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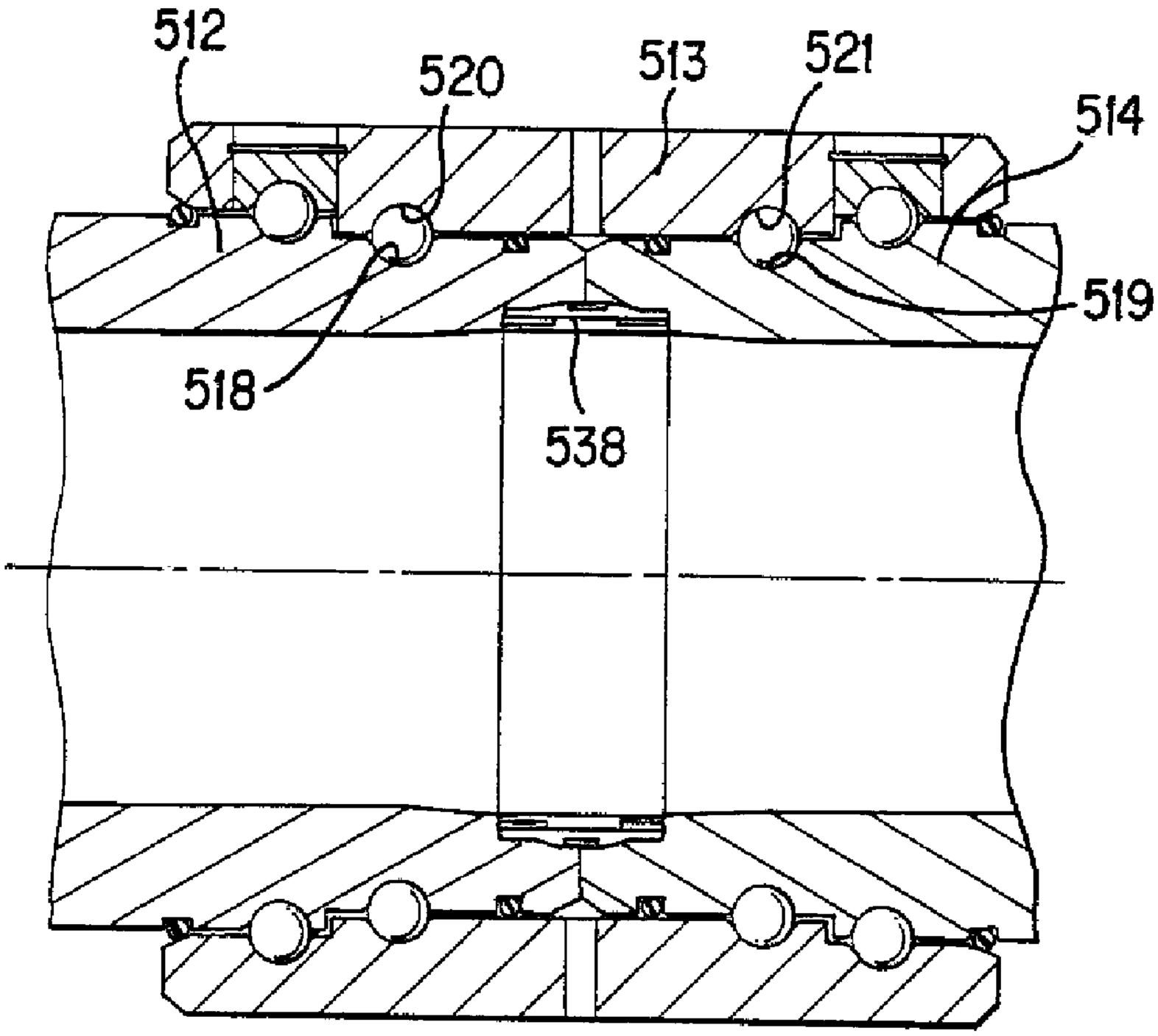
(54) Title: STEP BEARING RACE SWIVEL JOINT ASSEMBLY



(57) Abrégé/Abstract:
A bearing race assembly for use in a swivel joint (110) characterized by a male connector (112) having a central axis (126), a first end (unnumbered), and a plurality of outer annular grooves (120) each having a generally arcuate cross section and laying in a

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(57) Abrégé(suite)/Abstract(continued):
respective plane generally perpendicular to the central axis, the outer grooves (120) each having a generally constant radius measured from the central axis whereby each outer groove (120) has a greater radius than each adjacent outer groose closer to the first end (unnumbered); a female connector (114) coaxially aligned with the male connector (112) and adapted to receive and fit around the male connector, the female connector (114) having a first end (unnumbered) and a plurality of inner annular grooves (118) each having a generally arcuate cross section and laying in a respective plane generally perpendicular to the central axis, the inner grooves each corresponding to one of the outer grooves (120) and forming therewith an arcuate race; and a plurality of ball bearings (34, 35, 36) received in each race to facilitate relative rotation of the male (112) and female (114) connectors about the central axis (126).

