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(54) Title: HIGH DEGREE OF FREEDOM RISER TENSIONER SYSTEM

(57) Abstract: A riser tensioner system has a riser support device, an actuator, and a bearing assembly disposed between the riser support device and the actuator. The bearing assembly is configured to provide at least five degrees of freedom of movement of the riser support device relative to the actuator.

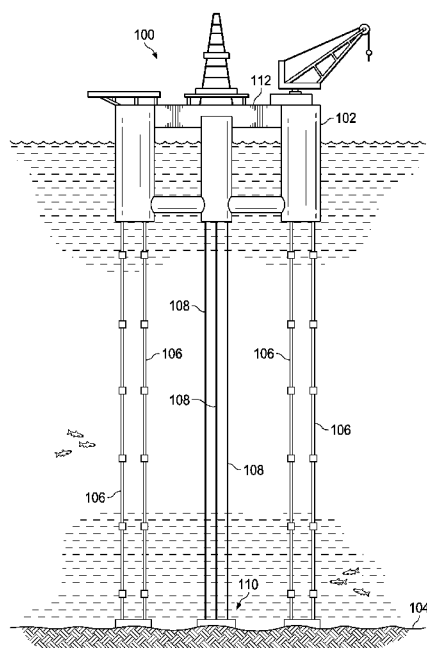
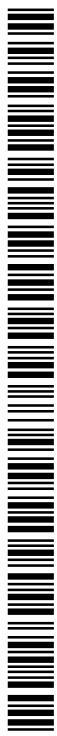


FIG. 1



HIGH DEGREE OF FREEDOM RISER TENSIONER SYSTEM

FIELD OF THE INVENTION

[0001] Embodiments described herein relate to systems and methods of providing flexible connections in riser tensioner systems.

BACKGROUND

[0002] Some riser tensioner systems comprise bearings configured to allow relative cocking motions between riser tensioner system components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is a schematic view of an offshore hydrocarbon production system that includes a high degree of freedom (HDOF) riser tensioner system.

[0004] FIG. 2 is a partial cutaway view of the HDOF riser tensioner system of the offshore hydrocarbon production system of FIG. 1, the HDOF riser tensioner system including an HDOF bearing assembly.

[0005] FIG. 3 is an oblique view of the HDOF bearing assembly of FIG. 2.

[0006] FIG. 4 is an orthogonal top view of the HDOF bearing assembly of FIG. 2.

[0007] FIG. 5 is an orthogonal cross-sectional view of the HDOF bearing assembly of FIG. 2 taken along the cutting line 5-5 of FIG. 4.

DETAILED DESCRIPTION

[0008] Referring to Figure 1, an offshore hydrocarbon production system 100 is shown. The offshore hydrocarbon production system 100 comprises a platform 102 that is secured to the ocean floor 104 by a plurality of tendons 106. The system further comprises risers 108 that extend between individual wells of a template 110 and a deck 112 that is supported by the platform 102. The risers 108 are flexibly connected to the platform 102 to permit relative motion between the risers 108 and platform 102 that can be caused by waves contacting the platform 102 and the risers 108 that extend up from the ocean floor 104.

[0009] Figure 2 illustrates a high degree of freedom (HDOF) riser tensioner system 114 comprising a riser 108 extending through a hole 116 of the deck 112. An upper portion of the riser 108 is coupled to a riser support device 118 that is configured to provide a convenient load bearing connection to the riser 108 capable of supporting the weight of the riser 108. Actuators 120, such as, but not limited to, hydraulic actuators, are coupled between the riser support device

