation systems. As illustrated in Fig. 5, methods of operating a hydrocarbon-related well are illustrated generally by flow chart 300. In some implementations, the methods 300 begin by conducting gravel packing operations at box 310. The gravel packing operations may be conducted according to any suitable gravel packing methods and utilizing any suitable gravel packing equipment, including sand screens, alternate path equipment and methods, and still to be developed technologies. The gravel used in the gravel packing operations may be any suitable gravel, sand, or other materials commonly used in gravel packing operations. Exemplary gravel may include resin-coated sand or proppant.

[**0069**] The methods 300 further include forming a gravel-based zonal isolation system in the well while conducting gravel packing operations, as at box 320. It should be noted that the gravel-based zonal isolation system is formed *in situ* in the well rather than being run into the well already formed. Forming the gravel-based zonal isolation system *in situ* allows the gravel packing and the formation of zonal isolation to occur during a single operating step. which may result in eliminating one or more of: 1) time, expense, operational complexity, and equipment associated with running equipment into and out of the well to activate the mechanical packers; 2) time, expense, operational complexity, and equipment associated with hydraulic pumping that may be used to inflate/activate mechanical packers; and 3) time,

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expense, operational complexity, and equipment associated with swelling a packer chemically.

[0070] Fig. 5 further illustrates that the methods 300 include conducting at least one additional operation in the well utilizing the gravel-based zonal isolation system, as at box 330. The additional operation may be any suitable operation for the given well. For example, the gravel packing operations may be continued to pack one or more additional gravel-pack zone 224, an additional gravel-based zonal isolation system 232 may be formed, treatment operations may be conducted, and/or production operations may be conducted. Regardless of the nature of the subsequent additional operation(s), the additional operation utilizes the gravel-based zonal isolation system. In treatment operations, for example, the gravel-based zonal isolation system 232 may be used to preferential treat one zone over another. In production operations, the gravel-based zonal isolation system may be used to control formation fluid flow through the well. Other manners of conducting operations in a well utilizing a gravel-based zonal isolation system will be readily apparent.

[0071] Fig. 6 provides a schematic flow chart 400 of methods for providing a gravel-based zonal isolation system in a hydrocarbon-related well. The methods 400 may be implemented in connection with the methods 300 of Fig. 5 and/or may be conducted independent of the methods of Fig. 5 (e.g., the methods 400 of Fig. 6 may or may not be implemented together with the gravel packing operations and/or may or may not be followed by conducting at least one additional operation in the well). Fig. 6 is another schematic flow chart intended to provide a general understanding of the methods within the scope of the present technologies. The methods will be better understood in connection with the description of the tubular assembly provided below and the schematic illustrations of various stages in an exemplary method within the scope of the present technology, which also are provided below.

[0072] The methods 400 of providing a gravel-based zonal isolation system are illustrated as beginning with providing a tubular assembly, at 402, which tubular assembly may be as described below. At 404, the methods continue by positioning the tubular assembly at a predetermined position with a well. As described above, the present technologies allow a gravel-based zonal isolation system to be formed *in situ* at virtually any location within a well. Accordingly, positioning the tubular assembly at a predetermined position refers to positioning the tubular assembly at whatever locations are suggested by the formation and reservoir characteristics and the operating plans for the well. In some implementations, multiple tubular assemblies may be provided and positioned within the well. The relative locations of the tubular assembly(ies) within the well are entirely dependent of the conditions of the well and the reservoir rather than the equipment or the

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operators. As will be understood from the description herein, the tubular assemblies may be positioned in series and/or may be spaced from each other to facilitate gravel packing of the well.

[0073] With the tubular assembly(ies) in position in the well, the methods 400 continue at 406 by pumping gravel-laden slurry to an upstream manifold of the tubular assembly. The upstream manifold may be configured to collect gravel-laden slurry from an annulus for redistribution among various flow conduits, as will be better understood with reference to Figs. 7-13. Additionally or alternatively, the upstream manifold may be configured to collect gravel-laden slurry from one or more flow conduits other than the annulus for redistribution among one or more downstream flow conduits. As just one example, a tubular assembly positioned downstream of another tubular assembly and/or downstream of another alternate path tubular may receive gravel-laden slurry from various flow paths, which may or may not include the annulus.

[0074] The gravel-laden slurry in the upstream manifold, or at least a portion thereof, is flowed, at 408, through a gravel packing conduit of the tubular assembly to gravel pack the annulus between the tubular assembly and the wellbore wall. The gravel packing conduit of the tubular assembly may be configured in a variety of suitable manners to receive gravel-laden slurry from the upstream manifold and to distribute the gravel-laden slurry to the annulus. In some implementations, the gravel packing conduit may be similar to gravel-packing shunt tubes of prior alternate path gravel packing technologies.

[0075] Fig. 6 further illustrates that methods 400 for forming gravel-based zonal isolation systems includes, at 410, dehydrating the gravel pack in the annulus through a leak-off conduit of the tubular assembly. In some implementations, the gravel-based zonal isolation systems may be positioned in a well adjacent a less permeable formation with limited leak-off characteristics. Gravel-laden slurry flowing into an annulus with no formation to provide leak-off generally does not form a gravel-pack. In such implementations, the leak-off conduit of the tubular assembly provides a flow path for dehydrating the gravel pack in the annulus allowing the gravel pack to form and compact as additional gravel-laden slurry is flowed into the annulus. In other implementations, the formation may be more permeable providing some leak-off from the annulus. In such implementations, the leak-off conduit may accelerate the dehydration. Dehydrating the gravel pack in the annulus through the leak-off conduit provides the advantage of having a more consistent or uniform gravel pack in the annulus. In some implementations, the leak-off conduit in association with the gravel pack conduit may be adapted to provide a more complete gravel pack in the region adjacent the tubular assembly.

[0076] At 412, Fig. 6 illustrates that the methods include gravel packing the leak-off conduit. During the gravel packing operations, the leak-off conduit provides a route for fluids

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to dehydrate the annulus. While advantageous during the gravel-packing operations, this dehydration flow route becomes a production fluid flow path or a treatment fluid flow path in subsequent operations, which would defeat the intended isolation established by the gravel packed annulus. Accordingly, the leak-off conduit is gravel packed to close or at least effectively close the fluid flow path through the leak-off conduit. In some implementations, the gravel pack in the leak-off conduit will be sufficient alone to effectively close the fluid flow path. Additionally or alternatively, the leak-off conduit may be provided with adaptive flow control features that can be triggered through various means to further close the flow through the leak-off conduit. Such features will be described further in connection with the Figures of the schematic tubular assembly.

[0077] Continuing with the discussion of Fig. 6, it can be seen that the formation of a gravel pack in the annulus and the formation of a gravel pack in the leak-off conduit together provide a gravel-based zonal isolation device restricting flow axially through the well between adjacent zones. The gravel pack in the annulus may have a permeability similar to other gravel-packed zones of the well, but may provide effective zonal isolation due to the inability of fluids to enter the tubular assembly, the distance the fluids would be required to travel through the gravel pack of the gravel-based zonal isolation device, and/or the characteristics of the formation.

[0078] Figs. 7A-7C provide various schematic side-view illustrations of exemplary tubular assemblies of the present technologies and will be discussed in turn. Each of Figs. 7A-7C illustrate a tubular assembly 500 comprising an upstream manifold 502, a gravel packing conduit 504, a leak-off conduit 506, a transport conduit 508, and a downstream flow path 510. Figs. 8 and 9 illustrate two examples of end-views of tubular assemblies associated with a base-pipe such as may be done according to the present technologies. Figs. 10-13 provide schematic illustrations of a tubular assembly 500 disposed in a well at various stages during the formation of a gravel-based zonal isolation system. The description of one or more of these Figures may refer to another Figure for reference or further clarity. It should be understood that each of the tubular assemblies of Figs. 7A-7C could be embodied in either of the manners illustrated in Figs. 8 and 9, or in other suitable manners. Moreover, any of the configurations illustrated in Figs. 7A-7C, 8, and 9, or other suitable configurations, may be implemented in the well as illustrated in Figs. 10-13.

[0079] Using Fig. 7A as an exemplary configuration, the upstream manifold 502 of the tubular assembly 500 may be of any suitable configuration adapted to receive a gravel-laden slurry. The configuration of a given implementation may depend on a variety of factors, including the configuration of adjacent components of the tubing string and the intended operations on the well. For example, in implementations where the gravel-laden slurry will be flowing through the annulus when arriving at the location of the upstream manifold 502,

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the upstream manifold may be configured to receive the gravel-laden slurry from the annulus. In other implementations, the upstream manifold may be suitably configured to receive gravel-laden slurry from one or more flow conduits, such as shunt tubes, base pipe, etc.

[0080] As illustrated in Fig. 7A, at least three flow conduits extend away from the upstream manifold 502 in fluid communication with the upstream manifold. The gravel packing conduit 504 extends longitudinally away from the upstream manifold and is adapted to be in fluid communication with the upstream manifold 502 and with the annulus between a wellbore wall and the gravel packing conduit 504, when the tubular assembly is disposed in a well. Fig. 7A schematically illustrates the fluid communication with the annulus as relatively large openings in the sidewalls of the gravel-packing conduit 504. The gravel packing conduit 504 may be configured in any suitable manner to allow fluid communication of gravel-laden slurry from inside the gravel packing conduit to the annulus. In this respect at least, the gravel packing conduit 504 may be configured in manners similar to the variety of shunt tubes used in alternative gravel packing technologies, such as those referred to above. For the sake of convenience herein, the various means that may be used to provide the fluid communication of the gravel-laden slurry will be referred to as ports 512. The ports may comprise valves, openings, slots, perforations, etc. adapted to allow flow from within the gravel packing conduit 504 to the annulus. In some implementations, the ports 512 may be adapted to provide one directional flow, such as from within the gravel pack conduit 504 through the port to the annulus. Additionally or alternatively, some implementations may be provided with one or more features on the ports 512 to render flow in one direction preferred. As one example, the ports 512 may be equipped with swelling material adapted to swell when contacted by certain downhole fluids, to limit or shut-off flow through the ports 512.

[0081] Fig. 7A illustrates still further that the gravel packing conduit 504 is at least substantially isolated from direct fluid communication with a downstream flow path 510. The downstream flow path 510 is representative of one or more flow conduits that may exist downstream of the tubular assembly 500 other than the annulus. In some implementations, the downstream flow path 510 may be provided by the upstream manifold of a subsequent tubular assembly. The gravel packing conduit 504 is in direct fluid communication with the annulus through the ports 512 and, therefore, is in communication with the annulus both upstream and downstream of the tubular assembly. However, as schematically represented by barrier 514, the gravel packing conduit 504 is not in fluid communication with the downstream flow path 510, at least not directly. As will be understood from the description herein, the fluids exiting the gravel packing conduit 504 are able to pass into the leak-off conduit 506, which is in fluid communication with the downstream flow path 510. However, this indirect fluid communication is consistent with the design and intent of the present

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technologies. The lack of direct fluid communication with downstream flow paths 510 promotes the formation of a gravel pack at the location of the tubular assembly and the formation of a gravel-based zonal isolation system.

[0082] With continuing reference to Fig. 7A, the tubular assembly 500 further includes a leak-off conduit 506 and a transport conduit 508, each of which are in fluid communication with the upstream manifold 502. In some implementations, as illustrated schematically in Fig. 7A by the varying widths of the conduits, the tubular assembly 500 may be configured to encourage flow of the gravel-laden slurry from the upstream manifold into the gravel packing conduit 504 rather than the remaining conduits. In some implementations it may be preferred to promote gravel-laden slurry flow into the gravel pack conduit 504 rather than the transport conduit 508, for example, so as to form the gravel-based zonal isolation system in a more timely and efficient manner. Additionally, such a configuration may promote a more complete gravel pack in the annular region of the gravel-based zonal isolation system. In some implementations, it may be preferred that at least a majority of the gravel-laden slurry is directed to the gravel packing conduit 504 when beginning the gravel packing operation around the tubular assembly. As will be better understood with reference to Figs. 10-13 below, the proportion of the gravel-laden slurry flowing to the gravel packing conduit will vary over time as the annulus becomes more gravel packed.

[0083] While flow to the gravel packing conduit 504 may be promoted merely by the relative sizes of the conduits and/or the number of conduits, one or more of the conduits, such as the transport conduit 508 and/or the leak-off conduit 506, may include flow control devices at the fluidic intersection with the upstream manifold. For example, the leak-off conduit 506 is illustrated in Fig. 7A as including a flow restrictor 516 at the intersection with the upstream manifold 502. The flow restrictor 516 may be configured in any suitable manner, including the use of valves, orifices, nozzles, etc. The degree to which the gravel-laden slurry is preferentially flowed to the gravel packing conduit 504 may vary in different implementations depending on the nature of the well, the nature of the formation, the position of the tubular assembly in the well, and other factors. In some implementations, the flow restrictor 516 on the leak-off conduit 506 may additionally function to promote leak-off from the annulus, as described below.

[0084] As mentioned above, Fig. 7A further illustrates, schematically, a leak-off conduit 506 fluidically coupled to the upstream manifold 502. As illustrated, the leak-off conduit 506 is in restricted fluid communication with the upstream manifold limiting the amount of gravel-laden slurry that can enter the leak-off conduit 506 from the upstream manifold 502. The leak-off conduit 506 is in fluid communication with the annulus through permeable media 518 adapted to retain particles while communicating fluids from the annulus to the interior of the leak-off conduit. Additionally, the leak-off conduit 506 is in fluid communication with the

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downstream flow paths. The restricted flow on the upstream side and the open flow on the downstream side of the leak-off conduit may function to maintain the fluid pressure in the leak-off conduit to below the fluid pressure in the annulus and the pressure in the gravel packing conduit when the annulus is being gravel packed. Accordingly, the leak-off conduit 506 is adapted to provide fluid leak-off from the annulus while gravel is being packed into the annulus to form the gravel-based zonal isolation system. As described above, the fluid leak-off available through the leak-off conduit 506 allows the gravel-based zonal isolation system to be positioned at virtually any location in the well, to be configured in a variety of lengths, to be utilized in series, etc.

[0085] The leak-off conduit 506 may be configured in any suitable manner to provide a permeable media 518 to retain particles while passing fluids, which may also be referred to as filtrate fluids. For example, the wall material providing the leak-off conduit may be slotted, may be perforated, or may otherwise include openings sized to retain the particles of the gravel-laden slurry while allowing fluids to enter. In some implementations, the leak-off conduit 506 may be configured with conventional sand control equipment, such as wire-wrap screens, etc. Fig. 7A additionally illustrates that the leak-off conduit 506 is provided with a flow control valve 520. The flow control valve 520 of Fig. 7A is illustrated as being positioned on the 'underside' of the tubular assembly. The functionality, utility, and configuration features of the flow control valve 520 will be described more fully in connection with Figures below.

[0086] As illustrated, the leak-off conduit 506 is in fluid communication with both the annulus (through the permeable media 518) and with the downstream flow path 510. Accordingly, fluid entering the leak-off conduit 506 from the annulus is allowed to flow to the downstream conduit 510 for mixing with the gravel-laden slurry flowing through the transport conduit 508 and for use with other operations further downstream in the well. In general, the leak-off conduit is in fluid communication with the downstream flow path 510 in a region longitudinally spaced from the upstream manifold 502. The schematic illustration of Fig. 7A illustrates the leak-off conduit 506 flowing directly into the schematic block representing downstream flow paths. The manner in which the leak-off conduit 506 connects, or fluidically couples, to the downstream flow path 510 may depend on a variety of factors and any suitable coupling configuration is within the scope of the present technologies. Figs. 7B and 7C illustrate exemplary configurations; additional configurations providing fluid communication between the downstream flow path 510 and the leak-off conduit 506 are within the scope of the present technologies.

[0087] Fig. 7A additionally illustrates that the tubular assembly 500 includes a transport conduit 508 extending between the upstream manifold 502 and the downstream flow path 510 and providing fluid communication therebetween. The transport conduit 508 provides

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fluid communication for the gravel-laden slurry through the tubular assembly 500 so that the transported gravel-laden slurry can be used in other downstream operations, such as gravel packing and/or the formation of additional gravel-based zonal isolation systems. As can be understood by one of ordinary skill in the art, the transport conduit 508 may be configured similar to transport conduits utilized in conventional alternate path technologies. As described above, the transport conduit 508 may be configured to influence the distribution of gravel-laden slurry from the upstream manifold 502, such as to preferentially flow to the gravel packing conduit 504.

[0088] Figs. 7B and 7C provide schematic illustrations of alternative couplings and relationships between the leak-off conduit 506, the transport conduit 508, and the downstream flow path 510. As illustrated in Fig. 7B, the leak-off conduit 506 is in fluid communication with the transport conduit 508 in a region longitudinally offset from the upstream manifold and is then in communication with the downstream flow path via the transport conduit. The manner of connecting the leak-off conduit 506 with the transport conduit 508 is illustrated as a simple J-shaped bend 522 in the leak-off conduit. Any suitable manipulation of the leak-off conduit and/or the transport conduit to provide fluid communication between the leak-off conduit and the downstream flow path may be used.

[0089] For example, Fig. 7C illustrates that the leak-off conduit 506 and the transport conduit 508 may be connected by a double-U-shaped connector 524. As described herein, the methods of the present technology include gravel packing the leak-off conduit 506 to form the gravel-based zonal isolation system. In the event that the tubular assembly 500 of Fig. 7A is installed in a vertical well, the gravel pack in the leak-off conduit 506 may be inclined to fall into the downstream flow path or to other spaces depending on the pressure maintained in the tubular assembly. In implementations such as those shown in Fig. 7C, where a double-U-shaped connector is implemented, the configuration of the connector may operate to retain the gravel in the desired position regardless of the pressure changes downstream. The double-U-shaped connector 524 is just one example of a suitable connector configuration where the connection between the leak-off conduit 506 and the downstream flow path 510 is selected to retain the gravel in the leak-off conduit after formation of the gravel-based zonal isolation system. Any such suitable configuration may be used in the present technologies.

[0090] Figs. 8 and 9 provide schematic end-views of tubular assemblies operatively associated with basepipes. Specifically, Fig. 8 illustrates a tubular assembly 600 associated as external shunt tubes on the periphery of a basepipe 630. Fig. 9 illustrates a tubular assembly 700 associated with a basepipe 730 and associated as a plurality of internal tubes concentrically disposed around the basepipe. Other configurations and associations are available and within the scope of the present technologies; these are illustrated as examples

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only. Beginning with Fig. 8, it can be seen that the tubular assembly 600 is illustrated here to further highlight the relationship between the various conduits. Similar to the configuration illustrated in Fig. 7A, the tubular assembly 600 includes a gravel packing conduit 604, a leak-off conduit 606, and a transport conduit 608, each disposed on the exterior of the basepipe 630. The gravel packing conduit 604, as described above, includes ports 612 to communicate fluid to the annulus. Similarly, the transport conduit 608 is as described above, being configured to transport fluids longitudinally. The leak-off conduit 606, while functionally the same as described in connection with Fig. 7A, is illustrated here in a manner to facilitate further discussion of its functionality.

[0091] As described above, the leak-off conduit 606 is configured with semi-permeable media 618 providing fluid communication between the annulus (outside of the tubular assembly 600) and the interior of the leak-off conduit. The permeable media is schematically represented here and may be provided in any of the configurations or implementations described above. Fig. 8 further illustrates a better perspective of the flow control valve 620. As described above, the leak-off conduit 606 is gravel packed through the process of forming a gravel-based zonal isolation system, which requires the dehydration of a gravel-laden slurry in the leak-off conduit. As can be understood from the description herein, the gravel-packing of the leak-off conduit 606 does not begin until the annulus has been gravel packed, which may limit the ability of slurry in the leak-off conduit 606 to dehydrate to the annulus. Additionally or alternatively, in some implementations the permeable media 618 may be configured to only allow flow in one direction (e.g., into the leak-off conduit to dehydrate the annulus). In either circumstance, the leak-off conduit would not be able to dehydrate and a gravel pack would not form in the leak-off conduit.

[0092] The flow control valve 620 illustrated in Fig. 8 provides controlled fluid communication between the leak-off conduit and the interior of the basepipe. Fig. 8 further illustrates a flow control valve 620' optionally disposed on the sidewall of the leak-off conduit. The flow control valve 620 may be disposed in any suitable location in the leak-off conduit to provide a flow path to dehydrate the leak-off conduit when it is being gravel packed. Flow control valves 620 may be distributed longitudinally and/or circumferentially. Additional implementations may provide fluid communication between the leak-off conduit 606 and the transport conduit 608, such as in a region closer to the upstream manifold, between the leak-off conduit and the upstream manifold, or between the leak-off conduit and any other flow path that will allow the leak-off conduit to be dehydrated when it is being gravel packed. In some implementations, the flow control valve 620 may be configured to allow flow in only one direction, only under certain pressure conditions, or under otherwise controlled circumstances. Additionally or alternatively, the flow control valve 620 may be adapted to be opened and/or closed at predetermined times and/or under predetermined conditions. For

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example, the flow control valve 620 may be configured with swellable or otherwise responsive material that closes the valve during production operations, such as by responding to the presence of hydrocarbons or other fluids. Additionally or alternatively, the flow control valve 620 and/or the flow control valve and cooperating components may be adapted to limit the flow of gravel or other particulates through the flow control valve 620, thereby encouraging the gravel packing of the leak-off conduit and limiting the valve to its dehydration objective. Exemplary implementations may include the use of screens, mesh, perforations, etc. to retain particles while passing fluids. As can be understood from this description of the flow control valve 620, the flow control valve may be configured in any suitable manner and disposed in any suitable relationship tc the remaining elements of the tubular assembly such that the flow control valve 620 assists in the dehydration of the gravel-laden slurry flowing into the leak-off conduit when gravel packing the leak-off conduit in the formation of a gravel-based zonal isolation system. Nctably, tubular assemblies within the scope of the present disclosure may comprise one or more than one flow control valves associated with the leak-off conduit.

[**0093**] Fig. 9, like Fig. 8, illustrates an end-view of a tubular assembly 700 associated with a basepipe 730. As can be seen in Fig. 9, the tubular assembly 700 is configured as a plurality of concentrically-disposed conduits associated with the basepipe 730. As illustrated, the conduits are spaced around the basepipe and within an outer shroud or liner 732. Some gravel packing operations in use today utilize internal shunts and conduits, referring to the shunts and conduits being internal to a screen or other component of the tubing string. Other gravel packing operations utilize external shunts, or shunts disposed outside of the sand control screen. Figs. 8 and 9 together illustrate that the tubular assemblies of the present technologies are compatible with alternate path gravel packing and the associated sand control equipment.

[**0094**] Fig. 9 schematically illustrates a tubular assembly 700 having a plurality of each of the conduits illustrated in Fig. 7A, including two transport conduits 708, two leak-off conduits 706, and three gravel packing conduits 704 having the features described above. The sizing, number, placement, etc. of the flow control conduits may be selected depending on the location within the well at which the tubular assembly will be disposed (such as the relative need for transport conduits), the need for leak-off conduits (such as the relative permeability of the formation in different implementations), the relative sizes of the well, the basepipe, and the various conduits, etc. Fig. 9 further illustrates that the plurality of conduits may be enclosed within an outer shroud 732. The outer shroud 732 may be of uniform configuration, such as a configuration adapted to not interfere with the functionality of the underlying conduits. Additionally or alternatively, the outer shroud 732 may be adapted according to the functionality of the underlying conduit, such as with ports adjacent to the

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gravel packing conduits 704 and with perforations or slits adjacent to the leak-off conduits 706.

[0095] Figs. 7A-7C, 8, and 9 should be viewed collectively as exemplary configurations to illustrate the diversity of configuration and implementation options that may be varied and selected in constructing a tubular assembly appropriate or suitable for its intended use. The present technologies include all tubular assembly configurations within the scope of the appended claims.

[0096] Figs. 10-13 provide schematic side-views of a tubular assembly 800 associated with a tubing string, such as a base pipe 830, and disposed in a well 832. Fig. 10 provides a basic side-view before isolation forming operations have begun and Figs. 11-13 progress through an exemplary illustration of a process for forming a gravel-based zonal isolation system. As used herein, the methods and steps associated with using the presently described tubular assemblies to form a gravel-based zonal isolation system are referred to as isolation forming operations. It should be understood from the description herein that the present tubular assemblies and operations enable the isolation forming operations to be conducted as part of a gravel packing operation or as a stand-alone operation. Base pipe 830 is representative of the various downhole equipment that may be coupled to the tubular assembly 800. For example, the tubular assembly may be coupled to any component commonly used in a tubing string, such as annular coiled tubing, a production tubing basepipe, sand control equipment, gravel pack equipment, etc. Fig. 10 illustrates the tubular assembly 800 disposed in a well 832 forming an annulus 834 between the wellbore wall 836 and the tubular assembly. In the exemplary illustration of Figs. 10-13, the upstream manifold 802 receives gravel-laden slurry from the annulus 834 and transfers the same to the various conduits of the tubular assembly 800. The gravel packing conduit 804 is represented in a manner similar to the representation of Fig. 7A. In addition to the ports 812 of the gravel packing conduit 804, Fig. 10 illustrates the barrier 814 disposed at the longitudinally distal end of the gravel packing conduit preventing, or at least substantially preventing fluid communication with the downstream flow path 810. As with Fig. 7A, the downstream flow path 810 is illustrated schematically to represent the plurality of downstream configurations with which the present tubular assemblies 800 may be associated. For simplicity in description, the schematic illustrations of Figs. 10-13 illustrate the downstream flow path 810 as a manifold on the downstream side to receive flow from the leak-off conduit 806 and the transport conduit 808 and flowing into a shunt tube 838 on the downstream side. The shunt tube 838 may be configured to carry the gravel-laden slurry further into the well to gravel pack more distal regions of the well. Additionally or alternatively, some implementations may fluidically connect the downstream flow path 810 with a subsequent upstream manifold commencing another tubular assembly according to the present technologies.

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[0097] Continuing now with Fig. 11, the tubular assembly 800 and well 832 of Fig. 10 are illustrated after gravel-laden slurry, represented by arrows 840, has been flowing into the upstream manifold for a time. The gravel-laden slurry 840 may enter the upstream manifold, rather than flowing through the annulus, for a variety of reasons, which are well understood by those in the industry. In some implementations, the present tubular assemblies 800 are adapted to function in a manner similar to conventional alternate path gravel packing tools to divert the gravel-laden slurry around premature sand bridges. In such implementations, the upstream manifold 802 may receive gravel-laden slurry according to conventional alternate path gravel packing operations when a sand bridge or an annular packer prevents packing the annulus around the tubular assembly 800. In some implementations, the upstream manifold may be longitudinally spaced from the conduits of the tubular assembly, such as in connection with other alternate path technologies. Additionally or alternatively, the upstream manifold 802 may be disposed adjacent or proximate to the conduits of the tubular assembly providing some alternate path functionality to allow gravel-laden slurry through the tubular assembly, such as through the transport conduit, and through the forming gravel-based zonal isolation system.

[0098] Once the tubular assembly 800 is disposed in the well, the gravel-laden slurry is pumped into the annulus to commence a gravel packing operation, which may be conventional, alternate path, or any other suitable form of gravel packing operation. Some of the gravel-laden slurry enters the upstream manifold, such as described above, and is diverted by the manifold into one of three conduit types, the gravel packing conduit 804, the leak-off conduit 806, and the transport conduit 808. In the absence of a gravel pack building downstream of the tubular assembly, such as by progression of the gravel pack operation and/or by the formation of a sand bridge, the gravel-laden slurry exiting the gravel packing conduit 804 flows into the annulus 834 and proceeds downstream to gravel pack the well in a manner similar to conventional alternate path gravel packing operations. As the building gravel pack approaches the tubular assembly 800, as illustrated in Fig. 11, the gravel-laden slurry 840' exiting the gravel packing conduit 804 begins to accumulate in the annulus adjacent the tubular assembly. The fluids in the gravel-laden slurry 840' are directed to the leak-off conduit 806, at least in part because of the lack of inlets to the base pipe as compared to the remaining lengths of the tubing string. The permeable media 818 permits the fluids to pass through as filtrate 842 into the leak-off conduit 806, which filtrate flows to the downstream flow path 810 (and/or the transport conduit, as described above). The dehydration of the gravel-laden slurry 840' results in the formation of a gravel pack 844 adjacent the gravel packing conduit and the leak-off conduit.

[0099] This gravel packing operation continues with more and more of the gravel-laden slurry being diverted to the transport conduit than the gravel packing conduit as the annulus

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adjacent the gravel packing conduit becomes more gravel packed. As illustrated in Fig. 12, there comes a time when very little gravel-laden slurry 840' is exiting the gravel packing conduit 804 (schematically represented by the presence of a substantially complete gravel pack and a single flow arrow 840') and the volume of filtrate 842 entering the leak-off conduit from the annulus is minimal. In some implementations, the annulus around the gravel packing conduit 804 will become gravel packed before the remainder of the wellbore, or a more distal region of the wellbore, is gravel packed. In such implementations, the gravel-laden slurry 840 received by the upstream manifold 802 will be diverted to the transport conduit 808 and/or the leak-off conduit 806 and to the downstream flow paths 810 to gravel pack the downstream regions of the well. As discussed above, the flow restrictor 816 will allow some of the gravel-laden slurry therethrough but restricts the flow to limit pressure in the leak-off conduit from the upstream manifold. It will be understood that very little of the gravel-laden slurry will dehydrate in the stage illustrated in Fig. 12 to form a gravel pack in the leak-off conduit due to the flow resistance imposed by the packed annulus and by the flow control valve 820. Accordingly, fluid, including filtrate 842 and gravel-laden slurry 840, entering the leak-off conduit 806 will flow to the lower-pressure, downstream flow paths 810 rather than packing in the leak-off conduit.

[0100] Fig. 13 illustrates that when the downstream regions of the well are sufficiently gravel packed, the pressure of the gravel-laden slurry in the downstream flow path 810, the transport conduit, and the leak-off conduit increases. The increased pressure causes the gravel-laden slurry to flow into the leak-off conduit 806 from the transport conduit and increasingly from the upstream manifold through the flow restrictor 816. As the pressure builds in the leak-off conduit, the fluids in the gravel-laden slurry will be driven to lower pressure regions, which may be found in the annulus back through the permeable media 818 and/or through one or more flow control valves 820. The resulting gravel pack in the leak-off conduit 806 is illustrated in Fig. 13. In order to limit the ability of the leak-off conduit forming a gravel pack before the annulus is sufficiently gravel packed, the flow control valve 820 may be configured to only allow flow from the leak-off conduit when the pressure differential across the valve exceeds a predetermined level, such as when the flow control valve 820 provides fluid communication between the leak-off conduit and the interior of the basepipe 830. As described above, the flow control valve 820, alone or together with supporting equipment, may be adapted to prevent, or substantially prevent, particulate matter, such as gravel, from flowing through the valve.

[0101] The flow restriction provided by the flow restrictor 816 and the flow control valve 820 may be varied and selected depending on the specifics of a given implementation. For example, depending on where in the tubing string the tubular assembly 800 will be disposed, where the flow control valve 820 communicates the fluids from the leak-off conduit, etc.

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Similarly, the number and spacing and positions of the ports 812, the configuration of the permeable media 818, and the configuration, number, position, etc. of the flow control valve 820 may vary to provide greater control over the gravel packing operations. In some implementations, the elements may be configured such that the annular region 834 is further packed during the time that the leak-off conduit is being gravel packed, such as with fluid from the upstream manifold 802. For example, as the pressure continues to build within the tubular assembly 800, the pressure may drive more gravel-laden slurry 840' into the annulus through the gravel packing conduit 804.

[0102] After the gravel pack forms in the leak-off conduit 820, the gravel-based zonal isolation system is formed, comprising the annular gravel pack adjacent the gravel packing conduit and the gravel pack in the leak-off conduit. As described above, the length of the gravel pack in the annulus and the leak-off conduit can be adjusted to vary the integrity or quality of the zonal isolation as desired by the specific implementation and as appropriate for the formation conditions. In some implementations, the degree of isolation desired may be accomplished using a single tubular assembly 800 and other implementations may utilize two or more tubular assemblies in series. In some implementations, the two or more tubular assemblies may be disposed immediately adjacent to each other in the tubing string. Advantageously, the isolation forming operations described in connection with Figs. 10-13 can be conducted during gravel packing operations, reducing the number of distinct operations run on a well before production begins and providing numerous benefits associated therewith.

[0103] In some implementations, the desired length of the gravel-based zonal isolation system, such as to accomplish the desired zonal isolation, may range from about 5 feet to about 200 feet, or longer. The only limit on the length of the gravel-based zonal isolation system is the practical realities of the well, such as the costs of the operations. A single tubular assembly as described herein may have a length between about 5 feet and about 80 feet, and perhaps more commonly 40 feet, or the length of common tubing string joint. However, the ability to connect multiple tubular assemblies in series allows gravel-based zonal isolation systems of any practical length.

[0104] Still additionally, the tubular assemblies and methods of the present disclosure may be used in combination with a packer, as first described in connection with Fig. 4. The combination of the gravel-based zonal isolation system and the conventional packer may relax the requirements of the packer and/or provide a secondary barrier in the event of failure of the packer.

[0105] While the present techniques of the invention may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed above have been shown by way of example. However, it should again be understood that the invention

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is not intended to be limited to the particular embodiments disclosed herein. Indeed, the present techniques of the invention are to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

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CLAIMS

What is claimed is:

1. A tubular assembly adapted for downhole use in wells, the tubular assembly comprising:

an upstream manifold adapted to receive a gravel-laden slurry;

a gravel packing conduit in fluid communication with the upstream manifold and extending longitudinally away from the upstream manifold; wherein the gravel packing conduit is adapted to receive at least a portion of the gravel-laden slurry from the upstream manifold; wherein the gravel packing conduit is adapted to be in fluid communication with an annulus between a wellbore wall and the tubular assembly when the tubular assembly is disposed downhole in a well; wherein the gravel packing conduit is adapted to communicate gravel-laden slurry into the annulus during isolation forming operations; and wherein the gravel packing conduit is at least substantially isolated from direct fluid communication with a downstream flow path;

a transport conduit in fluid communication with the upstream manifold and in fluid communication with the downstream flow path; and

a leak-off conduit; wherein the leak-off conduit is in at least partially restricted fluid communication with the upstream manifold; wherein the leak-off conduit is in fluid communication with the downstream flow path in a region longitudinally spaced from the upstream manifold; and wherein the leak-off conduit is in fluid communication with the annulus through permeable media adapted to retain particles while communicating fluids providing fluid leak-off from the annulus during the isolation forming operations.

2. The tubular assembly of claim 1 wherein the gravel packing conduit includes at least one flow path adapted to gravel pack an interval of the wellbore.

3. The tubular assembly of claim 1 wherein the at least partially restricted fluid communication between the upstream manifold and the leak-off conduit and the fluid communication between the leak-off conduit and the downstream flow path maintains fluid pressure in the leak-off conduit below a pressure in the annulus and a pressure in the gravel packing conduit during at least a portion of the isolation forming operations.

4 The tubular assembly of claim 3 wherein fluid pressure in the leak-off conduit increases as isolation forming operations progress.

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The tubular assembly of claim 4 wherein gravel-laden slurry enters the leak-off conduit from at least one of the downstream flow path and the transport conduit as isolation forming operations progress.

6. The tubular assembly of claim 5 wherein fluid in the gravel-laden slurry in the leak-off conduit exits the leak-off conduit into at least one of the annulus and a basepipe associated with the tubular assembly thereby gravel packing the leak-off conduit.

7. The tubular assembly of claim 6 wherein the fluid exits the leak-off conduit through at least one flow control valve.

8. The tubular assembly of claim 6 wherein the gravel packed leak-off conduit and the gravel-packed annulus together provide a zonal isolation assembly in the wellbore.

9. The tubular assembly of claim 1 wherein the leak-off conduit and the gravel packing conduit are adapted to provide a zonal isolation assembly in the wellbore in a region adjacent the tubular assembly.

10. The tubular assembly of claim 9 wherein the zonal isolation assembly is adapted to at least substantially isolate annular intervals on either side of the tubular assembly.

11. The tubular assembly of claim 9 wherein the zonal isolation assembly is formed during gravel packing operations.

12. The tubular assembly of claim 9 wherein the zonal isolation assembly is formed in association with an imperfect isolation device to provide enhanced zonal isolation.

13. The tubular assembly of claim 1 wherein at least one of the gravel packing conduit, the transport conduit, and the leak-off conduit is operatively associated with a base pipe.

14. The tubular assembly of claim 1 wherein at least one of the upstream manifold, the transport conduit, the leak-off conduit, and the gravel packing conduit are adapted to promote fluid flow from the upstream manifold into the gravel packing conduit.

15. The tubular assembly of claim 1 wherein the fluid communication between the leak-off conduit and the downstream flow path is through a double-U assembly.

16. A method for providing a gravel-based zonal isolation system in a hydrocarbon-related well, the method comprising:

providing a tubular assembly comprising:

an upstream manifold;

a gravel packing conduit in fluid communication with the upstream manifold and extending longitudinally away from the upstream manifold; wherein

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the gravel packing conduit is adapted to be in fluid communication with an annulus between a wellbore wall and the tubular assembly; and wherein the gravel packing conduit is at least substantially isolated from direct fluid communication with a downstream flow path;

a transport conduit in fluid communication with the upstream manifold and in fluid communication with the downstream flow path; and

a leak-off conduit; wherein the leak-off conduit is in at least partially restricted fluid communication with the upstream manifold; wherein the leak-off conduit is in fluid communication with the downstream flow path in a region longitudinally spaced from the upstream manifold; and wherein the leak-off conduit is in fluid communication with the annulus through permeable media adapted to retain particles while communicating filtrate fluids providing fluid leak-off from the annulus during isolation forming operations;

positioning the tubular assembly at a predetermined position within a well;

pumping gravel-laden slurry to the upstream manifold;

flowing at least a portion of the gravel-laden slurry to the gravel packing conduit to gravel pack an annulus between the tubular assembly and a wellbore wall;

dehydrating the gravel pack in the annulus through at least the permeable media of the leak-off conduit; wherein the filtrate through the permeable media flows through the leak-off conduit to the downstream flow path; and

gravel packing the leak-off conduit with gravel laden slurry from at least one of the upstream manifold, the downstream flow path, and the transport conduit; wherein the leak-off conduit gravel pack is dehydrated to at least one of the annulus and a basepipe associated with the tubular assembly; and wherein the leak-off conduit gravel pack and the annular gravel pack are adapted to provide a zonal isolation system.

17. The method of claim 16 wherein the tubular assembly is coupled to downhole equipment when positioned at a predetermined position within the well.

18. The method of claim 17 wherein the downhole equipment comprises one or more equipment selected from annular coiled tubing, production tubing basepipe, sand control equipment, and gravel pack equipment.

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19. The method of claim 16 wherein flowing at least a portion of the gravel-laden slurry to the gravel packing conduit comprises flowing at least a majority of the gravel-laden slurry in the upstream manifold to the gravel-packing conduit.

20. The method of claim 16 wherein the gravel packing conduit comprises at least two gravel packing conduits in fluid communication with the upstream manifold and the annulus.

21. The method of claim 16 wherein the gravel packing conduit is in direct fluid communication with only the upstream manifold and the annulus.

22. The method of claim 16 wherein dehydrating the gravel pack in the annulus includes dehydrating fluids through the wellbore wall to a formation.

23. The method of claim 16 wherein the permeable media of the leak-off conduit comprises a plurality of openings.

24. The method of claim 23 wherein the leak-off conduit comprises a slotted tube.

25. The method of claim 23 wherein the leak-off conduit comprises a sand screen.

26. The method of claim 16 further comprising gravel packing distal regions of the well with gravel-laden slurry; wherein at least a portion of the gravel-laden slurry used to gravel pack distal regions of the well flowed through the transport conduit.

27. The method of claim 26 wherein gravel packing distal regions of the well utilizes at least one of conventional gravel packing technology and alternate path gravel packing technology.

28 The method of claim 26 wherein gravel packing distal regions comprises providing at least one additional gravel-based zonal isolation assembly.

29. A method of operating a hydrocarbon-related well, the method comprising:

conducting gravel packing operations in a wellbore utilizing at least one sand screen;

forming a gravel-based zonal isolation system in the wellbore while conducting gravel packing operations; and

conducting at least one additional operation in the wellbore utilizing the gravel-based zonal isolation device.

30. The method of claim 29 wherein forming a gravel-based zonal isolation system utilizes a tubular assembly comprising:

an upstream manifold;

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a gravel packing conduit in fluid communication with the upstream manifold and extending longitudinally away from the upstream manifold; wherein the gravel packing conduit is adapted to receive a gravel-laden slurry from the upstream manifold; wherein the gravel packing conduit is adapted to be in fluid communication with an annulus between a wellbore wall and the tubular assembly when the tubular assembly is disposed downhole in a well; wherein the gravel packing conduit is adapted to communicate the gravel-laden slurry into the annulus during isolation forming operations; and wherein the gravel packing conduit is at least substantially isolated from direct fluid communication with a downstream flow path;

a transport conduit in fluid communication with the upstream manifold and in fluid communication with the downstream flow path; and

a leak-off conduit; wherein the leak-off conduit is in at least partially restricted fluid communication with the upstream manifold; wherein the leak-off conduit is in fluid communication with the downstream flow path in a region longitudinally spaced from the upstream manifold; and wherein the leak-off conduit is in fluid communication with the annulus through permeable media adapted to retain particles while communicating fluids providing fluid leak-off from the annulus during the isolation forming operations.

31. The method of claim 30 wherein the gravel packing conduit comprises at least two gravel packing conduits in fluid communication with the upstream manifold and the annulus.

32. The method of claim 30 wherein the gravel packing conduit is in direct fluid communication with only the upstream manifold and the annulus.

33. The method of claim 30 wherein forming a gravel-based zonal isolation system further comprises:

positioning the tubular assembly at a predetermined position within a well;

pumping gravel-laden slurry to the upstream manifold;

flowing at least a portion of the gravel-laden slurry to the gravel packing conduit to gravel pack an annulus between the tubular assembly and a wellbore wall;

dehydrating the gravel pack in the annulus through at least the permeable media of the leak-off conduit; wherein filtrate through the permeable media flows through the leak-off conduit to the downstream flow path;

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gravel packing the leak-off conduit with gravel laden slurry from at least one of the upstream manifold, the downstream flow path and the transport conduit; wherein the leak-off conduit gravel pack is dehydrated to at least one of the annulus and a basepipe associated with the tubular assembly; and wherein the leak-off conduit gravel pack and the annular gravel pack are adapted to provide a zonal isolation system.

34. The method of claim 33 wherein flowing at least a portion of the gravel-laden slurry to the gravel packing conduit comprises flow at least a majority of the gravel-laden slurry in the upstream manifold to the gravel-packing conduit.

35. The method of claim 33 wherein dehydrating the gravel pack in the annulus includes dehydrating fluids through the wellbore wall to a formation.

36. The method of claim 33 further comprising gravel packing distal regions of the well with gravel-laden slurry; wherein at least a portion of the gravel-laden slurry used to gravel pack distal regions of the well flowed through the transport conduit.

37. The method of claim 36 wherein gravel packing distal regions of the well utilizes conventional gravel packing technology.

38. The method of claim 36 wherein gravel packing distal regions comprises providing at least one additional gravel-based zonal isolation assembly.