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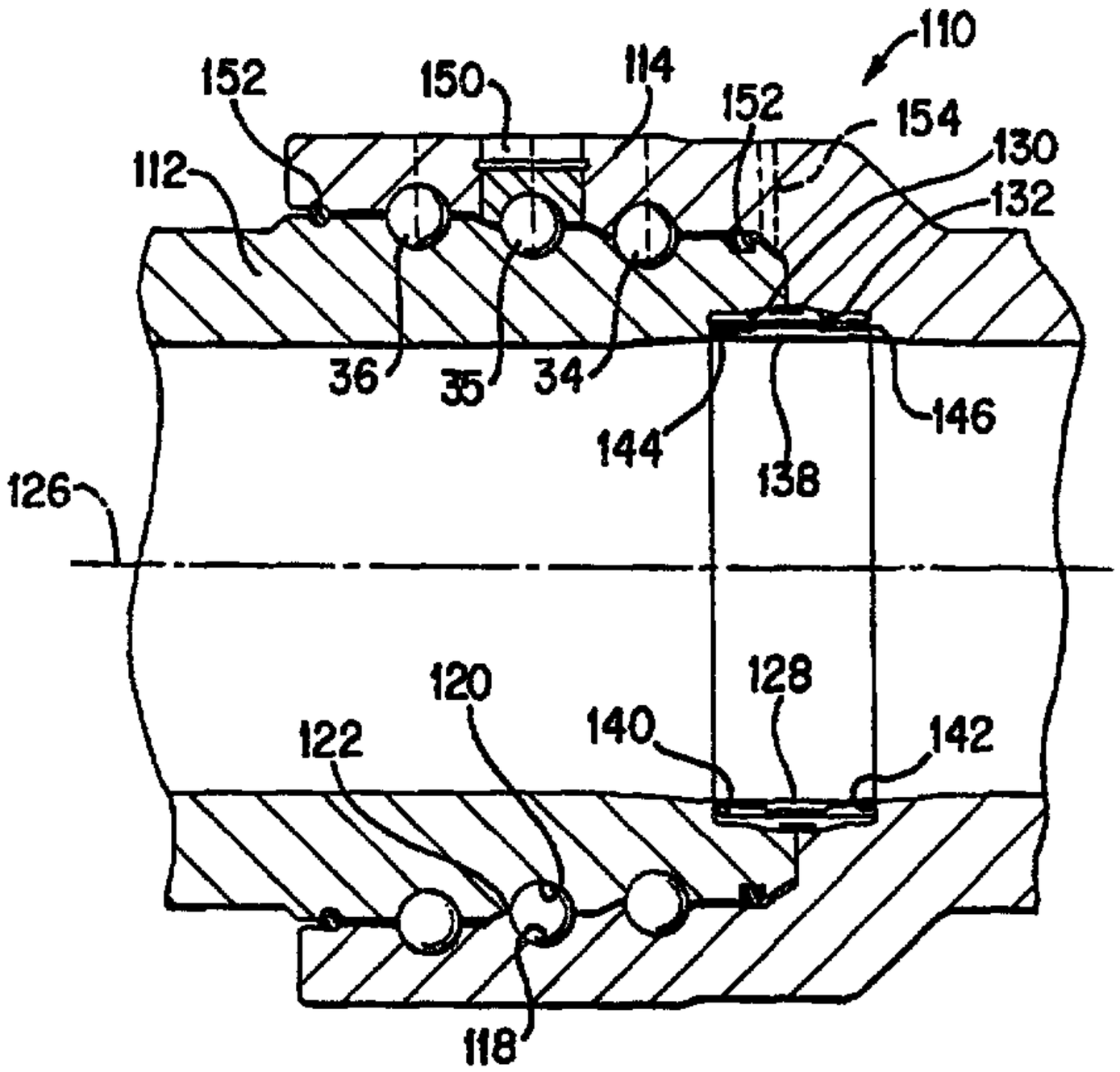
(54) Title: STEP BEARING RACE SWIVEL JOINT ASSEMBLY

(57) Abstract

A bearing race assembly for use in a swivel joint (110) characterized by a male connector (112) having a central axis (126), a first end (unnumbered), and a plurality of outer annular grooves (120) each having a generally arcuate cross section and laying in a respective plane generally perpendicular to the central axis, the outer grooves (120) each having a generally constant radius measured from the central axis whereby each outer groove (120) has a greater radius than each adjacent outer groose closer to the first end (unnumbered); a female connector (114) coaxially aligned with the male connector (112) and adapted to receive and fit around the male connector, the female connector (114) having a first end (unnumbered) and a plurality of inner annular grooves (118) each having a generally arcuate cross section and laying in a respective plane generally perpendicular to the central axis, the inner grooves each corresponding to one of the outer grooves (120) and forming therewith an arcuate race; and a plurality of ball bearings (34, 35, 36) received in each race to facilitate relative rotation of the male (112) and female (114) connectors about the central axis (126).



STEP BEARING RACE SWIVEL JOINT ASSEMBLY

The present invention relates to a bearing assembly and, more particularly, to a bearing race assembly which can be used to accommodate relative swiveling between connected fluid pipes or conduits in a fluid swivel joint.

Swivel joints are used to connect fluid pipes in oilfields and in other applications. Swivel joints are generally comprised of interfitting male and female members rotatably interconnected by a bearing assembly. Typically, inner and outer grooves are incorporated in the male and female members to form a bearing race and a plurality of ball bearings are housed within the race. Higher demand for compatibility with increased service pressure, wider operating temperature range, and greater variety of corrosive chemicals has resulted in swivel joint designs with multiple bearing races rather than one bearing race. Even with multiple bearing races high pressures can sometimes cause deformation or brinelling of ball races. Such brinelling relaxes seal compression and causes the seal to leak, preventing the swivel joint from swiveling smoothly under pressure and reducing race life significantly. Swivel joints are subject to other modes of failure as well under such conditions.

The present invention provides a multiple-race swivel joint bearing assembly for improved sealing under the above mentioned conditions having bearing races situated in a stepped relationship wherein each adjacent bearing race is positioned concentrically with respect to the next and has an incrementally greater radius than the next. The stepped configuration more equally distributes hydrostatic end loading to each bearing race section, enabling maximum total end loading while minimizing load concentration on a particular bearing race section. To further reduce end loading and improve sealing, a straight bore type seal is used to reduce surface area subject to axial pressure and to greatly reduce rotational friction associated with conventional pre-stress fitted elastomer compression seals. In addition, the present invention reduces brinelling of ball bearing races through an offset elongated radius configuration in race cross section enabling greater contact area between each ball bearing and

race, reducing load concentration. The present invention improves sealing under extreme conditions and specifically eliminates ball race brinelling at pressures much greater than is attained with conventional or known swivel joints with minimal increase in weight and cost.

According to an aspect of the present invention, there is provided in combination with a swivel joint forming a flow passage and having a central axis, the improvement comprising:

a hollow tubular male connector having a first end, an annular outer surface and a plurality of outer annular grooves formed on said outer surface concentric with said central axis, wherein each said outer groove comprises a generally arcuate cross-section and a radius measured from said central axis, and wherein the radius of each said outer groove is greater than the radius of each adjacent outer groove closer to said first end;

a hollow tubular female connector having an annular recess adapted to receive and fit around said outer surface and a plurality of inner annular grooves formed on said annular recess concentric with said central axis, said recess forming a shoulder within said female connector adjacent said first end, wherein each said inner groove comprises a generally arcuate cross-section and a radius measured from said central axis, and wherein the radius of each said inner groove is greater than the radius of each adjacent inner groove closer to said shoulder, said inner grooves each corresponding to one of said outer grooves and forming therewith an arcuate race; and

a plurality of ball bearings received in each race to secure said male and female connectors together and to facilitate relative rotation of said male and female connectors about said central axis;

wherein the cross-section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius; and

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the

same as the radius of the ball bearings positioned in the race formed by the corresponding outer or inner groove.