118 and the deck 112. The actuators 120 are selectively controlled to lengthen and shorten to maintain a desired amount of tension applied to the riser 108. For example, in cases where the platform 102 and deck 112 are moved upward, such as due to ocean wave activity, the actuators 120 can be selectively shortened to maintain a desired tension applied to the riser 108 and/or to prevent over-tensioning the riser 108. Similarly, in cases where the platform 102 and deck 112 are moved downward, the actuators 120 can be selectively lengthened to maintain a desired tension applied to the riser 108 and/or to prevent too much riser 108 weight from being transferred to the underwater components of the offshore hydrocarbon production system 100. While the actuators 120 can account for vertical relative movement between the riser 108 and the deck 112, actual ocean wave activity and other sources of perturbation may cause relative movement between the riser 108 and the deck 112 in any other spatial direction and/or in a variety of directional combinations. Accordingly, bearings are provided between the actuators 120 and the deck 112 as well as between the actuators 120 and the riser support device 118. More specifically, lower bearing assemblies 122 are disposed between the actuators 120 and the deck 112 and HDOF bearing assemblies 124 are disposed between the actuators 120 and the riser support device 118.

[0010] The lower bearing assemblies 122 comprise a high capacity laminate (HCL) lower spherical bearing stack 126 comprising a series of stacked spherical shell segment shaped elastomeric elements and complementarily shaped nonelastomeric shims. The bearing stack is disposed between a convex mount 128 coupled to the deck 112 and a concave mount 130 coupled to a lower end of the actuator 120. The lower spherical bearing stacks 126 allow relative cocking motions between the convex mount 128 and the concave mount 130, and hence, relative cocking motions between the deck 112 and the actuator 120.

[0011] The HDOF bearing assemblies 124 comprise HDOF spherical bearing stacks 132 substantially similar to lower spherical bearing stacks 126. The HDOF bearing assemblies 124 also comprise a convex mount 134 and a concave mount 136. The HDOF spherical bearing stack 132 is disposed between the convex mount 134 and the concave mount 136. In this embodiment, the convex mount 134 is disposed between the actuator 120 and the HDOF spherical bearing stack 132. In this embodiment, the HDOF spherical bearing stack 132 is configured to allow relative cocking motions between the convex mount 134 and the concave mount 136, and hence, between the actuator 120 and the riser 108 via the riser support device 118. The HDOF bearing assemblies 124 further comprise a plate mount 138 and a planar bearing stack 140 disposed between the plate mount 138 and the concave mount 136. Similar to the HDOF spherical bearing stack 132, the planar bearing stack 140 comprises an HCL bearing stack comprising a series of

stacked elastomeric elements and nonelastomeric shims, however, the elastomeric elements and nonelastomeric shims of the planar bearing stack 140 are substantially plate-like and are generally flat. The planar bearing stacks 140 are configured to allow translational movement of the plate mounts 138 relative to the concave mount 136.

[0012] Accordingly, through the combined utilization of the HDOF spherical bearing stack 132 and planar bearing stack 140, the HDOF bearing assembly 124 allow enables a six degree of freedom connection between the actuator 120 and the riser 108. More specifically, in some embodiments, the HDOF spherical bearing stack 132 allows for three degrees of freedom, such as the pitch, yaw, and roll of the cocking offset movements while the planar bearing stack 140 allows for two additional degrees of freedom in forward-backward and left-right substantially planar translational movements. The sixth degree of freedom of upward-downward movements, in some embodiments, is provided primarily by the lengthening and/or shortening of the actuators 120 and secondarily by the somewhat compressible nature of the HDOF spherical bearing stacks 132 and the planar bearing stacks 140, alternatively referred to as first bearing stacks and second bearing stacks, respectively.

[0013] Referring now to Figures 3-5, an HDOF bearing assembly 124 is shown in greater detail. Figure 3 is an oblique view of an HDOF bearing assembly 124. Figure 4 is an orthogonal top view of the HDOF bearing assembly 124 of Figure 3. Figure 5 is an orthogonal cross-sectional view of the HDOF bearing assembly 124 of Figure 4 taken along the cutting line 5-5 of Figure 4. HDOF bearing assembly 124 is shown as comprising a mounting receptacle 142 for receiving a portion of an actuator 120 and fastener holes 144 for receiving fasteners that can be used to connect the HDOF bearing assembly 124 to the actuator 120.

[0014] Other embodiments of the current invention will be apparent to those skilled in the art from a consideration of this specification or practice of the invention disclosed herein. Thus, the foregoing specification is considered merely exemplary of the current invention with the true scope thereof being defined by the following claims.