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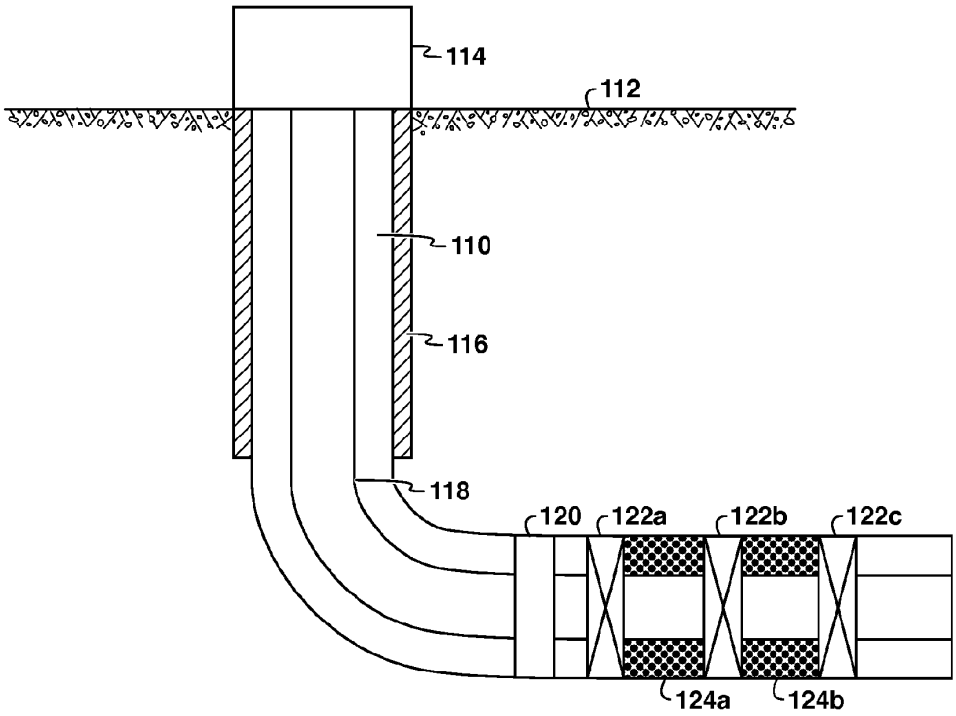


FIG. 1
(Prior Art)

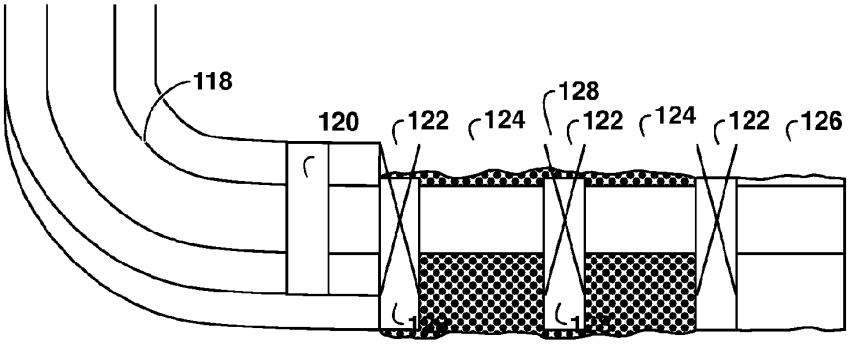
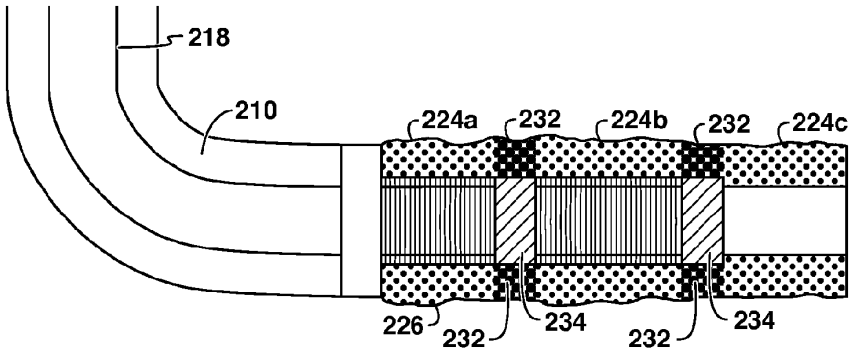


FIG. 2
(Prior Art)


218
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224b
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224c
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FIG. 3

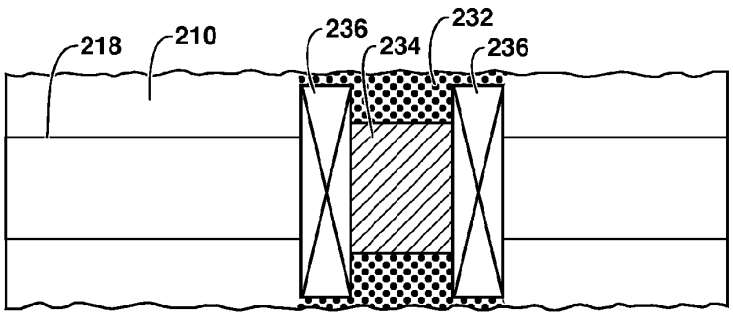
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FIG. 4

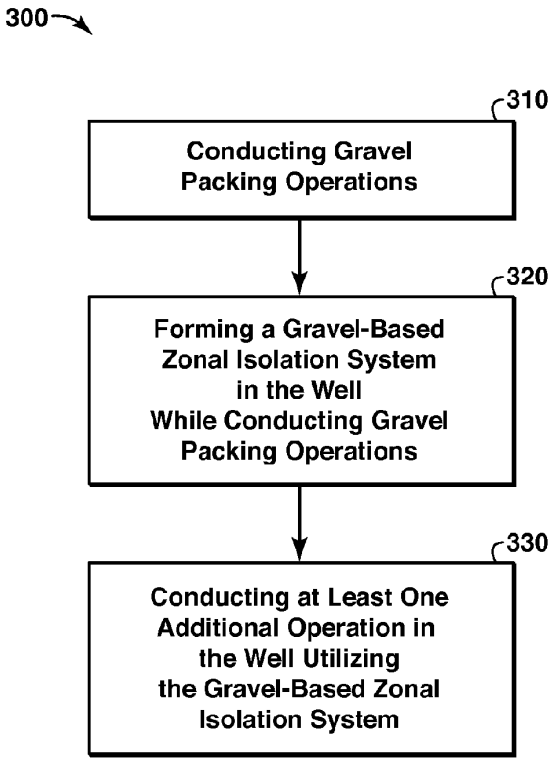
300
310
Conducting Gravel Packing Operations
320
Forming a Gravel-Based Zonal Isolation System in the Well While Conducting Gravel Packing Operations
330
Conducting at Least One Additional Operation in the Well Utilizing the Gravel-Based Zonal Isolation System

FIG. 5

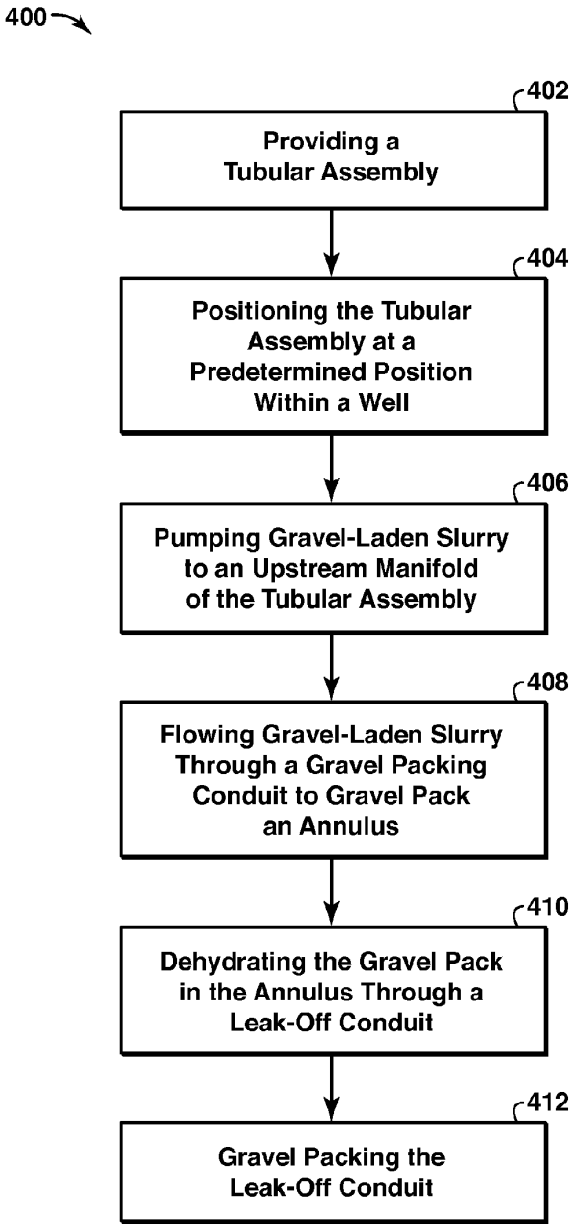
400
402
Providing a Tubular Assembly
404
Positioning the Tubular Assembly at a Predetermined Position Within a Well
406
Pumping Gravel-Laden Slurry to an Upstream Manifold of the Tubular Assembly
408
Flowing Gravel-Laden Slurry Through a Gravel Packing Conduit to Gravel Pack an Annulus
410
Dehydrating the Gravel Pack in the Annulus Through a Leak-Off Conduit
412
Gravel Packing the Leak-Off Conduit

FIG. 6

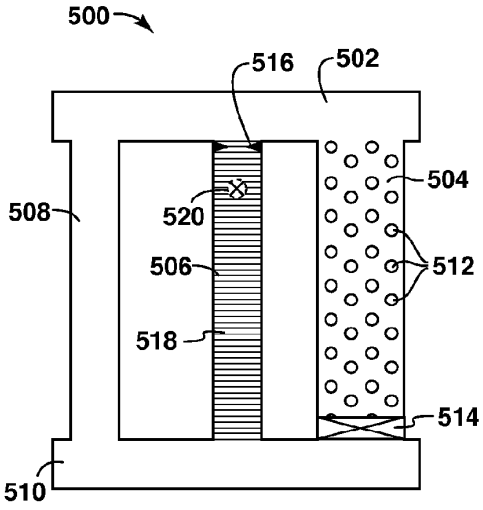

FIG. 7A

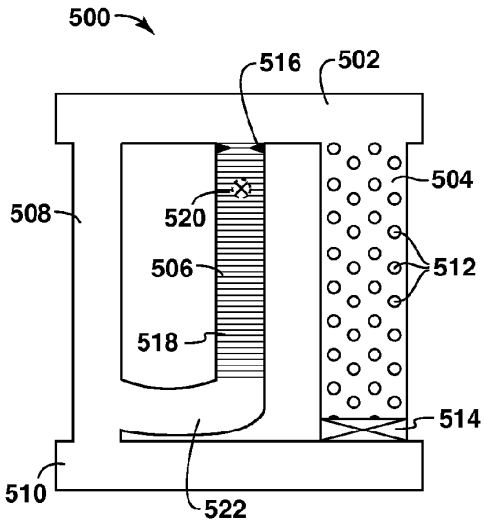

FIG. 7B

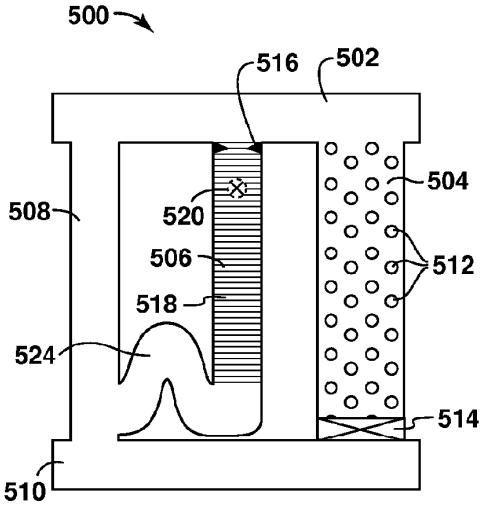

FIG. 7C

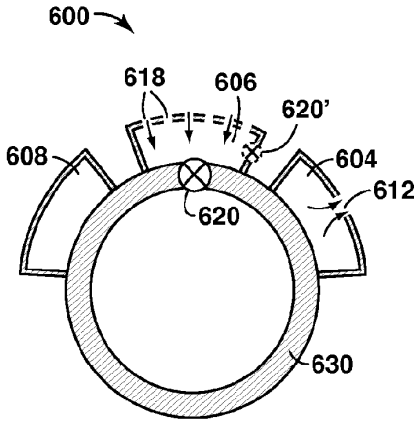

FIG. 8

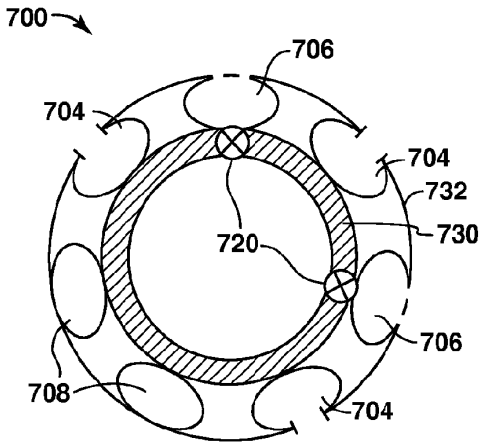
700
706
704
704
732
730
720
706
708
704

FIG. 9

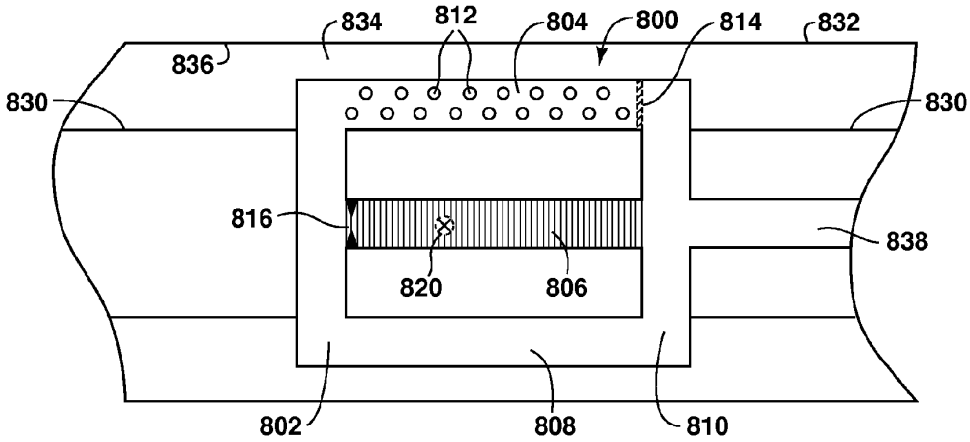
834
812
804
800
814
832
836
830
830
816
838
820
806
802
808
810

FIG. 10

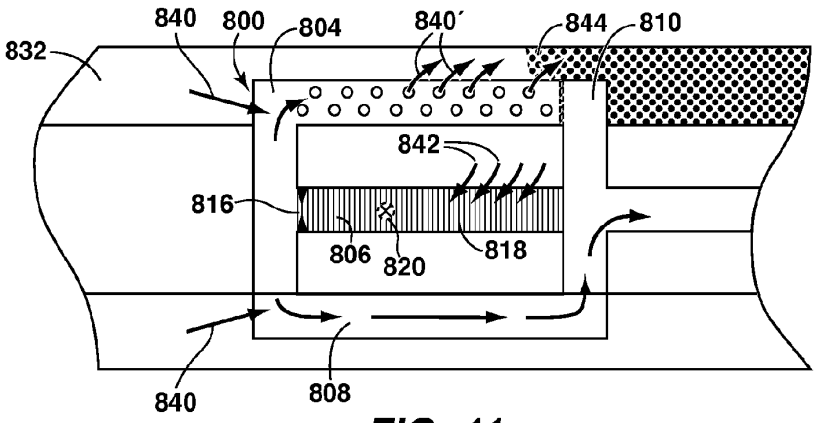

FIG. 11

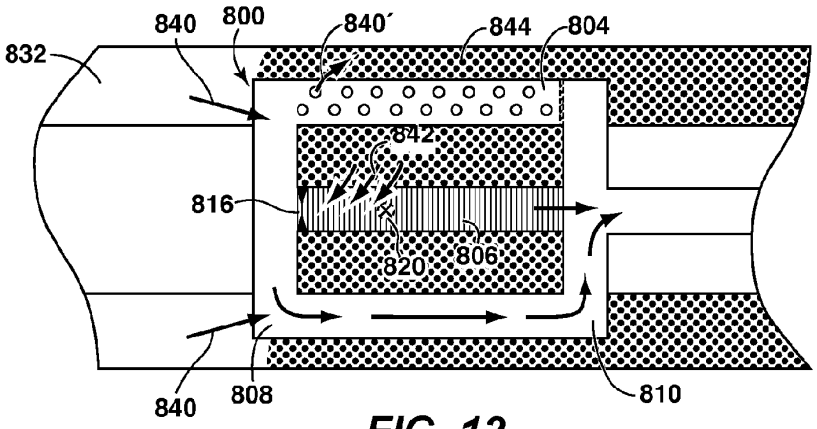

FIG. 12

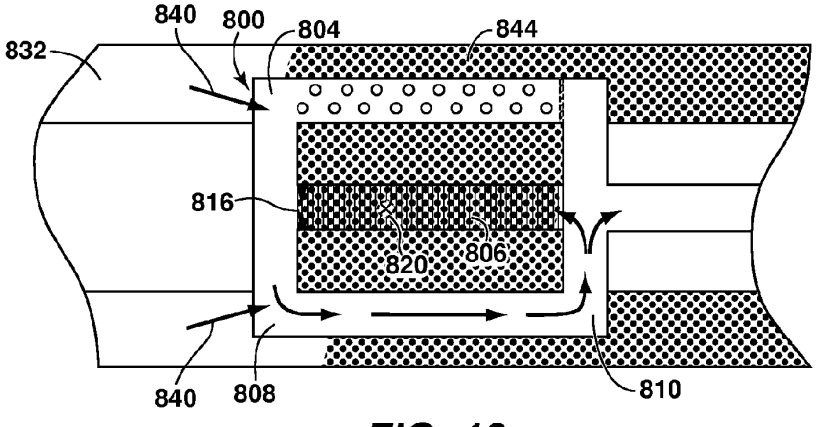

FIG. 13

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(60) **Références à d'autres documents nationaux apparentés :**

( ) **Demande(s) d'extension :**

(71) **Demandeur(s) :** *Halliburton Energy Services, Inc. Corporation* — US.

(72) **Inventeur(s) :** Coffin Maxime Philippe, Penno Andrew David et Bourgneuf Patrick Patchi.

(73) **Titulaire(s) :** Halliburton Energy Services, Inc. Corporation.

(74) **Mandataire(s) :** Withers & Rogers LLP.

(54) SYSTÈME DE TUBE DE DÉRIVATION POUR OPÉRATIONS DE GRAVILLONNAGE DES CRÉPINES.

(57) Un système de dérivation (126) pour un puits de forage (102) comprend un premier ensemble de tubes définissant une première pluralité de trajets de fluide et un second ensemble de tubes définissant une seconde pluralité de trajets de fluide. Le système de dérivation (126) comprend également une chambre de mélange (210) positionnée entre le premier ensemble de tubes et le second ensemble de tubes pour permettre aux boues liquides provenant de la première pluralité de trajets de fluide de se mélanger avant d'acheminer les boues liquides dans le second ensemble de tubes. En outre, le système de dérivation (126) peut être positionné à l'extérieur d'une ou plusieurs crépines à sable (114).

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Description

Titre de l'invention : SYSTÈME DE TUBE DE DÉRIVATION POUR OPÉRATIONS DE GRAVILLONNAGE DES CRÉPINES

Domaine technique

[0001] La présente invention concerne des systèmes de tubes de dérivation utilisés dans des opérations de gravillonnage des crépines de systèmes de puits d'hydrocarbures. Plus précisément, la présente invention concerne des chambres de mélange positionnées entre des sections de tubulure de dérivation dans les systèmes de tubes de dérivation utilisés dans les opérations de gravillonnage des crépines qui sont extérieures aux crépines à sable.

Contexte

[0002] Dans les puits produisant des hydrocarbures, des crépines à sable peuvent être utilisées pour filtrer le sable et d'autres débris en les séparant des fluides de production produits à partir du puits d'hydrocarbures jusqu'à une surface. Pour filtrer davantage le sable et les autres débris en les séparant des fluides de production, un espace annulaire entre la crépine à sable et une paroi du puits d'hydrocarbure peut être bourré de gravier, de sable ou d'agent de soutènement. Le gravier, le sable ou l'agent de soutènement pour un bloc de gravier bourrant l'espace annulaire peuvent être fournis à un emplacement approprié à l'aide de plusieurs tubes de dérivation. Si l'un des tubes de dérivation se bloque ou devient inutilisable, une opération de gravillonnage des crépines peut se poursuivre avec un tube de dérivation moins utilisable. Si vous complétez l'opération de gravillonnage des crépines avec un seul tube de dérivation moins utilisable, vous risquez d'augmenter les pertes de charge par frottement dans les tubes de dérivation restants, ce qui peut limiter la longueur maximale du gravillonnage des crépines pouvant être atteinte.

Brève description des dessins

[0003] La fig 1 est une vue en coupe d'un exemple d'un système de puits qui comprend une série de crépines à sable avec un système de dérivation selon certains aspects de la présente invention.

[0004] La fig 2 est une vue latérale du système de dérivation de la figure 1 positionné à l'extérieur le long d'une partie d'un élément tubulaire d'une crépine à sable selon certains aspects de la présente invention.

[0005] La fig 3 est une vue en perspective d'une chambre de mélange du système de dérivation de la figure 2 selon certains aspects de la présente invention.

[0006] La fig 4 est un organigramme d'un processus de mélange des boues liquides dans le système de dérivation de la figure 1 selon certains aspects de la présente invention.

Description détaillée

[0007] Certains aspects et exemples de l'invention concernent des systèmes de tubes de dérivation utilisés pour des opérations de gravillonnage des crépines dans un puits de forage qui sont positionnés à l'extérieur d'un ensemble de crépine à sable. Le positionnement des tubes de dérivation à l'extérieur de l'ensemble de crépine à sable peut augmenter la taille disponible des tubes de dérivation transportant des boues liquides pour l'opération de gravillonnage des crépines sans occuper d'espace dans un élément tubulaire de l'ensemble de crépine à sable utilisé pour produire des fluides de puits de forage à une surface d'un puits de forage. Dans un exemple, une boue liquide est définie comme un fluide porteur propre ayant des concentrations de particules (par exemple, du gravier, du sable ou un agent de soutènement) en suspension dans le fluide porteur propre. Le système de tube de dérivation peut comprendre une chambre de mélange positionnée à l'extérieur d'un raccord entre deux ensembles de crépine à sable. Dans un autre exemple, la chambre de mélange peut être positionnée à l'extérieur d'un ensemble de crépine à sable ou à tout autre emplacement externe par rapport à l'ensemble de crépine à sable. Les tubes de transmission du système de dérivation peuvent être couplés à des tubes de pontage de la chambre de mélange afin de fournir des trajets pour l'entrée et la sortie de boues liquides vers et depuis la chambre de mélange.

[0008] La création d'une chambre de mélange entre deux sections de tubes de transmission permet de mélanger les boues liquides provenant de plusieurs tubes de transmission parallèles à des intervalles définis. En conséquence, tout déséquilibre dans la concentration boues liquides/ agent de soutènement entre les multiples tubes de transmission parallèles peut être réduit lorsque les fluides boueux provenant des multiples tubes de transmission parallèles sont mélangés dans la chambre de mélange et acheminés dans des ensembles de tubes de transmission parallèles situés en fond de puits. En outre, la chambre de mélange peut permettre le contournement d'un bouchon dans l'un des tubes de transmission résultant d'une accumulation de l'agent de soutènement dans le tube de transmission. Le fait de contourner le bouchon avec la chambre de mélange permet aux boues liquides de continuer à s'écouler par les ensembles de tubes de transmission parallèles situés en fond de puits. Le contournement du bouchon peut réduire les pertes de charge par frottement dans le système de tubes de dérivation et améliorer la longueur maximale de gravillonnage des crépines pouvant être atteinte en rétablissant un nombre total maximal de tubes de transmission utilisables après la chambre de mélange lorsque l'un des tubes de transmission se trouvant le long d'une section précédente d'une crépine à sable a été rendu inutilisable à cause du bouchon.

[0009] L'équilibrage des concentrations en agent de soutènement des tubes de transmission et le contournement d'un tube de transmission bouché peuvent améliorer la fiabilité du système de tubes de dérivation. En conséquence, la mise en œuvre du système de tube de dérivation décrit ici peut entraîner une augmentation de la consistance d'un bloc de gravier autour d'une crépine à sable dans un puits de forage. En outre, le système de tube de dérivation peut augmenter la fiabilité d'une opération de gravillonnage des crépines dans le puits de forage.

[0010] Ces exemples illustratifs sont destinés à familiariser le lecteur avec le sujet général traité ici et ne sont pas destinés à limiter la portée des concepts objet de la description. Les sections suivantes décrivent diverses caractéristiques et divers exemples supplémentaires en référence aux dessins, dans lesquels les mêmes numéros désignent des éléments identiques, et des descriptions directionnelles sont utilisées pour décrire les aspects illustratifs mais, comme les aspects illustratifs, ne doivent pas être utilisées pour limiter la présente invention.

[0011] La figure 1 est une vue en coupe d'un exemple d'un système de puits 100 selon certains aspects. Le système de puits 100 peut comprendre un puits de forage 102 avec une section généralement verticale 104 qui se transforme en une section généralement horizontale 106 s'étendant à travers une formation de terre souterraine 108. Dans un exemple, la section verticale 104 peut s'étendre dans une direction de fond de puits à partir d'une partie du puits de forage 102 comportant un train de tubage cimenté 110. Une colonne tubulaire, telle qu'une colonne de tubes de production 112, peut être installée ou prolongée dans le puits de forage 102.

[0012] Une ou plusieurs crépines à sable 114 et un ou plusieurs dispositifs d'obturation 118 peuvent être interconnectés le long de la colonne de tubes de production 112, par exemple le long des éléments tubulaires 119 posés le long de la section horizontale 106 du puits de forage 102. Les éléments tubulaires 119 peuvent être fixés à une extrémité de fond de puits de la colonne de tubes de production 112. Les dispositifs d'obturation 118 peuvent sceller un espace annulaire 120 situé entre les éléments tubulaires 119 et les parois du puits de forage 102. En conséquence, les fluides 122 peuvent être produits à partir de multiples intervalles ou « zones de production » de la formation 108 à travers des parties isolées de l'espace annulaire 120 entre des paires adjacentes de dispositifs d'obturation 118.

[0013] Dans un exemple, les crépines à sable 114 peuvent être positionnés entre des paires de dispositifs d'obturation 118. Les crépines à sable 114 peuvent être de n'importe quel type de crépine à sable qui sont couplées aux éléments tubulaires 119 de manière mécanique ou avec un matériau adhésif. En fonctionnement, la crépine à sable 114 peut filtrer les fluides 122 s'écoulant dans les éléments tubulaires 119 depuis la formation 108 et à travers l'espace annulaire 120.

[0014] Alors que le système de puits 100 est décrit comme comprenant de multiples éléments tubulaires 119 et de multiples dispositifs d'obturation 118, ces composants décrits ne peuvent pas être utilisés dans tous les exemples dans lesquels la crépine à sable 114 est utilisée. Par exemple, le système de puits 100 peut inclure uniquement un élément tubulaire individuel 119. En outre, un exemple utilisant la crépine à sable 114 peut être mis en œuvre sans que les dispositifs d'obturation 118 n'isolent les différentes sections de la formation 108.

[0015] Pour aider les crépines à sable à filtrer les fluides 122 à partir de la formation 108, le système de puits 100 peut également inclure un système de dérivation 126. Les boues liquides peuvent être déviées de la colonne de tubes de production 112 (par exemple, en utilisant un manchon de fermeture (non représenté)) vers un espace annulaire 124 entre une paroi du puits de forage 102 et la colonne de tubes de production 112 lorsque les boues liquides se trouvent à un emplacement dans la colonne de tubes de production 112 en fond de puits à partir d'un dispositif d'obturation 125 d'un bloc à gravier. À partir de l'espace annulaire 124, les boues liquides sont reçues par le système de dérivation 126 qui fonctionne à la fois pour transmettre les boues liquides plus en profondeur et pour déposer les boues liquides autour des crépines à sable 114 afin de générer un bloc de gravier dans l'espace annulaire 120. Le système de dérivation 126, qui est positionné à l'extérieur des crépine à sable 114, est décrit plus en détail ci-dessous en relation avec les figures 2 à 4. Le bloc de gravier généré dans l'espace annulaire 120 par le système de dérivation 126 peut aider la crépine à sable 114 à empêcher la production de fines particules ou de sable à partir de la formation 108. Par exemple, le bloc de gravier dans l'espace annulaire 120 peut empêcher la migration des matériaux de formation de la formation 108 dans l'élément tubulaire 119. En outre, du fait que le système de dérivation 126 est positionné à l'extérieur des crépines à sable 114, les tubes associés au système de dérivation 126 peuvent être plus grands, car les tubes n'occupent aucun espace utilisé pour produire le fluide de production à partir du puits de forage 102.

[0016] La figure 2 est une vue latérale du système de dérivation 126 positionné extérieurement le long d'une partie de l'élément tubulaire 119 comprenant les crépines à sable 114 selon certains aspects. Comme illustré, des parties de l'élément tubulaire 119 entre les dispositifs d'obturation 118 peuvent comprendre de multiples sections de crépines à sable 202a et 202b. En conséquence, le système de dérivation 126 peut comprendre des ensembles de tubes de transport 204a et 204b et de tubes de garniture 206a et 206b qui correspondent aux sections de crépines à sable respectives 202a et 202b. Pour couvrir un raccord 208 entre les sections de crépines à sable 202a et 202b, une chambre de mélange 210 peut être installée entre les tubes de transport 204a et les tubes de transport 204b. La chambre de mélange 210 peut également être positionnée à

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d'autres endroits, par exemple directement au-dessus d'une des crépines à sable 114.

[0017] Dans un exemple, les tubes de transport 204a peuvent recevoir la boue provenant de l'espace annulaire 124 ou d'une chambre de mélange supérieure supplémentaire (non représentée). Lorsque les boues liquides pénètrent dans les tubes de transport 204a, une partie des boues liquides peut être déviée dans les tubes de garniture 206a. Les boues liquides déviées dans les tubes de garniture 206a peuvent sortir des tubes de garniture 206a au niveau des distributeurs de boues liquides 212a. Dans un exemple, les tubes de transport 204a comprennent une zone transversale supérieure à celle des tubes de garniture 206a.

[0018] Les distributeurs de boues liquides 212a peuvent être des trous ou des buses installés sur une longueur des tubes de garniture 206a. Dans un exemple, les distributeurs de boues liquides 212a peuvent permettre aux boues liquides de sortir des tubes de garniture 206a de sorte que les boues liquides remplissent l'espace annulaire 120 entourant l'élément tubulaire 119. Les boues liquides qui remplissent l'espace annulaire 120 peuvent être appelés un bloc de gravier. De plus, une partie de l'élément tubulaire 119 positionnée sous les tubes de garniture 206a (par exemple sur un côté de l'élément tubulaire 119) peut être un emplacement des crépines à sable 114. Ainsi, le bloc de gravier distribué par les tubes de garniture 206a peut fonctionner conjointement avec les crépines à sable 114 pour filtrer les débris indésirables provenant des fluides 122 produits à travers la colonne de tubes de production 112.

[0019] En poursuivant l'exemple, le système de dérivation 126 peut inclure les tubes de transport 204b positionnés plus bas dans le trou de forage 102 que les tubes de transport 204a. Les tubes de transport 204b peuvent recevoir des boues liquides mélangées provenant de la chambre de mélange 210 et la chambre de mélange 210 peut recevoir des boues liquides non mélangées provenant des tubes de transport individuels 204a. En raison du positionnement relatif des tubes de transport 204a dans le puits de forage 102, une fuite de fluide propre provenant des boues liquides peut être plus fréquente dans un tube de transport 204a avec des distributeurs de boues liquides 212a positionnés dans une direction 214 vers une paroi inférieure du puits de forage 102 que les distributeurs de boues liquides 212a positionnés dans une direction 216 vers une paroi supérieure du puits de forage 102. La fuite de fluide propre supplémentaire subie par le tube de transport 204a alimentant les distributeurs de boues liquides 212a dans la direction 214 peut entraîner une différence de concentration de l'agent de soutènement entre les boues liquides dans les deux tubes de transport parallèles 204a, en particulier sur une longueur d'un système de dérivation complet 126. En conséquence, lorsque les boues liquides non mélangées pénètrent dans la chambre de mélange 210 à différentes concentrations d'agent de soutènement provenant des tubes de transport 204a, la chambre de mélange 210 peut mélanger les boues liquides

non mélangées afin de fournir une concentration d'agent de soutènement plus uniforme dans des boues liquides mélangées fournies aux tubes de transport 204b.

[0020] Le mélange des boues liquides au niveau de la chambre de mélange 210 peut fournir à chaque nouvelle section de fond de puits des tubes de transport 204b des concentrations similaires de l'agent de soutènement dans les boues liquides. En raison du mélange des boues liquides dans la chambre de mélange 210, les boues liquides dans une ramification des tubes de transport 204b peuvent éviter de devenir plus chargées d'agent de soutènement qu'une autre ramification des tubes de transport 204b en raison d'une fuite de fluide propre basée sur une orientation des distributeurs de boues liquides 212. En conséquence, le risque d'obturation prématurée des tubes de transport 204 avec l'agent de soutènement est réduit par rapport à un système de dérivation sans la chambre de mélange 210.

[0021] En outre, la chambre de mélange 210 peut fournir une dérivation de boues liquides lorsque l'un des tubes de transport 204 est bouché avec un agent de soutènement. Par exemple, lorsque l'un des tubes de transport 204 est bouché avec un agent de soutènement, le tube de transport restant 204a peut toujours acheminer les boues liquides dans la chambre de mélange 210. Bien que la chambre de mélange 210 ne puisse pas mélanger les boues liquides provenant des deux tubes de transport 204a dans cet exemple, la chambre de mélange 210 peut fournir aux deux tubes de transport 204b les boues liquides pour une distribution continue des boues liquides afin de générer des blocs de gravier aux emplacements de fond de puits de l'espace annulaire 120.

[0022] Comme avec les tubes de transport 204a, lorsque les boues liquides se déplacent dans les tubes de transport 204b depuis la chambre de mélange 210, une partie des boues liquides peut être déviée dans les tubes de garniture 206b. Les boues liquides déviées dans les tubes de garniture 206b peuvent sortir des tubes de garniture 206b au niveau des distributeurs de boues liquides 212b. Dans un exemple, les tubes de transport 204b comprennent une zone transversale supérieure à celle des tubes de garniture 206b.

[0023] Les distributeurs de boues liquides 212b peuvent être des trous ou des buses installés sur une longueur des tubes de garniture 206b. Dans un exemple, les distributeurs de boues liquides 212b peuvent permettre aux boues liquides de sortir des tubes de garniture 206b de sorte que les boues liquides puissent remplir l'espace annulaire 120 entourant l'élément tubulaire 119. Les boues liquides et le gravier déposé qui remplit l'espace annulaire 120 peuvent être appelés un bloc de gravier. De plus, une partie de l'élément tubulaire 119 positionnée sous les tubes de garniture 206b (par exemple sur le côté de l'élément tubulaire des tubes de garniture 206b) peut être un emplacement des crépines à sable 114. Ainsi, le bloc de gravier distribué par les tubes de garniture 206b peut fonctionner conjointement avec les crépines à sable 114 pour filtrer les débris indésirables provenant des fluides 122 produits à travers la colonne de tubes de

production 112.

[0024] En outre, la chambre de mélange 210 peut être couplée de manière fluide aux tubes de transport 204a et 204b en utilisant des tubes de pontage 218a et 218b. Les tubes de pontage 218a et 218b peuvent se télescoper ou être autrement réglables de sorte que la chambre de mélange 210 et les tubes de pontage 218a et 218b couvrent une distance 220 entre les tubes de transport 204a et les tubes de transport 204b. En outre, alors que la figure 2 représente le système de dérivation 126 comprenant deux tubes de transport parallèles 204a fixés aux deux tubes de pontage parallèles 218a de la chambre de mélange 210 et deux tubes de transport parallèles 204b fixés aux deux tubes de pontage parallèles 218b de la chambre de mélange 210, plus ou moins de tubes de transport 204 et de tubes de pontage 218 peuvent être inclus dans le système de dérivation 126. Par exemple, les deux tubes de transport 204a peuvent fournir des boues liquides à la chambre de mélange 210, mais la chambre de mélange 210 ne peut acheminer les boues liquides mélangées qu'à un seul tube de transport 204b. Dans un autre exemple, le système de dérivation 126 peut comprendre trois tubes de transport 204a ou plus qui fournissent des boues liquides à la chambre de mélange 210, et le système de dérivation 126 peut également inclure trois tubes de transport 204b ou plus qui reçoivent les boues liquides mélangées provenant de la chambre de mélange 210.

[0025] Dans un exemple supplémentaire, un ou plusieurs systèmes de dérivation supplémentaires 126 peuvent être positionnés autour de l'élément tubulaire 119. Dans un tel exemple, des ensembles supplémentaires de tubes de transport 204a et 204b, des ensembles de tubes de garniture 206a et 206b, des ensembles de tubes de pontage 218a et 218b et des chambres de mélange 210 sont positionnés le long de l'élément tubulaire 119 pour une distribution de boues liquides autour des crépines à sable 114 de l'élément tubulaire 119. D'autres nombres et agencements de tubes de transport 204, de tubes de garniture 206, de tubes de pontage 218 et de chambre de mélange 210 sont également envisagés dans le cadre de la présente invention.

[0026] Alors que la chambre de mélange 210 est généralement décrite comme étant positionnée entre les tubes de pontage 218a et 218b et comme couvrant le raccord 208 entre les sections de crépines à sable 202a et 202b, la chambre de mélange 210 peut être positionnée à d'autres emplacements le long du système de dérivation 126. Dans un exemple, la chambre de mélange 210 peut être intégrée aux tubes de transport 204 (par exemple, à une position qui divise par deux les tubes de transport 204) tandis que les tubes de pontage 218 couvrent le raccord 208 entre les sections de crépines à sable 202a et 202b. Dans un autre exemple, la chambre de mélange 210 peut être intégrée aux tubes de transport 204 (par exemple, à la position qui divise par deux les tubes de transport 204) et une chambre de mélange supplémentaire 210 peut être positionnée entre les tubes de pontage 218a et 218b et couvrant le raccord 208 entre les sections de

crépine à sable 202a et 202b.

[0027] La figure 3 est une vue en perspective de la chambre de mélange 210 du système de dérivation 126 selon certains aspects de la présente description. Comme discuté en détail ci-dessus en ce qui concerne la figure 2, la chambre de mélange 210 peut inclure ou autrement être fixée à des tubes de pontage 218a et 218b. Dans un autre exemple, la chambre de mélange 210 peut être couplée directement à des tubes de transport 204a et 204b au-dessus de l'une des crépines à sable 114, par exemple. Les tubes de pontage 218a et 218b peuvent être extensibles de manière télescopique ou être réglés d'une autre manière, de sorte que les extrémités 302 des tubes de pontage 218a et 218b puissent s'accoupler avec les extrémités des tubes de transport 204a et 204b. Par exemple, les tubes de pontage 218a et 218b peuvent comprendre chacun deux tubes concentriques ou plus qui fournissent une fonctionnalité télescopique des tubes de pontage 218a et 218b tout en maintenant l'intégrité structurelle des tubes de pontage 218a et 218b lors de la transmission de boues liquides vers et depuis la chambre de mélange 210. Dans un ou plusieurs exemples, les tubes de pontage 218a et 218b peuvent être des tubes cylindriques ou des tubes rectangulaires. En outre, les tubes de pontage 218a et 218b peuvent être couplés aux tubes de transport 204a et 204b en utilisant une connexion filetée, un connecteur rapide ou tout autre type de connecteur approprié.

[0028] Un logement 303 de la chambre de mélange 210 peut couvrir un espace entre les tubes de pontage 218a et 218b sous n'importe quelle forme. Dans un autre exemple, le logement 303 peut s'étendre entre deux tubes de transport 204a ou 204b directement sur l'une des crépines à sable 114. Comme illustré, un contour aérien du logement 303 est rectangulaire. Cependant, d'autres formes de contour aérien sont également envisagées (par exemple, des bords circulaires, de forme ovale, arrondis, etc.). En outre, l'exemple du logement 303 représenté à la figure 3 comprend une surface externe arrondie 304 (c'est-à-dire la surface la plus proche de la paroi du puits de forage 102) et une surface interne arrondie 306 (c'est-à-dire la surface la plus proche de l'élément tubulaire 119). Un rayon d'un arc suivi par la surface externe 304 peut être tel que la surface externe 304 maintienne une distance minimale constante entre la surface externe 304 et l'élément tubulaire 119. De même, un rayon d'un arc suivi par la surface interne 306 peut également maintenir une distance minimale constante entre la surface interne 306 et l'élément tubulaire 119. Cependant, dans d'autres modes de réalisation, la surface externe 304 et la surface interne 306 peuvent ne comporter aucune courbure. Par exemple, la surface externe 304 et la surface interne 306 peuvent être plates de sorte que le logement 303 a la forme d'un prisme rectangulaire.

[0029] Dans un ou plusieurs exemples, un intérieur de la chambre de mélange 210 peut être vide. Autrement dit, la chambre de mélange 210 peut comprendre une cavité intérieure

creuse. Dans un autre exemple, des aubes ou des déflecteurs peuvent être positionnés à l'intérieur de la chambre de mélange 210 pour favoriser le mélange des boues liquides reçues par la chambre de mélange 210 après s'être déplacées d'orifices d'entrée 308 le long de trajets de fluide d'entrée 309. Lors du mélange dans la chambre de mélange 210, les boues liquides mélangées peuvent se déplacer vers les orifices de sortie 310 le long de trajets de fluide de sortie 312 en direction des tubes de transport 204b positionnés en fond de puits depuis la chambre de mélange 210.

[0030] La figure 4 est un organigramme d'un processus 400 pour mélanger les boues liquides dans le système de dérivation 126 qui est monté de manière externe sur les sections de crépine à sable 202a et 202b selon certains aspects. Au bloc 402, le processus 400 implique la réception de boues liquides provenant de tubes de dérivation séparés (par exemple, les tubes de pontage 218a) du système de dérivation 126 au niveau de la chambre de mélange 210 qui est positionnée à l'extérieur du raccord 208 entre les sections de crépine à sable 202a et 202b. Comme discuté ci-dessus à propos de la figure 2, les boues liquides reçues des tubes de dérivation séparés peuvent inclure divers rapports fluide propre/agent de soutènement. En d'autres termes, l'un des tubes de dérivation peut produire des boues liquides ayant subi une fuite de fluide propre plus importante que l'autre tube de dérivation. Dans un autre exemple, l'un des tubes de dérivation peut ne recevoir aucun boue liquide provenant d'un tube de transport associé 204a qui est bouché par une accumulation d'agent de soutènement (par exemple, en raison d'une fuite de fluide propre). Dans l'un ou l'autre exemple, les tubes de dérivation séparés peuvent fournir des boues liquides en quantités variables (c'est-à-dire des débits différents) et divers rapports fluide propre/agent de soutènement.

[0031] Au bloc 404, le processus 400 implique de permettre aux boues liquides provenant des multiples tubes de dérivation (par exemple, les tubes de pontage 218a) de se mélanger au niveau de la chambre de mélange 210. Par exemple, les boues liquides peuvent entrer dans la chambre de mélange à partir des multiples tubes de pontage 218a à différents débits et à différentes concentrations d'agent de soutènement. Une fois dans la chambre de mélange 210, on favorise le mélange des liquides boueux provenant des multiples tubes de pontage 218a. Un espace ouvert qui permet au fluide boueux de se mélanger peut généralement favoriser ce mélange. Des aubes, des déflecteurs ou d'autres protubérances peuvent également être positionnés dans la chambre de mélange 210 pour générer des turbulences qui favorisent davantage le mélange.

[0032] Au bloc 406, le processus 400 implique l'acheminement des boues liquides mélangées dans un ou plusieurs tubes de dérivation supplémentaires (par exemple, les tubes de pontage 218b). Lorsque les boues liquides se mélangent dans la chambre de

mélange 210, les boues liquides sont transportées dans les tubes de pontage 218b. Au niveau des tubes de pontage 218b, les boues liquides mélangées peuvent être acheminées dans les tubes de transport 204b. Dans un exemple, les boues liquides mélangées fournies aux tubes de pontage 218b peuvent avoir des concentrations en agent de soutènement similaires et des débits similaires du fait du mélange des boues liquides dans la chambre de mélange 210.

