



- (51) International Patent Classification:  
*F16L 23/20* (2006.01)
- (21) International Application Number:  
PCT/US2014/018885
- (22) International Filing Date:  
27 February 2014 (27.02.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
13/783,017 1 March 2013 (01.03.2013) US
- (71) Applicant: CAMERON INTERNATIONAL CORPORATION [US/US]; 1333 West Loop South, Suite 1700, Houston, Texas 77027 (US).
- (72) Inventor: GUIDRY, Kirk P.; Cameron, 6401 W. Sam Houston Parkway N., Houston, Texas 77041 (US).
- (74) Agent: EUBANKS IV, L. Lee; Eubanks PLLC, 19500 State Highway 249, Suite 465, Houston, Texas 77070 (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, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, 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, 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, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

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

**Published:**

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

(54) Title: MULTI-STAGE SEAL FOR WELL FRACTURING

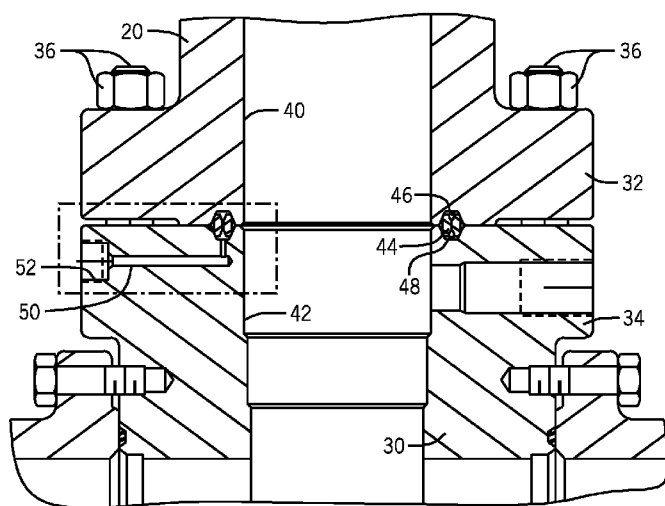


FIG. 3

(57) Abstract: A fracturing system (10) including a ring gasket (44) disposed between a fracturing tree (20, 24) and a wellhead component (30) is provided. In one embodiment, the ring gasket includes multiple sealing stages (56, 58) that seal against grooves (46, 48) in the fracturing tree and the wellhead component. The ring gasket may also include one or more recesses (68) between the sealing stages. In some embodiments, the ring gasket has a configuration that reduces gasket setting load and increases flange separation load compared to other gaskets used in fracturing operations. And in some embodiments, the system enables monitoring (84) of gasket sealing integrity, even during fracturing operations. Additional systems, devices, and methods are also disclosed.

## MULTI-STAGE SEAL FOR WELL FRACTURING

### BACKGROUND

[0001] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the presently described embodiments. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present embodiments. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0002] In order to meet consumer and industrial demand for natural resources, companies often invest significant amounts of time and money in finding and extracting oil, natural gas, and other subterranean resources from the earth. Particularly, once a desired subterranean resource such as oil or natural gas is discovered, drilling and production systems are often used to access and extract the resource. These systems may be located onshore or offshore depending on the location of a desired resource. Further, such systems generally include a wellhead assembly through which the resource is extracted. These wellhead assemblies may include a wide variety of components, such as various casings, valves, fluid conduits, and the like, that aid drilling or extraction operations.

[0003] Additionally, such wellhead assemblies may use a fracturing tree and other components to fracture a well and enhance production. As will be appreciated, resources such as oil and natural gas are generally extracted from fissures or other cavities formed in various subterranean rock formations or strata. To facilitate extraction of such resources, a well may be subjected to a fracturing process that creates one or more man-made fractures in a rock formation. This helps couple pre-existing fissures and cavities, allowing oil, gas, or the like to flow into the wellbore. Such fracturing processes typically include injecting a fracturing fluid—often a mixture including sand and water—into the well to increase the well's pressure and form the man-made fractures.

**SUMMARY**

[0004] Certain aspects of some embodiments disclosed herein are set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of certain forms the invention might take and that these aspects are not intended to limit the scope of the invention. Indeed, the invention may encompass a variety of aspects that may not be set forth below.

[0005] Embodiments of the present disclosure generally relate to well fracturing operations. In some embodiments, a fracturing tree and a wellhead component (e.g., a tubing spool) are joined via a flanged connection that includes a ring gasket with multiple sealing stages. In one embodiment, the ring gasket includes at least one recess in the body of the ring gasket between the sealing stages to decrease gasket setting load and increase flange separation load of the fracturing tree and the wellhead component. Additionally, some embodiments include a test port connected to a sealing groove in which the ring gasket is disposed, enabling the sealing integrity of the ring gasket to be monitored during fracturing.