CLAIMS

What is claimed is:

1. A riser tensioner system (114), comprising:
a riser support device (118);
an actuator (120); and
a high degree of freedom (HDOF) bearing assembly (124) disposed between the riser support device (118) and the actuator (120), the HDOF bearing assembly (124) being configured to provide at least five degrees of freedom of movement of the riser support device (118) relative to the actuator (120).
2. The riser tensioner system (114) of claim 1, wherein the HDOF bearing assembly (124) comprises at least two bearing stacks (132, 140).
3. The riser tensioner system (114) of claim 2, wherein at least one of the two bearing stacks comprises a HDOF spherical bearing stack (132).
4. The riser tensioner system (114) of claim 3, wherein the HDOF spherical bearing stack (132) allows a relative cocking motion.
5. The riser tensioner system (114) of claim 2, wherein at least one of the two bearing stacks comprises a planar bearing stack (140).
6. The riser tensioner system (114) of claim 5, wherein the planar bearing stack (140) allows a relative translational motion.
7. The riser tensioner system (114) of claim 2, wherein the at least two bearing stacks (132, 140) comprise a HDOF spherical bearing stack (132) configured to allow a relative cocking motion and planar bearing stack (140) configured to allow a relative translational motion.

8. An offshore hydrocarbon production system (100), comprising:
a riser tensioner system (114), comprising:
a riser support device (118);
an actuator (120); and
a high degree of freedom (HDOF) bearing assembly (124) disposed between the riser support device (118) and the actuator (120), the HDOF bearing assembly (124) being configured to provide at least five degrees of freedom of movement of the riser support device (118) relative to the actuator (120).
9. The riser tensioner system (114) of claim 8, wherein the HDOF bearing assembly (124) comprises at least two bearing stacks (132, 140).
10. The riser tensioner system (114) of claim 9, wherein at least one of the two bearing stacks comprises a HDOF spherical bearing stack (132).
11. The riser tensioner system (114) of claim 10, wherein the HDOF spherical bearing stack (132) allows a relative cocking motion.
12. The riser tensioner system (114) of claim 9, wherein at least one of the two bearing stacks comprises a planar bearing stack (140).
13. The riser tensioner system (114) of claim 12, wherein the planar bearing stack (140) allows a relative translational motion.
14. The riser tensioner system (114) of claim 9, wherein the at least two bearing stacks (132, 140) comprise a HDOF spherical bearing stack (132) configured to allow a relative cocking motion and planar bearing stack (140) configured to allow a relative translational motion.

15. A method of providing six degrees of freedom of movement between a riser (108) of an offshore hydrocarbon production system (100) and a platform (102), comprising:

disposing a high degree of freedom (HDOF) bearing assembly (124) between a riser (108) and an actuator (120), the HDOF bearing assembly (124) comprising at least two bearing stacks (132, 140).

16. The method of claim 15, wherein at least one of the two bearing stacks comprises a HDOF spherical bearing stack (132).

17. The method of claim 16, wherein the HDOF spherical bearing stack (132) allows a relative cocking motion.

18. The method of claim 15, wherein at least one of the two bearing stacks comprises a planar bearing stack (140).

19. The method of claim 18, wherein the planar bearing stack (140) allows a relative translational motion.

20. The method of claim 15, wherein the at least two bearing stacks (132, 140) comprise a HDOF spherical bearing stack (132) configured to allow a relative cocking motion and planar bearing stack (140) configured to allow a relative translational motion.