According to another aspect of the present invention, there is provided a bearing race assembly for use in a swivel joint comprising:

a pair of opposed tube-shaped connecting members each having a central axis coaxial with the other and each having a plurality of outer annular grooves, said members being positioned such that a first end of each is adjacent to the other, each outer groove having a generally arcuate cross-section and a radius measured from said central axis, wherein the radius of each said outer groove on a respective connecting member is greater than the radius of each adjacent outer groove closer to said first end on said respective connecting member;

a collar coaxially aligned with said connecting members and adapted to receive and fit around said connecting members, said collar having a plurality of inner annular grooves each having a generally arcuate cross-section and a radius measured from said central axis, wherein the radius of each said inner groove is greater than the radius of each adjacent inner groove closer to said first end of each said connecting member, said inner grooves each corresponding to one of said outer grooves and forming therewith an arcuate race; and

a plurality of ball bearings received in each race to facilitate relative rotation of said connecting members and said collar about said central axis;

wherein the cross-section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius; and

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the ball bearings positioned in the race formed by the corresponding outer or inner groove.

According to yet another aspect of the present invention, there is

provided a swivel joint comprising:

a central axis;

a hollow tubular male connector having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface concentric with the central axis;

a hollow tubular female connector having an inner annular recess forming an inner annular shoulder and at least first and second inner annular grooves formed on the inner recess concentric with the central axis;

wherein the inner recess is adapted to receive and overlap the outer surface such that the first end is adjacent the inner annular shoulder and each inner groove is in alignment with a corresponding outer groove to thereby define at least first and second arcuate races;

wherein the diameter of each arcuate race is greater than the diameter of each adjacent arcuate race closer to the first end of the male connector; and

a plurality of ball bearings received in each race to secure said male and female connectors together and to facilitate relative rotation of the male and female connectors about the central axis;

wherein the male and female connectors form a flow passage of the swivel joint;

wherein the cross-section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius; and

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the ball bearings positioned in the race formed by the corresponding outer or inner groove.

According to still yet another aspect of the present invention, there is provided a swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface coaxial with the central axis;

a tubular female member having an inner annular recess, an annular shoulder formed at an inner end of the recess and at least first and second inner annular grooves formed on the recess coaxial with the central axis;

wherein the outer surface of the male member is adapted to be received in the recess of the female member such that the first end is disposed proximate the shoulder and each outer groove is aligned with a corresponding inner groove to thereby define at least first and second annular races;

a plurality of balls disposed in each race to secure said male and female members together and to facilitate relative rotation of the male and female members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first end of the male member; and

wherein the number of balls in each race is just one more than the number of balls in each adjacent race closer to the first end.

According to still yet another aspect of the present invention, there is provided a swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface coaxial with the central axis;

a tubular female member having an inner annular recess, an annular shoulder formed at an inner end of the recess and at least first and second inner annular grooves formed on the recess coaxial with the central axis;

wherein the outer surface of the male member is adapted to be received in the recess of the female member such that the first end is disposed proximate the shoulder and each outer groove is aligned with a corresponding inner groove to thereby define at least first and second annular

races;

a plurality of balls disposed in each race to secure said male and female members together and to facilitate relative rotation of the male and female members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first end of the male member by an amount sufficient to enable each race to accommodate just one more ball than is disposed in the adjacent race.

According to still yet another aspect of the present invention, there is provided a swivel joint comprising:

a central axis;

a pair of tubular members each having a first end and a plurality of outer annular grooves formed coaxial with the central axis;

a collar member comprising a pair of inner cylindrical recesses each having a plurality of inner annular grooves formed coaxial with the central axis;

wherein each tubular member is adapted to be received in a corresponding recess of the collar member such that the first ends are proximate one another and each outer groove is aligned with a corresponding inner groove to thereby define a plurality of annular races;

a plurality of balls disposed in each race to secure said tubular members in said collar and to facilitate relative rotation of the tubular members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first ends of the tubular members; and

wherein the number of balls in each race is just one more than the number of balls in each adjacent race closer to the first ends of the tubular members.

FIG. 1 is a partial cross section of a PRIOR ART triple-race swivel joint bearing assembly.

FIG. 2 is a partial cross-section of a first embodiment of the present

invention having a stepped, triple-race bearing assembly and a straight bore seal.

FIG. 3 is a split, partial cross-section of the PRIOR ART assembly of FIG. 1 juxtaposed with a second embodiment of the present invention having a straight bore seal.

FIG. 4a is an enlarged, cross-section of a ball bearing in a PRIOR ART bearing race assembly.

FIG. 4b is an enlarged, cross-section of a ball bearing in a bearing race assembly of the present invention.

FIG. 5 is a partial cross-section of a second embodiment of the present invention having a double-ended stepped, double-race bearing assembly.

FIGURE 1 shows a known, prior art swivel joint 10 having a male connector 12 rotatably received inside of a female connector 14. A sealed fluid flow passage 16 is formed therethrough, in communication with fluid conduits or pipes (not shown) extending from each connector. Each connector 12, 14 has respectively formed thereon a plurality of annular grooves 18,20. When the connectors 12 and 14 are inserted together, the grooves 18 and 20 align with each other forming annular bearing races 22. A plurality of ball bearings 24 are housed in each race 22 to provide bearing support and to enable swiveling of the connectors 12,14 relative to each other. The races 22 and ball bearings 24 are coaxially positioned around a center axis 26 of the flow passage 16. The races 22 all have substantially the same radius. An annular elastomer compression seal 28 is positioned between axial faces of the male connector 12 and the female connector 14 to prevent fluid flow therebetween. The compression seal 28 is pre-stressed.

When fluid under pressure is introduced into the flow passage 16 there results a hydrostatic end load causing the male and female connectors 12,14 to be biased axially away from each other. The ball bearings 24 are then subject to axial resultant forces which are transmitted through contact surfaces between the ball bearings 24 and the races 22. The resultant force to which each bearing race 22 is subject is distributed in relation to the relative position of each race. For instance, the male member groove 20 closest to the seal 28 is subject to a first load, the second groove is subject to a second load which is cumulative of the first load, and so on. Thus, with each successive bearing race 22 moving away from the seal 28, the load on the male member groove 20 increases. The female connector 14 is subject to analogous loading, with the race closes to the seal bearing the greatest load.

In a typical triple-race bearing assembly 10 as shown in FIG. 1, the load distribution for each race 22 beginning with that closest to the seal 28 is approximately 47%, 31% and 22%. It is desirable then to distribute the load more equally so as to reduce the load on the first race without reducing the overall load bearing capacity of the bearing assembly. The present invention accomplishes this through the stepped configuration.

The first embodiment of the present invention is shown in FIG. 2. A swivel joint 110 has a male connector 112 rotatably received inside of a female connector 114. A sealed fluid flow passage 116 is formed therethrough, in communication with fluid conduits or pipes (not shown) extending from each connector. Each connector 112,114 has respectively formed thereon a plurality of annular grooves 118, 120. When the connectors 112 and 114 are inserted together, the grooves 118 and 120 align with each other forming annular bearing races 122. A plurality of ball bearings 124 are housed in each race 122 to provide bearing support and to enable swiveling of the connectors 112, 114 relative to each other. The races 122 and ball bearings 124 are coaxially positioned around a central axis 126 of the flow passage 116.