[0033] Lorsque les boues liquides mélangées sont fournies aux tubes de transport 204b, une partie des boues liquides mélangées dans chacun des tubes de transport 204b peut être redirigée vers les tubes de garniture 206b. Au niveau des tubes de garniture 206b, les boues liquides mélangées sont réparties dans l'espace annulaire 120 entre l'élément tubulaire 119 et une paroi du puits de forage 102. Les boues liquides mélangées distribuées génèrent un bloc de gravier dans l'espace annulaire 120.

[0034] Selon certains aspects, des systèmes, des dispositifs et des procédés de mise en œuvre et d'exploitation d'un système de dérivation pour des opérations de gravillonnage de crépines dans un puits de forage sont fournis selon un ou plusieurs des exemples suivants :

[0035] Telle qu'utilisée ci-dessous, toute référence à une série d'exemples doit être comprise comme faisant référence de manière séparée à chacun de ces exemples (par exemple, « Exemples 1 à 4 » doit être compris comme « Exemples 1, 2, 3 ou 4 »).

[0036] L'exemple 1 est un système de dérivation pour un puits de forage, le système de dérivation comprenant : un premier ensemble de tubes définissant une première pluralité de trajets de fluide ; un second ensemble de tubes définissant une seconde pluralité de trajets de fluide ; et une chambre de mélange positionnée entre le premier ensemble de tubes et le second ensemble de tubes pour permettre aux boues liquides provenant de la première pluralité de trajets de fluide de se mélanger avant d'acheminer les boues liquides dans le second ensemble de tubes, le système de dérivation pouvant être positionné à l'extérieur d'une ou plusieurs crépines à sable.

[0037] L'exemple 2 est le système de dérivation de l'exemple 1, dans lequel la chambre de mélange comprend un premier ensemble de tubes de pontage fixés au premier ensemble de tubes et un second ensemble de tubes de pontage fixés au second ensemble de tubes.

[0038] L'exemple 3 est le système de dérivation des exemples 1 à 2, dans lequel le premier ensemble de tubes et le second ensemble de tubes comprennent des tubes de transport pouvant être positionnés pour transporter les boues liquides à travers le système de dérivation.

[0039] L'exemple 4 est le système de dérivation des exemples 1 à 3, comprenant en outre : un premier ensemble de tubes de transport et un second ensemble de tubes de transport, le premier ensemble de tubes et le second ensemble de tubes étant des tubes

de pontage qui se raccordent au premier ensemble de tubes de transport et au second ensemble de tubes de transport.

[0040] L'exemple 5 est le système de dérivation des exemples 1 à 4, dans lequel le premier ensemble de tubes comprend : au moins deux tubes de transport pouvant être positionnés pour transporter les boues liquides dans la chambre de mélange ; et au moins deux tubes de garniture pouvant être positionnés pour transporter les boues liquides dans un espace annulaire situé entre les une ou plusieurs crépines à sable et une paroi du puits de forage.

[0041] L'exemple 6 est le système de dérivation de l'exemple 5, dans lequel le second ensemble de tubes comprend : au moins deux tubes de transport supplémentaires pouvant être positionnés pour recevoir des boues liquides mélangées provenant de la chambre de mélange ; et au moins deux tubes de garniture supplémentaires pouvant être positionnés pour transporter les boues liquides mélangées vers l'espace annulaire situé entre les une ou plusieurs crépines à sable et la paroi du puits de forage.

[0042] L'exemple 7 est le système de dérivation des exemples 5 à 6, dans lequel les au moins deux tubes de garniture comprennent une première section transversale avec une première zone en coupe transversale, et les au moins deux tubes de transport comprennent une seconde section transversale avec une seconde zone de section transversale qui est plus grande que la première zone de section transversale.

[0043] L'exemple 8 est le système de dérivation des exemples 5 à 7, dans lequel un premier tube de garniture des deux tubes de garniture est couplé de manière fluide à un premier tube de transport des deux tubes de transport, et un second tube de garniture des deux tubes de garniture est couplé de manière fluide à un second tube de transport des deux tubes de transport.

[0044] L'exemple 9 est le système de dérivation des exemples 1 à 8, dans lequel la chambre de mélange peut être positionnée à l'extérieur d'un raccord entre deux crépines à sable des une ou plusieurs crépines à sable.

[0045] L'exemple 10 est une chambre de mélange pour un système de dérivation destiné à acheminer des boues liquides dans des crépines à sable, la chambre de mélange comprenant : un premier orifice d'entrée pour un premier tube définissant un premier trajet de fluide d'entrée ; un second orifice d'entrée pour un deuxième tube définissant un second trajet de fluide d'entrée ; un premier orifice de sortie pour un troisième tube définissant un premier trajet de fluide de sortie ; un second orifice de sortie pour un quatrième tube définissant un second trajet de fluide de sortie ; et un logement définissant une zone dans laquelle le fluide provenant du premier trajet de fluide d'entrée et du second trajet de fluide d'entrée peut être mélangé avant de s'écouler à travers le premier orifice de sortie ou le second orifice de sortie, la chambre de mélange pouvant être positionnée à l'extérieur d'une ou plusieurs crépines à sable.

[0046] L'exemple 11 représente la chambre de mélange de l'exemple 10, dans laquelle la chambre de mélange peut être positionnée sur un raccord entre deux crépines à sable des une ou plusieurs crépines à sable.

[0047] L'exemple 12 est la chambre de mélange des exemples 10 à 11, dans laquelle le premier orifice d'entrée et le second orifice d'entrée peuvent être positionnés pour recevoir des boues liquides en provenance d'un premier tube de transport et d'un deuxième tube de transport, et le premier orifice de sortie et le second orifice de sortie peuvent être positionnés pour transmettre les boues liquides à un troisième tube de transport et à un quatrième tube de transport.

[0048] L'exemple 13 est la chambre de mélange des exemples 10 à 12, dans laquelle le premier tube, le deuxième tube, le troisième tube et le quatrième tube comprennent des tubes de pontage télescopiques qui peuvent être positionnés pour s'étendre entre le logement et un ensemble de tubes de transport.

[0049] L'exemple 14 est la chambre de mélange des exemples 10 à 13, dans laquelle le logement comprend une courbure de surface interne et une courbure de surface externe, chacune pouvant être positionnée de manière à maintenir une distance minimale constante d'une surface interne et d'une surface externe du logement par rapport aux une ou plusieurs crépines à sable.

[0050] L'exemple 15 est la chambre de mélange des exemples 10 à 14, dans laquelle le premier orifice de sortie et le second orifice de sortie sont positionnés par rapport au logement de sorte que le premier orifice de sortie et le second orifice de sortie reçoivent des quantités sensiblement similaires des boues liquides provenant du logement.

[0051] L'exemple 16 est la chambre de mélange des exemples 10 à 15, dans laquelle le logement comprend des aubes ou des déflecteurs positionnés dans la zone pour favoriser le mélange du fluide provenant du premier trajet de fluide d'entrée et du second trajet de fluide d'entrée.

[0052] L'exemple 17 est un procédé comprenant : le pompage de boues liquides à travers des tubes séparés vers une chambre de mélange ; le fait de permettre aux boues liquides provenant des tubes séparés de se mélanger dans la chambre de mélange qui est à l'extérieur d'une ou de plusieurs crépines ; et l'acheminement des boues liquides mélangées dans un ou plusieurs tubes de sortie à travers des orifices de sortie de la chambre de mélange.

[0053] L'exemple 18 est le procédé de l'exemple 17, dans lequel l'acheminement des boues liquides mélangées dans les un ou plusieurs tubes de sortie comprend l'acheminement des boues liquides mélangées dans un ou plusieurs tubes de transport et dans un ou plusieurs tubes de garniture.

[0054] L'exemple 19 est le procédé des exemples 17 à 18, comprenant en outre : le bourrage

d'un espace annulaire entre les une ou plusieurs crépines et une paroi d'un puits de forage avec les boues liquides mélangées.

[0055] L'exemple 20 est le procédé des exemples 17 à 19, dans lequel les tubes séparés comprennent au moins deux tubes de pontage couplés entre la chambre de mélange et au moins deux tubes de transport d'un système de dérivation.

[0056] La description qui précède de certains exemples, y compris les exemples illustrés, n'a été présentée qu'à des fins d'illustration et de description et n'est pas destinée à être exhaustive ni à limiter l'invention aux formes précises décrites. De nombreuses modifications, adaptations et utilisations de celles-ci seront évidentes pour le spécialiste du domaine sans sortir de la portée de l'invention.

Revendications

[Revendication 1] Système de dérivation (126) pour un puits de forage (102), le système de dérivation (126) comprenant :
un premier ensemble de tubes définissant une première pluralité de trajets de fluide ;
un second ensemble de tubes définissant une seconde pluralité de trajets de fluide ; et
une chambre de mélange (210) positionnée entre le premier ensemble de tubes et le second ensemble de tubes pour permettre aux boues liquides provenant de la première pluralité de trajets de fluide de se mélanger avant d'acheminer les boues liquides dans le second ensemble de tubes, le système de dérivation (126) pouvant être positionné à l'extérieur d'une ou plusieurs crépines à sable (114).

[Revendication 2] Système de dérivation (126) selon la revendication 1, dans lequel la chambre de mélange (210) comprend un premier ensemble de tubes de pontage (218a) fixés au premier ensemble de tubes et un second ensemble de tubes de pontage (218b) fixés au second ensemble de tubes, et dans lequel le premier ensemble de tubes de pontage (218a) et le second ensemble de tubes de pontage (218b) comprennent des tubes de pontage télescopiques qui s'étendent entre la chambre de mélange (210) et le premier ensemble de tubes et le second ensemble de tubes.

[Revendication 3] Système de dérivation (126) selon l'une quelconque des revendications 1 à 2, dans lequel le premier ensemble de tubes et le second ensemble de tubes comprennent des tubes de transport (204a, 204b) pouvant être positionnés pour transporter les boues liquides à travers le système de dérivation (126).

[Revendication 4] Système de dérivation (126) selon l'une quelconque des revendications 1 à 3, comprenant en outre :
un premier ensemble de tubes de transport (204a) et un second ensemble de tubes de transport (204b), dans lequel le premier ensemble de tubes et le second ensemble de tubes sont des tubes de pontage (218a, 218b) se raccordant au premier ensemble de tubes de transport (204a) et au second ensemble de tubes de transport (204b).

[Revendication 5] Système de dérivation (126) selon l'une quelconque des revendications 1 à 4, dans lequel le premier ensemble de tubes comprend :
au moins deux tubes de transport (204a, 204b) pouvant être positionnés pour transporter les boues liquides dans la chambre de mélange (210); et

au moins deux tubes de garniture (206a, 206b) pouvant être positionnés pour transporter les boues liquides dans un espace annulaire (124) situé entre les une ou plusieurs crépines à sable (114) et une paroi du puits de forage (102).

[Revendication 6] Système de dérivation (126) selon la revendication 5, dans lequel le second ensemble de tubes comprend :
au moins deux tubes de transport supplémentaires (204a, 204b) pouvant être positionnés pour recevoir des boues liquides mélangées provenant de la chambre de mélange (210), dans lequel les au moins deux tubes de transport supplémentaires (204a, 204b) sont positionnés par rapport à la chambre de mélange (210) de sorte que chacun des au moins deux tubes de transport supplémentaires (204a, 204b) reçoive des quantités sensiblement similaires de boues liquides mélangées provenant de la chambre de mélange (210); et
au moins deux tubes de garniture supplémentaires (206a, 206b) pouvant être positionnés pour transporter les boues liquides mélangées dans l'espace annulaire situé (124) entre les une ou plusieurs crépines à sable (114) et la paroi du puits de forage (102).

[Revendication 7] Système de dérivation (126) selon la revendication 5, dans lequel les au moins deux tubes de garniture (206a, 206b) comprennent une première section transversale avec une première zone de section transversale, et les au moins deux tubes de transport (204a, 204b) comprennent une seconde section transversale avec une seconde zone de section transversale qui est plus grande que la première zone de section transversale.

[Revendication 8] Système de dérivation (126) selon la revendication 5, dans lequel un premier tube de garniture (206a) des deux tubes de garniture (206a, 206b) est couplé de manière fluide à un premier tube de transport (204a) des deux tubes de transport (204a, 204b), et un second tube de garniture (206b) des deux tubes de garniture (206a, 206b) est couplé de manière fluide à un second tube de transport (204b) des deux tubes de transport (204a, 204b).

[Revendication 9] Système de dérivation (126) selon l'une quelconque des revendications 1 à 8, dans lequel la chambre de mélange (210) peut être positionnée à l'extérieur d'un raccord (208) entre deux crépines à sable (202a, 202b) des une ou plusieurs crépines à sable (114).

[Revendication 10] Système de dérivation (126) selon l'une quelconque des revendications

1 à 9, dans lequel la chambre de mélange (210) comprend :
un premier orifice d'entrée (308) pour un premier tube du premier ensemble de tubes définissant un premier trajet de fluide d'entrée de la première pluralité de trajets de fluide ;
un second orifice d'entrée (308) pour un deuxième tube du premier ensemble de tubes définissant un second trajet de fluide d'entrée de la première pluralité de trajets de fluide ;
un premier orifice de sortie (310) pour un troisième tube du second ensemble de tubes définissant un premier trajet de fluide de sortie de la seconde pluralité de trajets de fluide ;
un second orifice de sortie (310) pour un quatrième tube du second ensemble de tubes définissant un second trajet de fluide de sortie de la seconde pluralité de trajets de fluide ; et
un logement (303) définissant une zone dans laquelle un fluide provenant du premier trajet de fluide d'entrée et du second trajet de fluide d'entrée peut être mélangé avant de s'écouler à travers le premier orifice de sortie (310) ou le second orifice de sortie (310), dans lequel le logement comprend une courbure de surface interne (306) et une courbure de surface externe (304) qui peuvent chacune être positionnées pour maintenir une distance minimale constante d'une surface intérieure (306) et d'une surface extérieure du logement par rapport aux une ou plusieurs crépines à sable (114).

[Revendication 11] Système de dérivation (126 selon la revendication 10, dans lequel le logement (303) comprend des aubes ou des déflecteurs positionnés dans la zone pour favoriser le mélange du fluide provenant du premier trajet de fluide d'entrée et du second trajet de fluide d'entrée.

[Revendication 12] Procédé de dérivation, pour un puits de forage, le procédé comprenant :
le pompage des boues liquides à travers des tubes séparés vers une chambre de mélange (210);
le fait de permettre aux boues liquides provenant des tubes séparés de se mélanger dans la chambre de mélange (210) qui est à l'extérieur d'une ou plusieurs crépines (114); et
l'acheminement des boues liquides mélangées dans un ou plusieurs tubes de sortie à travers les orifices de sortie (310) de la chambre de mélange (210).

[Revendication 13] Procédé de dérivation, pour un puits de forage, selon la revendication 12, dans lequel l'acheminement des boues liquides mélangées dans les un ou plusieurs tubes de sortie comprend l'acheminement des boues

liquides mélangées dans un ou plusieurs tubes de transport (204a, 204b) et dans un ou plusieurs tubes de garniture (206a, 206b).

[Revendication 14] Procédé de dérivation, pour un puits de forage, selon l'une quelconque des revendications 12 à 13, comprenant en outre :
le bourrage d'un espace annulaire (124) entre les une ou plusieurs crépines (114) et une paroi du puits de forage (102) avec les boues liquides mélangées.

[Revendication 15] Procédé de dérivation, pour un puits de forage, selon l'une quelconque des revendications 12 à 14, dans lequel les tubes séparés comprennent au moins deux tubes de pontage (218a, 218b) couplés entre la chambre de mélange (210) et au moins deux tubes de transport (204a, 204b) d'un système de dérivation (126).

[Fig. 1]

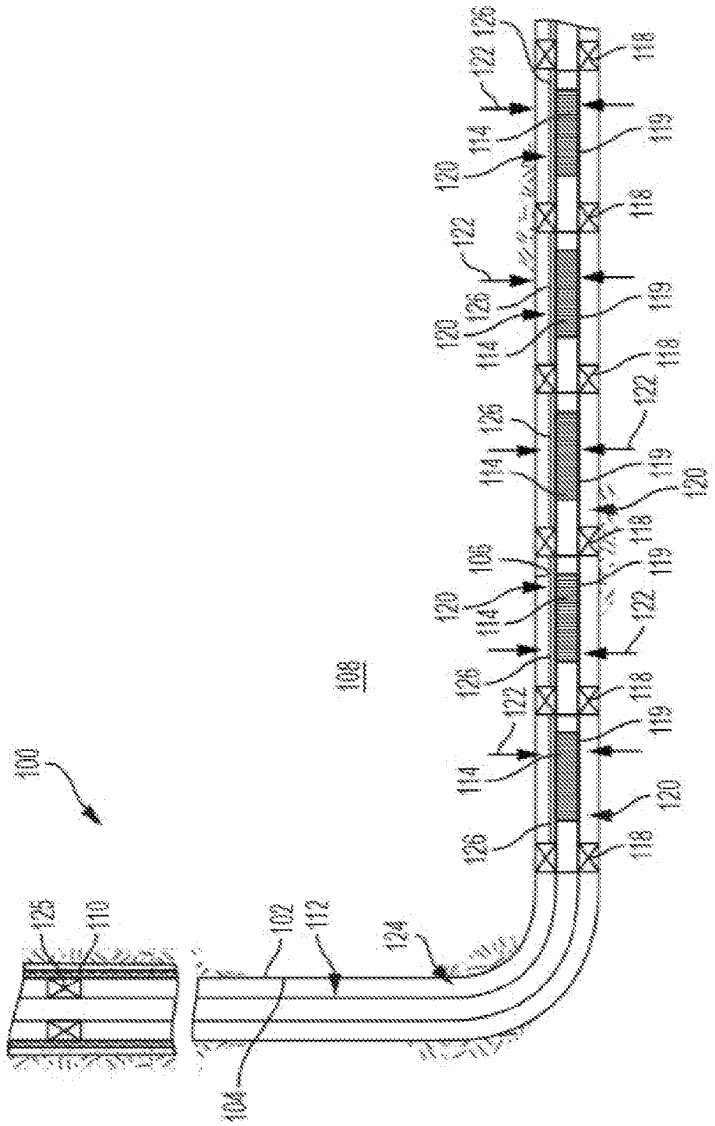

FIG. 1

[Fig. 2]

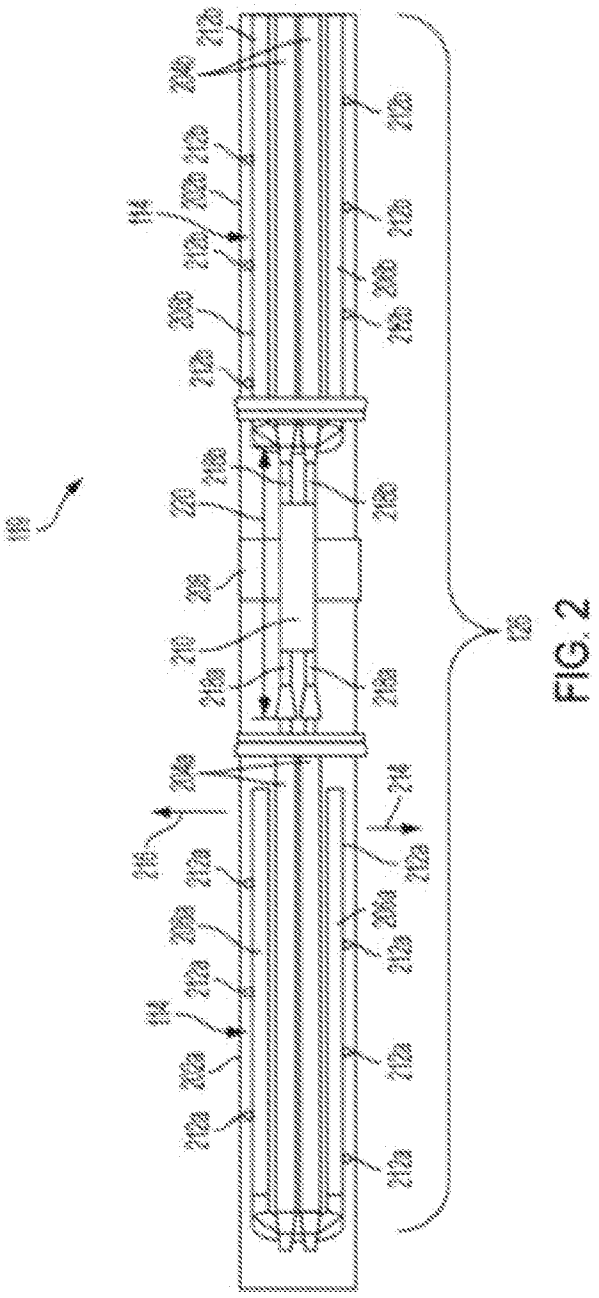

FIG. 2

[Fig. 3]

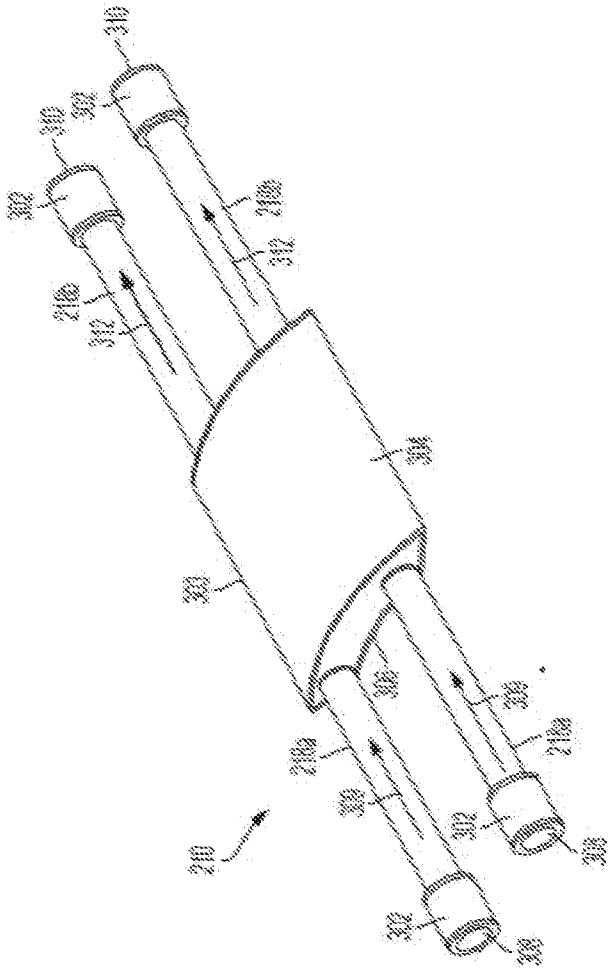

FIG. 3

[Fig. 4]

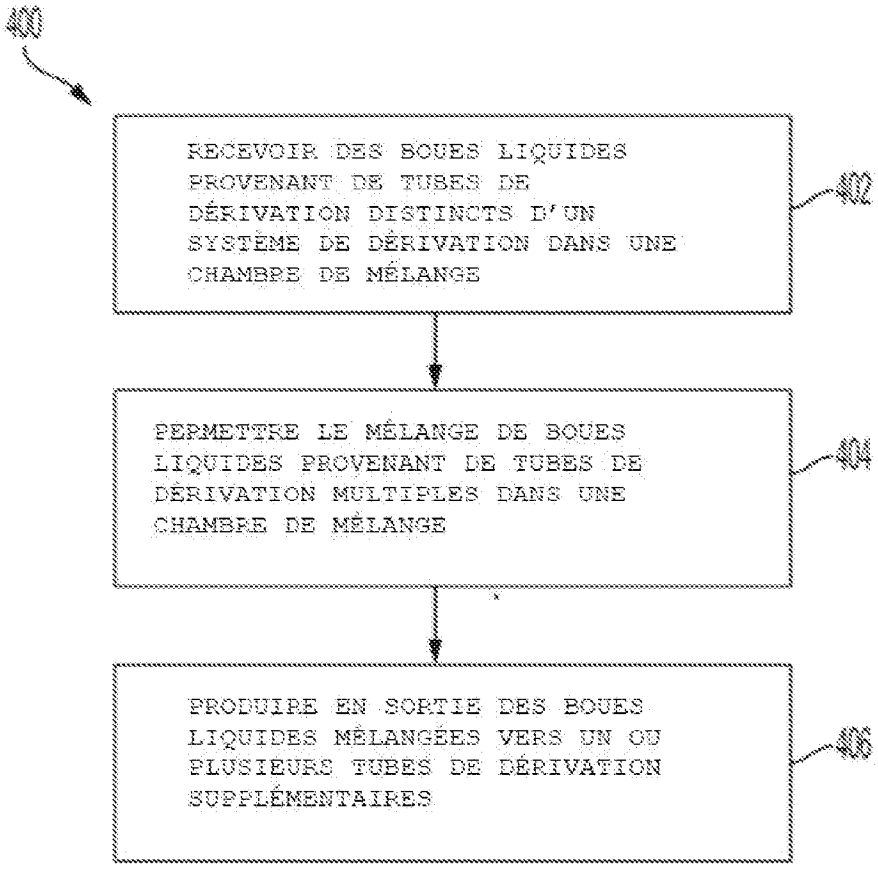
400
RECEVOIR DES BOUES LIQUIDES PROVENANT DE TUBES DE DÉRIVATION DISTINCTS D'UN SYSTÈME DE DÉRIVATION DANS UNE CHAMBRE DE MÉLANGE
402
PERMETTRE LE MÉLANGE DE BOUES LIQUIDES PROVENANT DE TUBES DE DÉRIVATION MULTIPLES DANS UNE CHAMBRE DE MÉLANGE
404
PRODUIRE EN SORTIE DES BOUES LIQUIDES MÉLANGÉES VERS UN OU PLUSIEURS TUBES DE DÉRIVATION SUPPLÉMENTAIRES
406

FIG. 4

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(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 3000 N. Sam Houston Parkway E., Houston, Texas 77032-3219 (US).

(72) Inventors: **COFFIN, Maxime Philippe**; 4115 E Crescent Way, Frisco, Texas 75034 (US). **FROSELL, Thomas Jules**; 8711 Boundbrook Ave., Dallas, Texas 75243 (US).

(74) Agent: **TIDWELL, Mark** et al.; Haynes and Boone, LLP, 2323 Victory Avenue, Suite 700, Dallas, Texas 75219 (US).

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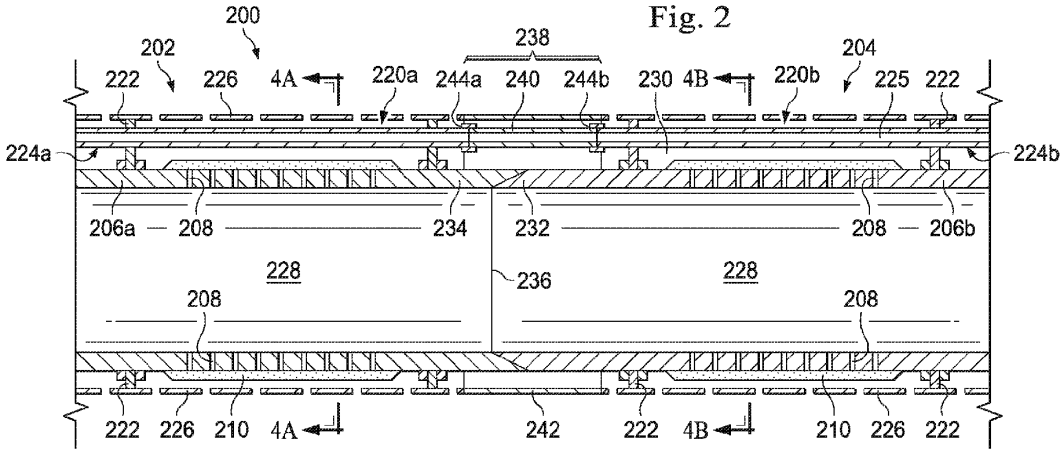
Fig. 2



(57) Abstract: The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies. A completion assembly for deployment in a wellbore, comprises a first sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, and a second sand screen assembly including the shunt tube assembly having a transport tube and a packing tube, wherein the first and second sand screen assemblies are arranged end to end relative to one another. And the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

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MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. provisional application no. 62/688,813, filed June 22, 2018.

FIELD OF INVENTION

The present disclosure relates to screen assemblies of lower production systems used in wellbore gravel packing, and more particularly to shunt tube systems utilized in the sand screen assemblies.

BACKGROUND

In the course of completing an oil and/or gas well, a string of production tubing can be run into the wellbore. During production of the formation fluid, formation sand may be swept into the flow path of the production fluid as it passes along the tubing string. The formation sand tends to be relatively fine sand that can erode production components in the flow path.

When formation sand is expected to be encountered, one or more lower production assemblies may be installed in the production zone between the formation and the production tubing. The lower production assemblies typically include a perforated base pipe surrounded by a sand screen to filter fines from the formation fluid. A packer is customarily set above the production assembly to seal off the annulus in the production zone where formation fluids flow into the production tubing. The annulus around the sand screen can then be "gravel packed" with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of carrier fluid such as water and/or gel and fills the annulus around the sand screen. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation. During the gravel packing process, a premature loss of the carrier fluid into the formation, known as leak-off, can occur,

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resulting in the formation of sand bridges in the annulus about the screening. With a premature loss of carrier fluid, incomplete packing around the sand screen and reduce the filtering efficiency of the gravel pack.

One conventional approach to overcoming this packing sand bridging problem has been to provide each production assembly with a series of shunt tubes that longitudinally extend through the sand screen section, with opposite ends of each shunt tube projecting outwardly beyond the active filter portion of the sand screen section. In the assembled sand screen structure, the shunt tube series are axially joined to one another to form a shunt path extending along the length of the sand screen assembly. The shunt path operates to permit the inflowing packing sand/gel slurry to bypass any sand bridges that may be formed and permit the slurry to enter the screen/casing or screen/open hole annulus beneath a sand bridge, thereby forming the desired sand pack beneath it.

In instances where production zones are elongated, a plurality of lower completion assemblies may be deployed end to end to form a lower completion assembly string that may stretch for hundreds of feet. To ensure that gravel packing slurry is deposited along the entire length of the lower completion assembly string from its upstream end to the downstream end, particularly in deep wellbores and deviated wellbores, relatively high pressures must be applied to the carrier fluid. Thus, each individual lower completion assembly utilized in the overall string is designed to withstand the high delivery pressures experienced at the upstream end of the lower completion assembly string.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

FIG. 1 is a cut-away view of a wellbore system having a lower completion system disposed therein.

FIG. 2 is a partial cross-sectional view of a lower completion assembly.

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FIG. 3 is a partial side view of an embodiment of a shunt tube assembly deployed on a base pipe of a lower completion assembly.

FIG. 4A is a cross-sectional view of an embodiment of a shunt tube assembly along line A-A′ of FIG. 2.

FIG. 4B is a cross-sectional view of an embodiment of a shunt tube assembly along line B-B′ of FIG. 2.

FIG. 5 is a method of installing in a wellbore a lower completion assembly having shunt tube systems with different pressure ratings.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the figures is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Moreover, even though a figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in wellbores having other

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orientations including, deviated wellbores, multilateral wellbores, or the like. Likewise, unless otherwise noted, even though a figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in onshore operations and vice-versa.

Generally, a lower completion assembly made up of at least two sand screen assemblies is provided, namely a first or upper sand screen assembly and a second or lower sand screen assembly. Each sand screen assembly includes a shunt system. Each shunt system includes a transport tube and a packing tube extending from a junction block. Each packing tube includes a plurality of nozzles spaced apart from the junction block and from each other. In one or more embodiments, the cross-sectional area of the transport tube in the first sand screen assembly is less than the cross-sectional area of the transport tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube in the first sand screen assembly is less than the cross-sectional area of the packing tube in the second sand screen assembly. In one or more embodiments, the cross-sectional area of the packing tube nozzles in the first sand screen assembly is less than the cross-sectional area of the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. In one or more embodiments, the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. In one or more embodiments, the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

Turning to Figure 1, shown is an elevation view in partial cross-section of a wellbore production system 10 utilized to complete wells intended to produce hydrocarbons from wellbore 12 extending through various earth strata in an oil and gas formation 14 located below the earth's surface 16. Wellbore 12 may be formed of a single or multiple bores, extending into the formation 14, and disposed in any orientation, such as the horizontal wellbore 12a illustrated in Figure 1. Formation 14 includes production zones 18 from which hydrocarbons are produced.

Production system 10 includes a rig or derrick 20. Rig 20 may include a hoisting apparatus 22, a travel block 24, and a swivel 26 for raising and lowering casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings or other types of conveyance vehicles such as wireline, slickline, and the like 30. In Figure 1, conveyance vehicle 30 is a substantially tubular, axially extending work string or production tubing, formed of a plurality of pipe joints coupled together end-to-end supporting a completion assembly as described below.

Rig 20 may be located proximate to or spaced apart from wellhead 40, such as in the case of an offshore arrangement as shown in Figure 1. One or more pressure control devices 42, such as blowout preventers (BOPs) and other equipment associated with drilling or producing a wellbore may also be provided at wellhead 40 or elsewhere in the system 10.

For offshore operations, as shown in Figure 1, rig 20 may be mounted on an oil or gas platform 44, such as the offshore platform as illustrated, semi-submersibles, drill ships, and the like (not shown). Although system 10 of Figure 1 is illustrated as being a marine-based production system, system 10 of Figure 1 may be deployed on land. In any event, for marine-based systems, one or more subsea conduits or risers 46 extend from deck 50 of platform 44 to a subsea wellhead 40. Tubing string 30 extends down from rig 20, through subsea conduit 46 and BOP 42 into wellbore 12.

A working or service fluid source 52, such as a storage tank or vessel, may supply, via flow lines 64, a working fluid to equipment disposed in wellbore 12, such as subsurface equipment 56. Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, gravel packing slurry, acidizing fluid, liquid water, steam or some other type of fluid.

Production system 10 may generally be characterized as having a pipe system 58. For purposes of this disclosure, pipe system 58 may include casing, risers, tubing, drill strings, completion or production strings, subs, heads or any other pipes, tubes or equipment that couples or attaches to the foregoing, such as string 30, conduit 46, and casing. In this regard, pipe system 58 may include one or more casing strings 60 that may be cemented in wellbore 12, such as the surface, intermediate and production casings 60 shown in Figure 1. An annulus 62 is formed between the walls of sets of adjacent tubular components, such as concentric casing strings 60 or the exterior of tubing string 30 and the inside wall of wellbore 12 or casing string

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60, as the case may be. While wellbore 12 is shown as uncased in the production zone 18 and along the entire depicted portion of horizontal wellbore 12a, all or a portion of wellbore 12 and/or horizontal wellbore 12a may be cased as well and the disclosure is not limited in that regard.

Production fluids and other debris returning to surface 16 from wellbore 12 are directed by a flow line 64 to storage tanks 54 and/or processing systems 66.

As shown in Figure 1, subsurface equipment 56 is illustrated as completion equipment and tubing string 30 in fluid communication with the completion equipment 56 is illustrated as production tubing 30. Although completion equipment 56 can be disposed in a wellbore 12 of any orientation, for purposes of illustration, completion equipment 56 is shown disposed in a substantially horizontal portion of wellbore 12 and includes a lower completion assembly 82 having various tools such as a packer 86, a sand screen assembly 88, a sand screen assembly 92, a sand screen assembly 96 and a packer 98. In embodiments where lower completion assembly 82 is deployed in a cased wellbore, an additional packer, such as packer 86, would be deployed at the distal end of the lower completion assembly. In the illustrated embodiment, packer 86 is generally located adjacent the upstream or proximal end of a production zone 18 and packer 98 is generally located adjacent the downstream or distal end of a production zone 18. Sand screen assemblies 88, 92 and 96 each include a shunt tube system 97 and are arranged so that the sand screen assembly having a shunt tube system with the highest operating pressure rating is upstream and the sand screen assembly having a shunt tube system with the lowest operating pressure rating is downstream. Thus, for example, in the illustrated embodiment sand screen assembly 88 includes a shunt tube assembly with a higher operating pressure than the shunt tube assembly of sand screen 96.

Disposed in wellbore 12 at the lower end of tubing string 30 is an upper completion assembly 104 that includes various tools such as a packer 106, and a fluid flow control module 112.

Extending uphole from upper completion assembly 104 are one or more lines 116, such as hydraulic tubing, pressurized fluid tubing and the like which extends to the surface 16.

A cross-sectional view of an embodiment of a lower completion assembly 200 is shown in FIG. 2. Lower completion assembly is generally comprised of a first sand screen assembly 202

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interconnected with a second sand screen assembly 204. In some embodiments, lower completion assembly 200 may be comprised of a plurality of interconnected first sand screen assemblies 202 at an upper portion of the lower completion assembly 200 and a plurality of interconnected second sand screen assemblies 204 at a lower portion of the lower completion assembly 200. Each sand screen assembly includes a base pipe 206 having a series of perforations 208 disposed therethrough, the base pipe 206 extending between a first end and a second end. A sand screen or filter media 210 is disposed about a portion of the base pipe 206 and the series of perforations 208 in order to screen incoming fluids from the formation. Each sand screen assembly also includes a shunt tube assembly 220 disposed outwardly of the filter media 220. Generally, shunt tube assembly 220 may include one or more retaining rings 222 supporting one or more shunt tubes 224 in the form of a transport tube or a packing tube disposed along and generally parallel to the base pipe 206. Shunt tubes 224 are tubular members having a passageway 225 defined therein with a cross-sectional flow area. While shown disposed outside of and generally parallel to the base pipe 206, other positions and alignment may be possible. An outer shroud 226 may be disposed about the base pipe 206, one or more shunt tubes 224, and filter media 210. In an embodiment, the retaining rings 212 are configured to retain the one or more shunt tubes 224 and/or outer shroud 226 in position relative to the base pipe 206.

While the base pipe 206 is illustrated as being perforated in FIG. 2, the base pipe 206 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication of production fluid between an interior throughbore 228 and an exterior 230 of the screen assembly.

The filter media 210 may be disposed about the base pipe 206 and can serve to limit and/or prevent the entry of sand, formation fines, and/or other particulate matter into the base pipe 206. In an embodiment, the filter media 210 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about a base pipe 206, with a spacing between the wire wraps being chosen to allow fluid flow through the filter media 210 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter media 210 is used in describing the present invention, it should be understood that the generic term "filter media" as used herein is intended to include and cover all types of similar structures which are commonly used in gravel pack well completions which permit the flow of fluids through the filter or screen while limiting and/or blocking the flow of

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particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

The base pipe 206 may generally comprise a pin end 232 and a box end 234 to allow the base pipe 206 to be coupled to an adjacent base pipe 206. In the illustrated embodiment, base pipe 206a of first sand screen assembly 202 is coupled to base pipe 206b of second sand screen assembly 204 forming a joint 236. As such, the first sand screen assembly 202 and the second sand screen assembly 204 can be joined together end-to-end so that the respective base pipes are in fluid communication with one another along their throughbores 228. As can be seen in FIG. 2, each base pipe 206 may have a coupling section 238 that extends beyond the shunt tube assembly 220 of the respective sand screen assemblies. This exposed portion of the base pipe 206 may be used during the coupling process to allow one or more tools to engage the exposed portion for makeup of the first and second sand screen assemblies 202, 204.

Shunt tubes 224 of adjacent sand screen assemblies may be joined together in fluid communication by a jumper tube 240. In the illustrated embodiment, shunt tube 224a is interconnected to shunt tube 224b by jumper tube 240. An additional shroud 242 may be used to protect jumper tube 240. While the disclosure is not limited to a particular shape for shunt tubes 224 or jumper tubes 240, in some embodiments, shunt tubes 224 may have a non-round cross-section (as shown in FIGs. 3A and 3B), while jumper tubes 240 may have a round cross-section. In such case, the end of each jump tube may include an adaptor or coupling 244 to transition from the non-round cross-section of the shunt tube 224 to the round cross-section of the jumper tubes 240.

Although the particular shape of the tubes described herein are not a limitation in certain embodiments, shunt tubes used in shunt tube systems generally have non-round cross-sectional shapes. These cross-sectional shapes allow for the shunt tubes to be arranged adjacent the wellbore tubular and provide a desired flow area without requiring an outer diameter that would otherwise be associated with the use of all round components. The jumper tubes used to couple shunt tubes on adjacent wellbore tubular joints are generally round cross-section while the shunt tubes are non-round in cross-section.

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With reference to FIG. 3, a side view of a lower completion assembly 200 is illustrated, with first sand screen assembly 202 interconnected with second sand screen assembly 204. In the illustrated embodiment, the filter media 210 and outer shrouds 226, 242 shown in FIG. 2 are removed to permit better illustration of the shunt tube assemblies. Additionally, the different types of shunt tubes 224 that comprise a shunt tube assembly 220 are illustrated in more detail. Specifically, in FIG. 3, base pipe assembly 206a is shown interconnected to base pipe assembly 206b at joint 236. First sand screen assembly 202 has two shunt tube assemblies 302 and 304. Likewise, second sand screen assembly 204 is illustrated with two shunt tube assemblies 306 and 308. Each shunt tube assembly described herein, including shunt tube assemblies 220 of FIG. 2, generally include a transport tube 310 and a packing tube 312 extending from a junction block 314 so as to be in fluid communication with one another.

As shown, the shunt tubes 310, 312 may form a branched structure from junction block 314 along the length of a sandscreen assembly 202 with the one or more transport tubes 310 forming the trunk line and the one or more packing tubes 312 forming the branch lines. In an embodiment, a plurality of branched structures may extend along the length of the sandscreen assembly 202. The use of a plurality of branched structures may provide redundancy to the shunt tubes system in the event that one of the branched structures is damaged, clogged, or otherwise prevented from operating as intended. Likewise, while junction block 314 is depicted as having only one inlet and two outlets, the disclosure is not limited to a particular junction block configuration. The "y-block" junction block depicted is for illustration purposes only unless otherwise stated for a particular configuration. In this regard, in certain configurations, the shunt tube assembly may only comprise a junction block 314 having one inlet and two outlets as depicted.

Each packing tube 312 includes one or more nozzles 316. Each nozzle 316 is spaced apart from its respective junction block 314 a distance D1. Likewise, each nozzle 316 along a packing tube 312 may be spaced apart from adjacent nozzles a distance D2. The spacing D2 between nozzles 216 along a particular packing tube 312 may be the same or different. Likewise, the spacing D2 between nozzles 216 of shunt tube assemblies of the same sand screen assembly may be the same or different.

Also shown in FIG. 3 is a jumper tube 240a interconnecting shunt tube assembly 302 with a shunt tube assembly 306 and a jumper tube 240b interconnecting shunt tube assembly 204 with

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shunt tube assembly 308. A coupling 244a is provided at distal end of transport tube 310a to facilitate attachment of jumper tube 240a, while a coupling 244b is provided at distal end of transport tube 310b to facilitate attachment of jumper tube 240b. In particular, jumper tube 240a interconnects junction block 314c with coupling 244a at the distal end of transport tube 310a, thereby allowing fluid communication between upper or high pressure shunt tube assembly 302 and lower or low pressure shunt tube assembly 306. Likewise, jumper tube 240b interconnects junction block 314d with coupling 244b at the distal end of transport tube 310b, spanning joint 236 between the first sand screen assembly 202 and the second sand screen assembly 204.

FIG. 4A illustrates a cross-sectional area A-A of first sand screen assembly 202 and shunt tubes 224a of FIG. 2 and FIG. 4B illustrates a cross-sectional area B-B of second sand screen assembly 204 and shunt tubes 224b of FIG. 2. As generally shown, the one or more shunt tubes 224 generally comprise tubular members disposed outside of and generally parallel to the base pipe 224. While described as tubular members (e.g., having substantially rectangular cross-sections), the one or more shunt tubes 224 may have shapes other cross-sectional shapes, such as round, elliptical, kidney shaped, and/or trapezoidal in shape. The retaining rings 222 may retain the shunt tubes 224 in position relative to the base pipe 206. The one or more shunt tubes 224 may be eccentrically aligned with respect to the base pipe 206 as best seen in FIG. 2. In each of FIGS. 4A and 4B, four shunt tubes 224 are arranged to one side of the base pipe 206. While illustrated in FIGS. 2 and 4 as having an eccentric alignment, other alignments of the one or more shunt tubes about the base pipe 206 may also be possible.