[0006] Various refinements of the features noted above may exist in relation to various aspects of the present embodiments. Further features may also be incorporated in these various aspects. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of some embodiments without limitation to the claimed subject matter.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0007] These and other features, aspects, and advantages of certain embodiments will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. 1 generally depicts a resource extraction system having a wellhead assembly that may be connected to a production tree or a fracturing tree to facilitate production from a well in accordance with an embodiment of the present disclosure;

[0009] FIG. 2 is an elevational view of a fracturing tree installed on a component of a wellhead assembly in accordance with one embodiment;

[0010] FIG. 3 is a cross-section of the connection between the fracturing tree and the wellhead component of FIG. 2 in accordance with one embodiment and includes an example of a ring gasket for sealing between the fracturing tree and the wellhead component;

[0011] FIG. 4 is a perspective view of the ring gasket of FIG. 3 removed from between the fracturing tree and the wellhead component;

[0012] FIG. 5 is a cross-section of the ring gasket depicted in FIG. 4;

[0013] FIG. 6 is a detail view of a portion of the fracturing tree connection depicted in FIG. 3 having a test port connected to a sealing groove in which the ring gasket is disposed to enable monitoring of gasket sealing integrity during a fracturing operation in accordance with one embodiment; and

[0014] FIG. 7 is a block diagram that represents a method for monitoring gasket integrity and controlling fracturing operations in accordance with one embodiment.

## **DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS**

[0015] One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another.

Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0016] When introducing elements of various embodiments, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Moreover, any use of “top,” “bottom,” “above,” “below,” other directional terms, and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0017] Turning now to the drawings, a resource extraction system 10 is illustrated in FIG. 1 by way of example. The depicted system 10 facilitates extraction of natural resources (e.g., oil or natural gas) from a well 12 via a wellbore 14 and a wellhead assembly 16. The wellhead assembly 16 may include a variety of components, such as a wellhead, a casing head, a tubing spool, and valves that control the flow of fluids through the assembly. In the presently illustrated embodiment, the well 12 is a surface well in that the equipment of the wellhead assembly 16 is installed at ground level on dry land. But it will be appreciated that in different embodiments the resource extraction system 10 may be provided in other environments, such as in connection with subsea or platform wells.

[0018] A production tree 18 is connected to the wellhead assembly 16 (e.g., to a tubing spool) and facilitates extraction of the natural resource from the well 12. In some instances, and to further facilitate production, a fracturing tree 20 may be connected to the wellhead assembly 16. By injecting a fracturing fluid into the well 12 via the fracturing tree 20, the system 10 increases the number or size of fractures in a resource-bearing rock formation (or strata) to enhance recovery of the desired resource.

[0019] A particular arrangement 24 of a fracturing tree 20 connected to a wellhead assembly 16 is depicted in FIG. 2 by way of further example. The arrangement 24

includes various valves 26 for controlling fluid flow through the wellhead assembly 16 and the fracturing tree 20. Fracturing fluid may be pumped from a source into the fracturing tree 20 through a fracturing head 28 (also known as a goat head). The fracturing tree 20 is connected to a component 30 of the wellhead assembly 16. In one embodiment, the component 30 is a tubing spool of the wellhead assembly 16. But it is noted that the fracturing tree 20 could instead be connected to another component of the wellhead assembly 16.

**[0020]** The connection of the fracturing tree 20 to the component 30 may be referred to as a fracturing connection. And in the present depiction, the fracturing tree 20 and the component 30 include respective flanges 32 and 34 (depicted as ring joint type flanges) joined together with fasteners 36 (such as nuts with studs of a studded flange 34), though other fasteners or manners of connecting the tree 20 and the component 30 could instead be used. Consequently, in those embodiments having such flanges, this connection between the fracturing tree 20 and the component 30 may also be referred to as a flanged connection. In at least some embodiments, the flanges 32 and 34 conform to Advanced Petroleum Institute (API) Specification 6A (i.e., the flanges 32 and 34 are API flanges). And in at least some of these embodiments the flanges 32 and 34 conform to the specifications of 6BX flanges in API Specification 6A (i.e., the flanges 32 and 34 are 6BX flanges).