The present invention provides for a stepped arrangement wherein the radii of the consecutive bearing races 122 increase progressively in consecutive races 122 in a direction moving away from the male connector end which contacts the female connector 114. This stepped design more

uniformly distributes loading per ball bearing 124 by more uniformly distributing tensile stress across each hub section at each respective race 122. The number of steps can vary from two or more and there can be one or more races per step. The lengths of race radii are determined as a function of the cross-sectional areas of the connector at each race location, end load, ball and race radius and other variables. The dimensions are calculated to divide the end load as nearly evenly as possible among each bearing race. It is desirable, though not required, that the ball bearings 124 are of uniform size throughout the assembly 110 and, thus, each race 122 will contain a different number of ball bearings 124.

The present invention utilizes a straight bore seal 128 of the type disclosed in U.S. Patent 4,930,791 made of non-metallic compositions such as "TEFLON"* having different properties than conventional elastomer compression seals such as the seal 28 of FIG. 1. Conventional elastomer seal materials have inherent limitations with respect to extrusion, fluid compatibility, temperature range, and rupture. The axial ends of the male and female connectors 112, 114 have recessed sections 130 and 132 respectively, which form one recessed groove 134 when the connectors 112,114 are fitted together as shown in FIG. 2. The straight bore seal 128 is received therein such that the inner circumferential surface 138 of the seal 128 is flush with the inner surface of the flow passage 116. The recessed sections 130 and 132 have axial end portions 140 and 142 facing toward each other which receive the axial ends of the straight bore seal 128. The end portions 140 and 142 are engaged by axial ends 144 and 146 of the straight bore seal 128. The outer circumferential surface 148 forms a seal with the inner circumferential surface of the groove 134. Because the geometry and material of the straight bore seal 128 allows a substantially smaller cross-sectional area than a comparable capacity conventional elastomer seal 28, hydrostatic end loading and, thus, contact area between each ball bearing 124 and race 122 are reduced significantly resulting in less brinelling of the race 122. The assembly 110 embodied in FIG. 2 further includes a ball bearing port 150 and secondary elastomer O-ring or other suitable seals 152. A leak detection port 154 is also provided.

*trade-mark

In order to further illustrate the novelty of the present invention, FIG. 3 juxtaposes the PRIOR ART assembly 10 of FIG. 1 with a second embodiment 210 of the present invention assembly along centerline 200. Because the straight bore seal 228 has a lower seal profile than the conventional seal 28, the sealing radius 256 of the present invention is smaller than the sealing radius 56 of the conventional seal 28. This results in a smaller area of the connectors subject to hydrostatic pressure and, thus, a reduced hydrostatic end load. While the conventional seal 28 is subject to pre-stress axial compression, the straight bore seal 228 is free of axial loading. Thus, friction forces between the connectors and the seal 228 are generally non-existent, while the conventional seal 28 contacts the female connector 14 on inner circumferential and axial surfaces and contacts the male connector 12 on an axial surface.

FIG. 4a illustrates a conventional beating arrangement subject to hydrostatic loading in which a ball beating 24 is received in a race 22 formed by male and female connector grooves 20,18. Typical bearing races such as the one illustrated in FIG. 4a are machined as grooves 18,20 having a constant radius 321. The groove radius 321 must be greater than the radius 322 of the ball bearings to the extent that assembly is possible. This results in concentrated contact areas 318,320 when connectors shift under axial load. Such load concentrations subject the races to brinelling.

In order to reduce concentration of contact areas as described above, the present invention provides offset radii as illustrated in FIG. 4b. As shown in FIG. 4b, the male connector groove 420 is formed with the substantially the same radius as the ball bearing 424 except that at the apex 422 of the groove 420 there is a straight line portion 425 formed by offsetting the center point 426 of the groove 420 to an offset center point 428. The female connector groove 418 can be formed with substantially the same curvature as the ball bearing 424. This design provides enough clearance to facilitate assembly while maximizing the contact areas on the ball bearing 424 to the respective grooves 418,420, thereby minimizing brinelling. Either connector groove for an individual race can have the offset radius feature, or both grooves can have a reduced offset distance.

FIG. 5 illustrates a third embodiment of the invention utilizing the stepped configuration illustrated in the embodiment of FIG. 2, having

connectors 512,514 that are placed end to end and joined by a collar 513 which fits around the connectors 512,514. Each connector 512,514 has a plurality of stepped grooves 518,519 corresponding to a plurality of stepped grooves 520,521 in the collar 513. A single straight bore seal 538 is utilized. The embodiment herein operates essentially the same way and utilizes essentially the same features as the first embodiment described in FIG. 2.

Although the best mode contemplated for carrying out the invention has been herein shown and described, it is understood that modification and variation may be made without departing from what is regarded as the subject matter of the invention.

What is claimed is:

1. A swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface coaxial with the central axis;

a tubular female member having an inner annular recess, an annular shoulder formed at an inner end of the recess and at least first and second inner annular grooves formed on the recess coaxial with the central axis;

wherein the outer surface of the male member is adapted to be received in the recess of the female member such that the first end is disposed proximate the shoulder and each outer groove is aligned with a corresponding inner groove to thereby define at least first and second annular races;

a plurality of balls disposed in each race to secure said male and female members together and to facilitate relative rotation of the male and female members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first end of the male member; and

wherein the number of balls in each race is just one more than the number of balls in each adjacent race closer to the first end.

2. The swivel joint of claim 1, further comprising means for sealing between the male and female members.

3. The swivel joint of claim 2, wherein the sealing means comprises an annular seal disposed between the first end of the male member and the shoulder of the female member.

4. The swivel joint of claim 3, wherein the annular seal is comprised of an elastomer.

5. The swivel joint of claim 2, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the male and female members.

6 The swivel joint of claim 1:

wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the balls.

7. A swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface coaxial with the central axis;

a tubular female member having an inner annular recess, an annular shoulder formed at an inner end of the recess and at least first and second inner annular grooves formed on the recess coaxial with the central axis;

wherein the outer surface of the male member is adapted to be received in the recess of the female member such that the first end is disposed proximate the shoulder and each outer groove is aligned with a corresponding inner groove to thereby define at least first and second annular races;

a plurality of balls disposed in each race to secure said male and female members together and to facilitate relative rotation of the male and female members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first end of the male member by an amount sufficient to enable each race to accommodate just one more ball than is disposed in the adjacent race.