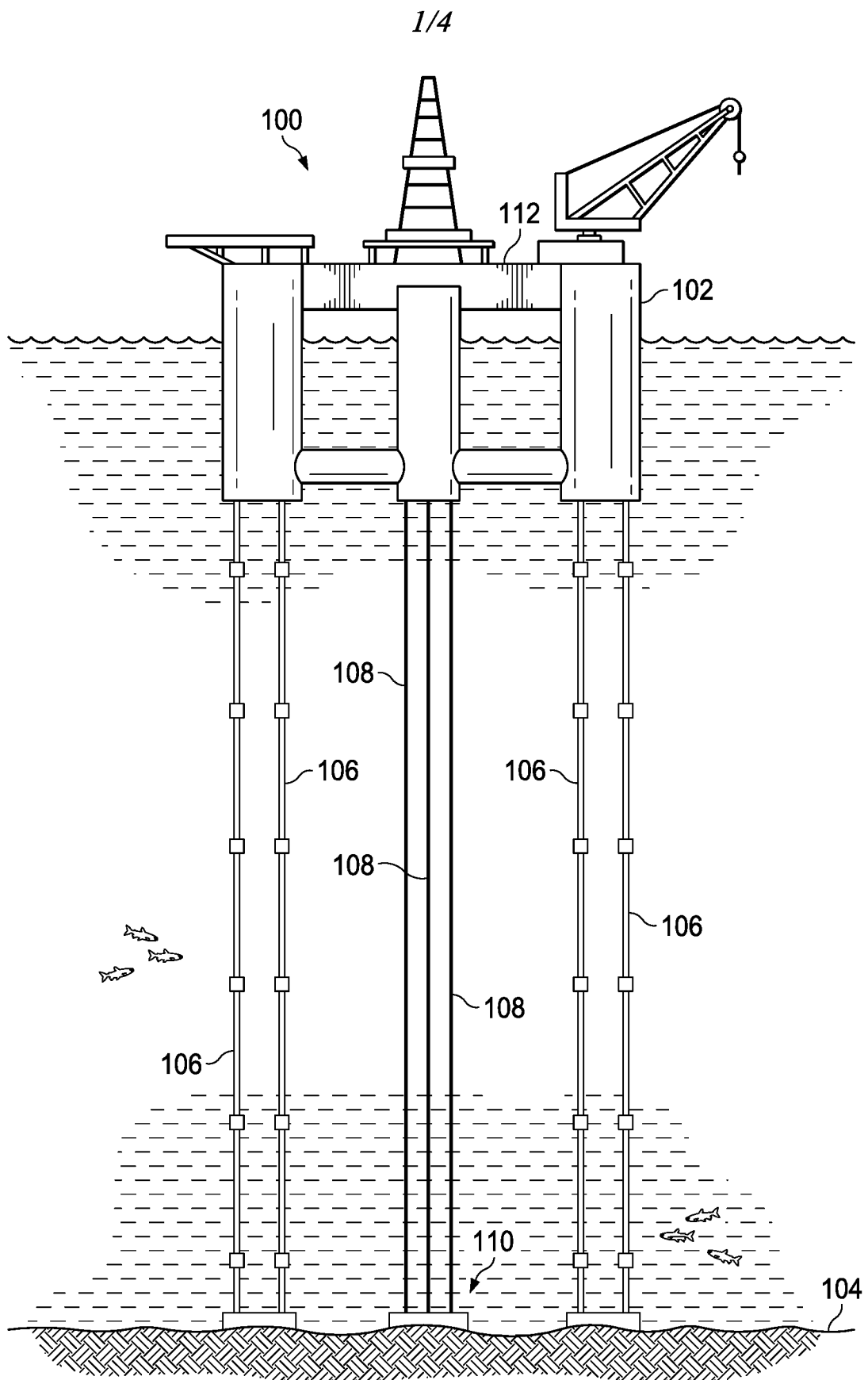


FIG. 1