**[0021]** Additional details about the fracturing connection of arrangement 24 are illustrated in the cross-section of FIG. 3 in accordance with one embodiment. As depicted, the connection of the fracturing tree 20 and the wellhead component 30 allow fluid to pass between their respective bores 40 and 42. The fracturing connection includes a ring gasket 44 to inhibit fluids from leaving the bores through the connection. The ring gasket 44 is positioned within and seals against opposing sealing grooves 46 and 48 of the fracturing tree 20 and the wellhead component 30. And in at least some embodiments the region of the fracturing connection in which the ring gasket 44 is disposed is connected by a conduit 50 to a test port 52. As discussed in greater detail below, such an arrangement enables measurement of pressure within the sealing grooves and monitoring of gasket sealing integrity.

[0022] In one embodiment generally depicted in FIGS. 4 and 5, the ring gasket 44 takes the form of a two-stage sealing gasket having an outer end portion or stage 56 and an inner end portion or stage 58. The outer end 56 of the ring gasket 44 includes outer sealing surfaces 60 and 62, while the inner end 58 includes inner sealing surfaces 64 and 66. The sealing surfaces seal against the grooves 46 and 48 of the fracturing tree 20 and the wellhead component 30 to inhibit leaking from the bores 40 and 42 at the fracturing connection. The ring gasket 44 may be formed of any suitable material, such as stainless steel. And, if desired, any or all of the ring gasket 44, the sealing groove 46, and the sealing groove 48 may include suitable coatings or platings, such as those that facilitate sealing engagement or minimize galling.

[0023] As noted above, the flanges 32 and 34 of some embodiments are 6BX flanges. API Specification 6A also defines a class of BX gaskets, and states that only such BX gaskets shall be used with 6BX flanges. But contrary to this instruction, in at least some embodiments (including that illustrated in FIG. 3) the ring gasket 44 installed between 6BX flanges 32 and 34 is not a BX gasket. For instance, the body of the ring gasket 44 may also include one or more recesses, such as the pair of opposing recesses 68 shown in FIG. 5. In the depicted embodiment, the recesses 68 are provided as circumferential grooves between the outer and inner sealing surfaces and generally separate the outer and inner end stages 56 and 58. Such an arrangement provides for lower gasket setting load (requiring less preload on the flanged connection to energize the seals of the gasket) in comparison to some other ring gaskets, such as BX ring gaskets defined in API Specification 6A. In turn, the depicted non-BX ring gasket 44 also provides increased flange separation load at the connection, allowing the connection to maintain sealing integrity while experiencing greater external forces (e.g., from bending moments and vibration) on the fracturing tree as compared to some other ring gaskets.

[0024] The ring gasket 44 also includes a pressure port 70 extending axially through its body. With reference to FIG. 6, this pressure port 70 allows balancing of pressure between a region 72 within the sealing groove 46 of the fracturing tree 20 (between sealing surfaces 62 and 66 of the ring gasket 44) and a region 74 within the sealing

groove 48 of the wellhead component 30 (between sealing surfaces 60 and 64 of the gasket 44).

**[0025]** As depicted in FIG. 6, the sealing surfaces 62 and 60 seal against the outer sides of the sealing grooves 46 and 48 and isolate the regions 72 and 74 from external pressure about the flanges 32 and 34 of the fracturing tree 20 and the wellhead component 30. Likewise, the sealing surfaces 66 and 64 seal against the inner sides of the sealing grooves 46 and 48 and isolate the regions 72 and 74 from internal pressure within the bores 40 and 42 of the fracturing tree 20 and the wellhead component 30. In contrast to previous arrangements in which a ring gasket was intended to continuously seal only against the inner sides of the sealing grooves (and only intermittently seal against the outer sides of the sealing grooves), in at least one embodiment of the present disclosure the ring gasket 44 is configured to maintain sealing along both the inner and outer surfaces of the sealing grooves 46 and 48.

**[0026]** The test port 52 is connected to the region 74 by the conduit 50. And as noted before, the region 74 is connected to the region 72 by the pressure port 70. The isolation of pressure within the regions 72 and 74 from pressure about the fracturing tree 20 and the wellhead component 30 and from pressure within the bores 40 and 42 facilitates monitoring of the sealing integrity of the ring gasket 44 in one embodiment. In one instance, the test port 52 may be used before a fracturing operation to ensure proper setting and adequate sealing of the ring gasket 44. For example, in an embodiment in which the ring gasket 44 is intended to maintain sealing at both the outer and inner stages 56 and 58 once installed in the sealing grooves 46 and 48, the regions 72 and 74 may be pressurized via the test port 52 and conduit 50. If both stages 56 and 58 are properly sealing against the grooves 46 and 48, the regions 72 and 74 will maintain the applied pressure. If not, the regions 72 and 74 will lose pressure, indicating loss of sealing integrity. Such testing may, of course, be performed after a fracturing operation as well.