8. The swivel joint of claim 7, further comprising means for sealing between the male and female members.

9. The swivel joint of claim 8, wherein the sealing means comprises an annular seal disposed between the first end of the male member and the shoulder of the female member.

10. The swivel joint of claim 9, wherein the annular seal is comprised of an elastomer.

11. The swivel joint of claim 8, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the male and female members.

12. The swivel joint of claim 7:

wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the balls.

13. A swivel joint comprising:

a central axis;

a pair of tubular members each having a first end and a plurality of outer annular grooves formed coaxial with the central axis;

a collar member comprising a pair of inner cylindrical recesses each having a plurality of inner annular grooves formed coaxial with the central axis;

wherein each tubular member is adapted to be received in a corresponding recess of the collar member such that the first ends are proximate one another and each outer groove is aligned with a corresponding inner groove to thereby define a plurality of annular races;

a plurality of balls disposed in each race to secure said tubular members in said collar and to facilitate relative rotation of the tubular members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first ends of the tubular members; and

wherein the number of balls in each race is just one more than the number of balls in each adjacent race closer to the first ends of the tubular members.

14. The swivel joint of claim 13, further comprising means for sealing between each tubular member and the collar member.

15. The swivel joint of claim 14, wherein the sealing means comprises an annular seal disposed between the first ends of the tubular members.

16. The swivel joint of claim 15, wherein the annular seal is comprised of an elastomer.

17. The swivel joint of claim 14, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the first ends of the tubular members.

18. The swivel joint of claim 13:

wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the balls.

