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(54) **Lubricant system for a rotary cone rock bit.**

(57) A radially disposed thrust bearing surface (43) formed in a rotary cone (28) of a rock bit is provided with at least a pair of grooves (44) and a ramp surface (50) on the trailing edge of the grooves. The groove provides a lubricant reservoir and the ramp serves to generate hydrodynamic pressures during rotation of the rotary cone on the thrust surface of a journal bearing (32) thereby distributing a film of lubricant on the opposing thrust bearing surfaces (40,42).

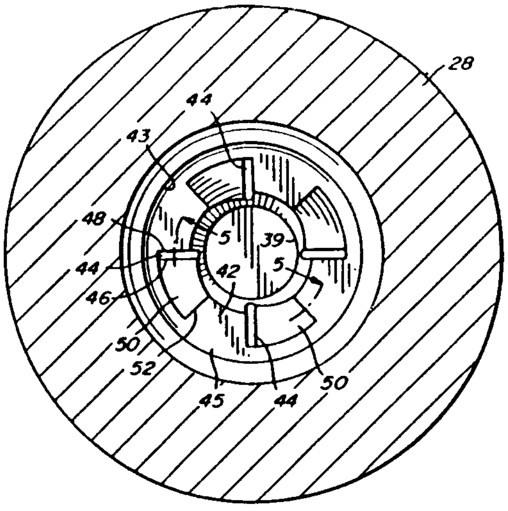

FIG. 4

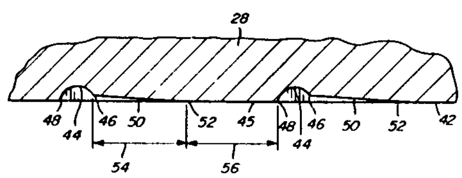

FIG. 5

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This invention relates to sealed bearing rotary cone rock bits and a means to lubricate opposing thrust bearing surfaces.

More particularly this invention relates to an improved method to distribute lubricant in the thrust surfaces formed in a rotary cone and at the end of a main bearing of a rotary cone rock bit.

It is known to provide chordally disposed lubrication slots in an axial thrust surface formed on the end of a main radial journal bearing for a rotary cone rock bit. The chordally disposed slots are formed in the axial thrust surface of the leg. These generally chordally disposed slots leave sharp edges. These edges tend to remove lubricant from the opposing thrust surfaces rather than distribute lubricant on these surfaces. The corners of the slots are deburred by secondary manufacturing operations but still leave sharp edges.

United States Patent No. 4,410,284 teaches a rolling cutter drill bit with at least one downwardly extending leg which supports a cantilevered bearing shaft. A cutter cone is rotatably mounted on the bearing shaft. A radially disposed thrust washer is positioned between the journal and the cone, the washer further includes a lubricant transferring means in each radially disposed side of the washer to assure adequate lubrication of the roller cone mounted on the journal bearing. The thrust washer forms at least a pair of passages to transfer lubricant through the washer from one bearing surface to an opposite bearing surface. Grooves on opposite sides of the thrust washer distribute lubricant to the bearing surfaces. The grooves however have relatively sharp edges and tend to wipe an opposing bearing surface clean rather than distribute lubricant thereon.

The present invention provides a means for applying a film of lubricant on bearing surfaces by providing a ramp emanating from grooves in the bearing surface or a shallow groove with rounded edges to create hydrodynamic pressures to facilitate distribution of the film of lubricant on the bearing surfaces.

A thrust bearing lubrication means is disclosed for a rotary cone rock bit comprising a rock bit body having a first pin end and a second cutting end. The body has at least one leg having a main journal bearing cantilevered from a cutting end of the leg. The journal has a cylindrical radial bearing surface and an axial thrust bearing surface. A rotary cone is mounted for rotation on the main bearing. The cone has a radial bearing surface and an axial thrust bearing surface. At least one substantially radially disposed groove is formed on one of the axial thrust bearing surfaces formed by the cantilevered journal bearing and the rotary cone. The groove communicates with a lubrication orifice formed in the leg of the bit. The orifice serves as a conduit for a source of lubricant contained in a lubricant reservoir formed in the leg. A ramp is formed in one of the axial bearing surfaces. The ramp extends from a trailing edge of the groove and gradually converges with a planar bearing surface of the axial bearing. The ramp serves to develop hydrodynamic pressure forces between thrust bearing surfaces when the cone is rotated on the main bearing, thereby distributing a film of lubricant between axial thrust bearing surfaces.

The means for generating hydrodynamic forces in the lubricant is preferably stamped or coined in at least one of the bearing surfaces.

Alternatively, a shallow groove is stamped into at least one of the axial bearing surfaces, the edges of the groove have inherent large external radii to develop hydrodynamic pressure forces, thereby distributing a film of lubricant between axial thrust bearing surfaces.

An advantage then of the present invention over the prior art is the means in which a film of lubricant is distributed along axial thrust bearing surfaces.

More particularly an advantage of the present invention over the prior art is the means in which a ramp is provided on the trailing edge of a radially disposed groove to generate hydrodynamic pressures to distribute a film of lubricant along thrust bearing surfaces.