**[0027]** But in addition to testing before or after operation, certain embodiments also allow the pressure within the regions 72 and 74 to be monitored via the test port 52 during operation of the wellhead assembly. If the initial pressure in the

regions 72 and 74 is between the environmental pressure outside the wellhead assembly and the pressure in the bores 40 and 42 in operation (e.g., the fracturing pressure in a fracturing operation), loss of sealing integrity of the ring gasket 44 will cause a change in the pressure in the regions 72 and 74. Particularly, loss of sealing integrity at inner sealing surfaces 64 or 66 will cause fluid from the bores 40 and 42 to leak into the regions 72 or 74, generally increasing the pressure in these regions. Alternatively, loss of sealing integrity at outer sealing surfaces 60 or 62 will result in leaking of fluid from the regions 72 or 74 to the exterior environment, generally decreasing the pressure in the regions 72 and 74. While loss of sealing integrity at both sealing stages of the ring gasket 44 may result in increasing or decreasing pressure within the regions 72 and 74 depending on the magnitude of failure at each stage of the ring gasket 44, the corresponding change in pressure can still be monitored and correlated to a loss of sealing integrity.

**[0028]** This capability of monitoring pressure and sealing integrity may be beneficial in a number of applications, including during well fracturing operations. One example of a method for performing fracturing operations is generally represented by block diagram 76 in FIG. 7. In this embodiment, the method includes installing a gasket (such as ring gasket 44) at a fracturing connection, as represented in block 78. For example, the installation may include positioning a ring gasket in a sealing groove of a wellhead component and then joining a fracturing tree to the wellhead component with fasteners such that the ring gasket also engages a sealing groove of the fracturing tree. In block 80, the ring gasket is then set into sealing engagement by applying a preload to the gasket (e.g., by tightening fasteners 36 joining the fracturing tree 20 and the wellhead component 30).

**[0029]** After the ring gasket is set, fracturing of the well may begin as indicated at block 82. It is noted that fracturing trees often experience significant vibration and bending moments as a result of receiving and transmitting high-pressure fracturing fluids into the well. Excessive forces on the fracturing tree could cause the ring gasket to lose sealing engagement at a sealing surface and result in leaking of fracturing fluid. But in accordance with the present technique, the sealing integrity of the ring gasket may be monitored (e.g., through the pressure monitoring described above) during

fracturing of the well as indicated at block 84. A sudden pressure change detected within a region between the sealing stages of the ring gasket 44 (e.g., within the regions 72 or 74) may be indicative of loss of sealing integrity and the fracturing operation may be suspended (block 86) to reduce or prevent leaking of fluid at the ring gasket 44. In such an instance, further integrity testing may be performed after suspension of fracturing and suitable adjustments may be made by the operator. For instance, additional preload may be applied or the ring gasket may be replaced, if needed. In some cases, the loss of sealing integrity at one stage of the ring gasket 44 may be detected before loss of sealing integrity at the other stage of the ring gasket 44, which may allow the fracturing operation to be suspended before any leaking of fracturing fluid through the connection to the surrounding environment can occur. Of course, it will be appreciated that the fracturing operation may also be completed (i.e., also end at block 86) without loss of sealing integrity at the ring gasket 44.

**[0030]** While the aspects of the present disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. But it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

**CLAIMS**

1. A well-fracturing system (10) comprising:
  - a wellhead component (30) including a sealing groove (48);
  - a fracturing tree (20, 24) coupled to the wellhead component such that the sealing groove of the wellhead component is aligned with an additional sealing groove (46) of the fracturing tree; and
  - a ring gasket (44) disposed between the wellhead component and the fracturing tree within the sealing groove and the additional sealing groove, wherein the ring gasket is a multi-stage sealing gasket including:
    - a first sealing stage (56) in the form of an outer end of the multi-stage sealing gasket having surfaces (60, 62) that seal against the sealing groove and the additional sealing groove, respectively;
    - a second sealing stage (58) in the form of an inner end of the multi-stage sealing gasket having surfaces (64, 66) that seal against the sealing groove and the additional sealing groove, respectively; and
    - a recess (68) in a surface of the multi-stage sealing gasket between the first and second sealing stages.
2. The well-fracturing system of claim 1, wherein the wellhead component includes a test port (52) that enables testing of pressure within the sealing groove.
3. The well-fracturing system of claim 2, including a pressure port (70) through the multi-stage sealing gasket, wherein the pressure port fluidly connects a region (74) in the sealing groove between the multi-stage sealing gasket and the wellhead component with another region (72) in the additional sealing groove between the multi-stage sealing gasket and the fracturing tree to enable testing of pressure within both regions via the test port.