In FIG. 4A, first sand screen assembly 202 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 410 and a packing tube 412. Each transport tube 410 has a cross-sectional flow area A1 bounded by a wall 414 of thickness T1. Likewise, each packing tube 412 has a cross-sectional flow area B1 bounded by a wall 416 of thickness T2. Each packing tube further includes one or more nozzles 418 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 418 may be in the form of a perforation or opening in wall 416 or a short tube with a taper or constriction. Nozzle 418 is characterized by a cross-sectional flow area C1.

Similarly, in FIG. 4B, second sand screen assembly 204 is illustrated as having two shunt tube assemblies 220, each comprising a transport tube 420 and a packing tube 422. Each transport

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tube 420 has a cross-sectional flow area A2 bounded by a wall 422 of thickness T3. Likewise, each packing tube 422 has a cross-sectional flow area B2 bounded by a wall 424 of thickness T4. Each packing tube further includes one or more nozzles 4426 through which fluids may flow to facilitate gravel packing. In some embodiments, nozzle 426 may be in the form of a perforation or opening in wall 424 or a short tube with a taper or constriction. Nozzle 426 is characterized by a cross-sectional flow area C2.

In one or more embodiments, the cross-sectional flow area A1 of the transport tube 410 of first sand screen assembly 202 is less than the cross-sectional flow area A2 of the transport tube 420 of the second sand screen assembly 204. In other words, the downstream sand screen assembly transport tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly transport tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area B1 of the packing tube 412 of first sand screen assembly 202 is less than the cross-sectional flow area B2 of the packing tube 422 of the second sand screen assembly 204. In other words, the downstream sand screen assembly packing tube which is closest to the distal end of the production zone, has a larger cross-sectional flow area than the upstream sand screen assembly packing tube closest to the proximal end of the production zone.

In one or more embodiments, the cross-sectional flow area C1 of a nozzle 418 of first sand screen assembly 202 is less than the cross-sectional flow area C2 of a nozzle 426 of the second sand screen assembly 204. In other words, the downstream sand screen assembly shunt tube nozzles which are closest to the distal end of the production zone, have a larger cross-sectional flow area than the upstream sand screen assembly shunt tube nozzles closest to the proximal end of the production zone.

In one or more embodiments, the packing tube assembly 412 of the first sand screen assembly 202 has fewer nozzles 418 than the number of nozzles 426 of the packing tube assembly 422 of the second sand screen assembly 204.

Referring back to FIG. 3, in one or more embodiments, the distance D1 of the first nozzle 316 of packing tube assembly 312a from the junction block 314a is greater than the distance D1 of

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the first nozzle 316 of packing tube assembly 312c from the junction block 314c for the interconnected shunt tube assemblies 302 and 306. Likewise, the distance D1 of the first nozzle 316 of packing tube assembly 312b from the junction block 314b is greater than the distance D1 of the first nozzle 316 of packing tube assembly 312d from the junction block 314d for the interconnected shunt tube assemblies 304 and 308.

Similarly, in one or more embodiments, the distance D2 between adjacent nozzle 316 of packing tube assembly 312a of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312c of the second sand screen assembly 204 for interconnected shunt tube assemblies 302 and 306. Likewise, the distance D2 between adjacent nozzle 316 of packing tube assembly 312b of first sand screen assembly 202 is greater than the distance D2 between adjacent nozzle 316 of packing tube assembly 312d of the second sand screen assembly 204 for interconnected shunt tube assemblies 304 and 308.

While each of the different geometries of a shunt tube assembly have been described, it will be appreciated that any one or more of the geometries can be combined to achieve the desired flow regime for a particular shunt tube assembly. In some cases, certain of the geometries will remain the same. For example, the transport tubes 410 and 420 may be the same with the same flow areas A1, A2, but the geometries of the respective packing tubes 412, 244 may differ in number of nozzles and/or cross-sectional flow areas B1, B2 and/or nozzle spacing along the respective packing tubes.

Traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the same pressure rating. In this regard, the shunt tube assemblies are selected based on the expected operating conditions of the shunt tube assemblies. For shorter gravel packing intervals, the gravel pack slurry flows into the wellbore annulus at about the same fluid pressure along the length of the interval. Of course, as gravel pack intervals have increased, an increased operating pressure is needed to ensure that gravel pack slurry flows along the entire length of the gravel pack interval. Thus, as gravel pack intervals increase, it has been necessary to employ shunt tube assemblies with increased operating pressure ratings or burst pressures, resulting in heavier and/or bulkier tubing and components to ensure that the shunt tube assemblies will not be subject to burst pressure. Since shunt tube assemblies for an entire lower production assembly are selected based on the highest

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operating pressure expected to be required across the entire length of the gravel packing interval, individual sand screen assemblies in a lower production assemblies have become increasingly heavier. However, as the slurry flows from the upstream portion of these elongated production zone to the downstream portion of the production zone, the pressure of the slurry drops off. As such, only the shunt tube assemblies deployed adjacent the upper portion of the production zone experience the highest pressures.

In addition, because of the high pressure experienced by shunt tube assemblies at the upper or upstream end of such lower production assemblies deployed in elongated production zones, there is a tendency for greater leak-off in the upstream portion of the production zone.

These drawbacks are addressed by above-described lower production assembly where the shunt tube system flow regime in the second sand screen assembly 204 is selected to allow a larger volume of fluid to flow therethrough than that of the first sand screen assembly 202 by adjusting cross-sectional flow areas, location and number of nozzles. In this regard, the geometries of the shunt tube assemblies 220 of the first sand screen assembly 202 may be selected to have a higher operating pressure than the shunt tube assemblies 220 of the second sandscreen assembly 204. In one or more embodiments, the thickness T1 of wall 414 of transport tube 410 of the first sand screen assembly 202 may be greater than thickness T3 of wall 422 of transport tube 420 of the second sandscreen assembly 204. Likewise, in one or more embodiments, the thickness T2 of wall 416 of packing tube 412 of the first sand screen assembly 202 may be greater than the thickness T4 of wall 424 of packing tube 422 of the second sandscreen assembly 204. In other embodiments, where geometries and dimensions are the same, the material of construction of transport tube 410 may be selected to be stronger than the material of construction of transport tube 420. In other words, the material of construction of transport tube 410 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of transport tube 420 of the second sandscreen assembly 204. In other embodiments, the material of construction of packing tube 412 of the first sand screen assembly 202 is selected to have a higher tensile or yield strength than the material of construction of packing tube 422 of the second sandscreen assembly 204. As such, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 may be selected to have an operating pressure at or above a select threshold, while the shunt tube assemblies 220 of the second sandscreen assembly 204 may be selected to have an operating pressure at or below a select threshold. In one or more embodiments, the shunt tube

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assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure or are otherwise rated at over 5000 psi while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 5000 psi. In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating or are otherwise rated between 5000 and 10000 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure or are otherwise rated at no more than 4000 psi. More broadly, it will be appreciated that the first and second sandscreen assemblies 202, 204 have different shunt tube assembly operating pressure ratings, with the shunt tube assembly 220 of the first sandscreen assembly 202 having a higher operating pressure rating than the shunt tube assembly 220 of the second sandscreen assembly 204.

In another embodiment, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have an operating pressure range or rating of between approximately 6,500 to 7,500 psi, while the shunt tube assemblies 220 of the second sandscreen assembly 204 have an operating pressure of approximately 3,500 to 3,750 psi. In certain embodiments, the shunt tube assemblies 220 utilized in the first sandscreen assembly 202 have are rated at or have an operating pressure of approximately 10,000 psi. In other words, the shunt tube assemblies upstream are selected to have a higher burst pressure than the shunt tube assemblies downstream in the overall lower production assembly.

Turning to FIG. 5, a method 500 of installing a completion assembly in a wellbore is generally illustrated. In a first step 502, a portion of the wellbore passing through a production zone to be gravel packed is identified for placement of a lower production assembly. The production zone portion of the wellbore can be characterized as having an upstream proximal end closest to the wellhead along the wellbore measured depth (MD) and a downstream distal end farthest from the wellhead in terms of MD. In step 504, the surface injection pressure necessary to deliver a gravel packing slurry to the most distal end of the production zone portion of the wellbore is determined, and based on this injection pressure, a high pressure shunt tube system to be positioned adjacent the proximal end of the production zone portion of the wellbore is selected for incorporation in a first or upstream sand screen assembly as described above. In step 506, the anticipated gravel pack slurry pressure at the distal end of the production zone portion of the wellbore is calculated, and based on this anticipated pressure, a low pressure shunt tube system to be positioned adjacent the distal end of the production zone portion of the

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wellbore is selected for incorporation in a second or downstream sand screen assembly as described above. Having selected the two sandscreen assemblies with their respective relative high pressure and low pressure shunt tube systems, the lower completion assembly can be made up into a tubing string by joining the first and second sandscreen assemblies together. In this regard, the base pipes of the assemblies are interconnected, and likewise, as described above, adjacent shunt tube assemblies are interconnected using jump tubes to establish fluid communication therebetween. In particular, the packing tube of an upstream sand screen assembly is interconnected to the shunt tube junction block of a downstream sandscreen assembly.

It will be appreciated that in one or more embodiments, the lower completion assembly will be made up of a plurality of sand screen assemblies, each carrying one or more shunt tube assemblies. In such case, it will be necessary to estimate the grave pack slurry injection pressure profile along the length of the production zone portion of the wellbore, and then select the appropriate number of first or second sandscreen assemblies for makeup into the tubing string, it being understood at used here that "first" sandscreen assemblies refers to those sandscreen assemblies with a high pressure shunt system and "second" sandscreen assemblies refers to those sandscreen assemblies with a low pressure shunt system. For example, a lower production assembly may be comprised of 10 first sandscreen assemblies and 15 second sandscreen assemblies, all joined end-to-end to form the tubing string.

In any event, once lower production assembly having the desired number of first and second sandscreen assemblies is assembled, the lower production assembly is installed in the production zone portion of the wellbore. In so doing, at step 508, the second sandscreen assembly is deployed at the distal end of the wellbore portion so that the low pressure shunt tube system is positioned in the wellbore adjacent the production zone distal end. Likewise, in step 510, in positioning the low pressure shunt tube system, the first sandscreen assembly is deployed at the proximal end of the wellbore portion. In so doing, the high pressure shunt tube system is accordingly positioned adjacent the production zone proximal end.

Lastly, in step 512, a working fluid, such as a gravel pack slurry, gel or other desired fluid, is pumped into the interconnected shunt tube assemblies. The working fluid may be pressurized in accordance with the operating pressure of the high pressure shunt tube system deployed adjacent the upper end of the wellbore production zone. Because the pressure of the working

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fluid drops along the length of the production zone, only those "first" sandscreen assemblies are subjected to the higher pressure working fluid, whereas the "second" sandscreen assemblies are only subject to the lower pressure working fluid. Moreover, in certain embodiments, because of the shunt tube system geometry of the "first" sandscreen assemblies, leak-off at the higher pressure is minimized in the upper sandscreen assemblies, thereby minimizing the likelihood of blockage along the shunt tube system or in the gravel pack adjacent the packing tubes. In any event, the working fluid is pumped into the interconnected shunt tube assemblies and injected via the nozzles of the packing tubes into the annulus around the lower production assembly. To the extent the working fluid is a gravel pack slurry, a gravel pack is formed around the lower production assembly so as to support the formation and/or filter production fluids before introduction into the production tubing of the system.

Thus, a wellbore completion assembly has been described. The completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube

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assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein a cross-sectional flow area of the transport tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the transport tube passageway in the second sand screen assembly. In other embodiments, the completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block

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where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly. Other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly. Still yet other embodiments of the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a

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portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly. Still yet other embodiments may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube extending from a junction block, the packing tube including a plurality of nozzles spaced apart from the junction block and from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; and wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen

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assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure. Other embodiments of the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi. Other embodiments of the wellbore completion assembly may include a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi. In other embodiments, the wellbore completion assembly may include a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first operational pressure rating and the second sand screen assembly comprises a shunt tube assembly with a second operational pressure rating less than the first operational pressure rating. In other embodiments, the wellbore completion assembly may include a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another; wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

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For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

Transport tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a transport tube of the second sandscreen assembly.

Packing tube of the first sand screen assembly has a wall thickness greater than a wall thickness of a packing tube of the second sandscreen assembly.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

Transport tube of the first sand screen assembly is formed of a first material and transport tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material is stronger than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher tensile strength than the second material.

Packing tube of the first sand screen assembly is formed of a first material and packing tube of the second sandscreen assembly is formed of a second material, where the first material has a higher yield strength than the second material.

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A cross-sectional flow area of the packing tube passageway in the first sand screen assembly is less than a cross-sectional flow area of the packing tube passageway in the second sand screen assembly.

A cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

The distance between the junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the junction block and the packing tube nozzles in the second sand screen assembly.

The distance between adjacent packing tube nozzles is greater in the first sand screen assembly than the distance between adjacent packing tube nozzles in the second sand screen assembly.

The number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

The cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

The cross-sectional flow areas of the first and second transport tubes is substantially round.

The cross-sectional flow areas of the first and second transport tubes is substantially rectangular.

The cross-sectional flow areas of the first and second transport tubes is oval shaped.

The second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen

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assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

At least two screen assemblies each comprise a shunt tube assembly having first and second sets of transport tube and packing tubes, wherein each set of tubes extends from a junction block.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 5000 psi.

The first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

The first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

A method of installing a completion assembly in a wellbore has been described. The installation method may include installing a lower sand screen assembly having a low pressure shunt tube system in a wellbore adjacent a production zone; and attaching an upper sand screen assembly having a high pressure shunt tube system to the lower sand screen assembly upstream of the lower sand screen assembly. Other embodiments of the method may include installing

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a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system. Still yet other embodiments of the method may include installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent a production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies, wherein each first sand screen assembly has a low pressure shunt tube system and each second sand screen assembly has a high pressure shunt tube system. Yet other methods of the installation method may include identifying an elongated production zone having an upstream proximal end and a downstream distal end; determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure; determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end. Likewise, other installation methods may include identifying an elongated production zone wellbore portion having an upstream proximal end and a downstream distal end; selecting a high pressure shunt tube system based on a proximal end shunt tube system operating pressure; selecting a low pressure shunt tube system based on a distal end shunt tube system operating pressure; positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end; introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

For any of the foregoing embodiments, one or more of the following elements may be combined alone therewith or with of the other following elements:

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The high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

The high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

Introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

Injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

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CLAIMS

What is claimed is:

1. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

2. The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

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3. The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

4. The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

5. The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is substantially the same.

6. The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising an coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

7. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over 5000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than 5000 psi.

8. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of between 5000 and 10000 psi and the second sand screen assembly has a shunt tube assembly with a pressure rating of less than 4000 psi.

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9. The completion assembly of claim 1, wherein the first sand screen assembly has a shunt tube assembly with a pressure rating of over a select threshold and the second sand screen assembly has a shunt tube assembly with a pressure rating of no more than the select threshold.

10. The completion assembly of claim 1, wherein a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

11. A completion assembly for deployment in a wellbore, the completion assembly comprising: a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure.

12. The completion assembly of claim 11, wherein the first sand screen assembly comprises a shunt tube assembly disposed to operate at pressures over 5000 psi and the second sand screen assembly has a shunt tube assembly disposed to operate at pressures of no more than 5000 psi.

13. The completion assembly of claim 11, further comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating over 5000 psi and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

14. A method of installing a completion assembly in a wellbore, the method comprising: installing a first sand screen assembly in a wellbore adjacent a production zone; and attaching a second sand screen assembly to the first sand screen assembly upstream of the first sand screen assembly, wherein the first sand screen assembly has a low pressure shunt tube system and the second sand screen assembly has a high pressure shunt tube system.

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15. The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to the uppermost first sand screen assembly upstream of the first sand screen assemblies.

16. The method of claim 14, further comprising:

identifying an elongated production zone having an upstream proximal end and a downstream distal end;

determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting the high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting the low pressure shunt tube system based on the distal end determined pressure, wherein the low pressure shunt tube system has a lower shunt tube operating pressure than the high pressure shunt tube system;

positioning the low pressure shunt tube system in the wellbore adjacent the production zone distal end; and

positioning the high pressure shunt tube system in the wellbore adjacent the production zone proximal end.

17. The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

18. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

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Weatherford v. Halliburton
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19. The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

20. The method of claim 17, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

21. A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another;

wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

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22. The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

23. The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first pressure rating.

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Page 487

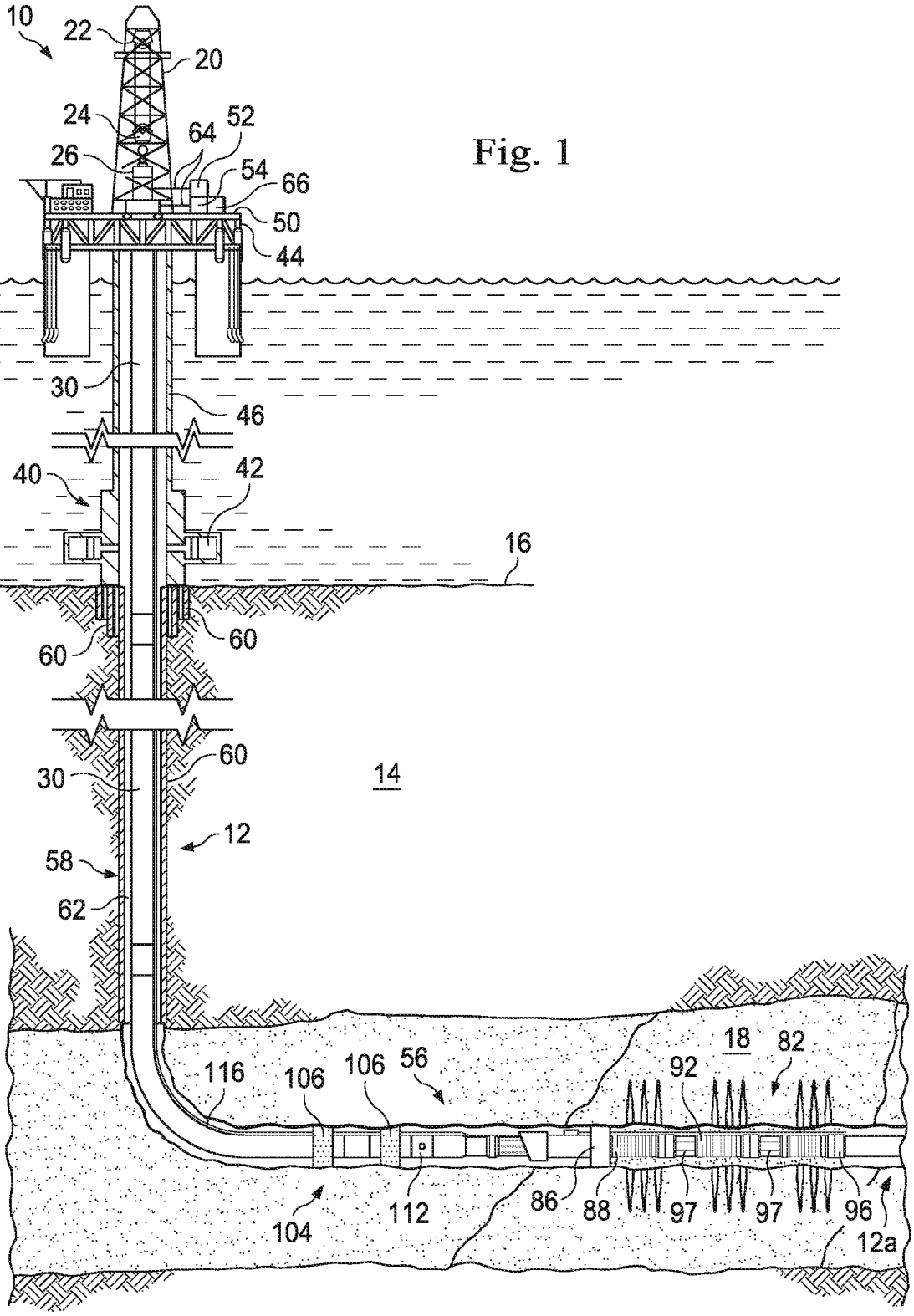
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Fig. 1

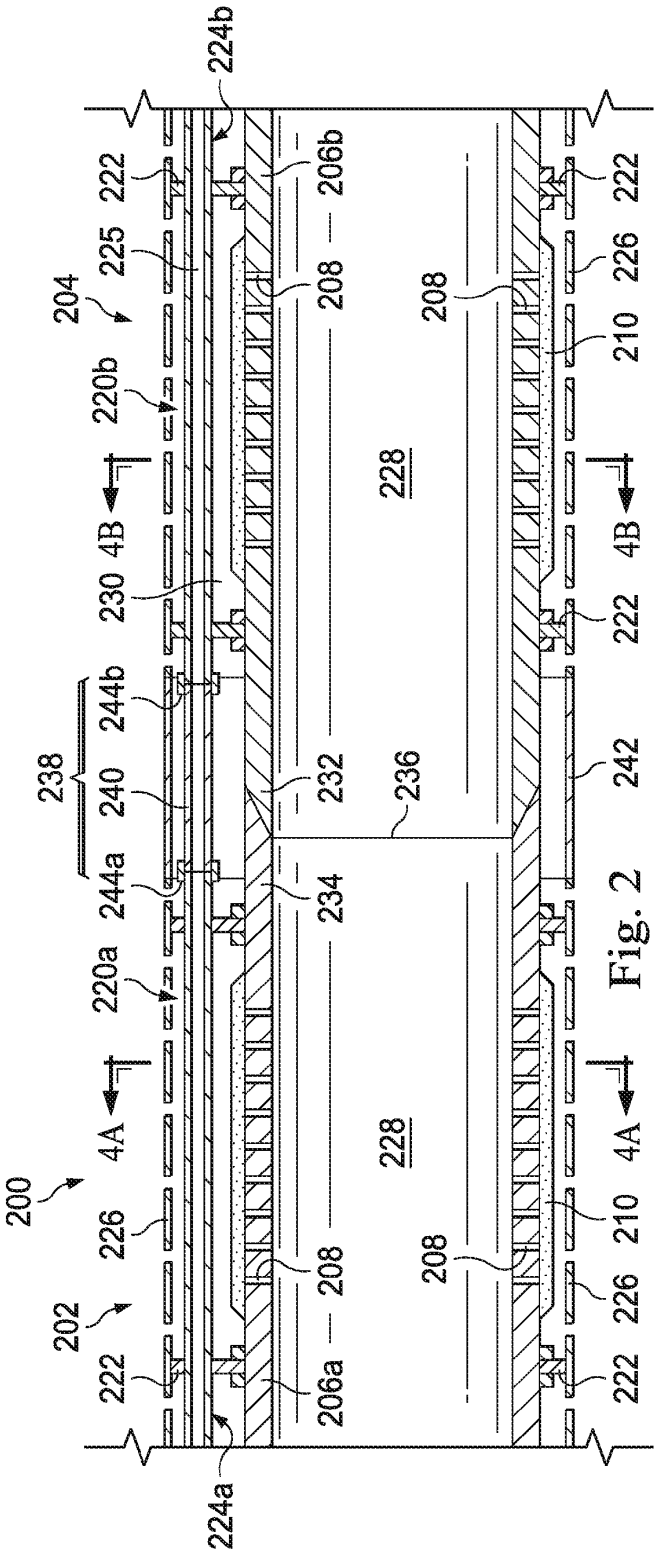
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Fig. 2

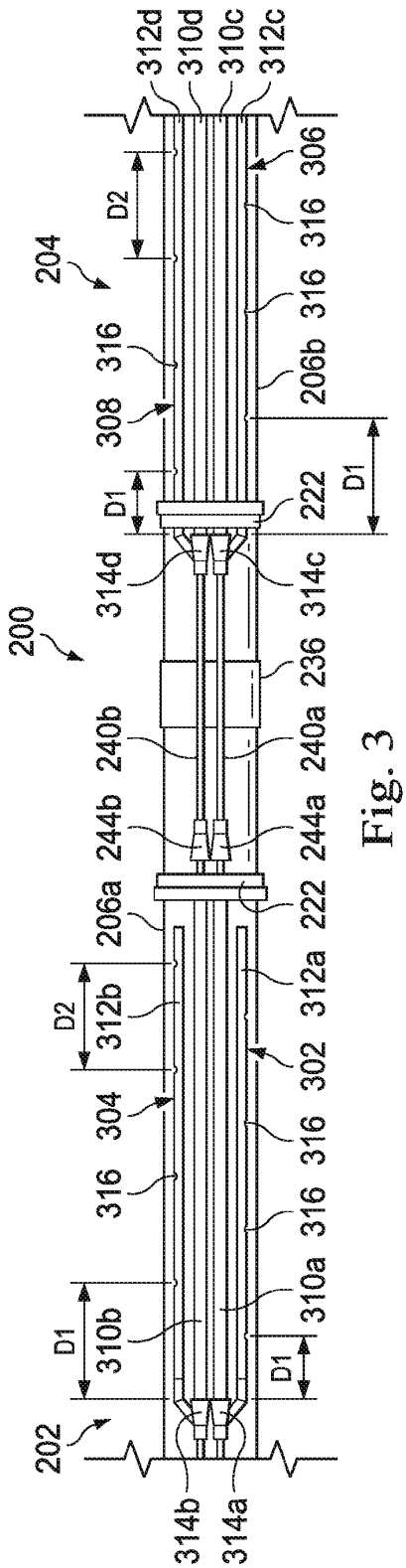
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Fig. 3

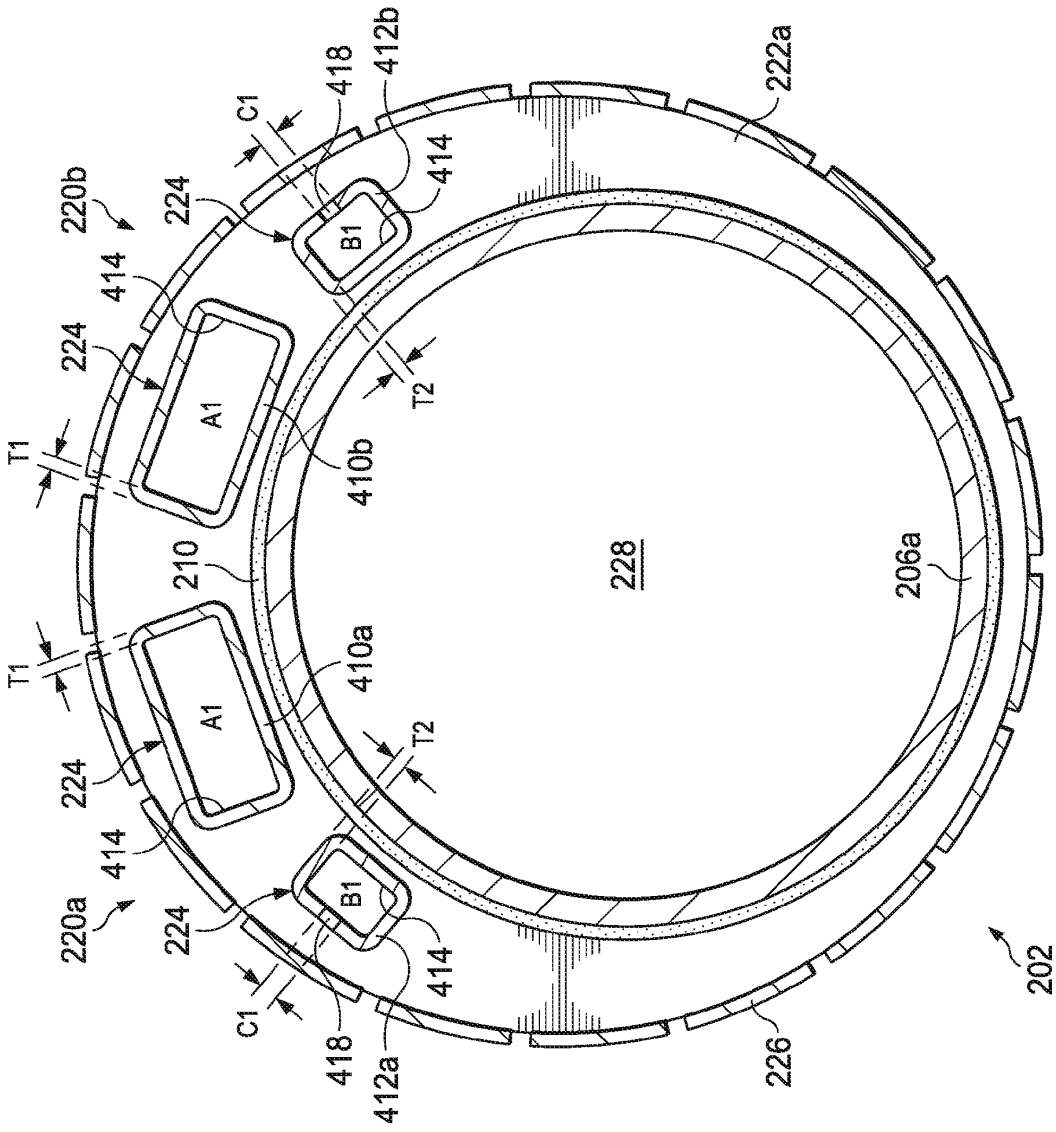
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Fig. 4A

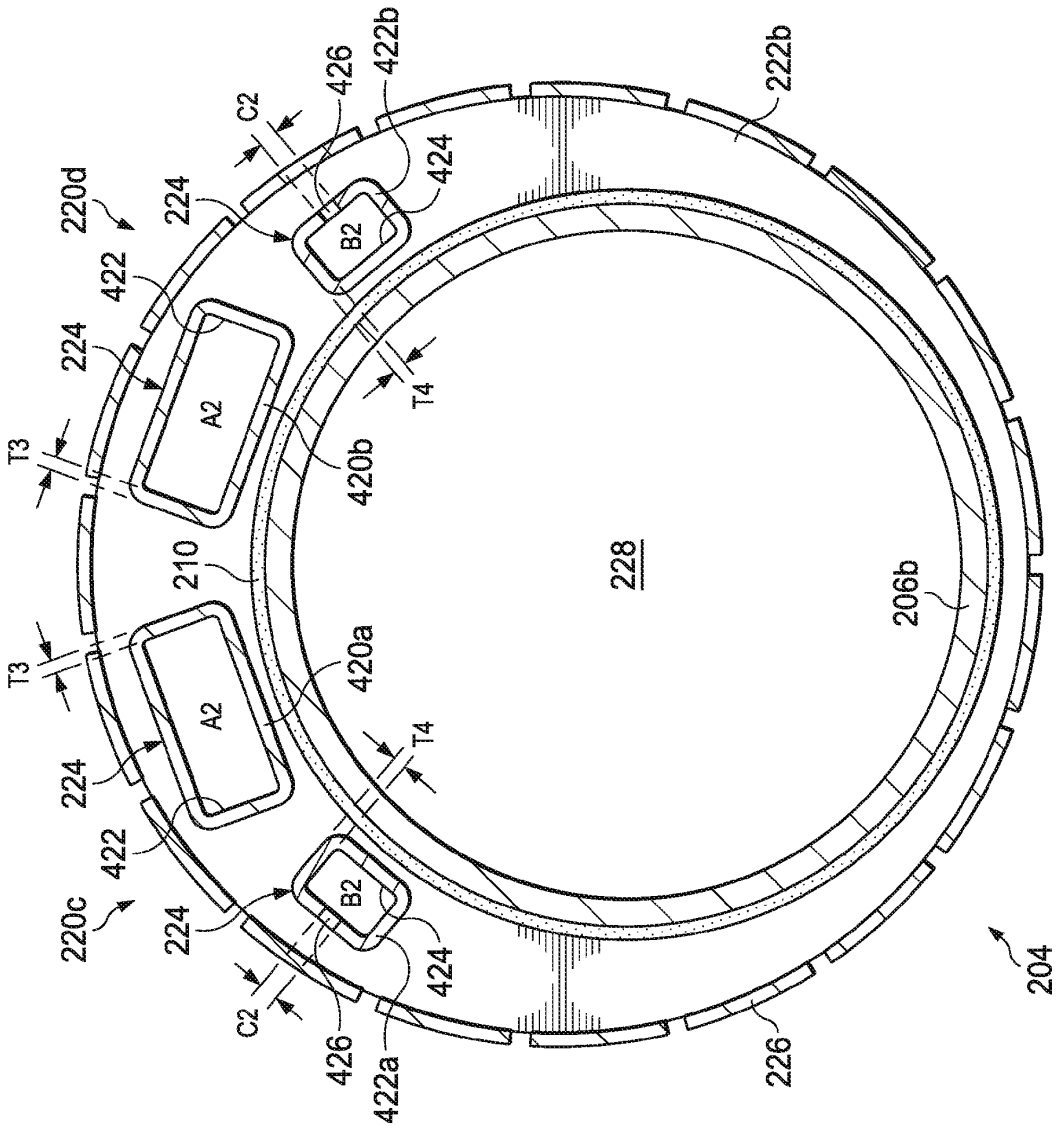
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Fig. 4B

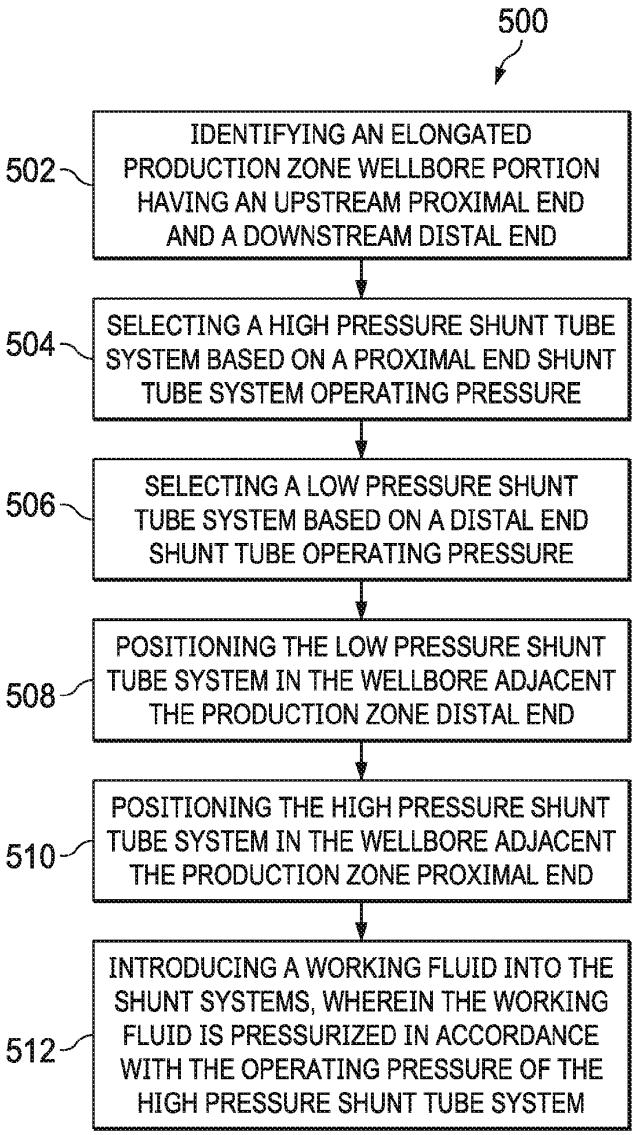
500
502
IDENTIFYING AN ELONGATED PRODUCTION ZONE WELLBORE PORTION HAVING AN UPSTREAM PROXIMAL END AND A DOWNSTREAM DISTAL END
504
SELECTING A HIGH PRESSURE SHUNT TUBE SYSTEM BASED ON A PROXIMAL END SHUNT TUBE SYSTEM OPERATING PRESSURE
506
SELECTING A LOW PRESSURE SHUNT TUBE SYSTEM BASED ON A DISTAL END SHUNT TUBE OPERATING PRESSURE
508
POSITIONING THE LOW PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE DISTAL END
510
POSITIONING THE HIGH PRESSURE SHUNT TUBE SYSTEM IN THE WELLBORE ADJACENT THE PRODUCTION ZONE PROXIMAL END
512
INTRODUCING A WORKING FLUID INTO THE SHUNT SYSTEMS, WHEREIN THE WORKING FLUID IS PRESSURIZED IN ACCORDANCE WITH THE OPERATING PRESSURE OF THE HIGH PRESSURE SHUNT TUBE SYSTEM

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/024626

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/04(2006.01)i, E21B 33/12(2006.01)i, E21B 34/06(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 19/16; E21B 43/08; E21B 33/12; E21B 34/06

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: completion, sand screen, shunt tube, transport tube, packing tube, wall thickness

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003-0029613 A1 (DANOS et al.) 13 February 2003 See paragraphs [0002]-[0046]; and figures 5-9.	1,5-23
A		2-4
Y	US 2010-0139919 A1 (YEH et al.) 10 June 2010 See paragraphs [0041]-[0092]; and figures 2A-3C, 5B, 11A-11B.	1,5-23
A	WO 2013-187878 A1 (HALLIBURTON ENERGY SERVICES, INC. et al.) 19 December 2013 See paragraphs [0036]-[0116]; and figures 1-14.	1-23
A	US 2014-0110131 A1 (HALLIBURTON ENERGY SERVICES, INC.) 24 April 2014 See paragraphs [0031]-[0047]; and figures 1-13.	1-23
A	US 2013-0008652 A1 (BROUSSARD et al.) 10 January 2013 See paragraphs [0051]-[0110]; and figures 2-12.	1-23

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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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
06 August 2019 (06.08.2019)	**07 August 2019 (07.08.2019)**

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

Authorized officer
PARK, Tae Wook
Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/024626

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International application No.

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INTERNATIONAL SEARCH REPORT

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International application No.

PCT/US2019/024626

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WIPO | PCT

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E21B 43/04 (2006.01) *E21B 33/13* (2006.01)
E21B 17/046 (2006.01)

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PCT/US2012/068524

(22) International Filing Date:
7 December 2012 (07.12.2012)

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(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 10200 Bellaire Boulevard, Houston, TX 77072 (US).

(72) Inventors: **LEAST, Brandon, Thomas**; 3218 Jubilee Trail, Dallas, TX 75229 (US). **CUNNINGHAM, Gregory, Scott**; 532 Chasewood Drive, Grapevine, TX 76051 (US). **LOPEZ, Jean, Marc**; 7308 Stoddard Lane, Piano, TX 75025 (US). **VEIT, Jan**; 3201 Dover Drive, Piano, TX 75075 (US).

(74) Agent: **YOUST, Lawrence, R.**; Lawrence Youst PLLC, One Waterway Court, Suite 3b, The Woodlands, TX 77380 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,

[Continued on nextpage]

(54) Title: GRAVEL PACKING APPARATUS HAVING LOCKING JUMPER TUBES

(57) Abstract: A gravel packing apparatus has first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly. Each slurry delivery subassembly includes a transport tube extending longitudinally along at least a portion of the sand control screen assembly. A jumper tube extends between and is sealably coupled to the transport tube of the first joint and the transport tube of the second joint. A first locking assembly is positioned between the jumper tube and the transport tube of the first joint and a second locking assembly is positioned between the jumper tube and the transport tube of the second joint.

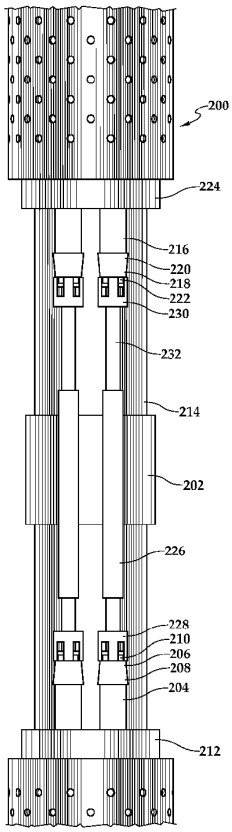

Fig.7D

WO 2014/088594 A1

HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:

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

Published:

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

GRAVEL PACKING APPARATUS HAVING LOCKING JUMPER TUBES

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to equipment utilized in conjunction with operations performed in relation to subterranean wells and, in particular, to a gravel packing apparatus having locking jumper tubes and a method for assembling the gravel packing apparatus on the rig floor.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background is described with reference to a sand control completion in a wellbore traversing an unconsolidated or loosely consolidated subterranean formation, as an example.

[0003] It is well known in the subterranean well drilling and completion art that particulate materials such as sand may be produced during the production of hydrocarbons from a well traversing an unconsolidated or loosely consolidated subterranean formation. Numerous problems may occur as a result of the production of such particulate. For example, the particulate may cause abrasive wear to components within the well. In addition, the particulate may partially or fully clog the well creating the need for an expensive workover. Also, if the particulate matter is produced to the surface, it must be removed from the hydrocarbon fluids by processing equipment at the surface.

[0004] One method for preventing the production of such particulate material to the surface is gravel packing the well adjacent the unconsolidated or loosely consolidated production interval. In a typical gravel pack completion, a sand control screen is lowered into the wellbore on a work string to a position proximate the desired production interval. A fluid slurry including a liquid carrier and a particulate material known as gravel is then pumped down the work string and into the well annulus formed between the sand control screen and the perforated well casing or open hole production zone.

[0005] The liquid carrier either flows into the formation or returns to the surface by flowing through the sand control screen or both. In either case, the gravel is deposited around the sand control screen to form a gravel pack, which is highly permeable to the flow of hydrocarbon fluids but blocks the flow of the particulate carried in the hydrocarbon fluids.

As such, gravel packs can successfully prevent the problems associated with the production of particulate materials from the formation.

[0006] It has been found, however, that a complete gravel pack of the desired production interval is difficult to achieve particularly in long or inclined/horizontal production intervals. These incomplete packs are commonly a result of the liquid carrier entering a permeable portion of the production interval causing the gravel to form a sand bridge in the annulus. Thereafter, the sand bridge prevents the slurry from flowing to the remainder of the annulus which, in turn, prevents the placement of sufficient gravel in the remainder of the annulus.

[0007] Prior art devices and methods have been developed which attempt to overcome this sand bridge problem. For example, attempts have been made to use tubing positioned exteriorly along the length of the sand control screens to provide an alternate path for the fluid slurry around the sand bridge. It has been found, however, that it is difficult and time consuming to establish fluid communication between the alternate path components of adjacent sand control screens on the rig floor prior to installation into the wellbore. Therefore, a need has arisen for an apparatus for gravel packing a production interval that overcomes the problems associated with sand bridges. A need has also arisen for such an apparatus wherein fluid communication between the alternate path components of adjacent sand control screens is easy to establish on the rig floor.

SUMMARY OF THE INVENTION

[0008] The present invention disclosed herein is directed to a gravel packing apparatus having locking jumper tubes. The gravel packing apparatus of the present invention is operable to overcome the problems associated with sand bridges. In addition, the gravel packing apparatus of the present invention enables fluid communication between the alternate path components of adjacent sand control screens to be easily established on the rig floor.

[0009] In one aspect, the present invention is directed to a gravel packing apparatus. The gravel packing apparatus includes first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly. Each slurry delivery subassembly includes at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly. At least one jumper tube extends between and is sealably coupled to the at least one transport tube of the first joint and the at least one transport tube of the second joint. A first locking assembly is positioned between

the at least one jumper tube and the at least one transport tube of the first joint and a second locking assembly is positioned between the at least one jumper tube and the at least one transport tube of the second joint.