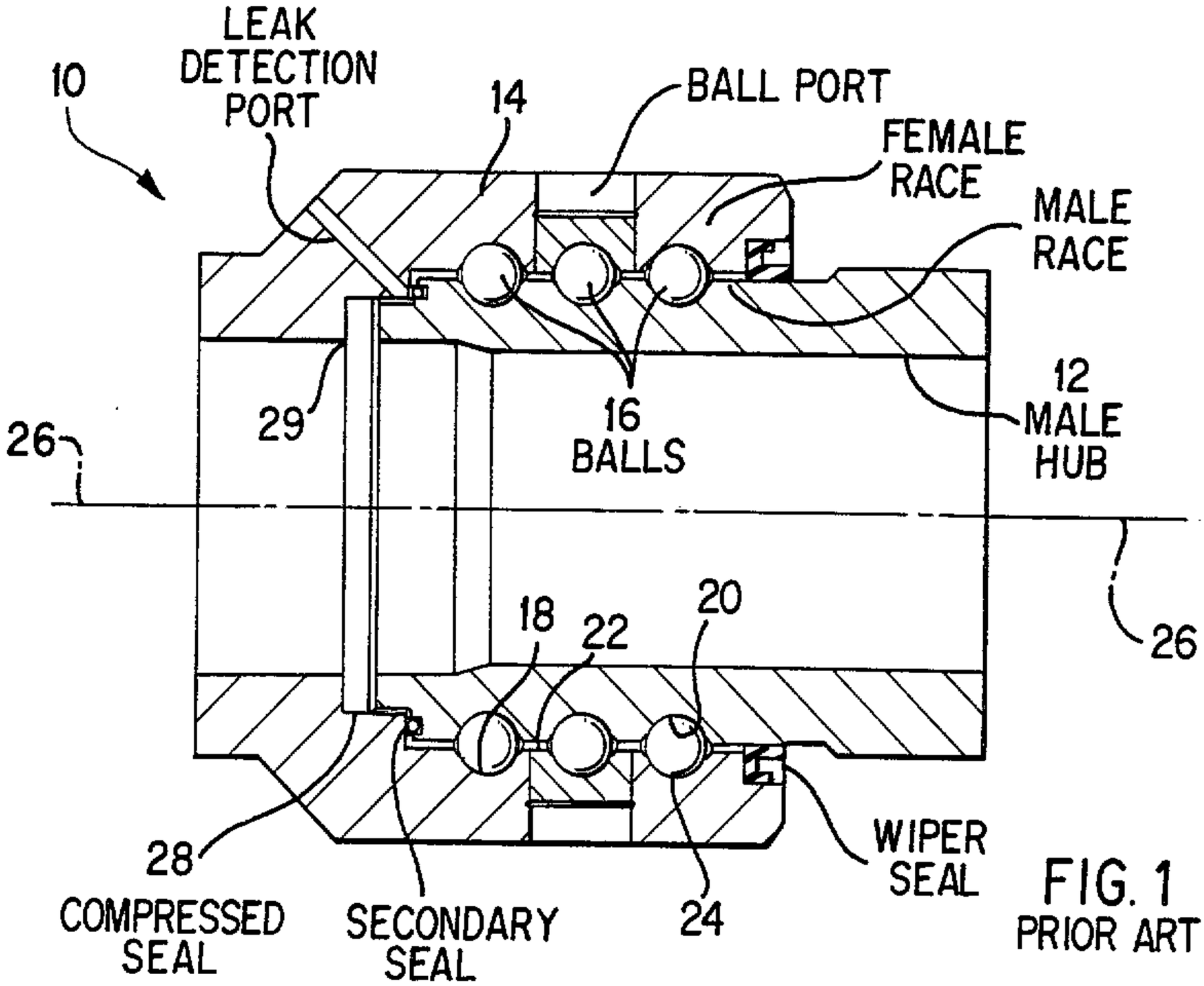


FIG. 1
PRIOR ART

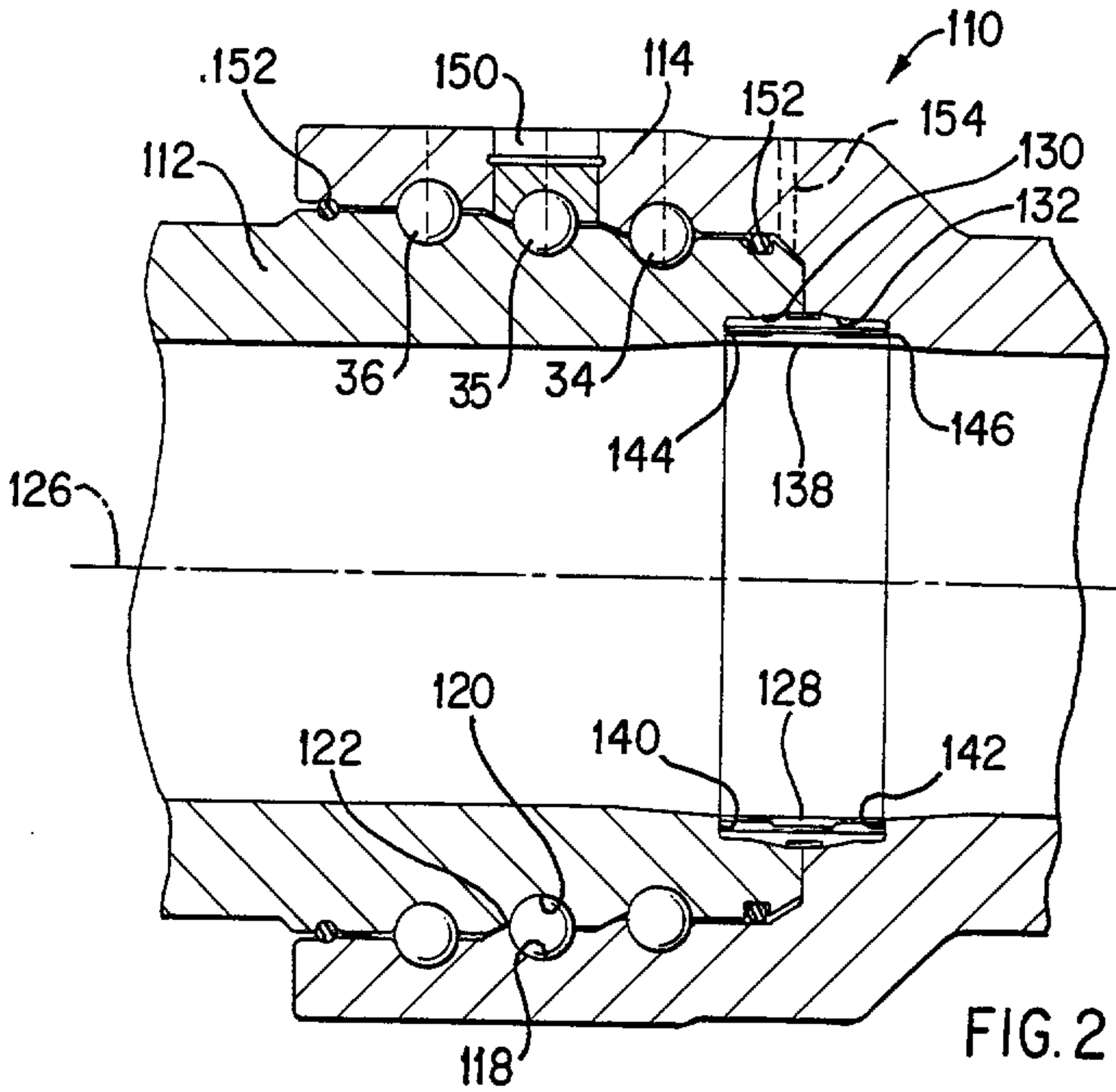


FIG. 2

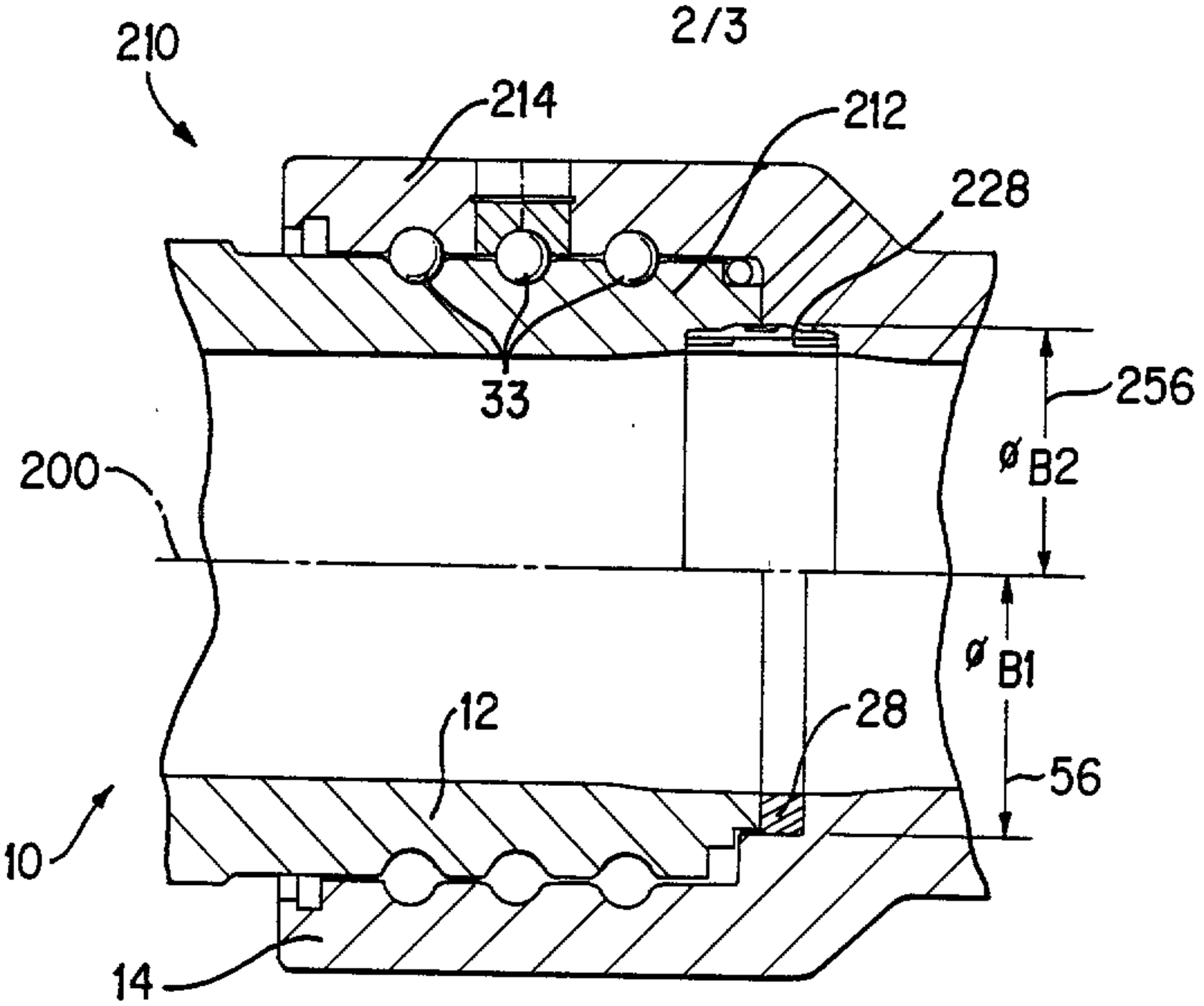