4. The well-fracturing system of claim 2, wherein the wellhead component and the fracturing tree are coupled together via a flanged connection (32, 34).

5. The well-fracturing system of claim 4, wherein the test port is in a flange (34) of the wellhead component and is fluidly connected to the sealing groove.

6. The well-fracturing system of claim 5, wherein the flange of the wellhead component is an API flange.

7. The well-fracturing system of claim 6, wherein the flange of the wellhead component is a 6BX flange.

8. The well-fracturing system of claim 7, wherein the ring gasket has a lower gasket setting load than a BX ring gasket.

9. The well-fracturing system of claim 1, wherein the recess in the surface of the multi-stage sealing gasket includes a first recess (68) between surfaces of the first and second sealing stages that seal against the sealing groove of the wellhead component and a second recess (68) between surfaces of the first and second sealing stages that seal against the additional sealing groove of the fracturing tree.

10. The well-fracturing system of claim 1, wherein pressure within the recess of the multi-stage sealing gasket during fracturing is less than bore pressure within the wellhead component and greater than environmental pressure outside of the wellhead component.

11. A well-fracturing method comprising:

beginning fracturing (82) of a well (12) using a fracturing tree (20, 24) coupled to a wellhead assembly (16, 30); and

monitoring (84), via pressure testing, sealing integrity of a gasket (44) between the fracturing tree and the wellhead assembly during the fracturing of the well.

12. The well-fracturing method of claim 11, wherein monitoring the sealing integrity of the gasket includes monitoring pressure within a recess (46, 48) in which the gasket is disposed.

13. The well-fracturing method of claim 12, wherein monitoring the pressure within the recess includes monitoring the pressure within a region (72, 74) between two sealing stages (56, 58) of the gasket in the recess.

14. The well-fracturing method of claim 11, comprising detecting, via the monitoring of the sealing integrity of the gasket, a loss of preload on the gasket during fracturing of the well.

15. The well-fracturing method of claim 14, stopping fracturing (86) of the well in response to the detected loss of preload on the gasket.