[0010] In one embodiment, a first component of the first locking assembly is supported by the transport tube of the first joint and a second component of the first locking assembly is supported by the jumper tube. Likewise, a first component of the second locking assembly is supported by the transport tube of the second joint and a second component of the second locking assembly is supported by the jumper tube. In this embodiment, the first component of the first and second locking assemblies may be a groove and the second component of the first and second locking assemblies may be a collet assembly, a locking ring or the like. In one configuration, the second component of the first and second locking assemblies is operably positionable to the exterior of the first component of the first and second locking assemblies, respectively. In another configuration, the second component of the first and second locking assemblies is operably positionable to the interior of the first component of the first and second locking assemblies, respectively.

[0011] In another aspect, the present invention is directed to a gravel packing apparatus. The gravel packing apparatus includes a first joint including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly, the transport tube including a first component of a first locking assembly. The gravel packing apparatus also includes a second joint including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly, the transport tube including a first component of a second locking assembly. At least one jumper tube is operable to be sealably coupled between the at least one transport tube of the first joint and the at least one transport tube of the second joint. The jumper tube includes a second component of the first locking assembly at a first end and a second component of the second locking assembly at a second end such that axial engagement of the at least one jumper tube with the transport tube of the first joint operatively engages the first and second components of the first locking assembly and axial engagement of the at least one jumper tube with the transport tube of the second joint operatively engages the first and second components of the second locking assembly.

[0012] In a further aspect, the present invention is directed to a method for assembling a gravel packing apparatus. The method includes providing first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly; threadably coupling the first and second joints together; axially engaging a first end of a jumper tube with the transport tube of the first joint to establish a sealing and locking relationship therebetween; telescopically extending the jumper tube; and axially engaging a second end of the jumper tube with the transport tube of the second joint to establish a sealing and locking relationship therebetween.

[0013] The method may also include engaging a first component of a first locking assembly supported by the transport tube of the first joint with a second component of the first locking assembly supported by the jumper tube and engaging a first component of a second locking assembly supported by the transport tube of the second joint with a second component of the second locking assembly supported by the jumper tube; engaging a first collet assembly with a first groove and engaging a second collet assembly with a second groove; engaging a first locking ring with a first groove and engaging a second locking ring with a second groove; disposing the first end of the jumper tube to the interior of the transport tube of the first joint and disposing the second end of the jumper tube to the interior of the transport tube of the second joint and/or positioning at least a portion of the first end of the jumper tube to the exterior of the transport tube of the first joint and positioning at least a portion of the second end of the jumper tube to the exterior of the transport tube of the second joint.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0015] Figure 1 is a schematic illustration of an offshore platform operating a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0016] Figure 2 is a side view partially in cut away of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0017] Figure 3 is a cross sectional view of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0018] Figure 4 is a cross sectional view of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0019] Figure 5 is a cross sectional view of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0020] Figure 6 is a cross sectional view of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0021] Figures 7A-7D are schematic illustration of the process of coupling two joints of a gravel packing apparatus having locking jumper tubes according to an embodiment of the present invention;

[0022] Figures 8A-8B are side and cross sectional views of a locking jumper tube for use in a gravel packing apparatus according to an embodiment of the present invention;

[0023] Figure 9 is a cross sectional view of a locking jumper tube for use in a gravel packing apparatus according to an embodiment of the present invention;

[0024] Figure 10 is a cross sectional view of a locking jumper tube for use in a gravel packing apparatus according to an embodiment of the present invention; and

[0025] Figure 11 is a cross sectional view of a locking jumper tube for use in a gravel packing apparatus according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0026] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the present invention.

[0027] Referring initially to figure 1, a gravel packing apparatus positioned in an interval of a wellbore and operating from an offshore oil and gas platform that is schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22 including blowout

preventers 24. Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as work string 30.

[0028] A wellbore 32 extends through the various earth strata including formation 14. A casing 34 is secured within wellbore 32 by cement 36. Work string 30 includes various tools including joints 38, 40, 42 that form the gravel packing apparatus of the present invention that is positioned in an interval of wellbore 32 adjacent to formation 14 between packers 44, 46. When it is desired to gravel pack annular region 48 surrounding joints 38, 40, 42, a fluid slurry including a liquid carrier and a particulate material such as sand, gravel or proppants is pumped down work string 30.

[0029] Some or all of the fluid slurry is typically injected directly into annular region 48 in a known manner, such as through a crossover tool (not pictured), which allows the slurry to travel from the interior of work string 30 to the exterior of work string 30. Once the fluid slurry is in annular region 48, a portion of the gravel in the fluid slurry is deposited in annular region 48. Some of the liquid carrier may enter formation 14 through perforation 50 while the remainder of the fluid carrier along with some of the gravel enters certain sections of joints 38, 40, 42 filling those sections with gravel. The sand control screens within joints 38, 40, 42 disallows further migration of the gravel but allows the liquid carrier to travel therethrough into work string 30 and up to the surface via annulus 52. If sand bridges form in annular region 48, some or all of the fluid slurry is injected or diverted into the slurry delivery subassemblies within and connected between joints 38, 40, 42 to bypass the sand bridges such that a complete pack can be achieved.

[0030] Even though figure 1 depicts the gravel packing apparatus of the present invention in a vertical wellbore, it should be understood by those skilled in the art that the gravel packing apparatus of the present invention is equally well suited for use in wellbores having other directional configurations including horizontal wellbores, deviated wellbores, slanted wells, lateral wells and the like. Accordingly, it should be understood by those skilled in the art that the use of directional terms such as above, below, upper, lower, upward, downward, uphole, downhole and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the well and the downhole direction being toward the toe of the well. Also, even though figure 1 depicts an offshore operation, it should be noted by one skilled in the art that the gravel packing apparatus of the present invention is equally well suited for use in onshore operations.

Further, even though figure 1 depicts the gravel packing apparatus of the present invention as having a particular number of joints, it should be understood by those skilled in the art that a gravel packing apparatus of the present invention may have any number of joints both less than or greater than the number shown.

[0031] Referring next to figure 2, therein is depicted a cut away view of a gravel packing apparatus of the present invention that is generally designated 100. Apparatus 100 has an outer tubular or shroud 102 that includes a plurality of openings 104 that are substantially evenly distributed around and along the length of outer tubular 102, which allow the flow of production fluids therethrough. Disposed within outer tubular 102 is a sand control screen assembly 106. Sand control screen assembly 106 includes a base pipe 108 that has a plurality of openings 110 which allow the flow of production fiuids into the production tubing. The exact number, size and shape of openings 110 are not critical to the present invention, so long as sufficient area is provided for fluid production and the integrity of base pipe 108 is maintained.

[0032] Positioned around base pipe 108 is a filter medium depicted as a fluid-porous, particulate restricting wire mesh screen 112. Screen 112 is designed to allow fluid flow therethrough but prevent the flow of particulate materials of a predetermined size from passing therethrough. Screen 112 preferably has a plurality of layers of wire mesh including one or more drainage layers and one or more filter layers wherein the drainage layers that have a mesh size that is larger than the mesh size of the filter layers. For example, a drainage layer may preferably be positioned as the outermost layer and the innermost layer of wire mesh screen 112 with the filter layer or layers positioned therebetween. Positioned around screen 112 is a screen wrapper 114 that has a plurality of openings 116 which allow the flow of production fluids therethrough. The exact number, size and shape of openings 116 is not critical to the present invention, so long as sufficient area is provided for fluid production and the integrity of screen wrapper 114 is maintained. Typically, various sections of screen 112 and screen wrapper 114 are manufactured together as a unit by, for example, diffusion bonding or sintering the layers of wire mesh that form screen 112 together with screen wrapper 114, then rolling the unit into a tubular configuration. The two ends of the tubular unit are then seam welded together. Several tubular units of the screen and screen wrapper combination may be placed over each joint of base pipe 108 and secured thereto by welding or other suitable technique. It should be understood by those skilled in the art that even though figure 2 has described a particular filter medium, other types of filter media could

alternatively be used in conjunction with the apparatus of the present invention, including, but not limited to, a wire wrapped sand control screen.

[0033] Disposed between outer tubular 102 and sand control screen assembly 106 is a slurry delivery subassembly 118. In the illustrated embodiment, slurry delivery subassembly 118 includes a pair of transport tubes 120, 122, a pair of packing tubes 124, 126 and a manifold 128 that provides fluid communication between transport tubes 120, 122 and packing tubes 124, 126. As illustrated, transport tubes 120, 122 extend longitudinally past outer tubular 102 such that the transport tubes 120, 122 of one joint can be fluidically coupled to the transport tubes 120, 122 of another joint as explained in greater detail below. Packing tubes 124, 126 each include a plurality of nozzles, such as nozzle 130 of packing tube 124 and nozzle 132 of packing tube 126. In the event of sand bridge formation or as part of a planned gravel packing process, some or all of the fluid slurry is injected into the slurry delivery subassembly 118 of the uppermost joint. The fluid slurry is able to travel from one joint to the next via the transport tubes 120, 122 and jumper tubes that are sealingly and lockably positioned therebetween, as explained in greater detail below. As the fluid slurry travels from joint to joint, portions of the fluid slurry enter packing tubes 124, 126 via manifold 128. From packing tubes 124, 126, the fluid slurry is able to enter the annular region surrounding gravel packing apparatus 100 by exiting slurry delivery subassembly 118 via nozzles 130, 132. In this manner, a complete gravel pack may be achieved even if sand bridges form in the annular region surrounding gravel packing apparatus 100.

[0034] In the illustrated embodiment, transport tubes 120, 122 extend through a ring assembly 134 that is preferably welded to base pipe 108. Likewise, outer tubular 102 may be welded to ring assembly 134. Ring assembly 134 may be eccentric in design such that it has suitable thickness to receive and support transport tubes 120, 122 on one side but may be thinner on the opposite side. Ring assembly 134 may be a single solid ring or may be formed from ring sections that substantially form a solid ring or may form a circumferentially segmented ring having gaps between the ring sections. Ring assembly 134 may include multiple components that receive and support transport tubes 120, 122 and may have notches, slots or openings that receive and support transport tubes 120, 122.

[0035] As best seen in figure 3, sand control screen assembly 106 may be eccentrically positioned within outer tubular 102 to enable slurry delivery subassembly 118 to be positioned therebetween while maintaining a desired outer diameter of gravel packing apparatus 100. It should be understood by those skilled in the art, however, that even though figures 2 and 3 have described a particular slurry delivery subassembly, other slurry delivery

subassembly having other configurations could alternatively be used in conjunction with the apparatus of the present invention. For example, as best seen in figure 4, a gravel packing apparatus 150 is depicted having a slurry delivery subassembly 152 including a single transport tube 154 and a pair of packing tubes 156, 158 each having a plurality of nozzles 160, 162 in an eccentric design. In another example, as best seen in figure 5, a gravel packing apparatus 170 is depicted having a slurry delivery subassembly 172 including a pair of slurry delivery tubes 174, 176 that serve as both transport tubes, as they extend from joint to joint, as well as packing tubes, as each has a plurality of nozzles 178, 180. Gravel packing apparatus 170 also has an eccentric design. In a further example, as best seen in figure 6, a gravel packing apparatus 190 is depicted having a slurry delivery subassembly 192 including three slurry delivery tubes 194, 196, 198 that serve as both transport tubes, as they extend from joint to joint, as well as packing tubes, as each has a plurality of nozzles 200, 202, 204. Unlike the previously described gravel packing apparatuses, gravel packing apparatus 190 has a concentric design wherein sand control screen assembly 106 is concentrically positioned within the outer tubular 102 with slurry delivery tubes 194, 196, 198 circumferentially distributed therebetween.

[0036] The operation of the assembling a gravel packing apparatus 200 of the present invention will now be described with reference to figures 7A-7D. A lower joint of gravel packing apparatus 200 is depicted as joint 202 having a pair of transport tubes 204 each including a first component of a locking assembly depicted a transition assembly 206, as best seen in figure 7A. In the illustrated embodiment, each transition assembly 206 has a transition section 208 that couples to the rectangular transport tube 204 on one end and has an oppositely disposed circular receiving end including locking groove 210. Each transition assembly 206 is supported by one transport tube 204 and may be secured thereto by welding, set screws or other suitable technique. Transport tubes 204 are supported by a ring assembly 212. Joint 202 is supported by the well platform in, for example, a screen table assembly attached to the rotary table generally located on the well floor of the platform (not pictured). An upper joint of gravel packing apparatus 200 is depicted as joint 214 having a pair of transport tubes 216 each including a first component of a locking assembly depicted a transition assembly 218. In the illustrated embodiment, each transition assembly 218 has a transition section 220 that couples to the rectangular transport tube 216 on one end and has an oppositely disposed circular receiving end including locking groove 222. Each transition assembly 218 is supported by one transport tube 216 and may be secured thereto by welding, set screws or other suitable technique. Transport tubes 216 are supported by a ring assembly

224. Upper joint 214 has been maneuvered into position above lower joint 202 using the hoisting apparatus of the well platform (not pictured). Joints 202 and 214 may now be threadably connected to one another, as best seen in figure 7B, and may be supported by the hoisting apparatus of the well platform (not pictured).

[0037] Once in this position, jumper tubes 226 may be coupled between transport tubes 204 of joint 202 and transport tubes 216 of joint 214, which establish fluid communication therebetween and preferably a fluid tight seal therebetween. As best seen in figure 7C, each jumper tube 226 includes the second components of the locking assemblies depicted as collet assemblies 228, 230. To operatively engage jumper tubes 226 with transport tubes 204, 216, each jumper tube 226 is axially shifted downwardly inserting the lower end of jumper tube 226 within a transition assembly 208. A relative axial force is then applied between each jumper tube 226 and transport tube 204 such that the collet fingers of each collet assembly 228 snaps into engagement with a locking groove 210 of a transition assembly 208. In this configuration, a sealing and locking relationship has been established between jumper tubes 226 and transport tubes 204. Inner tubes 232 of jumper tubes 226 may now be telescopically extended upwardly in the axial direction enabling insertion of the upper end of each jumper tube 226 within a transition assembly 218. A relative axial force is then applied between each jumper tube 226 and transport tube 216 such that the collet fingers of each collet assembly 230 snap into engagement with a locking groove 222 of a transition assembly 218. In this configuration, a sealing and locking relationship has been established between jumper tubes 226 and transport tubes 216, as best seen in figure 7D.

[0038] Referring next to figures 8A-8B, therein are depicted a portion of a gravel packing apparatus having locking jumper tubes according to the present invention that is generally designated 300. In the illustrated embodiment, a jumper tube 302 includes a first tubular member 304 and a second tubular member 306 that slidingly engages within first tubular member 304. Second tubular member 306 is configured to axially slidingly displace from at least one distal end of first tubular member 304 to telescopically extend the length of the jumper tube 302 so that jumper tube 302 may couple with transport tubes of adjacent joints as described above. The sliding relationship between first tubular member 304 and second tubular member 306 is such that the inside diameter of first tubular member 304 and the outside diameter of second tubular member 306 are substantially similar and configured to allow second tubular member 306 to be disposed within first tubular member 304.

[0039] A seal 308 between first tubular member 304 and second tubular member 306 may be used to create a sealing engagement therebetween preventing fluid from passing into

or out of jumper tube 302 at the location where first tubular member 304 and second tubular member 306 meet while still allowing for axial movement therebetween. In addition, an optional back-up seal 310 may be disposed between first tubular member 304 and second tubular member 306 to provide a second sealing engagement between first tubular member 304 and second tubular member 306. A fluid flow transition 312 is disposed within second tubular member 306 so that the inside diameter of at least a portion of second tubular member 306 is axially tapered. Fluid flow transition 312 is configured to transition fluid flow axially through jumper tube 302 at the location where second tubular member 306 and first tubular member 304 meet. At the opposite end, second tubular member 306 includes a seal 314 that is operable to create a sealing engagement between second tubular member 306 and an interior surface of a transition assembly 316 that is coupled to a transport tube 318 at its opposite end. In addition, an optional back-up seal 320 may be disposed between second tubular member 306 and transition assembly 316 to provide a second sealing engagement therebetween.

[0040] In the illustrated embodiment, a locking assembly 322 includes a first component supported by transport tube 318 and transition assembly 316 depicted as locking groove 324 and a second component supported by jumper tube 302 depicted as collet assembly 326 including a plurality of collet fingers 328. As described above, to operatively engage jumper tube 302 with transport tube 318, jumper tube 302 is axially shifted to insert the distal end of second tubular member 306 within transition assembly 316. A relative axial force is then applied between jumper tube 302 and transport tube 318 such that collet fingers 328 flex radially outwardly to pass over the end of transition assembly 316. Further axial shifting of second tubular member 306 relative to transition assembly 316 enables collet fingers 328 to snap radially inwardly into engagement with locking groove 324 of transition assembly 316. Preferably, the distal end of second tubular member 306 also contacts a shoulder 330 of transition assembly 316. In this configuration, a sealing and locking relationship has been established between jumper tube 302 and transport tube 318. In this manner, jumper tubes 302 can be quickly and easily installed between transport tubes of adjacent gravel packing joints to enable fluid communication therebetween and prevent disconnection thereof.

[0041] Referring next to figure 9, therein is depicted a portion of a gravel packing apparatus having locking jumper tubes according to the present invention that is generally designated 400. In the illustrated embodiment, a jumper tube 402 includes a first tubular member 404 and a second tubular member 406 that slidingly engages within first tubular

member 404. Second tubular member 406 is configured to telescopically extend the length of jumper tube 402 so that jumper tube 402 may couple with transport tubes of adjacent joints as described above. The sliding relationship between first tubular member 404 and second tubular member 406 is such that the inside diameter of first tubular member 404 and the outside diameter of second tubular member 406 are substantially similar and configured to allow second tubular member 406 to be disposed within first tubular member 404.

[0042] A seal 408 between first tubular member 404 and second tubular member 406 may be used to create a sealing engagement therebetween preventing fluid from passing into or out of jumper tube 402 at the location where first tubular member 404 and second tubular member 406 meet while still allowing for axial movement of therebetween. In addition, an optional back-up seal 410 may be disposed between first tubular member 404 and second tubular member 406 to provide a second sealing engagement between first tubular member 404 and second tubular member 406. A fluid flow transition 412 is disposed within second tubular member 406 so that the inside diameter of at least a portion of second tubular member 406 is axially tapered. Fluid flow transition 412 is configured to transition fluid flow axially through jumper tube 402 at the location where second tubular member 406 and first tubular member 404 meet. At the opposite end, second tubular member 406 includes a seal 414 that is operable to create a sealing engagement between second tubular member 406 and an interior surface of a transition assembly 416 that is coupled to a transport tube 418 at its opposite end. In addition, an optional back-up seal 420 may be disposed between second tubular member 406 and transition assembly 416 to provide a second sealing engagement therebetween.

[0043] In the illustrated embodiment, a locking assembly 422 includes a first component supported by transport tube 418 and transition assembly 416 depicted as locking groove 424 and a second component supported by jumper tube 402 depicted as a locking housing 426 and a locking ring 428, which is preferably a split ring or c-ring sized to be received within locking groove 424 and prevent relative axial movement between jumper tube 402 and transport tube 418 once received therein. As described above, to operatively engage jumper tube 402 with transport tube 418, jumper tube 402 is axially shifted to insert the distal end of second tubular member 406 within transition assembly 416. A relative axial force is then applied between jumper tube 402 and transport tube 418 such that locking ring 428 flexes radially outwardly within housing 426 to pass over the end of transition assembly 416. Further axial shifting of second tubular member 406 relative to transition assembly 416 enables locking ring 428 to snap radially inwardly into engagement with locking groove 424

of transition assembly 416. Preferably, the distal end of second tubular member 406 also contacts a shoulder 430 of transition assembly 416. In this configuration, a sealing and locking relationship has been established between jumper tube 402 and transport tube 418. In this manner, jumper tubes 402 can be quickly and easily installed between transport tubes of adjacent gravel packing joints to enable fluid communication therebetween and prevent disconnection thereof.

[0044] Referring next to figure 10, therein is depicted a portion of a gravel packing apparatus having locking jumper tubes according to the present invention that is generally designated 500. In the illustrated embodiment, a jumper tube 502 includes a first tubular member 504 and a second tubular member 506 that slidingly engages within first tubular member 504. Second tubular member 506 is configured to telescopically extend the length of jumper tube 502 so that jumper tube 502 may couple with transport tubes of adjacent joints as described above. The sliding relationship between first tubular member 504 and second tubular member 506 is such that the inside diameter of first tubular member 504 and the outside diameter of second tubular member 506 are substantially similar and configured to allow second tubular member 506 to be disposed within first tubular member 504.

[0045] A seal 508 between first tubular member 504 and second tubular member 506 may be used to create a sealing engagement therebetween preventing fluid from passing into or out of jumper tube 502 at the location where first tubular member 504 and second tubular member 506 meet while still allowing for axial movement of therebetween. In addition, an optional back-up seal 510 may be disposed between first tubular member 504 and second tubular member 506 to provide a second sealing engagement between first tubular member 504 and second tubular member 506. A fluid flow transition 512 is disposed within second tubular member 506 so that the inside diameter of at least a portion of second tubular member 506 is axially tapered. Fluid flow transition 512 is configured to transition fluid flow axially through jumper tube 502 at the location where second tubular member 506 and first tubular member 504 meet. At the opposite end, second tubular member 506 includes a seal 514 that is operable to create a sealing engagement between second tubular member 506 and an interior surface of a transition assembly 516 that is coupled to a transport tube 518 at its opposite end. In addition, an optional back-up seal 520 may be disposed between second tubular member 506 and transition assembly 516 to provide a second sealing engagement therebetween.

[0046] In the illustrated embodiment, a locking assembly 522 includes a first component supported by transport tube 518 and transition assembly 516 depicted as locking

groove 524 and a second component supported by jumper tube 502 depicted as collet assembly 526 including a plurality of collet fingers 528. To operatively engage jumper tube 502 with transport tube 518, jumper tube 502 is axially shifted to align the distal end of second tubular member 506 with transition assembly 516. A relative axial force is then applied between jumper tube 502 and transport tube 518 such that collet fingers 528 flex radially inwardly into the end of transition assembly 516. Further axial shifting of second tubular member 506 relative to transition assembly 516 enables collet fingers 528 to snap radially outwardly into engagement with locking groove 524 of transition assembly 516. In this configuration, a sealing and locking relationship has been established between jumper tube 502 and transport tube 518. In this manner, jumper tubes 502 can be quickly and easily installed between transport tubes of adjacent gravel packing joints to enable fluid communication therebetween and prevent disconnection thereof.

[0047] Referring next to figure 11, therein is depicted a portion of a gravel packing apparatus having locking jumper tubes according to the present invention that is generally designated 600. In the illustrated embodiment, a jumper tube 602 includes a first tubular member 604 and a second tubular member 606 that slidingly engages within first tubular member 604. Second tubular member 606 is configured to telescopically extend the length of jumper tube 602 so that jumper tube 602 may couple with transport tubes of adjacent joints as described above. The sliding relationship between first tubular member 604 and second tubular member 606 is such that the inside diameter of first tubular member 604 and the outside diameter of second tubular member 606 are substantially similar and configured to allow second tubular member 606 to be disposed within first tubular member 604.

[0048] A seal 608 between first tubular member 604 and second tubular member 606 may be used to create a sealing engagement therebetween preventing fluid from passing into or out of jumper tube 602 at the location where first tubular member 604 and second tubular member 606 meet while still allowing for axial movement of therebetween. In addition, an optional back-up seal 610 may be disposed between first tubular member 604 and second tubular member 606 to provide a second sealing engagement between first tubular member 604 and second tubular member 606. A fluid flow transition 612 is disposed within second tubular member 606 so that the inside diameter of at least a portion of second tubular member 606 is axially tapered. Fluid flow transition 612 is configured to transition fluid flow axially through jumper tube 602 at the location where second tubular member 606 and first tubular member 604 meet. At the opposite end, second tubular member 606 includes a seal 614 that is operable to create a sealing engagement between second tubular member 606 and an

interior surface of a transition assembly 616 that is coupled to a transport tube 618 at its opposite end. In addition, an optional back-up seal 620 may be disposed between second tubular member 606 and transition assembly 616 to provide a second sealing engagement therebetween.

[0049] In the illustrated embodiment, a locking assembly 622 includes a first component supported by transport tube 618 and transition assembly 616 depicted as locking groove 624 and a second component supported by jumper tube 602 depicted as a locking housing 626 and a locking ring 628, which is preferably a split ring or c-ring sized to be received within locking groove 624 and prevent relative axial movement between jumper tube 602 and transport tube 618 once received therein. To operatively engage jumper tube 602 with transport tube 618, jumper tube 602 is axially shifted to insert the distal end of second tubular member 606 within transition assembly 616. A relative axial force is then applied between jumper tube 602 and transport tube 618 such that locking ring 628 flexes radially inwardly then enters transition assembly 616. Further axial shifting of second tubular member 606 relative to transition assembly 616 enables locking ring 628 to snap radially outwardly into engagement with locking groove 624 of transition assembly 616. Preferably, the distal end of second tubular member 606 also contacts a shoulder 630 of transition assembly 616. In this configuration, a sealing and locking relationship has been established between jumper tube 602 and transport tube 618. In this manner, jumper tubes 602 can be quickly and easily installed between transport tubes of adjacent gravel packing joints to enable fluid communication therebetween and prevent disconnection thereof.

[0050] While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A gravel packing apparatus comprising:

first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly;

at least one jumper tube extending between and sealably coupled to the at least one transport tube of the first joint and the at least one transport tube of the second joint; and

a first locking assembly positioned between the at least one jumper tube and the at least one transport tube of the first joint and a second locking assembly positioned between the at least one jumper tube and the at least one transport tube of the second joint.

2. The apparatus as recited in claim 1 wherein a first component of the first locking assembly is supported by the transport tube of the first joint and a second component of the first locking assembly is supported by the jumper tube and wherein a first component of the second locking assembly is supported by the transport tube of the second joint and a second component of the second locking assembly is supported by the jumper tube.

3. The apparatus as recited in claim 2 wherein the first component of the first and second locking assemblies further comprises a groove.

4. The apparatus as recited in claim 2 wherein the second component of the first and second locking assemblies further comprises a collet assembly.

5. The apparatus as recited in claim 2 wherein the second component of the first and second locking assemblies further comprises a locking ring.

6. The apparatus as recited in claim 2 wherein the second component of the first and second locking assemblies is operably positionable to the exterior of the first component of the first and second locking assemblies, respectively.

7. The apparatus as recited in claim 2 wherein the second component of the first and second locking assemblies is operably positionable to the interior of the first component of the first and second locking assemblies, respectively.

8. A gravel packing apparatus comprising:

a first joint including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly, the transport tube including a first component of a first locking assembly;

a second joint including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly, the transport tube including a first component of a second locking assembly;

at least one jumper tube operable to be sealably coupled between the at least one transport tube of the first joint and the at least one transport tube of the second joint, the jumper tube including a second component of the first locking assembly at a first end and a second component of the second locking assembly at a second end,

wherein, axial engagement of the at least one jumper tube with the transport tube of the first joint operatively engages the first and second components of the first locking assembly; and

wherein, axial engagement of the at least one jumper tube with the transport tube of the second joint operatively engages the first and second components of the second locking assembly.

9. The apparatus as recited in claim 8 wherein the first component of the first and second locking assemblies further comprises a groove.

10. The apparatus as recited in claim 8 wherein the second component of the first and second locking assemblies further comprises a collet assembly.

11. The apparatus as recited in claim 8 wherein the second component of the first and second locking assemblies further comprises a locking ring.

12. The apparatus as recited in claim 8 wherein the second component of the first and second locking assemblies is operably positionable to the exterior of the first component of the first and second locking assemblies, respectively.

13. The apparatus as recited in claim 8 wherein the second component of the first and second locking assemblies is operably positionable to the interior of the first component of the first and second locking assemblies, respectively.

14. The apparatus as recited in claim 8 wherein axial engagement of the at least one jumper tube with the transport tube of the second joint further comprises telescopically extending the at least one jumper tube.

15. A method for assembling a gravel packing apparatus, the method comprising:

providing first and second joints each including a sand control screen assembly having a filter medium positioned exteriorly of a base pipe and a slurry delivery subassembly positioned exteriorly of the sand control screen assembly, the slurry delivery subassembly including at least one transport tube extending longitudinally along at least a portion of the sand control screen assembly;

threadably coupling the first and second joints together;

axially engaging a first end of a jumper tube with the transport tube of the first joint to establish a sealing and locking relationship therebetween;

telescopically extending the jumper tube; and

axially engaging a second end of the jumper tube with the transport tube of the second joint to establish a sealing and locking relationship therebetween.

16. The method as recited in claim 15 wherein axially engaging the first end of the jumper tube with the transport tube of the first joint further comprises engaging a first component of a first locking assembly supported by the transport tube of the first joint with a second component of the first locking assembly supported by the jumper tube and wherein axially engaging the second end of the jumper tube with the transport tube of the second joint further comprises engaging a first component of a second locking assembly supported by the transport tube of the second joint with a second component of the second locking assembly supported by the jumper tube.

17. The method as recited in claim 15 wherein axially engaging the first end of the jumper tube with the transport tube of the first joint further comprises engaging a first collet assembly with a first groove and wherein axially engaging the second end of the jumper tube with the transport tube of the second joint further comprises engaging a second collet assembly with a second groove.

18. The method as recited in claim 15 wherein axially engaging the first end of the jumper tube with the transport tube of the first joint further comprises engaging a first locking ring with a first groove and wherein axially engaging the second end of the jumper tube with the transport tube of the second joint further comprises engaging a second locking ring with a second groove.

19. The method as recited in claim 15 wherein engaging the first end of the jumper tube with the transport tube of the first joint further comprises disposing the first end of the jumper tube to the interior of the transport tube of the first joint and wherein axially engaging the second end of the jumper tube with the transport tube of the second joint further comprises disposing the second end of the jumper tube to the interior of the transport tube of the second joint.

20. The method as recited in claim 15 wherein engaging the first end of the jumper tube with the transport tube of the first joint further comprises positioning at least a portion of the first end of the jumper tube to the exterior of the transport tube of the first joint and wherein axially engaging the second end of the jumper tube with the transport tube of the second joint further comprises positioning at least a portion of the second end of the jumper tube to the exterior of the transport tube of the second joint.

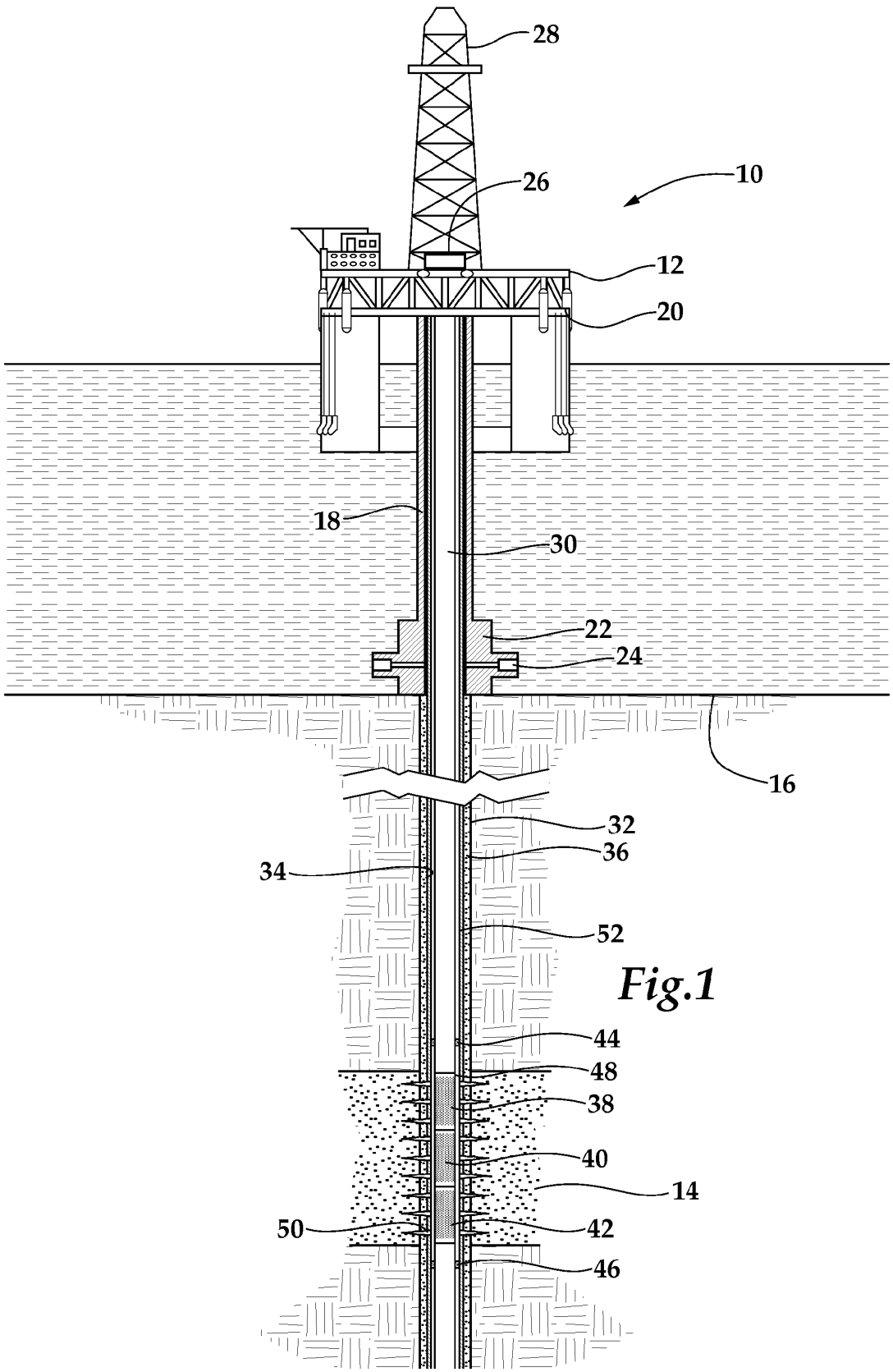

Fig.1

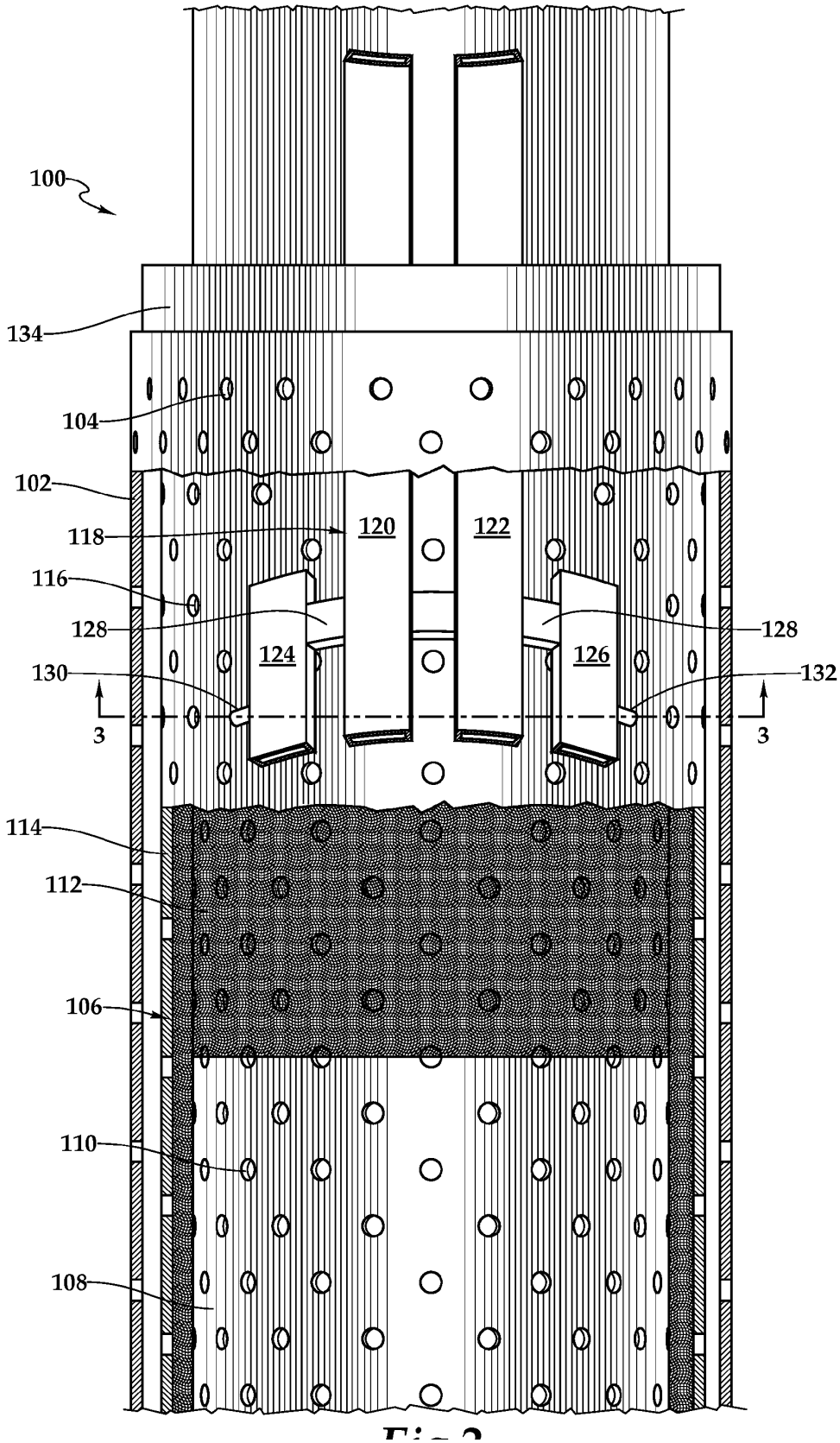
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Fig 2

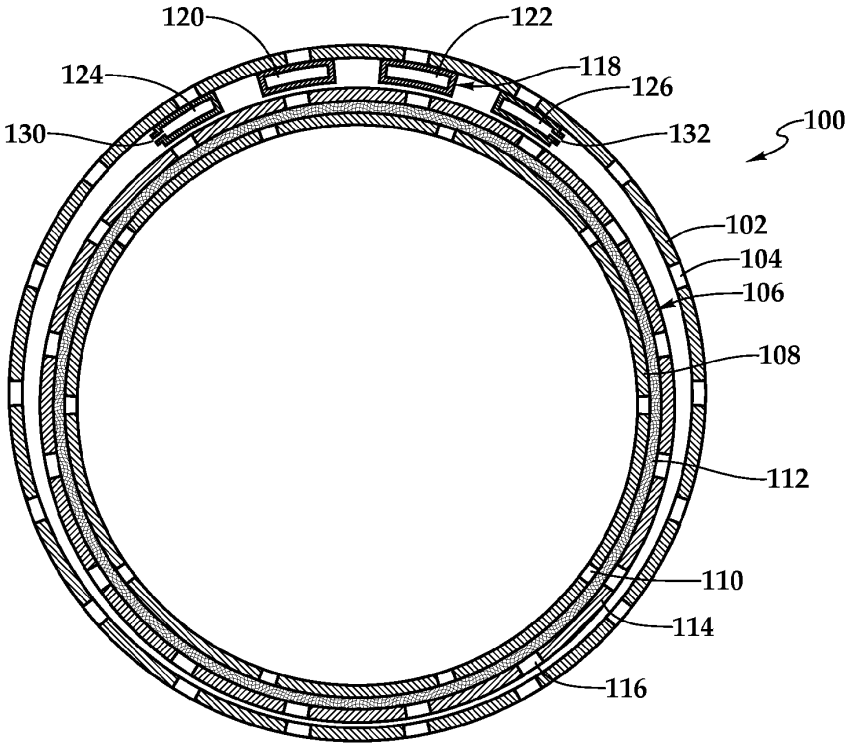
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Fig.3

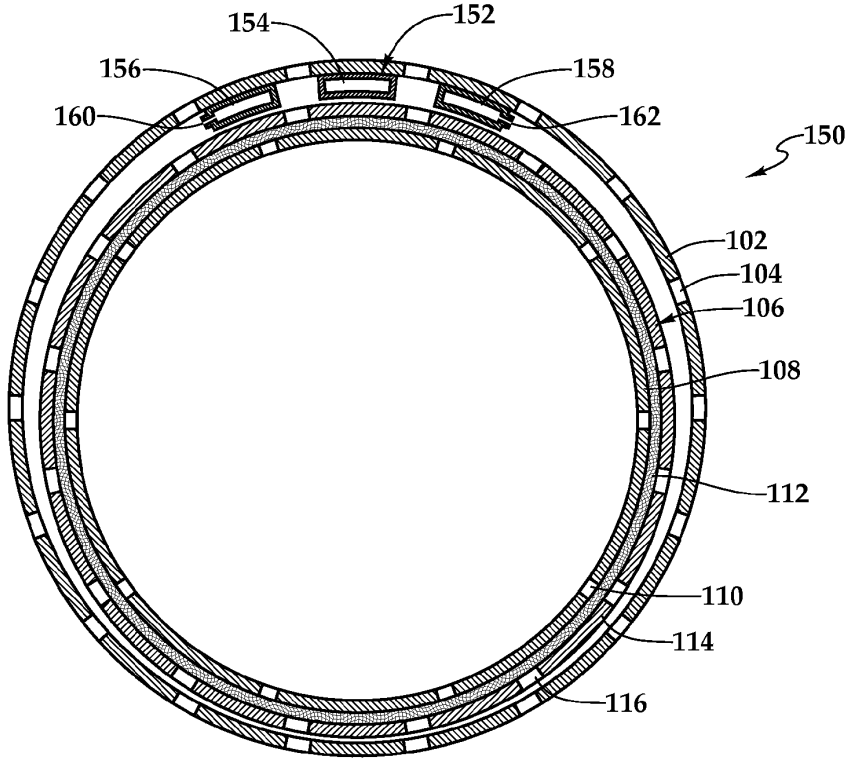
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Fig.4

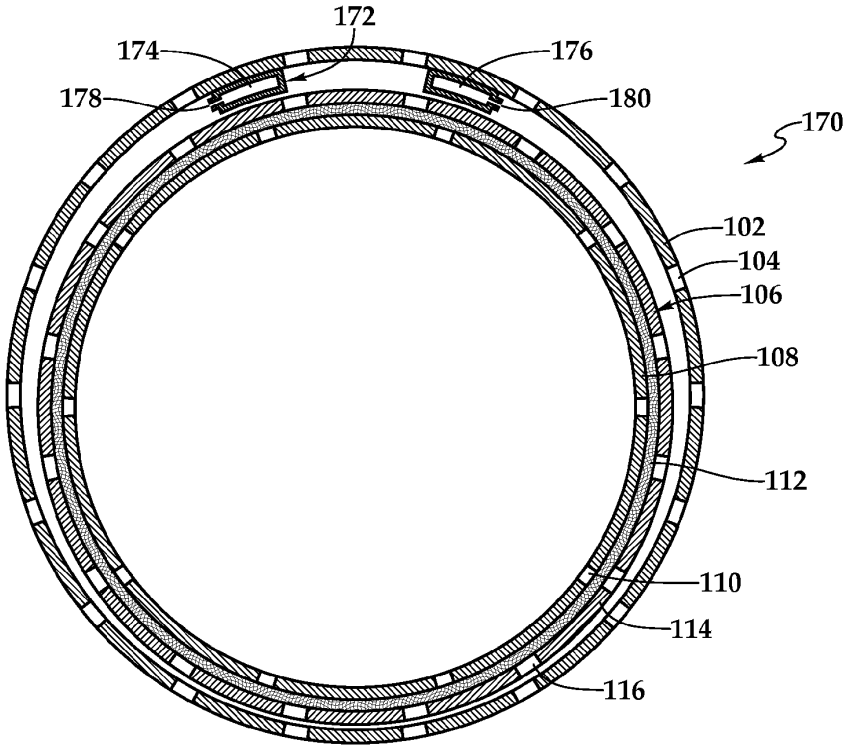
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Fig.5