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FIG. 3

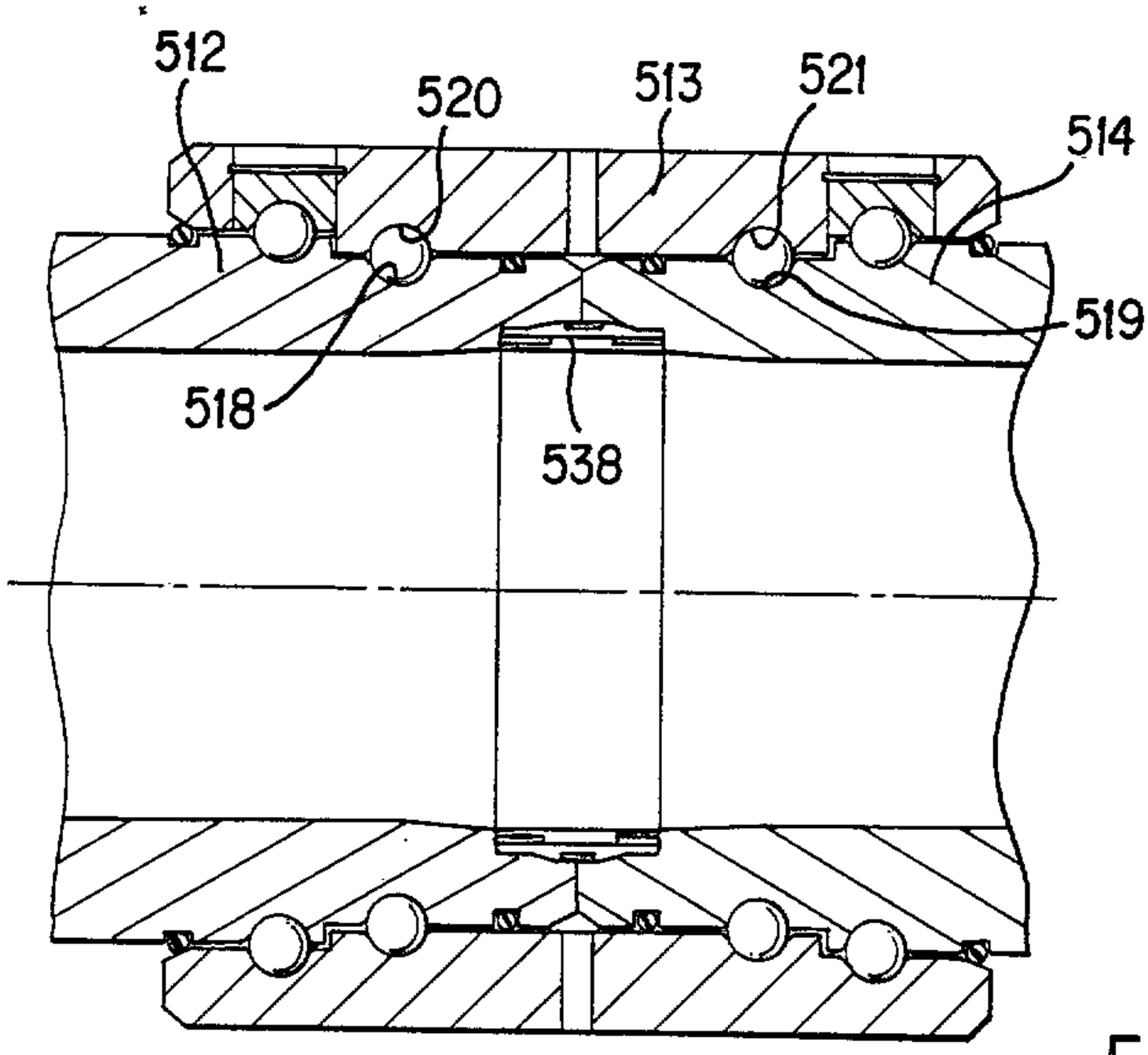
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FIG. 5