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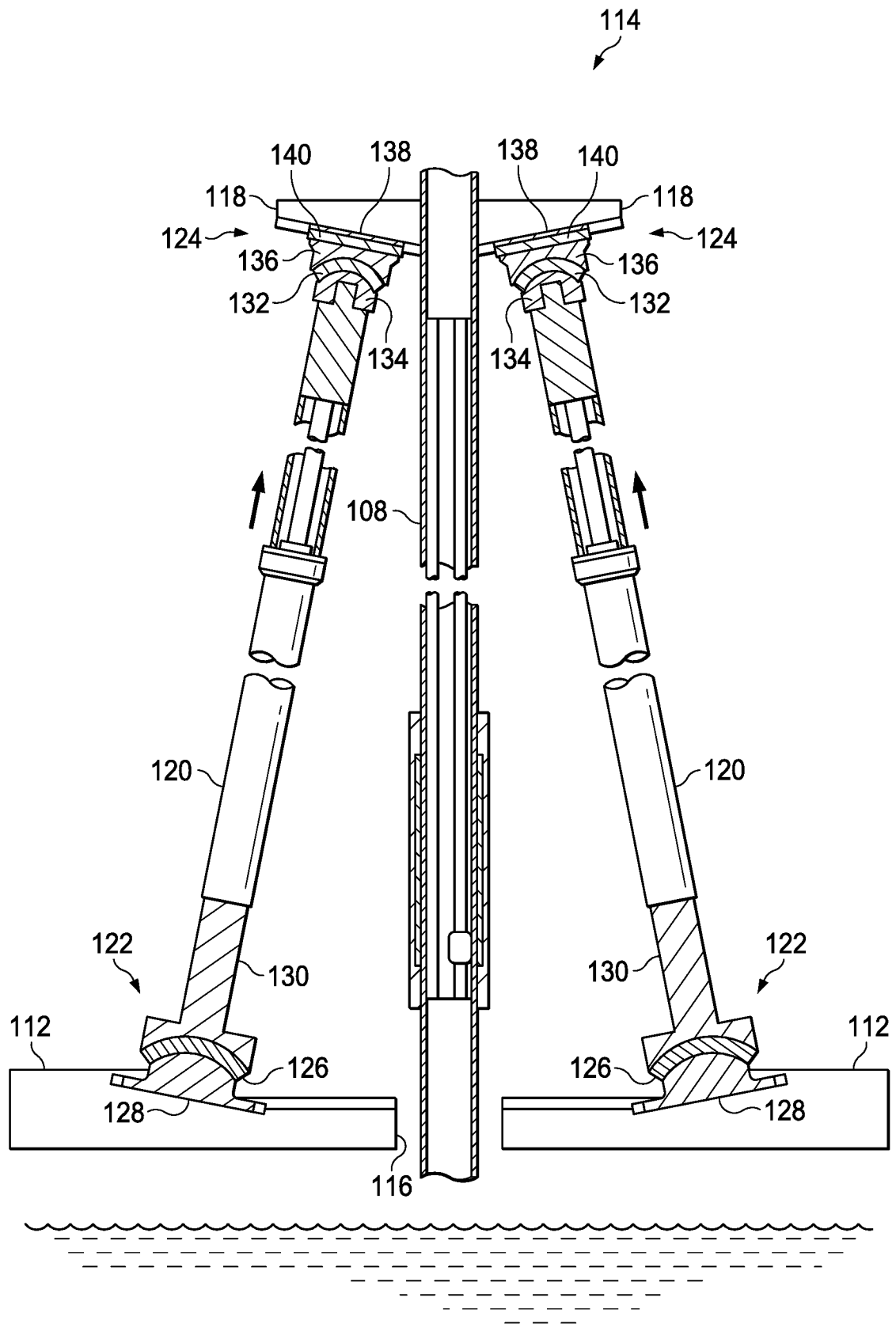