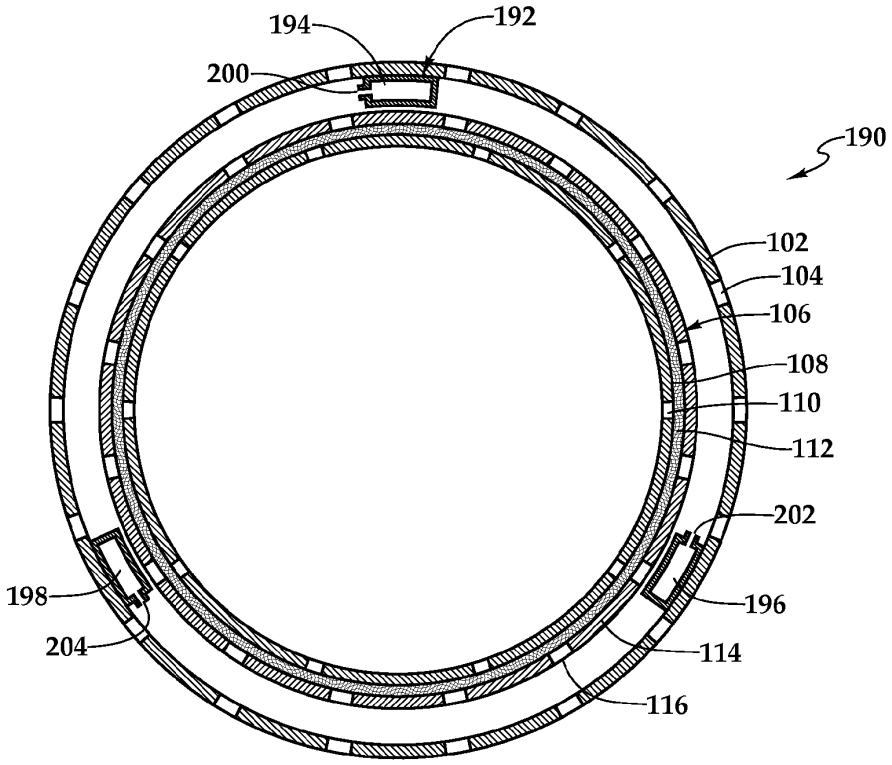
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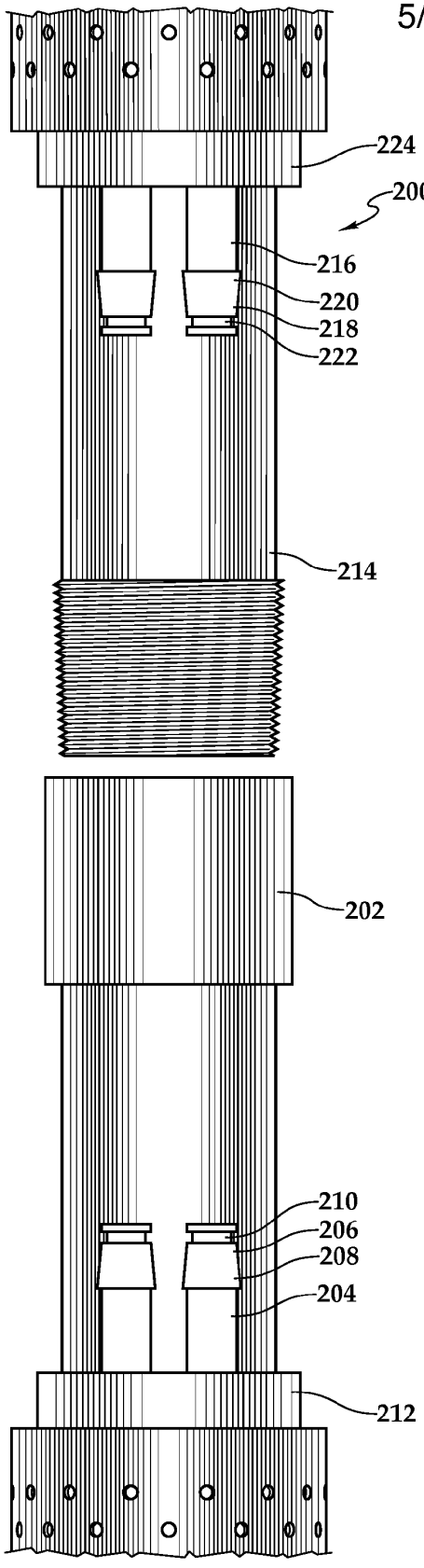
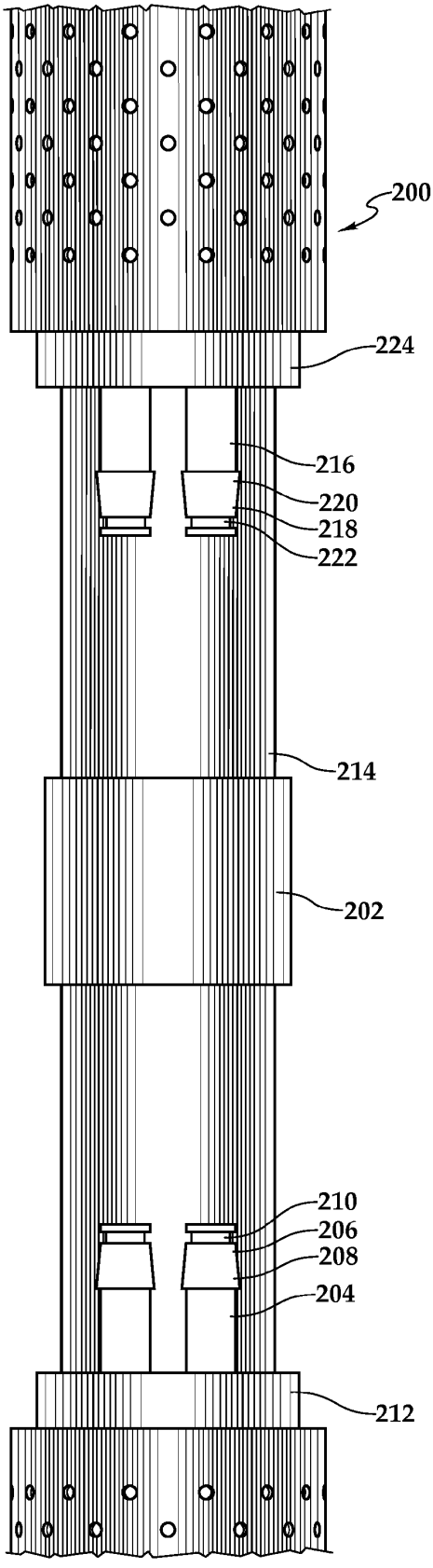
Fig.6





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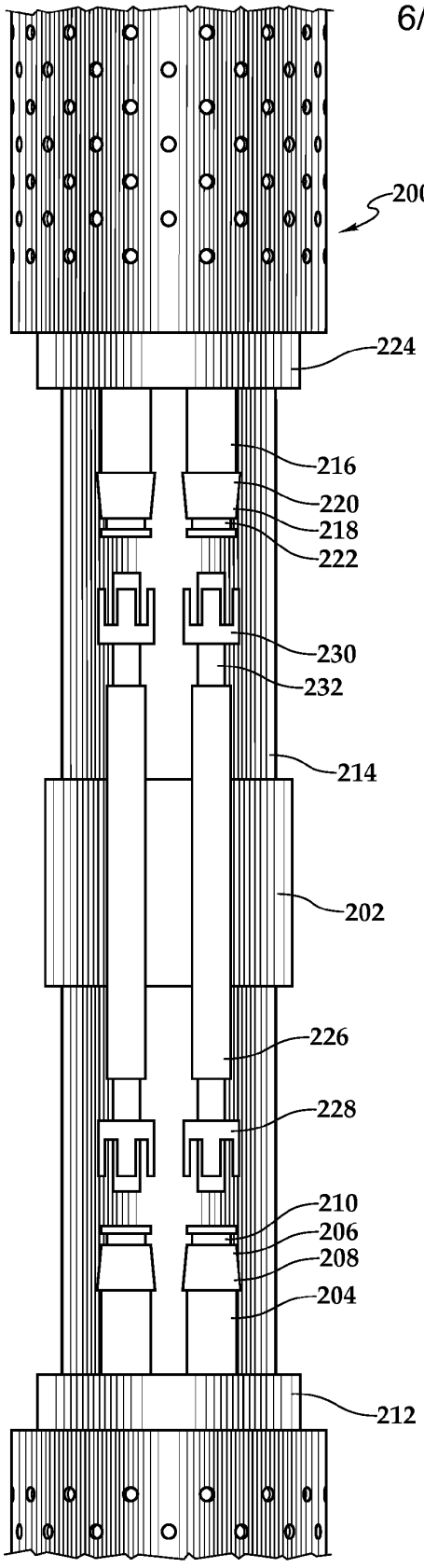
Page 523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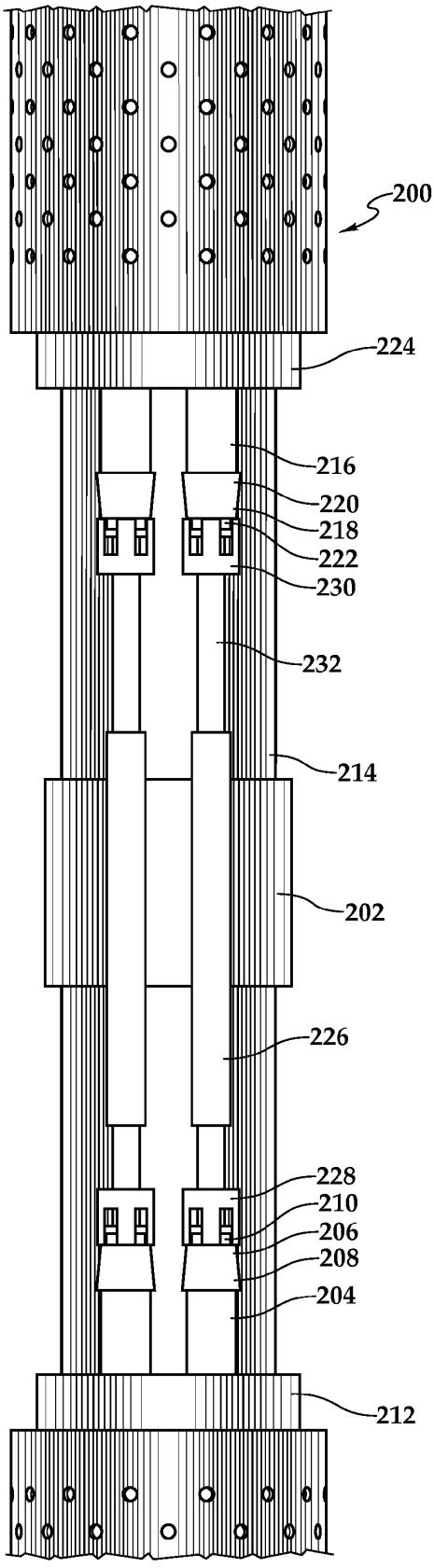
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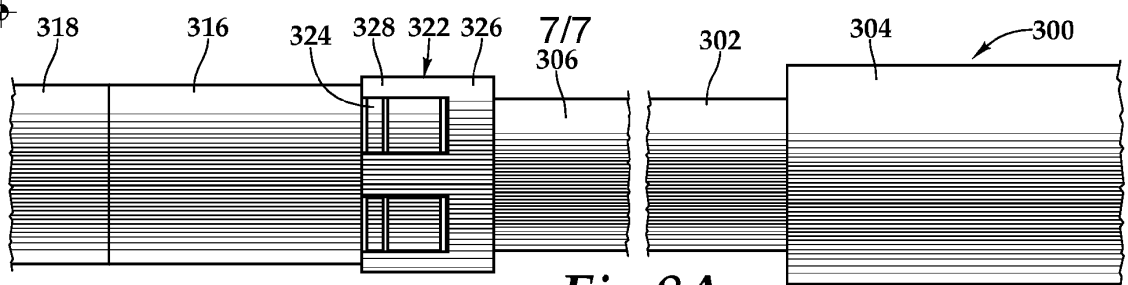

Fig.8A

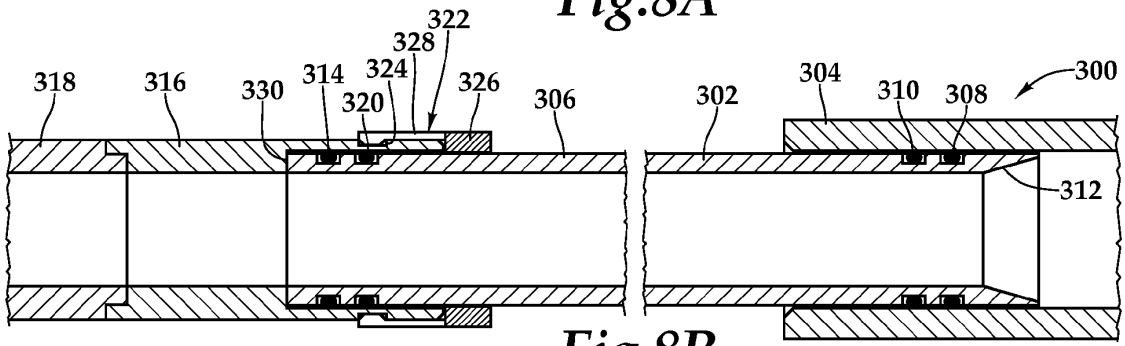

Fig.8B

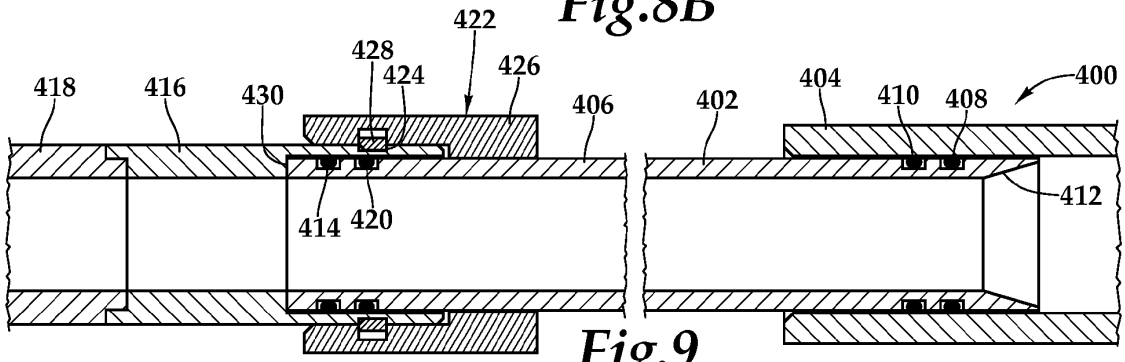

Fig.9

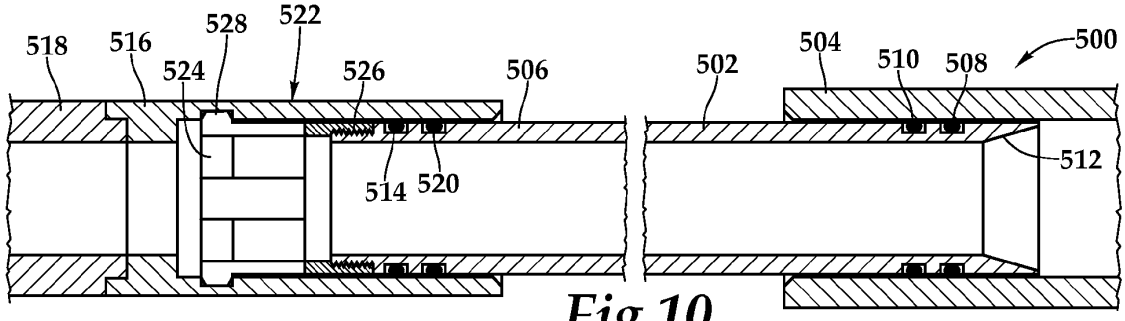

Fig.10

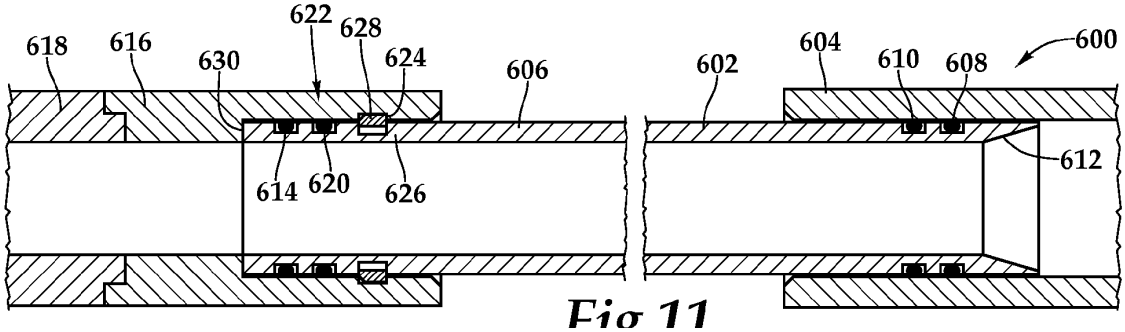

Fig.11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/068524

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/04(2006.01)i, E21B 17/046(2006.01)i, E21B 33/13(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; F16L 39/00; E21B 33/122; E21B 43/16; E21B 43/08; E21B 17/046; E21B 33/13

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: gravel packing, joint, sand control screen, filter medium, slurry, jumper tube, and locking assembly

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009-0159270 A1 (SETTERBERG, JR., JOHN RICHARD et al.) 25 June 2009 See abstract, paragraphs [0018], [0020]-[0023], and figures 1-5.	1-20
Y	US 5390966 A (COX, LARRY L. et al.) 21 February 1995 See column 3, line 39 - column 4, line 51 and figures 2, 4.	1-20
A	US 2009-0294128 A1 (DALE, BRUCE A. et al.) 03 December 2009 See paragraphs [0043], [0045]-[0046] and figures 3A-3D.	1-20
A	US 6298916 B1 (TIBBLES, RAYMOND J. et al.) 09 October 2001 See column 2, line 59 column 3, line 51 and figure 1.	1-20
A	US 2008-0190608 A1 (CORONADO, MARTIN et al.) 14 August 2008 See paragraphs [0015]-[0016] and figure 1.	1-20

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

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Date of the actual completion of the international search	Date of mailing of the international search report
21 August 2013 (21.08.2013)	**22 August 2013 (22.08.2013)**

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Authorized officer
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Telephone No. **+82-42-481-3360**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2012/068524

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Information on patent family members

International application No.
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In place of PTO-1449 Form	U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE			*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(use as many sheets as necessary)*				Application Number	16/347711
				Filing Date	May 6, 2019
				First Inventor Name	Coffin
				Art Unit	TBD
				Examiner Name	TBD
SHEET	1	OF	1	Attorney Docket Number	7523.1981US01

U. S. PATENTS

Examiner's Initials	Cite No.	Document Number	Issue Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document

U. S. PATENT APPLICATION PUBLICATIONS

Examiner's Initials	Cite No.	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document
	A1	2003/0029613 A1	02-13-2003	Danos et al.
	A2	2010/0139919 A1	06-10-2010	Yeh et al.
	A3	2013/0008652 A1	01-10-2013	Broussard et al.
	A4	2014/0110131 A1	04-24-2014	Cunningham et al.

FOREIGN PATENT DOCUMENTS

Examiner's Initials	Cite No.	Foreign Patent Document (Country Code – Number – Kind)	Publication Date MM-DD-YYYY	Patentee or Applicant of Cited Document	Translation Y/N
	B1	WO 2013/187878 A1	12-19-2013	Halliburton Energy Services, Inc.	

NON-PATENT LITERATURE DOCUMENTS

Examiner's Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article, title of the item, date, page(s), volume-issue number(s), publisher, city/country where published
	C1	International Search Report and Written Opinion issued for International Patent Application No. PCT/US2019/024626, dated August 7, 2019, 20 pages.

Examiner Signature	/JENNIFER H GAY/	Date Considered	06/28/2021

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include a copy of this form with next communication to applicant.

4843-2882-2953 v.1

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.H.G/

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E21B 43/04 (2006.01) *E21B 43/08* (2006.01)

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PCT/US2018/068170

(22) International Filing Date:
31 December 2018 (31.12.2018)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 3000 N. Sam Houston Parkway E., Houston, Texas 77032 (US).

(72) Inventors: **COFFIN, Maxime Philippe**; 4115 E Crescent Way, Frisco, Texas 75034 (US). **PENNO, Andrew David**; 11 Tuas South Ave 12, Singapore 637131 (SG). **BOURGNEUF, Patrick Patchi**; 3 Rue Johannes Kepler Zone Europa, 64000 Pau (FR).

(74) Agent: **GARDNER, Jason D.** et al.; KILPATRICK TOWNSEND & STOCKTON LLP, 4208 Six Forks Road, Suite 1400, Raleigh, North Carolina 27609 (US).

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

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

(54) Title: SHUNT TUBE SYSTEM FOR GRAVEL PACKING OPERATIONS

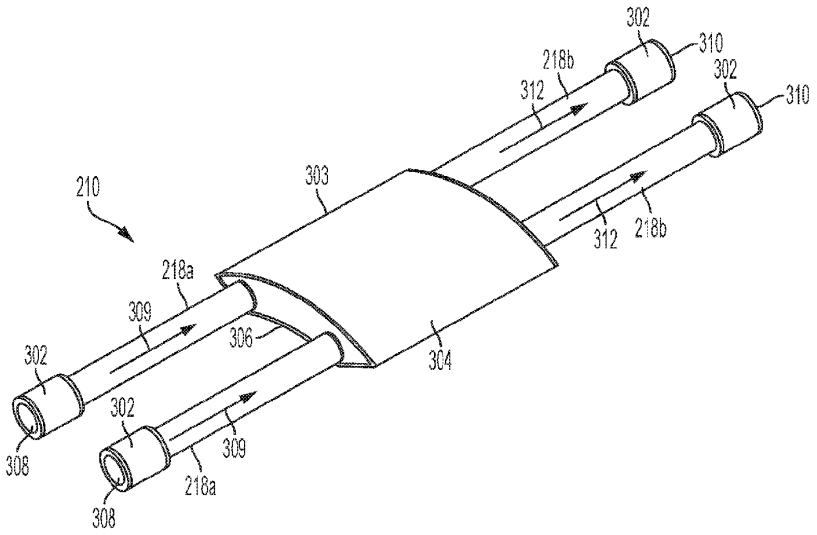

FIG. 3

(57) Abstract: A shunt system for a wellbore includes a first set of tubes defining a first plurality of fluid paths and a second set of tubes defining a second plurality of fluid paths. The shunt system also includes a mixing chamber positioned between the first set of tubes and the second set of tubes to allow slurry from the first plurality of fluid paths to mix together prior to outputting the slurry to the second set of tubes. Further, the shunt system is positionable external to one or more sand screens.

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TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

SHUNT TUBE SYSTEM FOR GRAVEL PACKING OPERATIONS

Technical Field

[0001] The present disclosure relates to shunt tube systems used in gravel packing operations of hydrocarbon well systems. More specifically, this disclosure relates to mixing chambers positioned between sections of shunt tubing in the shunt tube systems used in the gravel packing operations that are external to sand screens.

Background

[0002] In hydrocarbon-producing wells, sand screens may be used to filter sand and other debris from production fluids produced from the hydrocarbon well to a surface. To further filter the sand and other debris from the production fluids, an annulus between the sand screen and a wall of the hydrocarbon well may be packed with gravel, sand, or proppant. The gravel, sand, or proppant for a gravel pack filling the annulus may be provided to an appropriate location using multiple shunt tubes. If one of the shunt tubes become blocked or otherwise unusable, a gravel packing operation may continue with one less usable shunt tube. Completing the gravel packing operation with one less usable shunt tube may result in an increase in friction losses in the remaining shunt tubes, and the increased friction losses may limit a maximum achievable gravel packing length of the gravel packing operation.

Brief Description of the Drawings

[0003] FIG. 1 is a cross-sectional view of an example of a well system that includes a series of sand screens with a shunt system according to some aspects of the present disclosure.

[0004] FIG. 2 is a side view of the shunt system of FIG. 1 positioned externally along a portion of a sand screen tubular according to some aspects of the present disclosure.

[0005] FIG. 3 is a perspective view of a mixing chamber of the shunt system of FIG. 2 according to some aspects of the present disclosure.

[0006] FIG. 4 is a flowchart of a process for mixing slurry within the shunt system of FIG. 1 according to some aspects of the present disclosure.

Detailed Description

[0007] Certain aspects and examples of the disclosure relate to shunt tube systems used for gravel packing operations within a wellbore that are positioned external to a sand screen assembly. Positioning the shunt tubes external to the sand screen assembly may increase an available size of the shunt tubes transporting slurry for the gravel packing operation without occupying space within a tubular of the sand screen assembly used to produce wellbore fluids to a surface of a wellbore. In an example, slurry is defined as a clean carrier fluid with concentrations of particulate (e.g., gravel, sand, or proppant) suspended within the clean carrier fluid. The shunt tube system may include a mixing chamber positioned external to a joint between two sand screen assemblies. In another example, the mixing chamber may be positioned external to a sand screen assembly or in any other external location in relation to the sand screen assembly. Transmission tubes of the shunt system may couple to jumper tubes of the mixing chamber to provide paths for ingress and egress of slurry to and from the mixing chamber.

[0008] Providing a mixing chamber between two sections of transmission tubes enables mixing of the slurry from multiple parallel transmission tubes at defined

intervals. Accordingly, any imbalances in slurry proppant concentration between the multiple parallel transmission tubes may be reduced when the slurry fluids from the multiple parallel transmission tubes are mixed in the mixing chamber and output to downhole sets of parallel transmission tubes. Further, the mixing chamber may enable a bypass of a plug in one of the transmission tubes resulting from a buildup of proppant in the transmission tube. Bypassing the plug with the mixing chamber enables the slurry to continue flowing through the downhole sets of parallel transmission tubes. Providing the bypass to the plug may reduce friction losses in the shunt tube system and improve a maximum achievable gravel packing length by reestablishing a maximum total number of usable transmission tubes after the mixing chamber when one of the transmission tubes along a previous section of a sand screen was rendered unusable due to the plug.

[0009] Balancing proppant concentrations of transmission tubes and bypassing a plugged transmission tube may result in increased reliability of the shunt tube system. Accordingly, implementing the shunt tube system described herein may result in increases in consistency of a gravel pack around a sand screen within a wellbore. Further, the shunt tube system may provide an increase in reliability of a gravel packing operation within the wellbore.

[0010] These illustrative examples are given to introduce the reader to the general subject matter discussed here and are not intended to limit the scope of the disclosed concepts. The following sections describe various additional features and examples with reference to the drawings in which like numerals indicate like elements, and directional descriptions are used to describe the illustrative aspects but, like the illustrative aspects, should not be used to limit the present disclosure.

[0011] FIG. 1 is a cross-sectional view of an example of a well system 100 according to some aspects. The well system 100 may include a wellbore 102 with a generally vertical section 104 that transitions into a generally horizontal section 106 extending through a subterranean earth formation 108. In an example, the vertical section 104 may extend in a downhole direction from a portion of the wellbore 102 having a cemented in casing string 110. A tubular string, such as a production tubing string 112, may be installed or extended into the wellbore 102.

[0012] One or more sand screens 114 and one or more packers 118 may be interconnected along the production tubing string 112, such as along tubulars 119 positioned along the horizontal section 106 of the wellbore 102. The tubulars 119 may be attached to a downhole end of the production tubing string 112. The packers 118 may seal an annulus 120 located between the tubulars 119 and walls of the wellbore 102. As a result, fluids 122 may be produced from multiple intervals or "pay zones" of the formation 108 through isolated portions of the annulus 120 between adjacent pairs of packers 118.

[0013] In an example, the sand screens 114 may be positioned between pairs of the packers 118. The sand screens 114 may be any type of sand screens that are coupled to the tubulars 119 mechanically or with an adhesive material. In operation, the sand screen 114 may filter the fluids 122 flowing into the tubulars 119 from the formation 108 and through the annulus 120.

[0014] While the well system 100 is described as including multiple tubulars 119 and multiple packers 118, these described components may not be used in every example in which the sand screen 114 is used. For example, the well system 100 may include only an individual tubular 119. Further, an example using the sand screen 114

may be implemented without the packers 118 isolating the various sections of the formation 108.

[0015] To assist the sand screens with filtering the fluids 122 from the formation 108, the well system 100 may also include a shunt system 126. The slurry may be diverted from the production string 112 (e.g., using a closing sleeve (not shown)) to an annulus 124 between a wall of the wellbore 102 and the production tubing string 112 when the slurry is at a location within the production tubing string 112 downhole from a gravel pack packer 125. From the annulus 124, the slurry is received by the shunt system 126 that functions to both transmit the slurry further downhole and to deposit the slurry around the sand screens 114 to generate a gravel pack within the annulus 120. The shunt system 126, which is positioned external to the sand screens 114, is described in further detail below with respect to FIGS. 2-4. The gravel pack generated in the annulus 120 by the shunt system 126 may assist the sand screen 114 in preventing the production of fine particulate or sand from the formation 108. For example, the gravel pack in the annulus 120 may prevent migration of formation materials from the formation 108 into the tubular 119. Further, because the shunt system 126 is positioned external to the sand screens 114, the tubes associated with the shunt system 126 may be larger because the tubes do not take up any space used to produce the production fluid from the wellbore 102.

[0016] FIG. 2 is a side view of the shunt system 126 positioned externally along a portion of the tubular 119 including the sand screens 114 according to some aspects. As illustrated, portions of the tubular 119 between the packers 118 may include multiple sand screen sections 202a and 202b. Accordingly, the shunt system 126 may include sets of transport tubes 204a and 204b and packing tubes 206a and 206b that correspond with the respective sand screen sections 202a and 202b. To span a joint

208 between the sand screen sections 202a and 202b, a mixing chamber 210 may be installed between the transport tubes 204a and the transport tubes 204b. The mixing chamber 210 may also be positioned in other locations such as directly above one of the sand screens 114.

[0017] In an example, the transport tubes 204a may receive the slurry from the annulus 124 or from an additional uphole mixing chamber (not shown). As the slurry travels into the transport tubes 204a, some of the slurry may be diverted into the packing tubes 206a. The slurry diverted into the packing tubes 206a may exit the packing tubes 206a at slurry distributors 212a. In an example, the transport tubes 204a include a cross-sectional area that is larger than a cross-sectional are of the packing tubes 206a.

[0018] The slurry distributors 212a may be holes or nozzles installed along a length of the packing tubes 206a. In an example, the slurry distributors 212a may allow the slurry to exit the packing tubes 206a such that the slurry fills the annulus 120 surrounding the tubular 119. The slurry that fills the annulus 120 may be referred to as a gravel pack. Additionally, a portion of the tubular 119 positioned under the packing tubes 206a (e.g., on a side of the tubular 119) may be a location of the sand screens 114. Thus, the gravel pack distributed by the packing tubes 206a may work in conjunction with the sand screens 114 to filter unwanted debris from the fluids 122 produced through the production tubing string 112.

[0019] Continuing with the example, the shunt system 126 may include the transport tubes 204b positioned further downhole within the wellbore 102 than the transport tubes 204a. The transport tubes 204b may receive mixed slurry from the mixing chamber 210, and the mixing chamber 210 may receive unmixed slurry from the individual transport tubes 204a. Because of the relative positioning of the transport

tubes 204a within the wellbore 102, leak-off of clean fluid from the slurry may be more prevalent in a transport tube 204a with slurry distributors 212a positioned facing a direction 214 toward a lower wall of the wellbore 102 than the slurry distributors 212a positioned facing a direction 216 toward an upper wall of the wellbore 102. The additional clean fluid leak-off experienced by the transport tube 204a feeding the slurry distributors 212a facing the direction 214 may result in a difference in proppant concentration between the slurry in the two parallel transport tubes 204a, especially over a length of an entire shunt system 126. Accordingly, when the unmixed slurry enters the mixing chamber 210 at differing proppant concentrations from the transport tubes 204a, the mixing chamber 210 may mix the unmixed slurry to provide a more uniform proppant concentration in a mixed slurry provided to the transport tubes 204b.

[0020] Mixing the slurry at the mixing chamber 210 may provide each new downhole section of transport tubes 204b with similar concentrations of proppant within the slurry. Because of the mixing of slurry within the mixing chamber 210, the slurry in one branch of the transport tubes 204b may avoid becoming more proppant laden than another branch of the transport tubes 204b due to clean fluid leak-off based on an orientation of the slurry distributors 212. Accordingly, the likelihood of the transport tubes 204 plugging with proppant prematurely is reduced when compared to a shunt system without the mixing chamber 210.

[0021] Further, the mixing chamber 210 may provide a slurry bypass when one of the transport tubes 204 is plugged with proppant. For example, when one of the transport tubes 204a is plugged with proppant, the remaining transport tube 204a may still deliver the slurry to the mixing chamber 210. While the mixing chamber 210 may not mix the slurry from the two transport tubes 204a in such an example, the mixing chamber 210 may provide both of the transport tubes 204b with the slurry for continued

distribution of the slurry to generate gravel packs at downhole locations of the annulus 120.

[0022] As with the transport tubes 204a, as the slurry travels into the transport tubes 204b from the mixing chamber 210, some of the slurry may be diverted into the packing tubes 206b. The slurry diverted into the packing tubes 206b may exit the packing tubes 206b at slurry distributors 212b. In an example, the transport tubes 204b include a cross-sectional area that is larger than a cross-sectional are of the packing tubes 206b.

[0023] The slurry distributors 212b may be holes or nozzles installed along a length of the packing tubes 206b. In an example, the slurry distributors 212b may allow the slurry to exit the packing tubes 206b such that the slurry is able to fill the annulus 120 surrounding the tubular 119. The slurry and deposited gravel that fills the annulus 120 may be referred to as a gravel pack. Additionally, a portion of the tubular 119 positioned under the packing tubes 206b (e.g., on the tubular side of the packing tubes 206b) may be a location of the sand screens 114. Thus, the gravel pack distributed by the packing tubes 206b may work in conjunction with the sand screens 114 to filter unwanted debris from the fluids 122 produced through the production tubing string 112.

[0024] Further, the mixing chamber 210 may be fluidly coupled to the transport tubes 204a and 204b using jumper tubes 218a and 218b. The jumper tubes 218a and 218b may telescope or be otherwise adjustable such that the mixing chamber 210 and the jumper tubes 218a and 218b span a distance 220 between the transport tubes 204a and the transport tubes 204b. Moreover, while FIG. 2 depicts the shunt system 126 including two parallel transport tubes 204a attached the two parallel jumper tubes 218a of the mixing chamber 210 and two parallel transport tubes 204b attached to the

two parallel jumper tubes 218b of the mixing chamber 210, more or fewer transport tubes 204 and jumper tubes 218 may be included in the shunt system 126. For example, the two transport tubes 204a may provide slurry to the mixing chamber 210, but the mixing chamber 210 may output the mixed slurry to only a single transport tube 204b. In another example, the shunt system 126 may include three or more transport tubes 204a that provide slurry to the mixing chamber 210, and the shunt system 126 may also include three or more transport tubes 204b that receive the mixed slurry from the mixing chamber 210.

[0025] In an additional example, one or more additional shunt systems 126 may be positioned around the tubular 119. In such an example, additional sets of transport tubes 204a and 204b, sets of packing tubes 206a and 206b, sets of jumper tubes 218a and 218b, and mixing chambers 210 are positioned along the tubular 119 for distribution of slurry around the sand screens 114 of the tubular 119. Other numbers and arrangements of transport tubes 204, packing tubes 206, jumper tubes 218, and mixing chamber 210 are also contemplated within the scope of the present disclosure.

[0026] While the mixing chamber 210 is generally described as being positioned between the jumper tubes 218a and 218b and spanning the joint 208 between the sand screen sections 202a and 202b, the mixing chamber 210 may be positioned at other locations along the shunt system 126. In an example, the mixing chamber 210 may be integrated with the transport tubes 204 (e.g., at a position that halves the transport tubes 204) while the jumper tubes 218 span the joint 208 between the sand screen sections 202a and 202b. In another example, the mixing chamber 210 may be integrated with the transport tubes 204 (e.g., at the position that halves the transport tubes 204) and an additional mixing chamber 210 may be positioned between the

jumper tubes 218a and 218b and spanning the joint 208 between the sand screen sections 202a and 202b.

[0027] FIG. 3 is a perspective view of the mixing chamber 210 of the shunt system 126 according to some aspects of the present disclosure. As discussed above with respect to FIG. 2, the mixing chamber 210 may include or otherwise be attached to jumper tubes 218a and 218b. In another example, the mixing chamber 210 may be coupled directly to transport tubes 204a and 204b over one of the sane screens 114, for example. The jumper tubes 218a and 218b may be telescopically extendable or otherwise adjustable such that ends 302 of the jumper tubes 218a and 218b are able to mate with ends of the transport tubes 204a and 204b. For example, the jumper tubes 218a and 218b may each include two or more concentric tubes that provide telescoping functionality of the jumper tubes 218a and 218b while maintaining structural integrity of the jumper tubes 218a and 218b during transmission of slurry to and from the mixing chamber 210. In one or more examples, the jumper tubes 218a and 218b may be cylindrical tubes or rectangular tubes. Further, the jumper tubes 218a and 218b may be coupled to the transport tubes 204a and 204b using a threaded connection, a quick connector, or any other type of suitable connector.

[0028] A housing 303 of the mixing chamber 210 may span a gap between the jumper tubes 218a and 218b in any shape. In another example, the housing 303 may extend between two transport tubes 204a or 204b directly over one of the sand screens 114. As illustrated, an overhead outline of the housing 303 is rectangular. However, other overhead outline shapes are also contemplated (e.g., circular, oval-shaped, rounded edges, etc.). Further, the example of the housing 303 depicted in FIG. 3 includes a rounded outer surface 304 (i.e., the surface closest to the wall of the wellbore 102) and a rounded inner surface 306 (i.e., the surface closest to the tubular

119). A radius of an arc along which the outer surface 304 tracks may be such that the outer surface 304 maintains a constant shortest distance between the outer surface 304 and the tubular 119. Likewise, a radius of an arc along which the inner surface 306 tracks may also maintain a constant shortest distance between the inner surface 306 and the tubular 119. However, in other embodiments, the outer surface 304 and the inner surface 306 may not include any curvature. For example, the outer surface 304 and the inner surface 306 may be flat such that the housing 303 is in the shape of a rectangular prism.

[0029] In one or more examples, an interior of the mixing chamber 210 may be empty. That is, the mixing chamber 210 may include a hollow inner cavity. In another example, blades or baffles may be positioned within the mixing chamber 210 to encourage mixing of the slurry received by the mixing chamber 210 after traveling from inlet ports 308 along inlet fluid paths 309. Upon mixing within the mixing chamber 210, the mixed slurry may travel to the outlet ports 310 along outlet fluid paths 312 toward the transport tubes 204b positioned downhole from the mixing chamber 210.

[0030] FIG. 4 is a flowchart of a process 400 for mixing slurry within the shunt system 126 that is externally mounted to the sand screen sections 202a and 202b according to some aspects. At block 402, the process 400 involves receiving slurry from separate shunt tubes (e.g., the jumper tubes 218a) of the shunt system 126 at the mixing chamber 210 that is positioned external to the joint 208 between the sand screen sections 202a and 202b. As discussed above with respect to FIG. 2, the slurry received from the separate shunt tubes may include varying clean fluid to proppant ratios. That is, one of the shunt tubes may provide slurry that experienced a greater amount of clean fluid leak-off than the other shunt tube. In another example, one of the shunt tubes may not receive any slurry from an associated transport tube 204a

that is plugged by a buildup of proppant (e.g., due to clean fluid lead-off). In either example, the separate shunt tubes may provide slurry of varying quantities (i.e., different flow rates) and varying clean fluid to proppant ratios.

[0031] At block 404, the process 400 involves allowing slurry from the multiple shunt tubes (e.g., the jumper tubes 218a) to mix at the mixing chamber 210. For example, the slurry may enter the mixing chamber from the multiple jumper tubes 218a at different flow rates and proppant concentrations. Once in the mixing chamber 210, the slurry fluids from the multiple jumper tubes 218a are encouraged to mix. The encouragement to mix may be provided generally by an open space that allows the slurry fluids to mix. Blades, baffles, or other protuberances may also be positioned within the mixing chamber 210 to generate turbulence that further encourages mixing.

[0032] At block 406, the process 400 involves outputting the mixed slurry to one or more additional shunt tubes (e.g., the jumper tubes 218b). As the slurry mixes within the mixing chamber 210, the slurry is transported toward the jumper tubes 218b. At the jumper tubes 218b, the mixed slurry may be output toward the transport tubes 204b. In an example, the mixed slurry provided to the jumper tubes 218b may have similar proppant concentrations and similar flow rates due to the mixing of the slurry in the mixing chamber 210.

[0033] As the mixed slurry is provided to the transport tubes 204b, a portion of the mixed slurry in each of the transport tubes 204b may be redirected to the packing tubes 206b. At the packing tubes 206b, the mixed slurry is distributed into the annulus 120 between the tubular 119 and a wall of the wellbore 102. The distributed mixed slurry generates a gravel pack within the annulus 120.

[0034] In some aspects, systems, devices, and methods for implementing and operating a shunt system for gravel packing operations within a wellbore are provided according to one or more of the following examples:

[0035] As used below, any reference to a series of examples is to be understood as a reference to each of those examples disjunctively (e.g., "Examples 1-4" is to be understood as "Examples 1, 2, 3, or 4").

[0036] Example 1 is a shunt system for a wellbore, the shunt system comprising: a first set of tubes defining a first plurality of fluid paths; a second set of tubes defining a second plurality of fluid paths; and a mixing chamber positioned between the first set of tubes and the second set of tubes to allow slurry from the first plurality of fluid paths to mix together prior to outputting the slurry to the second set of tubes, the shunt system being positionable external to one or more sand screens.

[0037] Example 2 is the shunt system of example 1, wherein the mixing chamber comprises a first set of jumper tubes attached to the first set of tubes and a second set of jumper tubes attached to the second set of tubes.

[0038] Example 3 is the shunt system of examples 1 to 2, wherein the first set of tubes and the second set of tubes comprise transport tubes being positionable to transport the slurry through the shunt system.

[0039] Example 4 is the shunt system of examples 1 to 3, further comprising: a first set of transport tubes and a second set of transport tubes, wherein the first set of tubes and the second set of tubes are jumper tubes mate with the first set of transport tubes and the second set of transport tubes.

[0040] Example 5 is the shunt system of examples 1 to 4, wherein the first set of tubes comprises: at least two transport tubes being positionable to transport the slurry to the mixing chamber; and at least two packing tubes being positionable to

transport the slurry to an annulus between the one or more sand screens and a wall of the wellbore.

[0041] Example 6 is the shunt system of example 5, wherein the second set of tubes comprises: at least two additional transport tubes being positionable to receive a mixed slurry from the mixing chamber; and at least two additional packing tubes being positionable to transport the mixed slurry to the annulus between the one or more sand screens and the wall of the wellbore.

[0042] Example 7 is the shunt system of examples 5 to 6, wherein the at least two packing tubes comprise a first cross-section with a first cross-sectional area, and the at least two transport tubes comprise a second cross-section with a second cross-sectional area that is larger than the first cross-sectional area.

[0043] Example 8 is the shunt system of examples 5 to 7, wherein a first packing tube of the two packing tubes is fluidly coupled to a first transport tube of the two transport tubes, and a second packing tube of the two packing tubes is fluidly coupled to a second transport tube of the two transport tubes.

[0044] Example 9 is the shunt system of examples 1 to 8, wherein the mixing chamber is positionable external to a joint between two sand screens of the one or more sand screens.

[0045] Example 10 is a mixing chamber for a shunt system for delivering slurry to sand screens, the mixing chamber comprising: a first inlet port for a first tube defining a first inlet fluid path; a second inlet port for a second tube defining a second inlet fluid path; a first outlet port for a third tube defining a first outlet fluid path; a second outlet port for a fourth tube defining a second outlet fluid path; and a housing defining an area in which fluid from the first inlet fluid path and the second inlet fluid path is mixable prior to flowing through the first outlet port or the second

outlet port, wherein the mixing chamber is positionable external to one or more sand screens.

[0046] Example 11 is the mixing chamber of example 10, wherein the mixing chamber is positionable over a joint between two sand screens of the one or more sand screens.