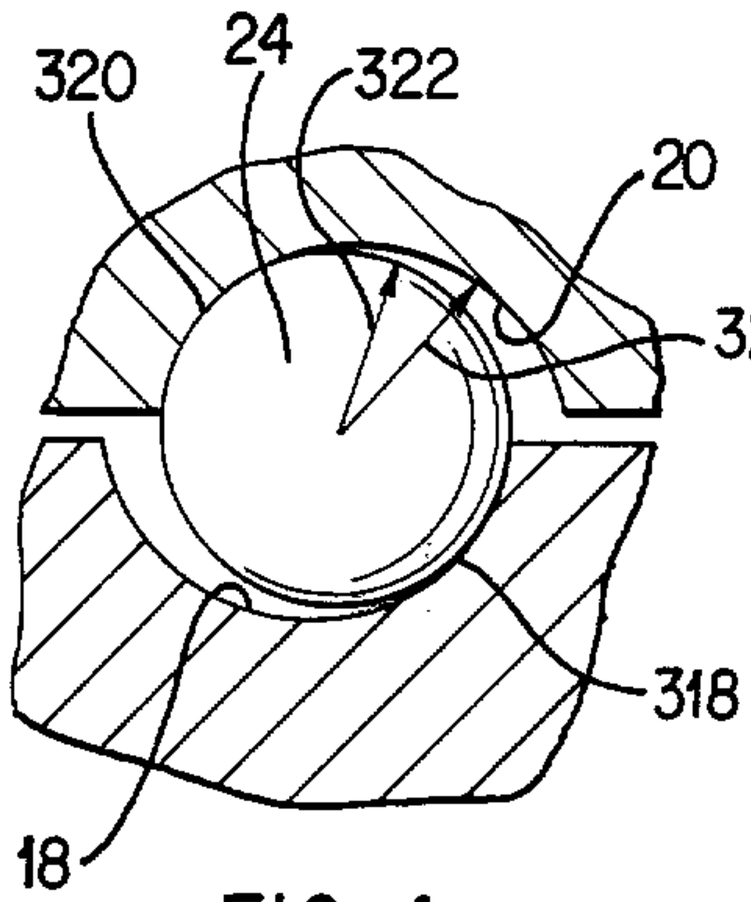


FIG. 4a
PRIOR ART

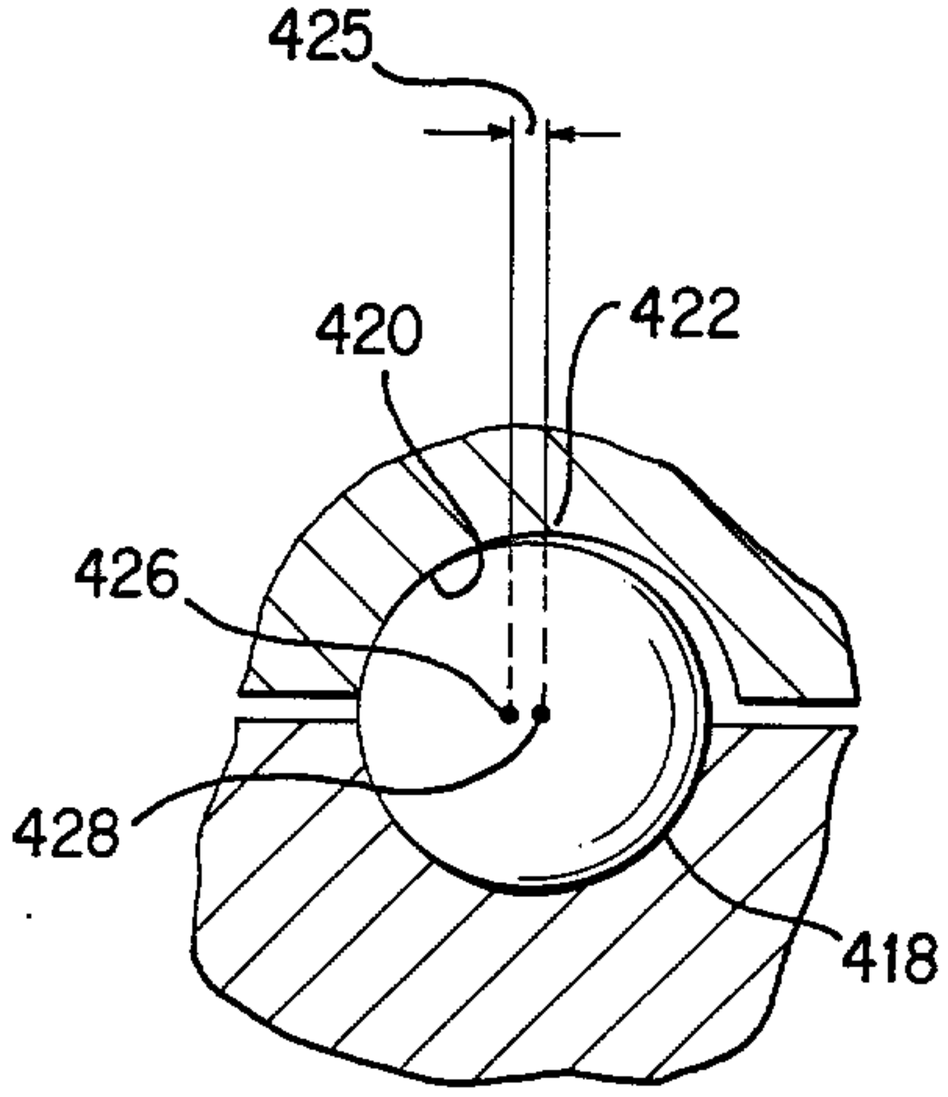
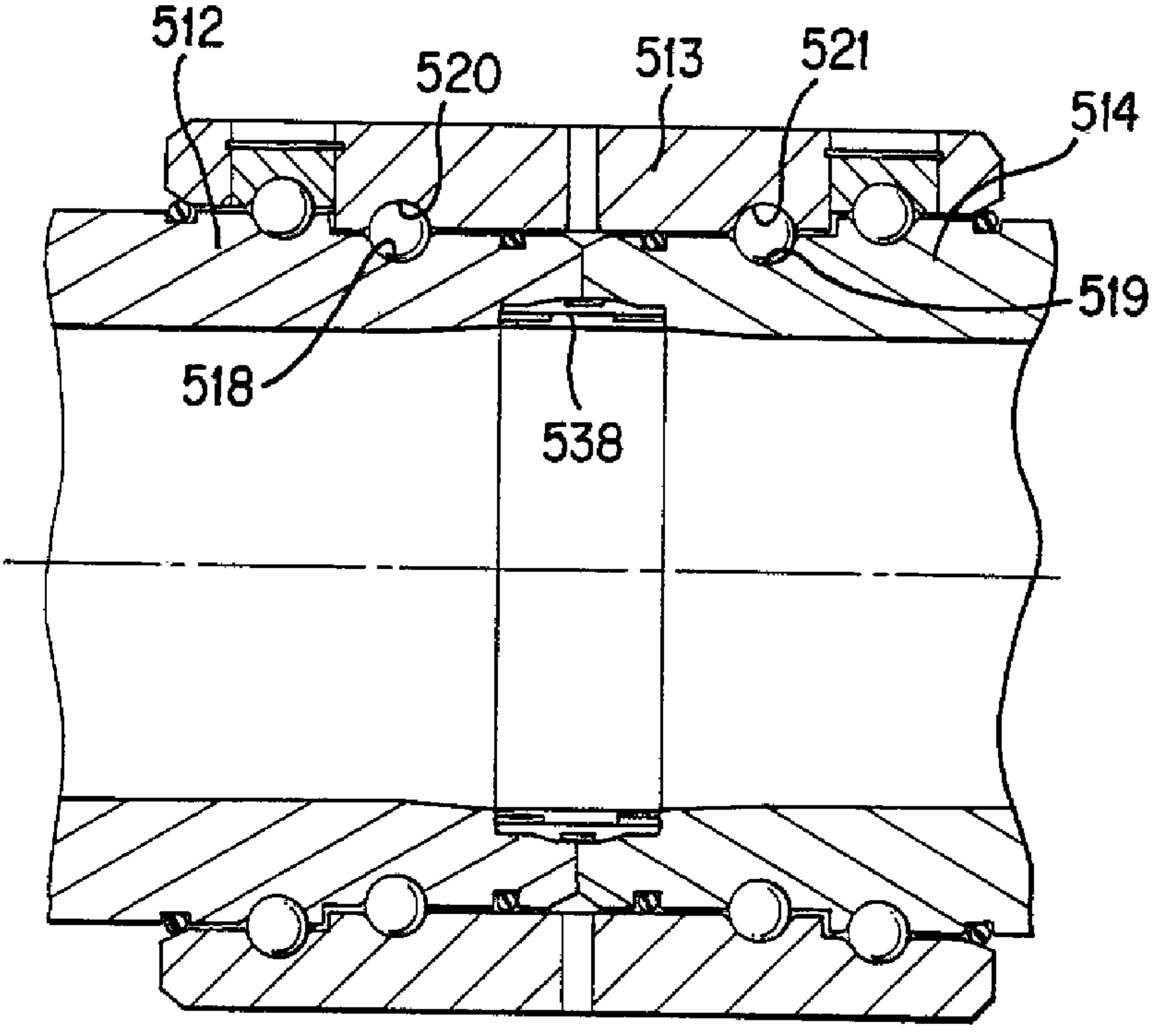


FIG. 4b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