FIG. 2

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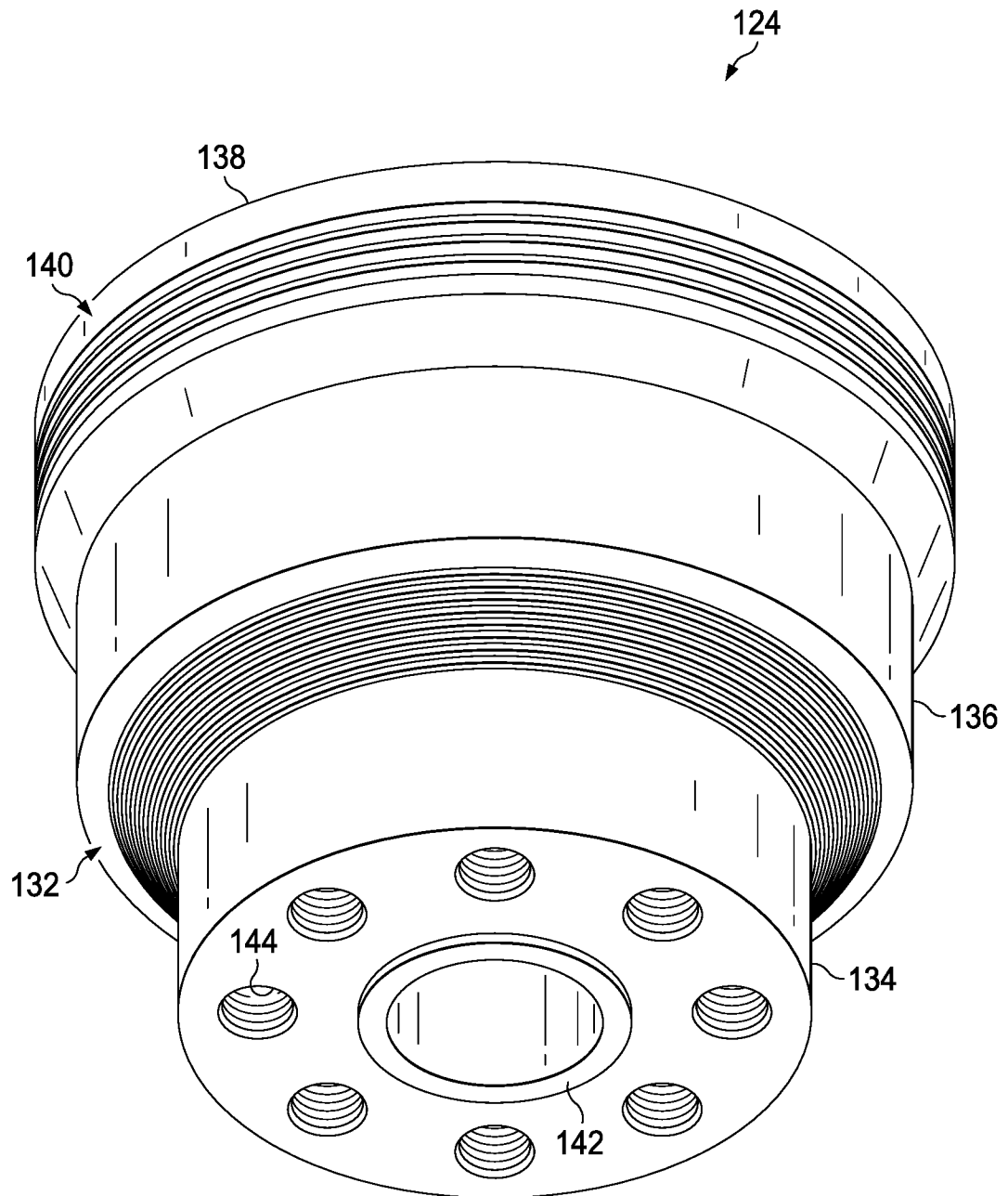
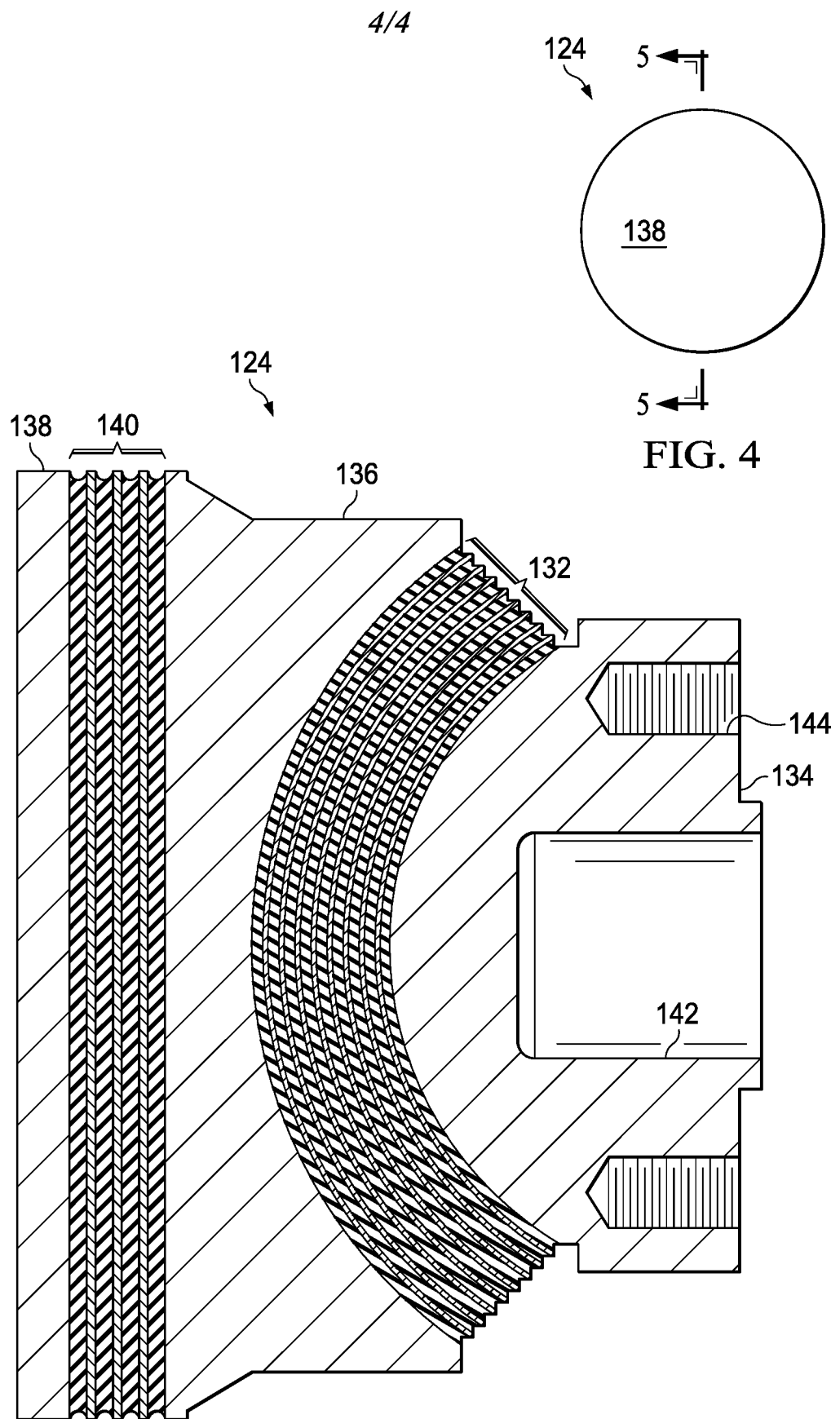


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/049265

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B19/00 E21B4/00
ADD.

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/062735 A2 (LORD CORP [US]; JONES PETER [US]; CUNE GREGG [US]; FUHRER ZACHARY [US]) 2 May 2013 (2013-05-02)	1,8
Y	paragraph [0027] - paragraph [0028]; figure 3	2-7,9-14
Y	----- WO 2015/066472 A1 (LORD CORP [US]) 7 May 2015 (2015-05-07) paragraph [0015] - paragraph [0017]; figures 2a-2c	2-7,9-14
X	----- WO 2008/019067 A2 (WYBRO PIETER G [US]; KIPP ROBERT M [US]) 14 February 2008 (2008-02-14) page 12, line 12 - page 13, line 3; figures 6,7 ----- -/-	1,8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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04/05/2017

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/049265

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 883 387 A (MYERS RODERICK J [US] ET AL) 28 November 1989 (1989-11-28) column 3, line 34 - line 61; figure 2 -----	1,8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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