[0047] Example 12 is the mixing chamber of examples 10 to 11, wherein the first inlet port and the second inlet port are positionable to receive slurry from a first transport tube and a second transport tube, and the first outlet port and the second outlet port are positionable to transmit slurry to a third transport tube and a fourth transport tube.

[0048] Example 13 is the mixing chamber of examples 10 to 12, wherein the first tube, the second tube, the third tube, and the fourth tube comprise telescoping jumper tubes that are positionable to extend between the housing and a set of transport tubes.

[0049] Example 14 is the mixing chamber of examples 10 to 13, wherein the housing comprises an inner surface curvature and an outer surface curvature that are each positionable to maintain a constant shortest distance of an inner surface and an outer surface of the housing to the one or more sand screens.

[0050] Example 15 is the mixing chamber of examples 10 to 14, wherein the first outlet port and the second outlet port are positioned in relation to the housing such that the first outlet port and the second outlet port receive substantially similar amounts of the slurry from the housing.

[0051] Example 16 is the mixing chamber of examples 10 to 15, wherein the housing comprises blades or baffles positioned within the area to encourage mixing of the fluid from the first inlet fluid path and the second inlet fluid path.

[0052] Example 17 is a method comprising: pumping slurry through separate tubes to a mixing chamber; allowing the slurry from the separate tubes to mix in the mixing chamber that is external to one or more screens; and outputting mixed slurry to one or more output tubes through outlet ports of the mixing chamber.

[0053] Example 18 is the method of example 17, wherein outputting the mixed slurry to the one or more output tubes comprises outputting the mixed slurry to one or more transport tubes and to one or more packing tubes.

[0054] Example 19 is the method of examples 17 to 18, further comprising: packing an annulus between the one or more screens and a wall of a wellbore with the mixed slurry.

[0055] Example 20 is the method of examples 17 to 19, wherein the separate tubes comprise at least two jumper tubes coupled between the mixing chamber and at least two transport tubes of a shunt system.

[0056] The foregoing description of certain examples, including illustrated examples, has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Numerous modifications, adaptations, and uses thereof will be apparent to those skilled in the art without departing from the scope of the disclosure.

Claims

What is claimed is:

1. A shunt system for a wellbore, the shunt system comprising:

a first set of tubes defining a first plurality of fluid paths;

a second set of tubes defining a second plurality of fluid paths; and

a mixing chamber positioned between the first set of tubes and the second set of tubes to allow slurry from the first plurality of fluid paths to mix together prior to outputting the slurry to the second set of tubes,

the shunt system being positionable external to one or more sand screens.

2. The shunt system of claim 1, wherein the mixing chamber comprises a first set of jumper tubes attached to the first set of tubes and a second set of jumper tubes attached to the second set of tubes.

3. The shunt system of claim 1, wherein the first set of tubes and the second set of tubes comprise transport tubes being positionable to transport the slurry through the shunt system.

4. The shunt system of claim 1, further comprising:

a first set of transport tubes and a second set of transport tubes, wherein the first set of tubes and the second set of tubes are jumper tubes mate with the first set of transport tubes and the second set of transport tubes.

5. The shunt system of claim 1, wherein the first set of tubes comprises:

at least two transport tubes being positionable to transport the slurry to the mixing chamber; and

at least two packing tubes being positionable to transport the slurry to an annulus between the one or more sand screens and a wall of the wellbore.

6. The shunt system of claim 5, wherein the second set of tubes comprises:

at least two additional transport tubes being positionable to receive a mixed slurry from the mixing chamber; and

at least two additional packing tubes being positionable to transport the mixed slurry to the annulus between the one or more sand screens and the wall of the wellbore.

7. The shunt system of claim 5, wherein the at least two packing tubes comprise a first cross-section with a first cross-sectional area, and the at least two transport tubes comprise a second cross-section with a second cross-sectional area that is larger than the first cross-sectional area.

8. The shunt system of claim 5, wherein a first packing tube of the two packing tubes is fluidly coupled to a first transport tube of the two transport tubes, and a second packing tube of the two packing tubes is fluidly coupled to a second transport tube of the two transport tubes.

9. The shunt system of claim 1, wherein the mixing chamber is positionable external to a joint between two sand screens of the one or more sand screens.

10. A mixing chamber for a shunt system for delivering slurry to sand screens, the mixing chamber comprising:

a first inlet port for a first tube defining a first inlet fluid path;

a second inlet port for a second tube defining a second inlet fluid path;

a first outlet port for a third tube defining a first outlet fluid path;

a second outlet port for a fourth tube defining a second outlet fluid path; and

a housing defining an area in which fluid from the first inlet fluid path and the second inlet fluid path is mixable prior to flowing through the first outlet port or the second outlet port,

wherein the mixing chamber is positionable external to one or more sand screens.

11. The mixing chamber of claim 10, wherein the mixing chamber is positionable over a joint between two sand screens of the one or more sand screens.

12. The mixing chamber of claim 10, wherein the first inlet port and the second inlet port are positionable to receive slurry from a first transport tube and a second transport tube, and the first outlet port and the second outlet port are positionable to transmit slurry to a third transport tube and a fourth transport tube.

13. The mixing chamber of claim 10, wherein the first tube, the second tube, the third tube, and the fourth tube comprise telescoping jumper tubes that are positionable to extend between the housing and a set of transport tubes.

14. The mixing chamber of claim 10, wherein the housing comprises an inner surface curvature and an outer surface curvature that are each positionable to maintain a constant shortest distance of an inner surface and an outer surface of the housing to the one or more sand screens.

15. The mixing chamber of claim 10, wherein the first outlet port and the second outlet port are positioned in relation to the housing such that the first outlet port and the second outlet port receive substantially similar amounts of the slurry from the housing.

16. The mixing chamber of claim 10, wherein the housing comprises blades or baffles positioned within the area to encourage mixing of the fluid from the first inlet fluid path and the second inlet fluid path.

17. A method comprising:

pumping slurry through separate tubes to a mixing chamber;

allowing the slurry from the separate tubes to mix in the mixing chamber that is external to one or more screens; and

outputting mixed slurry to one or more output tubes through outlet ports of the mixing chamber.

18. The method of claim 17, wherein outputting the mixed slurry to the one or more output tubes comprises outputting the mixed slurry to one or more transport tubes and to one or more packing tubes.

19. The method of claim 17, further comprising:

packing an annulus between the one or more screens and a wall of a wellbore with the mixed slurry.

20. The method of claim 17, wherein the separate tubes comprise at least two jumper tubes coupled between the mixing chamber and at least two transport tubes of a shunt system.

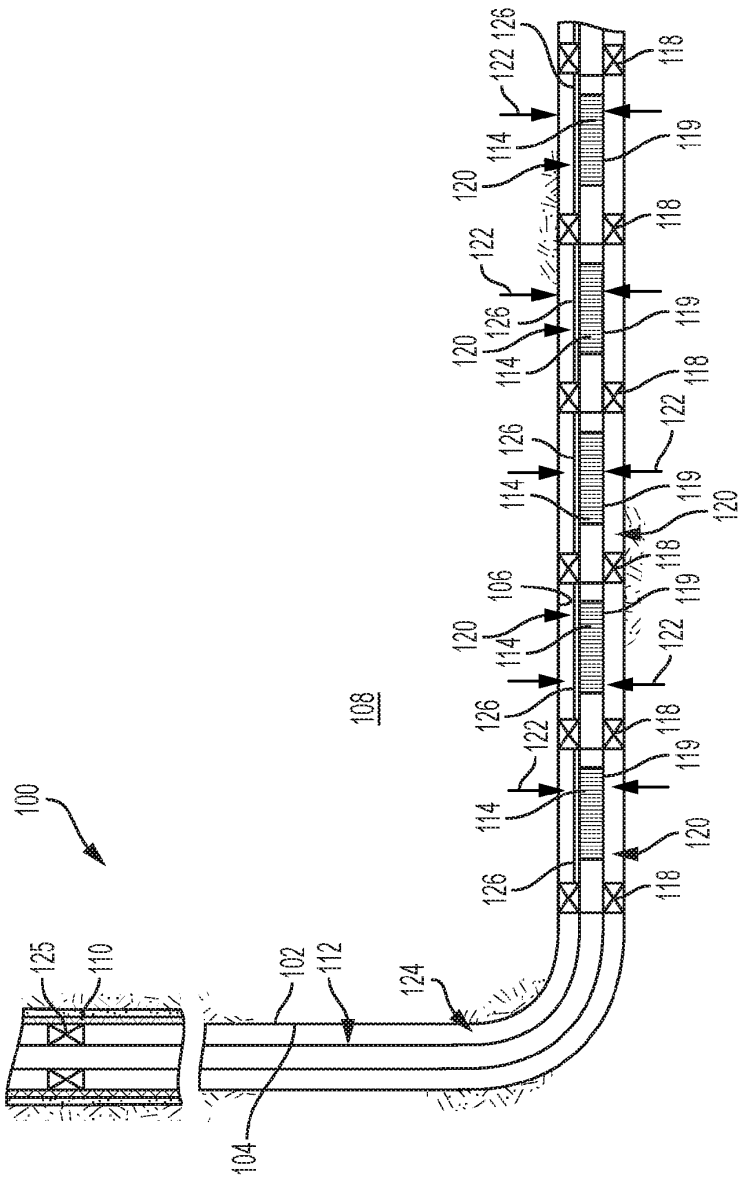

FIG. 1

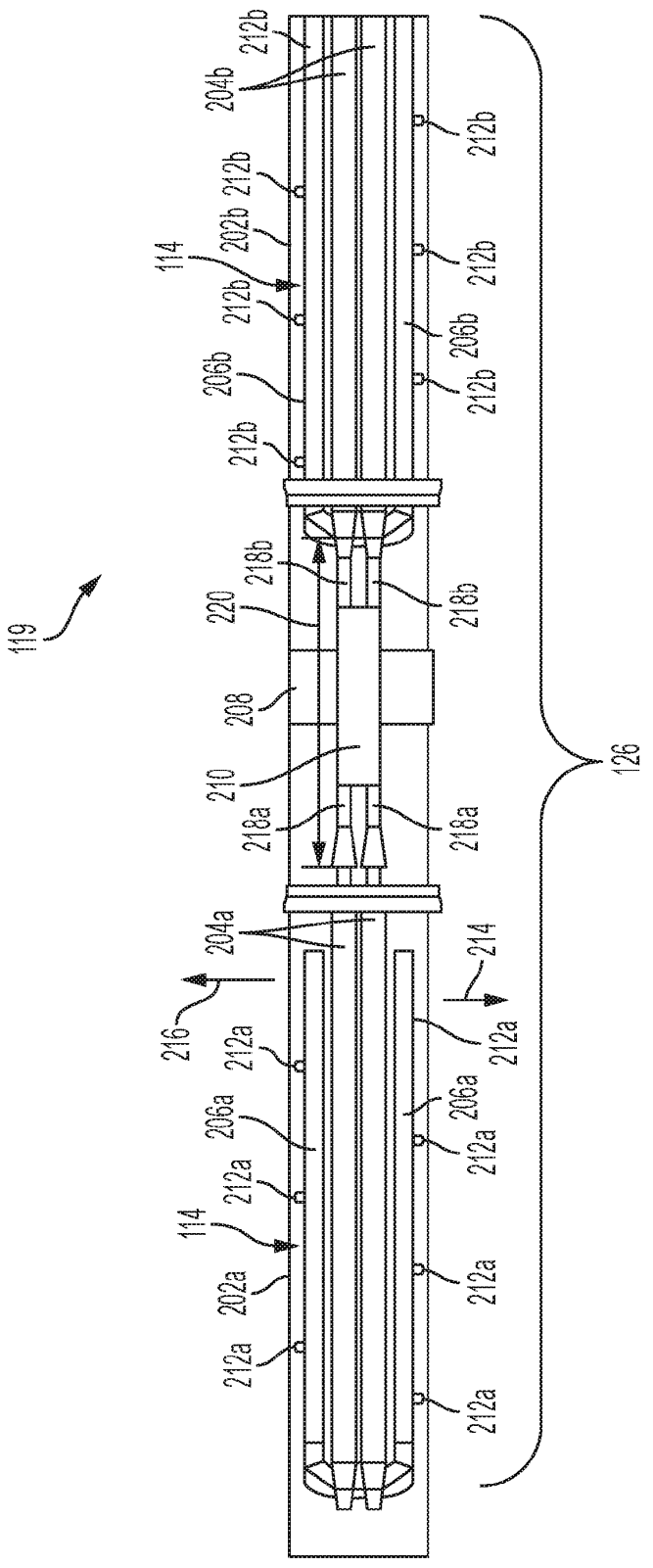
119
114
114
202b
202a
204b
204a
206b
206a
208
210
212b
212a
214
216
218b
218a
220
126

FIG. 2

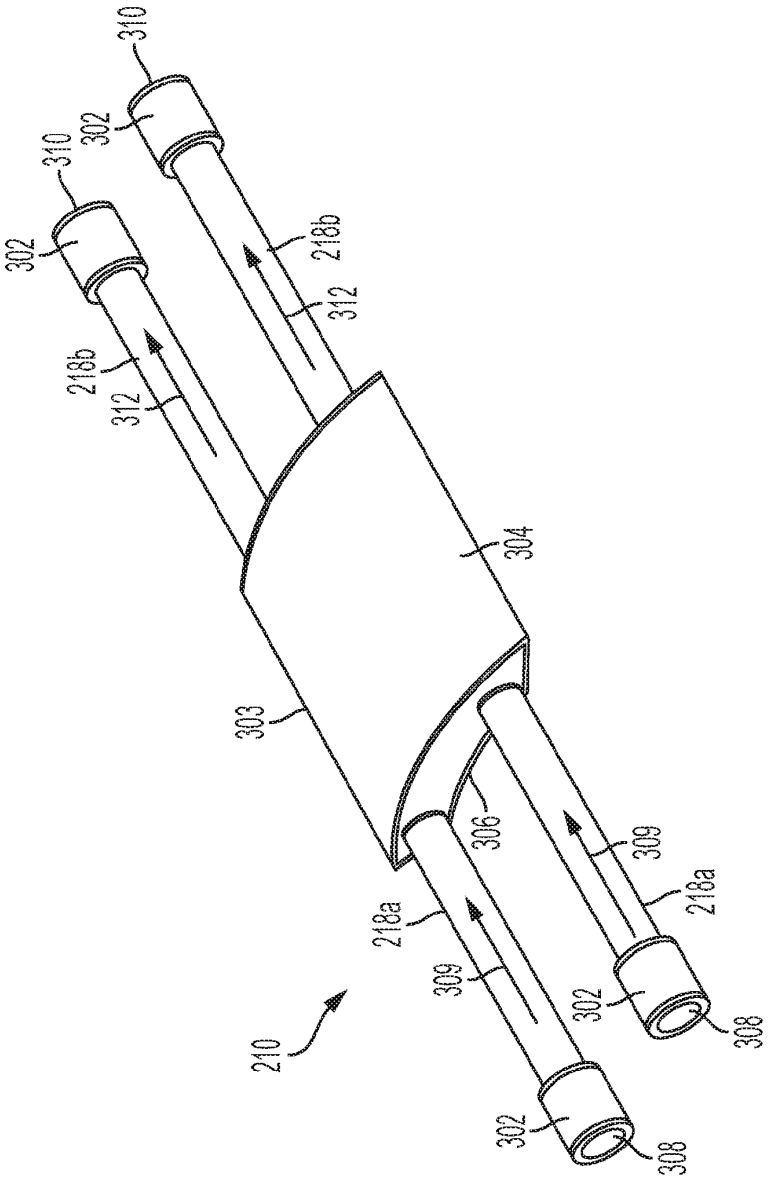
310
302
310
302
218b
312
218b
312
304
303
306
309
218a
218a
309
302
308
210
302
308

FIG. 3

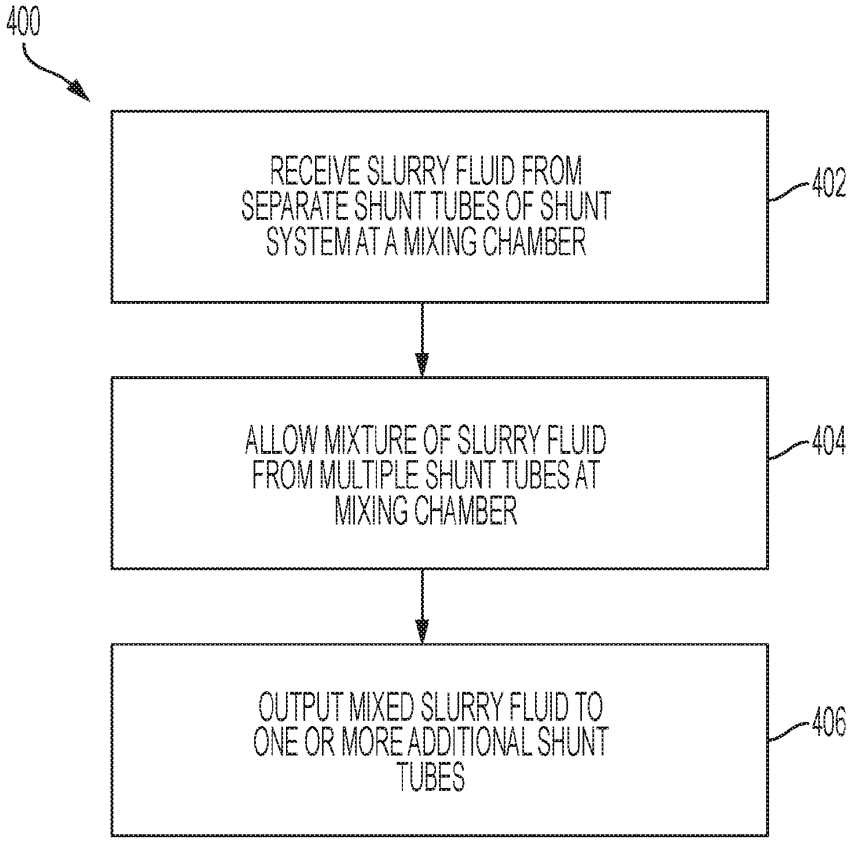
400
RECEIVE SLURRY FLUID FROM SEPARATE SHUNT TUBES OF SHUNT SYSTEM AT A MIXING CHAMBER
402
ALLOW MIXTURE OF SLURRY FLUID FROM MULTIPLE SHUNT TUBES AT MIXING CHAMBER
404
OUTPUT MIXED SLURRY FLUID TO ONE OR MORE ADDITIONAL SHUNT TUBES
406

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/068170

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/04(2006.01)i, E21B 43/08(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 43/08; E21B 43/12; 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: gravel packing, slurry, shunt tube, mixing chamber, sandscreen, jumper tube, packing tube

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2007-0084601 A1 (WANG et al.) 19 April 2007 See paragraphs [0024], [0025], [0050], [0051] and figures 1, 11.	1,3,5-8,10,12 ,14-15,17-19 2,4,9,11,13,16,20
Y	US 2016-0265318 A1 (HALLIBURTON ENERGY SERVICES, INC.) 15 September 2016 See paragraphs [0030], [0031] and figures 2, 3.	2,4,9,11,13,20
Y	US 2014-0008066 A1 (LEAST et al.) 09 January 2014 See paragraphs [0051], [0056] and figure 5A.	16
A	US 2014-0262208 A1 (CUNNINGHAM et al.) 18 September 2014 See paragraphs [0112]-[0116] and figures 13, 14.	1-20
A	US 2015 0233216 A1 (WEATHERFORD/LAMB, INC.) 20 August 2015 See paragraphs [0043], [0044] and figures 4A, 4B.	1 20

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2019 (25.09.2019)	**26 September 2019 (26.09.2019)**

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

Authorized officer
PARK, Tae Wook
Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/068170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		NO 2859177 T3	29/09/2018

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/068170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 9260953 B2	16/02/2016
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UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01

CONFIRMATION NO. 5449

27683
HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

PUBLICATION NOTICE

Title:MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Publication No.US-2021-0277750-A1
Publication Date:09/09/2021

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

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Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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Weatherford v. Halliburton
Page 560

UNITED STATES PATENT AND TRADEMARK OFFICE

USPTO Automated Interview Request (AIR)

Sep 27 2021

This paper requesting to schedule and/or conduct an interview is appropriate because:

This submission is requested to be accepted as an authorization for this interview to communicate via the internet. Recognizing that Internet communications are not secure, I hereby authorize the USPTO to communicate with the undersigned concerning scheduling of the interview via video conference, instant messaging, or electronic mail, and to conduct the interview in accordance with office practice including video conferencing.

Name(s):
Harold Azeeze Borland

S-signature:
/Harold Azeeze Borland/

Registration Number:
57854

U.S. Application Number:
16347711

Confirmation Number:
5449

E-mail Address:
harold.borland@haynesboone.com

Phone Number:
+1 7135472881

Proposed Time of Interview:
10-4-2021 3:00 PM ET

Prefered Interview Type:
Telephonic

I am the applicant or applicant's representative for this application.

Topic for Discussion:
Enablement objections and discuss a change in the shunt tubes over length of the system

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 16/347,711	Filing Date 05/06/2019	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $100 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $460 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT	10/06/2021	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 23	Minus	** 23	= 0		x $100 =	0
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $480 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/CHERYL A CLARK/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Halliburton Energy Services, Inc.	§	Group Art Unit: 3619
Application No.: 16/347,711	§	Examiner: Jennifer Hawkins Gay
Filing Date: May 6, 2019	§	Confirmation No.: 5449
Title: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	Attorney Docket No.: 7523.1981US01

RESPONSE TO NON-FINAL OFFICE ACTION DATED JULY 6, 2021

Dear Commissioner:

This paper is submitted in response to the non-final Office Action dated July 6, 2021 (the "Office Action"). Should any additional fees be required for any reason relating to this submission, the Commissioner is authorized to deduct the required fees from Haynes and Boone, LLP's Deposit Account No. 08-1394, referencing matter No. 7523.1981US01.

Amendments to the Claims are reflected in the listing of the claims, which begins on page 2 of this paper.

Remarks begin on page 8 of this paper.

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AMENDMENTS TO THE CLAIMS

Listing of Claims:

1. (Currently Amended) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a source of pressurized working fluid fluidly coupled to an upstream end of the transport tube of the first sand screen assembly;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another such that the transport tube of the second sand screen assembly is fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the first sand screen assembly; and

wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

2. (Original) The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

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3. (Original) The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

4. (Original) The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

5. (Currently Amended) The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is ~~substantially~~ the same.

6. (Currently Amended) The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising [[an]] a coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

7. (Currently Amended) The completion assembly of claim 1, wherein the ~~first sand screen assembly has a~~ shunt tube assembly [[with]] of the first sand screen assembly has a pressure rating ~~of over~~ between 5000 psi and 10000 psi, and the ~~second sand screen assembly has a~~ shunt tube assembly [[with]] of the second sand screen assembly has a pressure rating of no more than 5000 psi.

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8. (Currently Amended) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a ~~shunt tube assembly with a~~ pressure rating of between 5000 and 10000 psi and the shunt tube assembly of the second sand screen assembly has a ~~shunt tube assembly with a~~ pressure rating of less than 4000 psi.

9. (Currently Amended) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a ~~shunt tube assembly with a~~ pressure rating of over a select threshold and the shunt tube assembly of the second sand screen assembly has a ~~shunt tube assembly with a~~ pressure rating of no more than the select threshold.

10. (Currently Amended) The completion assembly of claim 1, wherein [[a]] the shunt tube assembly [[with]] of the first sand screen assembly has a first burst pressure and the shunt tube assembly of the second sand screen assembly ~~comprises a shunt tube assembly with~~ has a burst pressure less than the first burst pressure.

11. (Currently Amended) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a source of pressurized working fluid;

a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure, and wherein the shunt tube assembly with the first burst pressure is fluidly coupled between the source of pressurized working fluid and the shunt tube assembly with the burst pressure less than the first burst pressure.

12. (Currently Amended) The completion assembly of claim 11, wherein the ~~first sand screen assembly comprises a~~ shunt tube assembly of the first sand screen assembly is disposed to operate at pressures ~~over~~ between 5000 psi and 10000 psi and the ~~second sand screen assembly has a~~ shunt tube assembly of the second sand screen assembly is disposed to operate at pressures of no more than 5000 psi.

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13. (Currently Amended) The completion assembly of claim 11, further comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having an operating pressure rating [[over]] between 5000 psi and 10000 psi, and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

14. (Currently Amended) A method of installing a completion assembly in a wellbore, the method comprising:

identifying an elongated production zone having an upstream proximal end and a downstream distal end with respect to a source of pressurized working fluid;

determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure;

installing a first sand screen assembly in a wellbore adjacent [[a]] the distal downstream end of the elongated production zone; [[and]]

attaching a second sand screen assembly to the first sand screen assembly ~~upstream of the first sand screen assembly~~ at the proximal upstream end of the elongated production zone, wherein the first sand screen assembly has [[a]] the low pressure shunt tube system and the second sand screen assembly has [[a]] the high pressure shunt tube system, such that a downstream end of the high pressure shunt tube system is coupled to an upstream end of the low pressure shunt tube system; and

coupling the source of pressurized working fluid to an upstream end of the high pressure shunt tube system.

15. (Currently Amended) The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to [[the]] an uppermost first sand screen assembly upstream of the first sand screen assemblies.

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16. (Cancelled).

17. (Original) The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

18. (Original) The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

19. (Original) The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

20. (Original) The method of claim 17, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

21. (Currently Amended) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a source of pressurized working fluid;

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; and

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

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wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another and the source of pressurized working fluid, the transport tube of the second sand screen assembly fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the fist sand screen assembly; and

wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

22. (Original) The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

23. (Original) The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first pressure rating.

24. (New) The method of claim 14, wherein installing the first sand screen assembly and attaching the second sand screen assembly include disposing the first sand screen assembly and the second sand screen assembly in a horizontal portion of the wellbore.

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REMARKS

I. CLAIM STATUS

Claims 1-15 and 17-24 are currently pending, of which claims 1, 5-15 and 21 are amended herein and claim 24 is newly presented. In view of the amendments above and the remarks below, Applicant requests allowance of the claims.

II. EXAMINER INTERVIEW

Applicant wishes to thank the Examiner for the courtesies extended to Applicant's representative, Harold Borland (Reg. No. 57,854), in a telephonic interview conducted October 4, 2021. In the interview, the rejections based on enablement and official notice taken by the Examiner were discussed. No specific claim language was agreed upon.

III. CLAIM OBJECTION

Claim 6 stands objected to for reciting an improper article "an" with the term "coupling" Claim 6 has been amended to recite "a coupling," and accordingly, Applicant requests withdrawal of the objection to claim 6.

IV. CLAIM REJECTIONS UNDER 35 U.S.C. § 112

Claims 1-15 and 17-23 stand rejected under 35 U.S.C. § 112 as failing to comply with the enablement requirement. According to page 3 of the Office Action, the "pressure of the gravel slurry decreasing as the slurry flows from the upstream portion to the downstream portion is considered not be enabled." The Office Action notes that paragraph [0003] of U.S. Patent Application Publication No. 2021/0123327 to Langlais et al. (hereinafter "Langlais") describes that the "*frictional pressure*" increases at a rate of 1 psi/foot, and therefore concludes that "Applicant has failed to establish how the gravel slurry can decrease in pressure as the depth of the wellbore increases." Even if a "*hydrostatic pressure*" generally increases with depth, the "*frictional pressure*" is not similarly related to depth but acts in a direction opposite the direction of fluid flow as a function of the length of pipe through which the fluid flows[1].

In an example illustrated in the FIG. A[2] below, a bottom hole pressure (BHP) may be calculated from a pump pressure (PP) (or another source of pressurized fluid), a hydrostatic

[1] See, e.g., FIG. 1 of https://www.drillingformulas.com/understand-about-friction-pressure-acting-frp-in-wellbore/ where a pressure drop of 2000 psi occurs over a length of pipe and 1000 psi pressure drop occurs at the middle..
[2] Modified from FIG. 7 of https://www.drillingformulas.com/understand-about-friction-pressure-acting-frp-in-

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pressure (HP) and a frictional pressure (FrP). Those skilled in the art can readily determine these values for a particular working fluid and a particular pipe geometry. In the example below, a bottom hole pressure of BHP = 3000 psi may be calculated by subtracting the frictional pressure FrP from the sum of the pump pressure PP and the hydrostatic pressure HP.

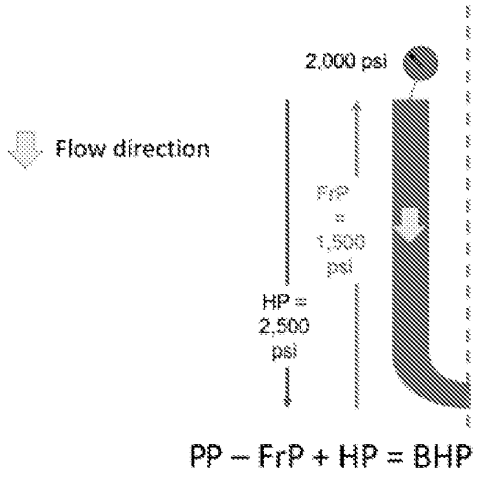

FIG. A

The BHP of 3000 psi would be available for delivering the working fluid along a length of a pipe in an elongated production zone as illustrated in FIG. B below. If the 1 psi/foot estimate described by Langlais is considered, the fluid may be delivered over along a 3000 foot length.

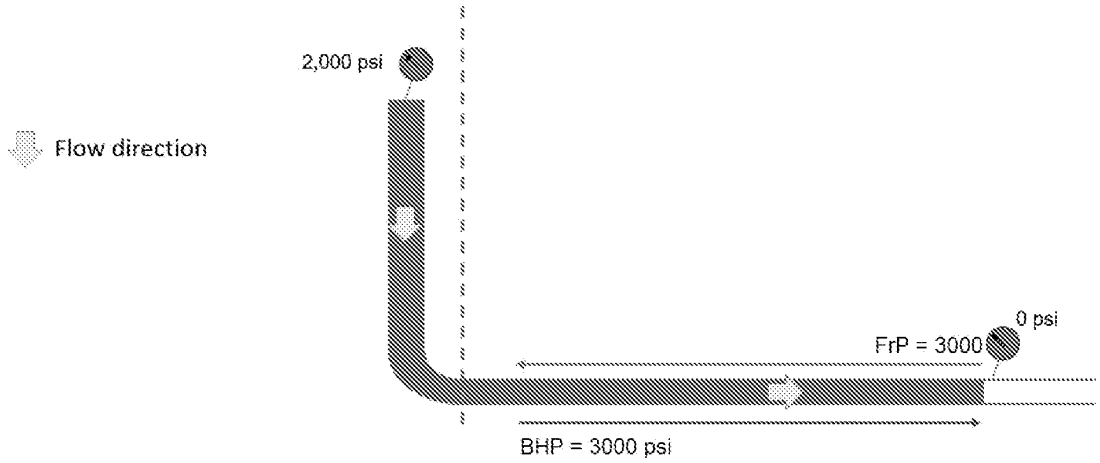

FIG. B

wellbore including an equation for the Bottom Hole Pressure BHP of a drilling system. The principles described in FIG. 7 are applicable to a completion system as well.

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At the end of the 3000 feet, a fluid pressure would be a local ambient pressure (0 psi) and the working fluid would be delivered no further. Thus, to deliver the working fluid over an additional length of the production zone, a greater pump pressure PP would need to be provided (or other adjustment made) to overcome an increased friction pressure FrP caused by the additional length over which the working fluid is to be moved.

Since the friction pressure FrP is based on a length of pipe and acts opposite the direction of fluid flow, Applicant respectfully submits that one skilled in the art would recognize that that the friction pressure FrP caused by a working fluid flowing in a transport tube or shunt tube assembly would decrease a pressure of the working fluid according to a distance "downstream" of a pressurized fluid source. At least since independent claims 1, 11, 14 and 21 have been amended to recite a fluid source and various tubes coupled downstream of the fluid source or a similar arrangement, Applicant requests withdrawal of the rejections of claims 1-15 and 17-23 under 35 U.S.C. § 112 as failing to comply with the enablement requirement.

Claim 5 stands rejected under 35 U.S.C. § 112 as being indefinite for reciting the relative term "substantially." Without acquiescing to the propriety of the rejection, Applicant notes that claim 5 has been amended to remove the term "substantially," and accordingly, requests withdrawal of the rejection of claim 5 as being indefinite under 35 U.S.C. § 112.

Claims 7, 8, 12 and 13 stand rejected under 35 U.S.C. § 112 as being indefinite for reciting open ended numerical ranges. The Office Action indicates that each of each of claims 7, 8, 12 and 13 recite ranges encompassing values that may not be possible in practice and cites MPEP 2173.05(c)(II). However, MPEP 2173.05(c)(II) indicates that claims are "not indefinite simply because the claims may be read in theory to include [values] that are impossible in fact." Thus Applicant respectfully submits that even if claims 7, 8 12 and 13 recite ranges encompassing values that might be impossible, that claims 7, 8 12 and 13 "distinctly point out" the boundaries of the claims as required MPEP 2173 and are definite under 35 U.S.C. § 112.

The rejections of claims 7, 8, 12 and 13 also indicate that the claimed ranges may not be "fully enabled." Claims 7, 12 and 13 have been amended to set an upper limit to the ranges, which one skilled in the art would be enabled to practice. Applicant respectfully submits, however, that the upper limit recited in claim 8, specifically, "a pressure rating of less than 4000 psi" is fully enabled. As MPEP 2173.05(c)(II) indicates a specified range up to a stated value "includes zero as a lower limit." Applicant respectfully submits that any shunt tube rated to handle pressures up

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to 4000 psi would comfortably handle pressures down to zero as well. In light of the amendments to claims 7, 12 and 13 and the arguments above, Applicant requests withdrawal of the rejections of claims 7, 8, 12 and 13 under 35 U.S.C. § 112 as being indefinite and/or non-enabled.

Claims 7-10 stand rejected under 35 U.S.C. § 112 as being indefinite for being unclear if the recited shunt tube assemblies related to the shunt tube assemblies recited in claim 1 or to new shunt tube assemblies. Claims 7-10 have been amended to clarify that the shunt tube assemblies referred to the shunt tube assemblies recited in claim 1. Accordingly, Applicant requests withdrawal of the rejections of claims 7-10 as being indefinite under 35 U.S.C. § 112.

Claim 15 stands rejected under 35 U.S.C. § 112 as being indefinite for lacking sufficient antecedent basis for the recited "the uppermost sand screen assembly." Claim 15 has been amended to recite "an" uppermost sand screen assembly. Accordingly, Applicant requests withdrawal of the rejection of claims 15 as being indefinite under 35 U.S.C. § 112.

V. CLAIM REJECTIONS UNDER 35 U.S.C § 103

Claims 1, 5-15 and 18-23 stand rejected under 35 U.S.C. § 103 as being unpatentable over U.S. Patent Application Publication No. 2019/01452321 to Sessa et al. (hereinafter "Sessa") in view of Langlais. The Office Action indicates at least on page 11 that Lang is relied upon for selecting a shunt tube having a sufficient operating pressure rating to accommodate the pressure required for the shunt tube, noting that Lang suggests that a transport tube extending 3000 feet must have an operating pressure of at least 3000psi and a transport tube extending 5000 feet must have an operating pressure of at least 5000 psi. The Office Action asserts that it would have been obvious to have modified the tubes of Sessa to accommodate the "varying operating pressures along the length of the assembly as suggested by Lang. Applicant respectfully submits however, that "traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the *same pressure rating*" (paragraph [0047] of Applicant's specification as published in US 2021/0277750). Thus, Applicant respectfully submits that it would not have been obvious to change the characteristics of the shunt tube assemblies along the length of a production zone at a location downstream of a source of pressurized fluid as recited in the independent claims 1, 11, 14 and 21 (for example, placing the higher pressure rated components at an upstream location and lower pressure rated components at a downstream location).

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Accordingly, Applicant requests withdrawal of the rejections of claims 1, 5-15 and 18-23 under 35 U.S.C. § 103 as unpatentable over Sessa in view of Langlais.

VI. NEW CLAIM

Claims 24 is newly presented herein and recites subject matter related to installing sand screen assemblies in a horizontal portion of a wellbore. Claim 24 is supported at least in FIG. 14 of Applicant's specification, adds no new matter and is allowable at least due to its dependence on claim 14. Accordingly, Applicant requests entry and allowance of new claim 24.

CONCLUSION

In view of the above amendments and arguments, Assignee respectfully submits that the instant application is in good and proper order for allowance and early notification to this effect is respectfully solicited. If, in the opinion of the Examiner, a telephone conference would expedite prosecution of the instant application, the Examiner is encouraged to call the undersigned at (713) 547-2881.

Respectfully submitted,

/Harold A. Borland/
Harold A. Borland
Registration No. 57,854

Date: October 6, 2021
HAYNES AND BOONE, LLP
2323 Victory Ave., Suite 700
Dallas, Texas 75219
Telephone: 713-547-2881
Facsimile: 214-200-0853
File: 7523.1981US01

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Page 574

Electronic Acknowledgement Receipt	
EFS ID:	43968379
Application Number:	16347711
International Application Number:	
Confirmation Number:	5449
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Customer Number:	27683
Filer:	Harold Borland/Erika Vasquez
Filer Authorized By:	Harold Borland
Attorney Docket Number:	7523.1981US01
Receipt Date:	06-OCT-2021
Filing Date:	06-MAY-2019
Time Stamp:	20:53:30
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		7523-1981US01-Response.pdf	311210 2faf384ec75835db7c29cd0d80c097b0f13e47f8	yes	12

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	7
	Applicant Arguments/Remarks Made in an Amendment	8	12
Warnings:			
Information:			
	Total Files Size (in bytes):	311210	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

27683 7590 10/07/2021

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

EXAMINER
GAY, JENNIFER HAWKINS

ART UNIT	PAPER NUMBER
3619	

NOTIFICATION DATE	DELIVERY MODE
10/07/2021	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocketing@haynesboone.com

Applicant-Initiated Interview Summary	Application No. 16/347,711	Applicant(s) Coffin et al.		
	Examiner JENNIFER H GAY	Art Unit 3619	AIA (First Inventor to File) Status Yes	Page 1 of 2

All Participants (applicant, applicants representative, PTO personnel)	Title	Type
JENNIFER H GAY	Primary Examiner	Telephonic
Harold Borland	Attorney of Record	

Date of Interview: 04 October 2021

Issues Discussed:

35 U.S.C. 112

Applicant explained that the pressure losses described in the specification and addressed in the claims refer to the pressure loss from the upstream portion of the production zone to the downstream portion of the production zone as presented in a horizontal wellbore. Examiner Gay indicated that amending the claims to replace "first" and "second" with "upstream" and "downstream", locate the upstream and downstream at the respective ends of the wellbore and require that the wellbore be a horizontal well would overcome the outstanding 35 USC 112(a) rejection. Examiner Gay indicated that, while Applicant was correct that the pressure losses would work as implied in the claims in a horizontal well, the discrepancy referred to in the 35 USC 112(a) rejection would be applicable to a vertical well.

35 U.S.C. 103

Examiner Gay indicated that, as noted by Applicant in the provided agenda and noted above, amending the claims to place the higher pressure rated components at an upstream location and the lower rated components at a downstream location would overcome the Examiner's Official Notice so long as these locations were in a horizontal well.

☑ Attachment

/JENNIFER H GAY/ Primary Examiner, Art Unit 3619	

Applicant is reminded that a complete written statement as to the substance of the interview must be made of record in the application file. It is the applicants responsibility to provide the written statement, unless the interview was initiated by the Examiner and the Examiner has indicated that a written summary will be provided. See MPEP 713.04
Please further see:
MPEP 713.04
Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews, paragraph (b)
37 CFR § 1.2 Business to be transacted in writing

Applicant recordation instructions: The formal written reply to the last Office action must include the substance of the interview. (See MPEP section 713.04). If a reply to the last Office action has already been filed, applicant is given a non-extendable period of the longer of one month or thirty days from this interview date, or the mailing date of this interview summary form, whichever is later, to file a statement of the substance of the interview.

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Applicant-Initiated Interview Summary	**Application No.** 16/347,711	**Applicant(s)** Coffin et al.		
	Examiner JENNIFER H GAY	**Art Unit** 3619	**AIA (First Inventor to File) Status** Yes	**Page** **2 of 2**

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

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Weatherford v. Halliburton
Page 579

From:	Borland, Hal
To:	Gay, Jennifer (AU3676)
Cc:	Vasquez, Erika
Subject:	RE: USPTO Automated Interview Request (AIR): Action Required - Received interview for US Application Number 16347711
Date:	Friday, October 1, 2021 7:28:04 PM

CAUTION: This email has originated from a source outside of USPTO. **PLEASE CONSIDER THE SOURCE** before responding, clicking on links, or opening attachments.

Examiner Gay,

Thank you for agreeing to speak with me on Monday, October 4, 2021 at 3 PM ET. I will plan to call you then, but you may reach me at the number below if you need to for any reason.

First, I wanted to discuss the enablement rejections. On page 3 of the Office Action, the rejection indicates that claims 1, 11, 14 and 12 "require that the operating pressure of the shunt tube assemblies *lower* in the well be less than that of shunt tube assemblies *higher up* in the well." I would like to discuss arguments that this is not entirely accurate. Paragraph [0047] of Applicant's specification as published in US20210277750 states "as the slurry flows from the *upstream* portion of these elongated production zone to the *downstream* portion of the production zone, the pressure of the slurry drops off. For a horizontal production zone, such as the production zone 18 illustrated in FIG. 1, the pressure loss in a the shunt tube system due to friction will occur as commonly known in the art. For example, the widely known "Darcy Weisbach Equation" may characterize the pressure loss from friction in a pipe. Are there any claim terms that might be modified to "upstream" or "downstream" that would help overcome this rejection?

Next, I wanted to discuss the obviousness rejections based on Official Notice. Page 12 of the Office Action indicates that Official Notice is taken "that it would have been obvious that the pressure rating . . . of the lower . . . sand screen assembly was higher than that of the upper . . . sand screen assembly. This is exactly opposite of what is disclosed here, see Abstract (The shunt system of the upper sand screen assembly has a higher pressure rating than the shunt system of the lower sand screen assembly.) Also, as indicated in paragraph [0047] of Applicant's specification "Traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies *all of the same pressure rating*." Thus, I wanted to see if amendments directed to placing the higher pressure rated components at an upstream location and lower pressure rated components at a downstream location might advance prosecution.

I am looking forward to speaking with you.

Best regards,

Hal

HAYNES BOONE

Harold Borland | Counsel
harold.borland@haynesboone.com | (t) +1 713.547.2881

From: Gay, Jennifer (AU3676) <Jennifer.Gay@USPTO.GOV>
Sent: Tuesday, September 28, 2021 5:18 AM
To: Borland, Hal <Harold.Borland@haynesboone.com>
Subject: FW: USPTO Automated Interview Request (AIR): Action Required - Received interview for US Application Number 16347711
Importance: High

EXTERNAL: Sent from outside Haynes and Boone, LLP

Mr. Borland,

I am available for an interview on October 4th at 3 PM ET. If you have any specific arguments or amendments with respect to your topic of discussion or otherwise please email them to me no later than COB on the 1st.

Thank you, Jennifer Gay

Jennifer H Gay
Primary Examiner/SCE – TF 59
AU 3619
Location: KNX 4/C74 (Hoteling)
Phone: 571-272-7029

From: PTO Automated Interview Request <PTOAutomatedInterviewRequest@USPTO.GOV>
Sent: Monday, September 27, 2021 9:15 PM
To: Gay, Jennifer (AU3676) <Jennifer.Gay@USPTO.GOV>
Cc: PTO Automated Interview Request <PTOAutomatedInterviewRequest@USPTO.GOV>
Subject: USPTO Automated Interview Request (AIR): Action Required - Received interview for US Application Number 16347711
Importance: High

JENNIFER GAY,

This is an Automated Interview Request (AIR) made by **Harold Azeeze Borland** for application number **16/347,711** for **10-4-2021 3:00 PM ET**. The preferred interview type is: **Telephonic**. Please respond to this interview request within **1 business day**.