1 / 4

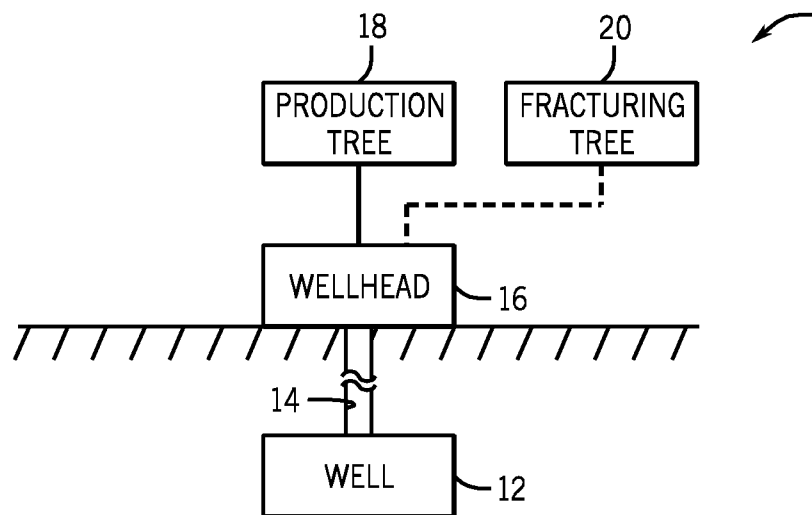


FIG. 1

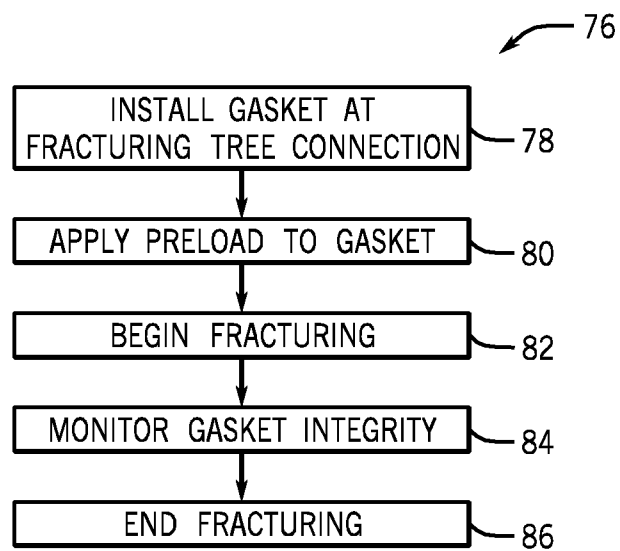


FIG. 7

2 / 4

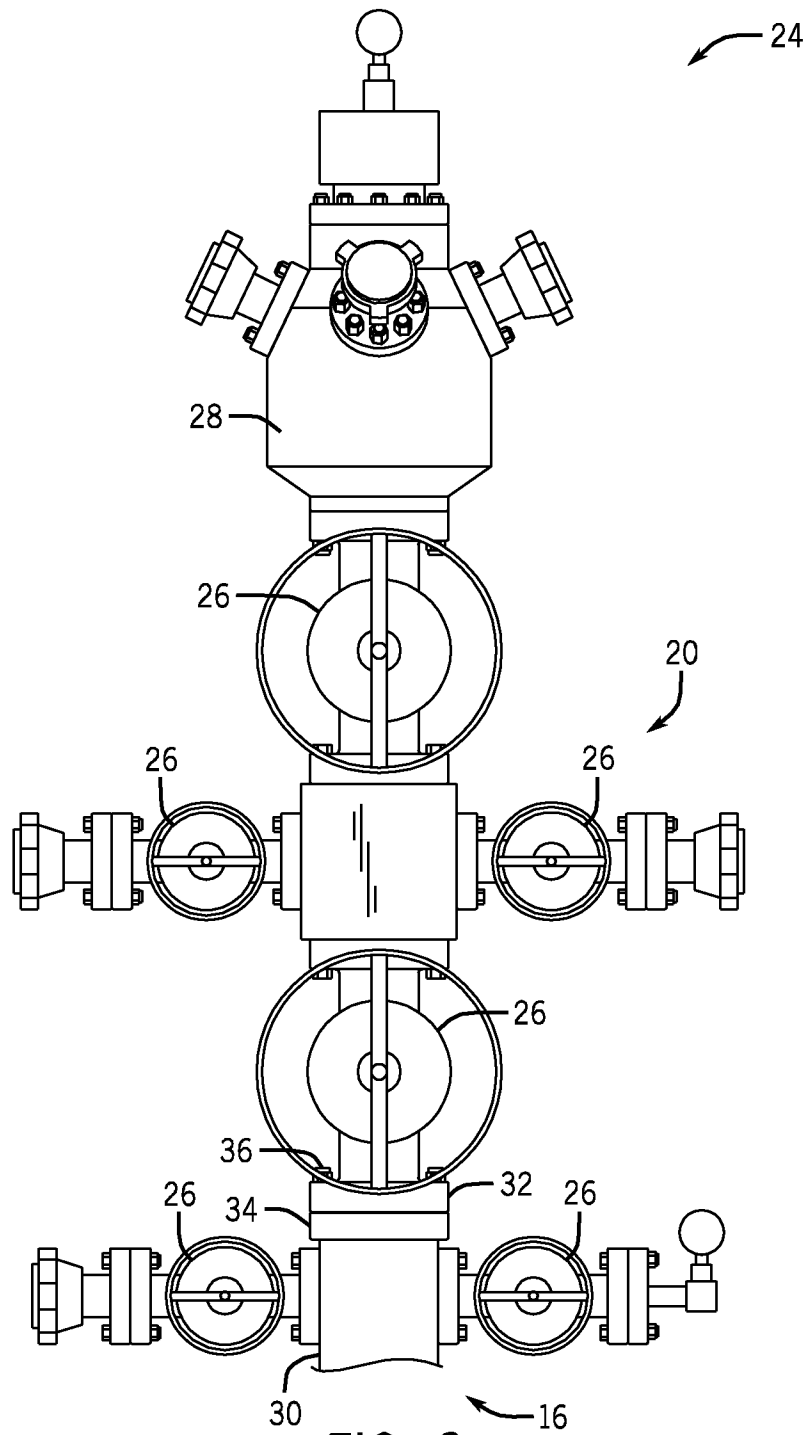


FIG. 2

3 / 4

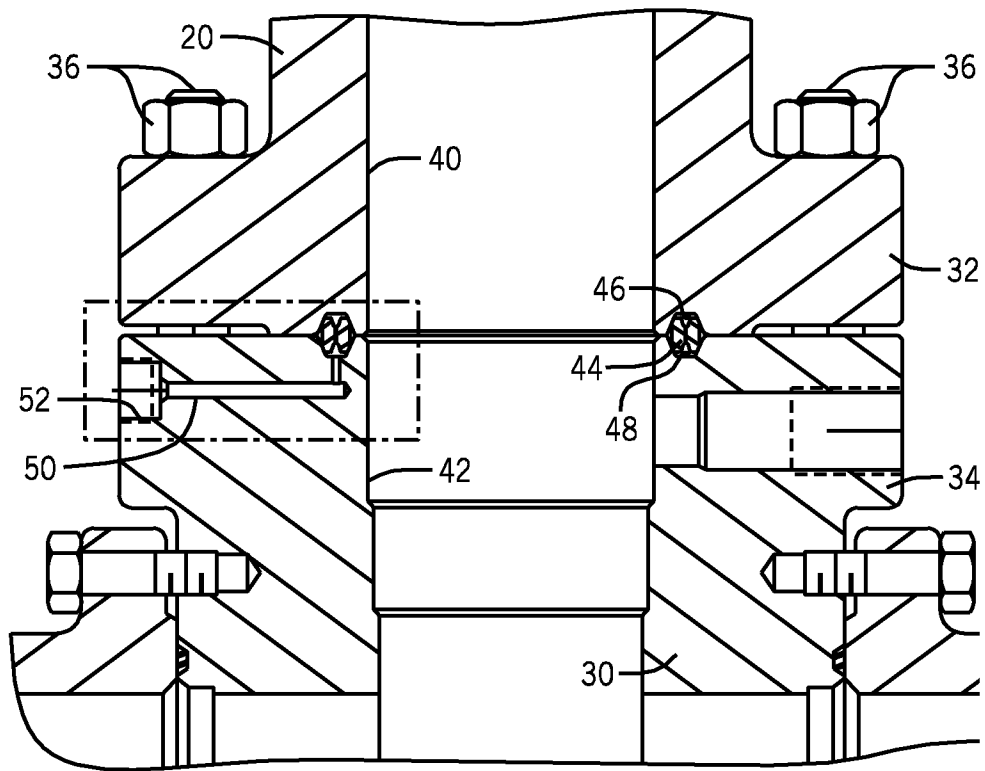


FIG. 3

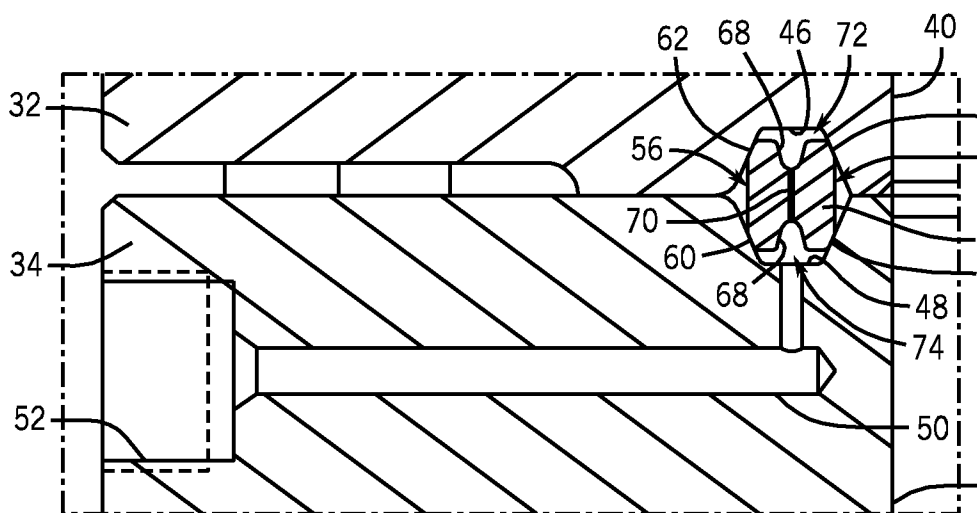
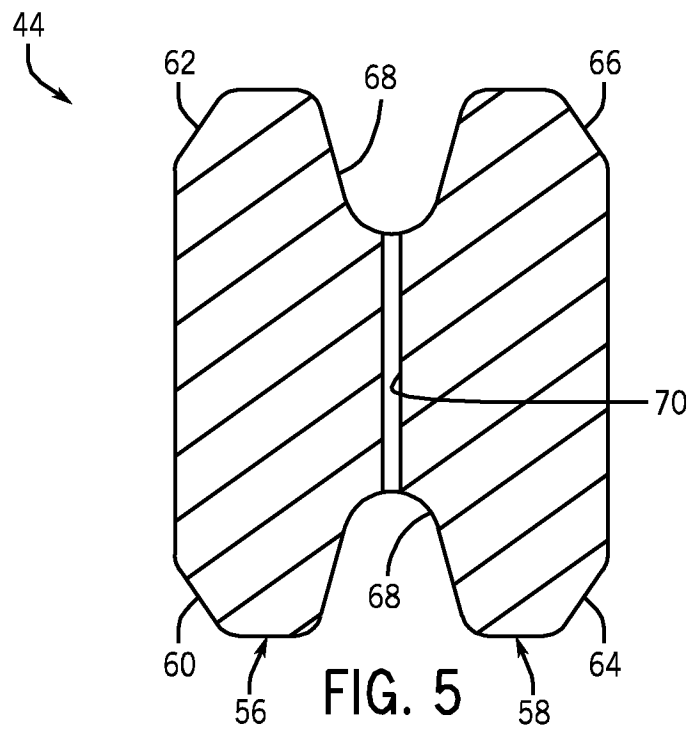
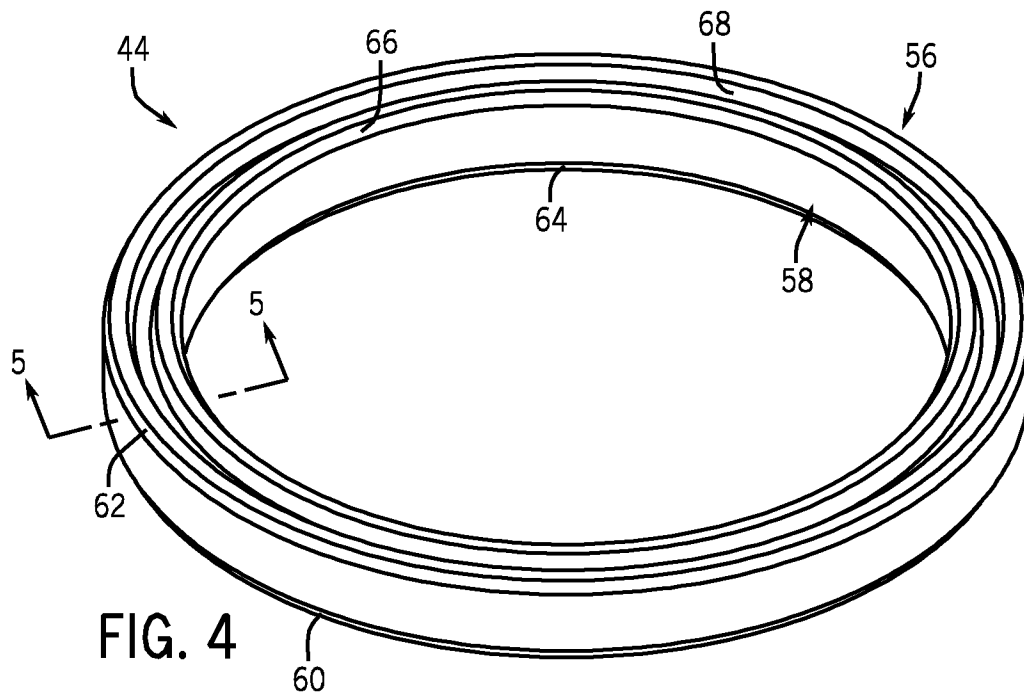


FIG. 6

4 / 4



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2014/018885

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16L 23/20 (2014.01)

USPC - 277/318

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(8) - F16L 23/20; G01M 3/04, 3/22 (2014.01)

USPC - 73/46; 277/314, 318, 320, 614, 626, 641; 285/93, 336, 363, 917

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
CPC - F16L 23/167, 23/20; G01M 3/04, 3/223, 3/2853 (2014.02)

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

Orbit, Google Patents, Google

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category*   | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                    | Relevant to claim No. |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X<br>-<br>Y | US 4,410,186 A (PIERCE JR) 18 October 1983 (18.10.1983) entire document                                                                                                                                                                                                                                               | 1-6, 9, 10            |
| Y           | SUNRY PETRO. Archived webpage from sunrypetro.com. 10 November 2012 [retrieved on 22 May 2014]. Retrieved from the internet:<br><URL: <a href="http://web.archive.org/web/20121110215202/http://sunrypetro.com/api_flange.html">http://web.archive.org/web/20121110215202/http://sunrypetro.com/api_flange.html</a> > | 7, 8, 11-15           |
| Y           | US 2011/0083852 A1 (BERTRAND) 14 April 2011 (14.04.2011) entire document                                                                                                                                                                                                                                              | 7, 8                  |
| A           | US 5,090,871 A (STORY et al) 25 February 1992 (25.02.1992) entire document                                                                                                                                                                                                                                            | 11-15                 |
| A           | US 5,348,310 A (BROWNING et al) 20 September 1994 (20.09.1994) entire document                                                                                                                                                                                                                                        | 1-15                  |

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


## \* 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

22 May 2014

Date of mailing of the international search report

13 JUN 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents  
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300  
PCT OSP: 571-272-7774