Topic for Discussion: **Enablement objections and discuss a change in the shunt tubes over length of the system**

Please contact **Harold Azeeze Borland** by calling **+1 7135472881** or emailing harold.borland@haynesboone.com to set up an interview or deny if appropriate. Note, if you are denying an interview, the interview request flag will not be cleared until you've

contacted your SPE.

Examiner may **grant** or **deny** the interview in accordance with current USPTO interview policy, practice and procedure (See MPEP 713).

By receiving this AIR submission, the applicant has certified that:
This submission is requested to be accepted as an authorization for this interview to communicate via the internet. Recognizing that Internet communications are not secure, I hereby authorize the USPTO to communicate with the undersigned concerning scheduling of the interview via video conference, instant messaging, or electronic mail, and to conduct the interview in accordance with office practice including video conferencing.

Next step:
Once determined if an interview is appropriate, Examiner may **email** or **call** the applicant to set up or deny the interview.

If you're going to deny the interview, please contact your SPE to clear the tracking off of your dashboard.

If you need assistance please contact your SPE, an Interview Specialist from your TC or see Quick Reference Guide.

Thank you.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

27683 7590 10/21/2021

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

EXAMINER
GAY, JENNIFER HAWKINS

ART UNIT	PAPER NUMBER
3619	

NOTIFICATION DATE	DELIVERY MODE
10/21/2021	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocketing@haynesboone.com

Office Action Summary	Application No. 16/347,711	Applicant(s) Coffin et al.	
	Examiner JENNIFER H GAY	Art Unit 3619	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on 06 October 2021.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☑ This action is **FINAL.** 2b) ☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-15 and 17-24 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☑ Claim(s) 1-7,9-15 and 17-24 is/are allowed.

7) ☑ Claim(s) 8 is/are rejected.

8) ☐ Claim(s) _____ is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Response to Amendment

2. This Action is in response to Applicant's Reply of October 6, 2021.

3. Claim 16 has been cancelled and claim 24 added.

4. Applicant's amendment to claim 6 overcomes the previously presented objection thereto.

5. Applicant's amendment to claims 1, 11, 14, and 21, in conjunction with the arguments with respect thereto, overcome the previously presented 35 USC 112(a) rejection.

6. Applicant's amendment to claims 5, 7-10, 12, 13, and 15 overcome the previously presented 35 USC 112(b) rejection thereof with the exception of one outstanding rejection of claim 8 repeated below.

7. Applicant's amendment to claims 1, 11, 14, and 21 overcome the previously presented 35 USC 103 rejection thereof.

Response to Arguments

8. Applicant's arguments have been fully considered but they are not persuasive.

Applicant has argued that the phrase "a pressure rating of less than 4000 psi" in claim 8 is fully enabled as MPEP 2173.05(c)(II) indicates that a "specified range up to a stated value 'includes zero as a lower limit'".

While MPEP 2173.05(c)(II) does indicate that the phrase "up to" is to be interpreted as including zero as the lower limit, the phrase in question in claim 8 does not include "up to" but rather uses "less than". The phrase "less than" is not considered fully enabled, and thus is indefinite, because the lower limit is not known within the scope of the claim and the instant specification provides no clear indication as to what that lower limit is to be considered.

Applicant has further argued that "any shunt tube rated to handle pressures up 4000 psi would be comfortable handling pressures down to zero as well."

The ability of a shunt tube rated to handle pressures "less than 4000 psi" being able to handle pressure as low as zero is not in contention. The question is what the phrase "less than 4000 psi" covers and if that full coverage is enabled by the instant specification. As correctly noted by Applicant, this phrase would cover a pressure rating between 0 psi and 4000 psi however there is no basis for this full range in the instant disclosure. In order for the specification to provide basis for this full range the specification must specifically list the full range or the full range make sense and be possible within the scope of how the associated shunt tube is to be used.

Page 13, line 32 through page 14, line 19 does list the various pressure ranges for the shunt tubes however a pressure rating less than 3,500 psi is not included in this list. As such, the specification does not provide basis for a pressure rating less than 3,500 psi.

Further, the pressure rating of the shunt tubes of the second sand screen assembly, while capable of being as low as zero, would not be functional as a shunt tube in the wellbore. The pressure of the fluid in the shunt tubes would only be zero at the very end or bottom of the wellbore however the second shunt tube does not exist only at the very end of the wellbore. As such any portion of the second shunt tube above the very end of the wellbore would need a pressure rating that is within a range including a lower limit above zero however it is not clear what Applicant considers this lower limit.

Due to the lack of disclosure of a lower limit to the pressure rating of the second shunt tube and the lower limit of zero not making sense within the scope of the claims and specification, the phrase "less than 4000 psi" is not fully enabled and thus indefinite.

Claim Rejections - 35 USC § 112

9. The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

10. Claim 8 is rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor (or for applications subject to pre-AIA 35 U.S.C. 112, the applicant), regards as the invention.

Claim 8 recites "**a pressure rating of less than 4000 psi**". This is a range with an unbounded lower limit, and therefore encompasses a pressure rating so inconceivable low that it cannot reasonably be possible in the present invention. To make a point through hyperbole, the present application does not provide full enablement for 0 psi or 10 psi (increasable *ad nauseam*), even though these amounts are encompassed in the claimed range. See MPEP 2173.05(c)(II), reproduced below.

> **II. OPEN-ENDED NUMERICAL RANGES**
>
> Open-ended numerical ranges should be carefully analyzed for definiteness. For example, when an independent claim recites a composition comprising "at least 20% sodium" and a dependent claim sets forth specific amounts of nonsodium ingredients which add up to 100%, apparently to the exclusion of sodium, an ambiguity is created with regard to the "at least" limitation (unless the percentages of the nonsodium ingredients are based on the weight of the nonsodium ingredients). On the other hand, the court held that a composition claimed to have a theoretical content greater than 100% (i.e., 20-80% of A, 20-80% of B and 1-25% of C) was not indefinite simply because the claims may be read in theory to include compositions that are impossible in fact to formulate. It was observed that subject matter which cannot exist in fact can neither anticipate nor infringe a claim. *In re Kroekel,* 504 F.2d 1143, 183 USPQ 610 (CCPA 1974).
>
> In a claim directed to a chemical reaction process, a limitation required that the amount of one ingredient in the reaction mixture should "be maintained at less than 7 mole percent" based on the amount of another ingredient. The examiner argued that the claim was indefinite because the limitation sets only a maximum amount and is inclusive of substantially no ingredient resulting in termination of any reaction. The court did not agree, holding that the claim was clearly directed to a reaction process, and explaining that "[t]he imposition of a maximum limit on the quantity of one of the reactants without specifying a minimum does not warrant distorting the overall meaning of the claim to preclude performing the claimed process."*In re Kirsch,* 498 F.2d 1389, 1394, 182 USPQ 286, 290 (CCPA 1974).
>
> Some terms have been determined to have the following meanings in the factual situations of the reported cases: the term "up to" includes zero as a lower limit, *In re Mochel,* 470 F.2d 638, 176 USPQ 194 (CCPA 1974); and "a moisture content of not more than 70% by weight" reads on dry material, *Ex parte Khusid,* 174 USPQ 59 (Bd. App. 1971).

Allowable Subject Matter

11. Claims **1-7, 9-15, and 17-24** are allowed.

12. Claim **8** would be allowable if rewritten or amended to overcome the rejection(s) under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), 2nd paragraph, set forth in this Office action.

13. The following is a statement of reasons for the indication of allowable subject matter:

Regarding claim 1: The prior art of record fails to disclose or suggest a completion assembly that includes a first and second sand screen assembly that each include a transport tube, wherein the upstream end of the first transport tube is fluidly coupled to a source of pressurized working fluid and the second transport tube is fluidly coupled to the source of pressurized working fluid downstream of the first transport tube and wherein the first transport tube has a first wall thickness and the second transport tube has a second wall thickness, the first wall thickness being greater than the second wall thickness as recited in the claimed combination.

Regarding claims 2-10: These claims are considered allowable due to their dependence on claim 1.

Regarding claim 11: The prior art of record fails to disclose or suggest a completion assembly that includes a first and second sand screen assembly that each include a shunt tube assembly having a burst pressure, wherein the burst pressure of the second shunt tube assembly is lower than the burst pressure of the first shunt tube assembly and wherein the first shunt tube assembly is fluidly coupled between a source

of pressurized working fluid and the second shunt tube assembly as recited in the claimed combination.

Regarding claims 12 and 13: These claims are considered allowable due to their dependence on claim 11.

Regarding claim 14: The prior art of record fails to disclose or suggest a method of installing a completion assembly in a well, the method comprising determining a shunt tube system operating pressure at an upstream proximal end and downstream distal end of a production zone, the proximal and distal ends being with respect to a source of pressurized working fluid, and selecting a high pressure shunt tube system based on the proximal end determined pressure and a low pressure shunt tube system based on the distal end determined pressure; installing a first sand screen assembly, with the low pressure shunt tube system, adjacent the distal downstream end and attaching a second sand screen assembly, with the high pressure shunt tube system, to the first sand screen assembly at the proximal upstream end such that a downstream end of the high pressure shunt tube system is coupled to an upstream end of the low pressure shunt tube system and coupling the source of pressurized working fluid to an upstream end of the high pressure shunt tube system as recited in the claimed method.

Regarding claims 15, 17-20, and 24: These claims are considered allowable due to their dependence on claim 14.

Regarding claim 21: The prior art of record fails to disclose or suggest a completion assembly that includes a first and second sand screen assembly that each include a transport tube, wherein the second transport tube is fluidly coupled to a source of pressurized working fluid downstream of the first transport tube and wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material as recited in the claimed combination.

Regarding claims 22 and 23: These claims are considered allowable due to their dependence on claim 21.

Conclusion

14. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event,

however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

15. Any inquiry concerning this communication or earlier communications from the examiner should be directed to JENNIFER H GAY whose telephone number is (571)272-7029. The examiner can normally be reached Monday through Thursday, 6-3:30 and every other Friday 6-11.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Anna M Momper can be reached on 571-270-5788. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: https://patentcenter.uspto.gov. Visit https://www.uspto.gov/patents/apply/patent-center for more information about Patent Center and https://www.uspto.gov/patents/docx for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/JENNIFER H GAY/
Primary Examiner, Art Unit 3619

JHG
10/14/2021

Notice of References Cited	Application/Control No. 16/347,711	Applicant(s)/Patent Under Reexamination Coffin et al.	
	Examiner JENNIFER H GAY	Art Unit 3619	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20210277750-A1	09-2021	Coffin; Maxime Philippe	E21B43/086	1/1
	B					
	C					
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	Art Unit
	JENNIFER H GAY	3619

CPC - Searched*		
Symbol	**Date**	**Examiner**
E21B 17/02, 43/04,08,086,10	06/29/2021	JHG
updated	10/14/2021	JHG

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
E21B 17/02, 43/04,08,086,10 - text search only	06/29/2021	JHG
PE2E Search	06/29/2021	JHG
Backward/forward search	06/29/2021	JHG
PE2E Search	10/14/2021	JHG

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
	Interference Search	10/14/2021	JHG

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PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
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L3	14	("20030029613" "20100139919" "20130008652" "20140110131").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:16 PM
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L6	13	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1 OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1).did. AND PGPB.dbnm.)	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/28 03:19 PM
L7	24186	(E21B43/04 OR E21B43/08 OR E21B17/02 OR E21B43/086).cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR,	OR	ON	ON	2021/06/28 03:20 PM

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			GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L8	8772	(E21B43/04).cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:21 PM
L9	1567	8 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:24 PM
L10	450	9 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:24 PM
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L13	12	"50883835".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/28 03:35 PM
L14	16	("20090159270" "5390966" "20090294128" "6298916" "20080190608").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:36 PM
L15	13	"50488602".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2021/06/28 03:39 PM

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			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)				
L16	4	("20140110131").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:40 PM
L17	425	9 AND jumper	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:44 PM
L18	225	17 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:44 PM
L19	31	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2 OR US-9260953-B2 OR US-8967240-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1 OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1 OR US-20170022789-A1 OR US-20150285038-A1 OR US-20150129194-A1 OR US-20150027700-A1 OR US-20090294128-A1 OR US-20140262208-A1 OR US-20140158373-A1 OR US-20190145232-A1 OR US-20140110131-A1 OR US-	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/28 03:47 PM

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		20130327542-A1 OR US-20210002987-A1).did. AND PGPB.dbnm.) OR ((WO-2014088594-A1 OR WO-2013187877-A1 OR WO-2014062180-A1 OR FR-3091309-A1 OR WO-2020142076-A1).did. AND FTDB.dbnm.)					
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L21	21	19 AND pressure	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 04:13 PM
L22	2073	7 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:54 AM
L23	1127	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (thickness cross pressure material))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:55 AM
L24	435	23 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:55 AM
L25	704	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH ((upper	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR,	OR	ON	ON	2021/06/29 06:54 AM

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		AND lower) (first AND second)))	GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L26	423	25 NOT 24	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 06:54 AM
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L28	10	"51262733".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/29 09:18 AM
L29	89	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH (production near3 (zone formation reservoir)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:20 AM
L30	2	("20160251913").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:31 AM
L31	41	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2 OR US-9260953-B2 OR US-10100616-B2 OR US-8967240-B2 OR US-9725988-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/29 09:32 AM

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		OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1 OR US-20170022789-A1 OR US-20150285038-A1 OR US-20150129194-A1 OR US-20150027700-A1 OR US-20090294128-A1 OR US-20140262208-A1 OR US-20140158373-A1 OR US-20040140089-A1 OR US-20150345257-A1 OR US-20190145232-A1 OR US-20140110131-A1 OR US-20020174984-A1 OR US-20160003014-A1 OR US-20130327542-A1 OR US-20130220635-A1 OR US-20160215570-A1 OR US-20160251913-A1 OR US-20210002987-A1 OR US-20190284913-A1).did. AND PGPB.dbnm.) OR ((WO-2014088594-A1 OR WO-2013187877-A1 OR WO-2014062180-A1 OR FR-3091309-A1 OR WO-2020142076-A1).did. AND FTDB.dbnm.)					
L32	8816	e21b$.cpc. AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:39 AM
L33	2545	32 AND (pressure WITH (thickness cross tensile rating material strength))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:39 AM
L34	390	33 AND ((((shunt	(US-PGPUB; USPAT;	OR	ON	ON	2021/06/29

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		transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (thickness cross tensile rating material strength)))	USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				09:40 AM
L35	1247	32 AND (pressure WITH (gravel slurry))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 10:31 AM
L36	501	35 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (gravel slurry)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 10:33 AM
L37	105	35 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (burst rupture)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 11:34 AM
L38	20	("4945991" "5113935" "5515915" "6227303").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 11:53 AM
L39	0	e21b$.cpc. AND ((gravel slurr) WITH decreas$4 WITH pressure WITH (depth downhole))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/30 07:52 AM
L40	25	e21b$.cpc. AND ((gravel slurry) WITH decreas$4 WITH pressure WITH (depth downhole))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/30 07:52 AM
L41	2	"20210277750"	(US-PGPUB; USPAT;	OR	ON	ON	2021/10/04

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			USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)				01:14 PM
L42	2111	7 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:27 PM
L43	452	42 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:27 PM
L44	53	43 AND (friction$3 near3 pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:28 PM
L45	407	((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure) AND (friction$3 near3 pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:34 PM
L46	364	45 NOT 44	(US-PGPUB; USPAT;	OR	ON	ON	2021/10/14

			USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)				01:36 PM
L47	363	7 AND (@PD>"20210628")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:44 PM
L48	11	(34 36 37 39 40) AND (@PD>"20210628")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:50 PM

PE2E SEARCH - Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
N1	69	((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure) AND	(US-PGPUB; USPAT)	OR	ON	ON	2021/10/14 01:43 PM

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Page 604

		(friction$3 near3 pressure)					

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Page 605

Bibliographic Data

Application No: 16/347,711

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☐ No ☐ Met After Allowance

Verified and Acknowledged: /JENNIFER H GAY/ (Examiner's Signature) (Initials)

Title: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
05/06/2019	166	3619	7523.1981US01
RULE			

APPLICANTS

Halliburton Energy Services, Inc., Houston, TX, UNITED STATES

INVENTORS

Maxime Philippe Coffin, Frisco, TX, UNITED STATES

Thomas Jules Frosell, Dallas, TX, UNITED STATES

CONTINUING DATA

This application is a 371 of PCT/US2019/024626 03/28/2019

PCT/US2019/024626 has PRO of 62688813 06/22/2018

FOREIGN APPLICATIONS

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 16/347,711	Filing Date 05/06/2019	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $100 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $460 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT	12/08/2021	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 23	Minus	** 23	= 0		x $100 =	0
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $480 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/TARA A WASHINGTON/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
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This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Halliburton Energy Services, Inc.	§	Group Art Unit: 3619
Application No.: 16/347,711	§	Examiner: Jennifer Hawkins Gay
Filing Date: May 6, 2019	§	Confirmation No.: 5449
Title: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	Attorney Docket No.: 7523.1981US01

RESPONSE TO FINAL OFFICE ACTION DATED OCTOBER 21, 2021

Dear Commissioner:

This paper is submitted in response to the non-final Office Action dated October 21, 2021 (the "Office Action"). Should any additional fees be required for any reason relating to this submission, the Commissioner is authorized to deduct the required fees from Haynes and Boone, LLP's Deposit Account No. 08-1394, referencing matter No. 7523.1981US01.

Amendments to the Claims are reflected in the listing of the claims, which begins on page 2 of this paper.

Remarks begin on page 8 of this paper.

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AMENDMENTS TO THE CLAIMS

Listing of Claims:

1. (Previously Presented) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

a source of pressurized working fluid fluidly coupled to an upstream end of the transport tube of the first sand screen assembly;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another such that the transport tube of the second sand screen assembly is fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the first sand screen assembly; and

wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

2. (Original) The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen assembly.

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3. (Original) The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and wherein the second sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly.

4. (Original) The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly.

5. (Previously Presented) The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is the same.

6. (Previously Presented) The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further comprising a coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies.

7. (Previously Presented) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a pressure rating between 5000 psi and 10000 psi, and the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than 5000 psi.

8. (Currently Amended) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of between 5000 and 10000 psi

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~~and the shunt tube assembly of the second sand screen assembly has a pressure rating of less than 4000 psi~~.

9. (Previously Presented) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of over a select threshold and the shunt tube assembly of the second sand screen assembly has a pressure rating of no more than the select threshold.

10. (Previously Presented) The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a first burst pressure and the shunt tube assembly of the second sand screen assembly has a burst pressure less than the first burst pressure.

11. (Previously Presented) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a source of pressurized working fluid;

a first sand screen assembly attached to a second sand screen assembly, wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure, and wherein the shunt tube assembly with the first burst pressure is fluidly coupled between the source of pressurized working fluid and the shunt tube assembly with the burst pressure less than the first burst pressure.

12. (Previously Presented) The completion assembly of claim 11, wherein the shunt tube assembly of the first sand screen assembly is disposed to operate at pressures between 5000 psi and 10000 psi and the shunt tube assembly of the second sand screen assembly is disposed to operate at pressures of no more than 5000 psi.

13. (Previously Presented) The completion assembly of claim 11, further comprising: a plurality of first sand screen assemblies forming a lower portion of the completion assembly and attached to a plurality of second sand screen assemblies forming an upper portion of the completion assembly, wherein the first sand screen assemblies each comprises a shunt tube assembly having

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an operating pressure rating between 5000 psi and 10000 psi, and the second sand screen assembly has a shunt tube assembly having an operating pressure rating of no more than 5000 psi.

14. (Previously Presented) A method of installing a completion assembly in a wellbore, the method comprising:

identifying an elongated production zone having an upstream proximal end and a downstream distal end with respect to a source of pressurized working fluid;

determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure;

determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure;

installing a first sand screen assembly in a wellbore adjacent the distal downstream end of the elongated production zone;

attaching a second sand screen assembly to the first sand screen assembly at the proximal upstream end of the elongated production zone, wherein the first sand screen assembly has the low pressure shunt tube system and the second sand screen assembly has the high pressure shunt tube system, such that a downstream end of the high pressure shunt tube system is coupled to an upstream end of the low pressure shunt tube system; and

coupling the source of pressurized working fluid to an upstream end of the high pressure shunt tube system.

15. (Previously Presented) The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to an uppermost first sand screen assembly upstream of the first sand screen assemblies.

16. (Cancelled).

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17. (Original) The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system.

18. (Original) The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000.

19. (Original) The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold.

20. (Original) The method of claim 17, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus.

21. (Previously Presented) A completion assembly for deployment in a wellbore, the completion assembly comprising:

a source of pressurized working fluid;

a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; and

a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;

wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes

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are in fluid communication with one another and the source of pressurized working fluid, the transport tube of the second sand screen assembly fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the fist sand screen assembly; and

wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material.

22. (Original) The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thickness.

23. (Original) The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first pressure rating.

24. (Previously Presented) The method of claim 14, wherein installing the first sand screen assembly and attaching the second sand screen assembly include disposing the first sand screen assembly and the second sand screen assembly in a horizontal portion of the wellbore.

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REMARKS

I. CLAIM STATUS

Claims 1-15 and 17-24 are currently pending, of which claim 8 has been amended herein. In view of the amendments above and the remarks below, Applicant requests allowance of the claims.

II. ALLOWABLE SUBJECT MATTER

Applicant wishes to thank the Examiner for the indication of allowable subject matter in claims 1-15 and 17-24. As indicated on pages 5 and 6 of the Office Action, claims 1-7, 9-15 and 17-24 are allowed and claim 8 would be allowable if rejections under 35 U.S.C. § 112 were overcome.

III. CLAIM REJECTIONS UNDER 35 U.S.C. § 112

Claim 8 stands rejected under 35 U.S.C. § 112 as being indefinite for reciting an open ended numerical range. Specifically, claim 8 is rejected for reciting "a pressure rating of less than 4000 psi." Without acquiescing to the propriety of the rejection, Applicant notes that this language has been removed from claim 8. Accordingly, Applicant requests withdrawal of the rejection of claim 8 under 35 U.S.C. § 112.

CONCLUSION

In view of the above amendments and arguments, Applicant respectfully submits that the instant application is in good and proper order for allowance and early notification to this effect is respectfully solicited. If, in the opinion of the Examiner, a telephone conference would expedite prosecution of the instant application, the Examiner is encouraged to call the undersigned at (713) 547-2881.

Respectfully submitted,

/Harold A. Borland/
Harold A. Borland
Registration No. 57,854

Date: December 8, 2021
HAYNES AND BOONE, LLP
2323 Victory Ave., Suite 700
Dallas, Texas 75219
Telephone: 713-547-2881
Facsimile: 214-200-0853
File: 7523.1981US01

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Electronic Acknowledgement Receipt	
EFS ID:	44465548
Application Number:	16347711
International Application Number:	
Confirmation Number:	5449
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Customer Number:	27683
Filer:	Harold Borland/Delaunda Kittrell
Filer Authorized By:	Harold Borland
Attorney Docket Number:	7523.1981US01
Receipt Date:	08-DEC-2021
Filing Date:	06-MAY-2019
Time Stamp:	14:41:26
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		7523-1981US01_Response.pdf	57913 573facbaf61c6d2226dc3aa20a5ab3c845f05ce7	yes	8

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Response After Final Action	1	1
	Claims	2	7
	Applicant Arguments/Remarks Made in an Amendment	8	8
Warnings:			
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HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

EXAMINER	
GAY, JENNIFER HAWKINS	
ART UNIT	PAPER NUMBER
3619	

DATE MAILED: 01/21/2022

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

TITLE OF INVENTION: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$0.00	$1200	04/21/2022

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

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III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PTOL-85 (Rev. 02/11)

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PART B - FEE(S) TRANSMITTAL

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Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

27683 7590 01/21/2022
HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

TITLE OF INVENTION: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$0.00	$1200	04/21/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
GAY, JENNIFER HAWKINS	3619	166-278000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1_____
2_____
3_____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/06/2019	Maxime Philippe Coffin	7523.1981US01	5449

27683 7590 01/21/2022

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

EXAMINER	
GAY, JENNIFER HAWKINS	
ART UNIT	**PAPER NUMBER**
3619	

DATE MAILED: 01/21/2022

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

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Page 620

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 16/347,711	Applicant(s) Coffin et al.	
	Examiner JENNIFER H GAY	Art Unit 3619	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to Applicant's Reply of 12/8/21.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-15 and 17-24 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☑ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/JENNIFER H GAY/
Primary Examiner, Art Unit 3619

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Weatherford v. Halliburton
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EXAMINER'S COMMENT

1. This Allowance is in response to Applicant's Reply of December 8, 2021.

2. Claim 16 has been cancelled.

3. Applicant's amendment to claim 8 overcomes the previously presented 35 USC 112(b) rejection thereof.

4. Claims 1-15 and 17-24 are allowed.

Reasons for Allowance

5. The following is an examiner's statement of reasons for allowance:

The claims remain allowable for the reasons set forth in the previous Office Action.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to JENNIFER H GAY whose telephone number is (571)272-7029. The examiner can normally be reached Monday through Thursday, 6-3:30 and every other Friday 6-11.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Anna M Momper can be reached on 571-270-5788. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: https://patentcenter.uspto.gov. Visit https://www.uspto.gov/patents/apply/patent-center for more information about Patent Center and https://www.uspto.gov/patents/docx for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/JENNIFER H GAY/
Primary Examiner, Art Unit 3619

JHG
1/3/2022

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	**Art Unit**
	JENNIFER H GAY	3619

CPC						
Symbol					**Type**	**Version**
E21B	/	43	/	04	F	2013-01-01
E21B	/	43	/	086	I	2013-01-01
E21B	/	43	/	10	I	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	23	
/JENNIFER H GAY/ Primary Examiner, Art Unit 3619	03 January 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	14	2

U.S. Patent and Trademark Office — Part of Paper No.: 20220103

Weatherford Exhibit 1002
Weatherford v. Halliburton
Page 625

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	**Art Unit**
	JENNIFER H GAY	3619

INTERNATIONAL CLASSIFICATION				
CLAIMED				
E21B43/04	/	43	/	04
E21B43/08	/	43	/	08
E21B43/10	/	43	/	10

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	23	
/JENNIFER H GAY/ Primary Examiner, Art Unit 3619	03 January 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	14	2

U.S. Patent and Trademark Office — Part of Paper No.: 20220103

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	**Art Unit**
	JENNIFER H GAY	3619

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	10	10	19	19										
2	2	11	11	17	20										
3	3	12	12	21	21										
4	4	13	13	22	22										
5	5	14	14	23	23										
6	6	15	15	20	24										
7	7		16												
8	8	16	17												
9	9	18	18												

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	23	
/JENNIFER H GAY/ Primary Examiner, Art Unit 3619	03 January 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	14	2

U.S. Patent and Trademark Office — Part of Paper No.: 20220103

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Weatherford v. Halliburton
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	Art Unit
	JENNIFER H GAY	3619

CPC - Searched*		
Symbol	Date	Examiner
E21B 17/02, 43/04,08,086,10	06/29/2021	JHG
updated	10/14/2021	JHG
updated	01/03/2022	JHG

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
E21B 17/02, 43/04,08,086,10 - text search only	06/29/2021	JHG
PE2E Search	06/29/2021	JHG
Backward/forward search	06/29/2021	JHG
PE2E Search	10/14/2021	JHG
PE2E Search	01/03/2022	JHG

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Weatherford v. Halliburton
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/347,711	Coffin et al.
	Examiner	Art Unit
	JENNIFER H GAY	3619

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
	Interference Search	10/14/2021	JHG
	Interference Search	01/03/2022	JHG

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APPROVED: /J.H.G/

01/03/2022 **IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re application of: Halliburton Energy Services, Inc.	§	Group Art Unit: 3619
Application No.: 16/347,711	§	Examiner: Jennifer Hawkins Gay
Filing Date: May 6, 2019	§	Confirmation No.: 5449
Title: ***Multiple Shunt Pressure Assembly for Gravel Packing***	§	Attorney Docket No.: 7523.1981US01

RESPONSE TO FINAL OFFICE ACTION DATED OCTOBER 21, 2021

Dear Commissioner:

This paper is submitted in response to the non-final Office Action dated October 21, 2021 (the "Office Action"). Should any additional fees be required for any reason relating to this submission, the Commissioner is authorized to deduct the required fees from Haynes and Boone, LLP's Deposit Account No. 08-1394, referencing matter No. 7523.1981US01.

Amendments to the Claims are reflected in the listing of the claims, which begins on page 2 of this paper.

Remarks begin on page 8 of this paper.

Weatherford Exhibit 1002
Weatherford v. Halliburton
Page 630

Bibliographic Data

Application No: 16/347,711

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /JENNIFER H GAY/ (Examiner's Signature) | (Initials)

Title: MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
05/06/2019	166	3619	7523.1981US01
RULE			

APPLICANTS

Halliburton Energy Services, Inc., Houston, TX, UNITED STATES

INVENTORS

Maxime Philippe Coffin, Frisco, TX, UNITED STATES

Thomas Jules Frosell, Dallas, TX, UNITED STATES

CONTINUING DATA

This application is a 371 of PCT/US2019/024626 03/28/2019

PCT/US2019/024626 has PRO of 62688813 06/22/2018

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

05/29/2021

STATE OR COUNTRY

UNITED STATES

ADDRESS

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219
UNITED STATES

FILING FEE RECEIVED

$2,340

PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	6	("0000110" OR "0000213" OR "0000424" OR "0000610" OR "0000708" OR "0000722").pn.	(US-PGPUB; USPAT)	OR	ON	ON	2021/06/28 03:11 PM
L2	63	"6588506" "20040140089"	(US-PGPUB; USPAT)	OR	ON	ON	2021/06/28 03:11 PM
L3	14	("20030029613" "20100139919" "20130008652" "20140110131").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:16 PM
L4	3	wo-2013187878-$.did.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:17 PM
L5	24	"49758559".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/28 03:17 PM
L6	13	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1 OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1).did. AND PGPB.dbnm.)	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/28 03:19 PM
L7	24186	(E21B43/04 OR E21B43/08 OR E21B17/02 OR E21B43/086).cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR,	OR	ON	ON	2021/06/28 03:20 PM

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			GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L8	8772	(E21B43/04).cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:21 PM
L9	1567	8 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:24 PM
L10	450	9 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:24 PM
L11	4	("20170362918" OR "20190145232" OR "7938184" OR "9010417").pn.	(US-PGPUB; USPAT)	OR	ON	ON	2021/06/28 03:26 PM
L12	4	"71141366".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/28 03:29 PM
L13	12	"50883835".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/28 03:35 PM
L14	16	("20090159270" "5390966" "20090294128" "6298916" "20080190608").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:36 PM
L15	13	"50488602".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2021/06/28 03:39 PM

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			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)				
L16	4	("20140110131").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:40 PM
L17	425	9 AND jumper	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:44 PM
L18	225	17 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:44 PM
L19	31	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2 OR US-9260953-B2 OR US-8967240-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1 OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1 OR US-20170022789-A1 OR US-20150285038-A1 OR US-20150129194-A1 OR US-20150027700-A1 OR US-20090294128-A1 OR US-20140262208-A1 OR US-20140158373-A1 OR US-20190145232-A1 OR US-20140110131-A1 OR US-	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/28 03:47 PM

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		20130327542-A1 OR US-20210002987-A1).did. AND PGPB.dbnm.) OR ((WO-2014088594-A1 OR WO-2013187877-A1 OR WO-2014062180-A1 OR FR-3091309-A1 OR WO-2020142076-A1).did. AND FTDB.dbnm.)					
L20	27	19 AND jumper	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 03:47 PM
L21	21	19 AND pressure	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/28 04:13 PM
L22	2073	7 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:54 AM
L23	1127	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (thickness cross pressure material))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:55 AM
L24	435	23 AND nozzle	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 05:55 AM
L25	704	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH ((upper	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR,	OR	ON	ON	2021/06/29 06:54 AM

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		AND lower) (first AND second)))	GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L26	423	25 NOT 24	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 06:54 AM
L27	3	wo-2014120167-$.did.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:18 AM
L28	10	"51262733".fmid.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; JPO)	OR	ON	ON	2021/06/29 09:18 AM
L29	89	22 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH (production near3 (zone formation reservoir)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:20 AM
L30	2	("20160251913").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:31 AM
L31	41	((US-9670756-B2 OR US-9638012-B2 OR US-9638011-B2 OR US-9133705-B2 OR US-7497267-B2 OR US-7100690-B2 OR US-8893789-B2 OR US-9074458-B2 OR US-9260953-B2 OR US-10100616-B2 OR US-8967240-B2 OR US-9725988-B2).did. AND USPT.dbnm.) OR ((US-20080142227-A1	(USPAT; US-PGPUB; FPRS; USOCR; IBM_TDB; EPO; JPO; DERWENT; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO))	OR	ON	ON	2021/06/29 09:32 AM

		OR US-20080128129-A1 OR US-20100139919-A1 OR US-20140014314-A1 OR US-20140332211-A1 OR US-20170022789-A1 OR US-20150285038-A1 OR US-20150129194-A1 OR US-20150027700-A1 OR US-20090294128-A1 OR US-20140262208-A1 OR US-20140158373-A1 OR US-20040140089-A1 OR US-20150345257-A1 OR US-20190145232-A1 OR US-20140110131-A1 OR US-20020174984-A1 OR US-20160003014-A1 OR US-20130327542-A1 OR US-20130220635-A1 OR US-20160215570-A1 OR US-20160251913-A1 OR US-20210002987-A1 OR US-20190284913-A1).did. AND PGPB.dbnm.) OR ((WO-2014088594-A1 OR WO-2013187877-A1 OR WO-2014062180-A1 OR FR-3091309-A1 OR WO-2020142076-A1).did. AND FTDB.dbnm.)					
L32	8816	e21b$.cpc. AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:39 AM
L33	2545	32 AND (pressure WITH (thickness cross tensile rating material strength))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 09:39 AM
L34	390	33 AND ((((shunt	(US-PGPUB; USPAT;	OR	ON	ON	2021/06/29

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		transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (thickness cross tensile rating material strength)))	USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				09:40 AM
L35	1247	32 AND (pressure WITH (gravel slurry))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 10:31 AM
L36	501	35 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (gravel slurry)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 10:33 AM
L37	105	35 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) SAME (pressure WITH (burst rupture)))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 11:34 AM
L38	20	("4945991" "5113935" "5515915" "6227303").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/29 11:53 AM
L39	0	e21b$.cpc. AND ((gravel slurr) WITH decreas$4 WITH pressure WITH (depth downhole))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/30 07:52 AM
L40	25	e21b$.cpc. AND ((gravel slurry) WITH decreas$4 WITH pressure WITH (depth downhole))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/06/30 07:52 AM
L41	2	"20210277750"	(US-PGPUB; USPAT;	OR	ON	ON	2021/10/04

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			USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)				01:14 PM
L42	2111	7 AND (((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:27 PM
L43	452	42 AND ((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:27 PM
L44	53	43 AND (friction$3 near3 pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:28 PM
L45	407	((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure) AND (friction$3 near3 pressure)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:34 PM
L46	364	45 NOT 44	(US-PGPUB; USPAT;	OR	ON	ON	2021/10/14

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			USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)				01:36 PM
L47	363	7 AND (@PD>"20210628")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:44 PM
L48	11	(34 36 37 39 40) AND (@PD>"20210628")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2021/10/14 01:50 PM
L49	221	7 AND (@PD>"20211014")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO,	OR	ON	ON	2022/01/03 10:56 AM

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			NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L50	9	(34 36 37 39 40) AND (@PD>"20211014")	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, OA, RU, SU, WO, MC, MD, MY, NL, NO, NZ, PH, PL, PT, RO, RS, SE, SG, SI, SK, TH, TN, TR, TW, UA, VN); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/01/03 10:56 AM

PE2E SEARCH - Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
N1	69	((((shunt transport pack$4) near3 tube) (alternat$4 near3 flowpath)) WITH pressure) AND (friction$3 near3 pressure)	(US-PGPUB; USPAT)	OR	ON	ON	2021/10/14 01:43 PM
N2	0	N1 AND (@PD>"20211014")	(US-PGPUB; USPAT)	OR	ON	ON	2022/01/03 10:59 AM

Doc Code: IFEE PTOL/85B-EFS

Document Description: Issue Fee Payment (PTO-85B)

Issue Fee Transmittal Form

Application Number	Filing Date	First Named Inventor	Atty. Docket No.	Confirmation No.
16347711	06-May-2019	Maxime Philippe Coffin	7523.1981US01	5449

TITLE OF INVENTION :

MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Entity Status	Application Type	Art Unit	Class - Subclass	EXAMINER
Regular Undiscounted	U.S. National Stage under 35 USC 371	3619	278000	

Issue Fee Due	Publication Due	Total Fee(s) Due	Date Due	Prev. Paid Fee
$1200	$0	$1200	21-Apr-2022	$0

1.Change of Correspondence Address and/or Indication Of Fee Address (37 CFR 1.33 & 1.363)

Current Correspondence Address:	Current Indicated Fee Address :
27683 HAYNES AND BOONE, LLP IP Section 2323 Victory Avenue Suite 700 Dallas TX 75219 UNITED STATES 214-651-5000 ipdocketing@haynesboone.com	
☐ Change of correspondence address requested, system generated AIA/122-EFS form attached	☐ Fee Address indication requested, system generated SB/47-EFS form attached

2.Entity Status

Change in Entity Status

○ Applicant certifying micro entity status; system generated Micro Entity certification form attached. See 37 CFR 1.29.
Note: Absent a valid certification of micro entity status, issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment. If this box is checked, you will be prompted to choose a micro entity status on the gross income basis (37 CFR 1.29(a)) or the institution of higher education basis (37 CFR 1.29(d)), and make the applicable certification online.

○ Applicant asserting small entity status. See 37 CFR 1.27.
Note: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

◉ Applicant changing to regular undiscounted fee status.
Note: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

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Doc Code: IFEE PTOL/85B-EFS

Document Description: Issue Fee Payment (PTO-85B)

3.The Following Fee(s) Are Submitted:

☒ Issue Fee	☐ I authorize USPTO to apply my previously paid issue fee to the current fees due
☐ Publication Fee	☐ The Director is hereby authorized to apply my previously paid issue fee to the current fee due and to charge deficient fees to Deposit Account Number _____
☐ Advance Order - # of copies _____	☒ If **in addition to** the payment of the issue fee amount submitted with this form, there are any discrepancies in any amount(s) due, the Director is authorized to charge any deficiency, or credit any overpayment, to Deposit Account Number 081394 . The **issue fee must be submitted** with this form. **If payment of the issue fee does not accompany this form, checking this box and providing a deposit account number will NOT be effective to satisfy full payment of the fee(s) due.**

4.Firm and/or Attorney Names To Be Printed

NOTE: If no name is listed, no name will be printed
For printing on the patent front page, list to be displayed as entered

1. HAYNES AND BOONE, LLP
2.
3.

5.Assignee Name(s) and Residence Data To Be Printed

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

Name	City	State	Country	Category
Halliburton Energy Services, Inc.	Houston	TEXAS	UNITED STATES	corporation

6.Signature

I certify, in accordance with 37 CFR 1.4(d)(4) that I am an attorney or agent registered to practice before the Patent and Trademark Office who has filed and has been granted power of attorney in this application. I also certify that this Fee(s) Transmittal form is being transmitted to the USPTO via EFS-WEB on the date indicated below.

Signature	/Harold A. Borland/	**Date**	04-18-2022
Name	Harold Borland	**Registration Number**	57854

WEB IFEE 1.0

Electronic Patent Application Fee Transmittal

Application Number:	16347711
Filing Date:	06-May-2019
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Filer:	Harold Borland/Delaunda Kittrell
Attorney Docket Number:	7523.1981US01

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPL ISSUE FEE	1501	1	1200	1200
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1200**

Electronic Acknowledgement Receipt	
EFS ID:	45496945
Application Number:	16347711
International Application Number:	
Confirmation Number:	5449
Title of Invention:	MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING
First Named Inventor/Applicant Name:	Maxime Philippe Coffin
Customer Number:	27683
Filer:	Harold Borland/Delaunda Kittrell
Filer Authorized By:	Harold Borland
Attorney Docket Number:	7523.1981US01
Receipt Date:	18-APR-2022
Filing Date:	06-MAY-2019
Time Stamp:	15:18:16
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1200
RAM confirmation Number	E20224HF18123480
Deposit Account	081394
Authorized User	Delaunda Kittrell
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.20 (Post Issuance fees) 37 CFR 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Web85b.pdf	62621 16a347964fbf4d8290c559b0aa80f1f92c8c9478	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	40544 8fd1a003b8c4ec0647790e7cb453b7e79c8d3b06	no	2
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		Total Files Size (in bytes):	103165		

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If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/347,711	05/17/2022	11333007	7523.1981US01	5449

27683 7590 04/27/2022

HAYNES AND BOONE, LLP
IP Section
2323 Victory Avenue
Suite 700
Dallas, TX 75219

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Patents Stakeholder Experience (OPSE), Stakeholder Support Division (SSD) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site http://pair.uspto.gov for additional inventors):

Maxime Philippe Coffin, Frisco, TX;
Thomas Jules Frosell, Dallas, TX;

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Halliburton Energy Services, Inc., Houston, TX;

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PTO/AIA/123 (08-12)
Approved for use through 03/31/2021. OMB 0651-0035
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Patent

Address to:
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Patent Number	11,333,007
Issue Date	May 17, 2022
Application Number	16/347711
Filing Date	May 6, 2019
First Named Inventor	Coffin
Attorney Docket Number	7523.1981US01

Please change the Correspondence Address for the above-identified patent to:

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☐ Patentee.

☐ If the Patentee was not the applicant for patent (37 CFR 1.42), then a Statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is enclosed or was filed on _____. See 37 CFR 3.71.

☑ Attorney or agent of record. Registration Number 54255.

☐ Patent practitioner acting in a representative capacity whose correspondence address is the correspondence address of record. Notice has been given to the patentee or owner. Registration Number 54255.

Signature /Jade O. Laye/

Typed or Printed Name Jade O. Laye

Date June 15, 2022 | Telephone 713-547-2118

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Doc Code: MFEE.C.AD
Document Description: Maintenance Fee Address Change

PTO/AIA/47 (11-21)
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☐ The attached Request for Customer Number form (PTO/SB/125)

PATENT NUMBER (if known)	APPLICATION NUMBER
11,333,007	16/347711

Completed by (check one):

☐ Applicant/Inventor

☑ Attorney or Agent of record 54255 (Reg. No.)

☐ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(c) (Form PTO/AIA/96) is enclosed or was filed on _____ (Date)

/Jade O. Laye/
Signature

Jade O. Laye
Typed or printed name

713-547-2118
Requester's telephone number

June 15, 2022
Date

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ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
16/347,711	**06/15/2022 03:33:11 PM ET**	**7523.1981US01**

Title of Invention

MULTIPLE SHUNT PRESSURE ASSEMBLY FOR GRAVEL PACKING

Application Information

APPLICATION TYPE	Utility - U.S. National Stage under 35 USC 371	PATENT #	11333007
CONFIRMATION #	5449	FILED BY	Delaunda Kittrell
PATENT CENTER #	60721028	FILING DATE	05/06/2019
CUSTOMER #	27683	FIRST NAMED INVENTOR	Maxime Philippe Coffin
INTL. APPLICATION #	-	INTL. FILING DATE	-
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Jade Laye

Documents

TOTAL DOCUMENTS: 2

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
7523-1981US01_COCA.pdf	2	Change of Address	246 KB
7523-1981US01_FAIF.pdf	2	Maintenance Fee Address Change	268 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
7523-1981US01_COCA.pdf	CD4AEDC0282A45167315 0B78AD15DBED747579506FCE9F6F3 3B5F291C811E9CFDFE3C15DF83DC3EC922269AB7EAE376F7

	6F7B8F72DC887AB93352037C4B9622F
7523-1981US01_FAIF.pdf	F827DCE6C279A209EB646EB527938A1866045B2CBC5F4E9312843C32CE57EDD50284CF80CD20A10C4198943122738362485EE3FAA4B07253C8A38A54B37B9AC6

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