The above noted objects and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

FIGURE 1 is a perspective view of a typical sealed bearing rotary cone rock bit;

FIGURE 2 is a partially broken away section of one leg of the rock bit of FIGURE 1 illustrating the cone rotatably secured to a cantilevered journal bearing extending from the leg;

FIGURE 3 is a cross-section of the rotary cone;

FIGURE 4 is a view taken through 4-4 of FIGURE 3 illustrating a plan view of the thrust bearing surface formed in the cone;

FIGURE 5 is a view taken through 5-5 of FIGURE 4 illustrating the groove and its associated ramp formed in the axial thrust bearing surface of the cone;

FIGURE 6 is an exploded perspective view of an alternative embodiment of the present invention;

FIGURE 7 is a view taken through 7-7 of FIGURE 6;

FIGURE 8 is a view through 8-8 of FIGURE 7;

FIGURE 9 is a plan view of an alternative groove; and

FIGURE 10 is a view taken through 10-10 of FIGURE 9.

With reference now to FIGURE 1 the sealed bearing rotary cone rock bit generally designated as 10 comprises a rock bit body 12 with a pin end 11 and a cutting end generally designated as 26. Each cone 28 associated with the cutting end 26 is rotatably attached to a journal bearing extending from a leg 14 that terminates in a shirttail portion 16. Each of the cones 28 has, for example, a multiplicity of substantially equally spaced tungsten carbide cutter inserts 29 interference fitted within insert holes formed in the cone body 28. An O-ring 30 seals the cone on the leg.

A lubricant reservoir generally designated as 18 is provided in each of the legs 14 to supply lubricant to bearing surfaces formed between the rotary cones and their respective journals. Three or more nozzles 13 communicate with a chamber formed inside the bit body 12 (not shown). The chamber receives drilling fluid or "mud" through the pin end 11; and the fluid then is directed out through the nozzles 13 during bit operation.

Turning now to FIGURE 2, the sectional rock bit leg 14 illustrates the lubricant reservoir system generally designated as 18. The reservoir system comprises a reservoir cover cap 20 that closes out a lubricant reservoir cavity 19. The reservoir is isolated from the cover cap by a resilient diaphragm 22; the diaphragm being responsive to exterior pressures through a hole 25 formed in the cover cap 20.

The lubricant is passed down a lubricant channel 23 formed in leg 14 toward a ball hole 36 formed through the shirttail portion 16. Lubricant then enters into a lubrication channel 24 formed in a ball hole plug 37. The lubricant exits through a ball race 33 formed in a radial journal bearing 32 and a ball race 34 formed in the cone body 28. The ball hole plug 37 is slotted along surface 24 to allow lubricant passing through the conduit 23 to move along the ball plug hole 36 and through the ball races 33 and 34 formed between the cone 28 and the journal 32. The lubricant moves through the ball races 33 and 34 towards an axial thrust bearing surface or "snoochy" 40 formed on the end of the radial bearing. The opposing thrust bearing surface 42 formed in the rotary cone 28 is directed against the axial thrust bearing surface 40 through an outward thrust generated when the rock bit 10 is rotated in a borehole. The outward thrust generates a great deal of force against these axial thrust bearing surfaces 40 and 42. The radial bearing surface 39 formed in the cone 28 engages a pin 31 projecting from the axial thrust bearing surface 40 of the radial bearing. A secondary axial thrust bearing resides at the end of the pin (40a).

With reference now to FIGURE 3 the cone 28 is illustrated without the inserts 29 for clarity. The axial thrust bearing surface 42 is shown with a groove 44 formed in the surface 42.

FIGURES 4 and 5 clearly depicts the groove 44 formed in the thrust bearing surface 42 of the cone 28. The thrust bearing surface 42 defines a leading edge 48 and a trailing edge 46 of the shallow groove 44. The trailing edge 46 is below the planar surface 45 of the thrust bearing surface 42. The trailing edge 46 transitions into a ramped surface 50. The surface 50 intersects (becomes coincident) with planar surface 45 at point 52. It is clear that this geometry may also be applied to the secondary thrust surface 40a. The distance between the intersection edge 52 and the leading edge 48 of the next groove 44 is about half way between the grooves 44 in the example shown in FIGURES 3 and 4 where there are four equidistantly spaced grooves 90° apart around the circumference of the axial thrust bearing surface 42. Preferably there are at least a pair of such grooves and ramps for adequately distributing lubricant to the axial thrust bearing surfaces.

For example, a standard 7-7/8" (20 cm.) diameter rotary cone would have a main journal bearing of approximately 5 cm. with a pin 31 having a diameter of approximately 2.5 cm. The depth of the groove 44 is approximately 50 micrometers, the leading edge of 46 being below the planar surface 45 approximately 13 micrometers. The ramp angles would be approximately 0.2° to 3°, the ramp intersecting the planar surface 45 at point 52. The intersecting point 52 is approximately midway between the leading edge the of the groove and trailing edge of the adjacent groove 44 in axial thrust surface 42.

If desired, one may use more or fewer grooves and ramps formed in the thrust bearing surfaces 42 of the cones 28. Also, one may form the grooves in a spiral or chordal orientation instead of radially as shown.

The depth of the grooves 44 are relatively shallow with non-sharp leading edges 48. The grooves 44 are preferably stamped or coined into the thrust bearing surfaces 42 of the cones 28 by a die. The die plastically deforms the metal material of the cones 28. Typically the cones are fabricated from steel. The die is so configured to form all of the grooves 44, the ramps 50 and the adjacent the thrust bearing surface 42 of a cone 28 at the same time. Since the die acts on a body that is essentially closed, the stamping may be referred to as coining.

It would also be acceptable to form the grooves 44 and the ramps 50 through other metal forming processes such as a milling machine without departing from the scope of this invention.

FIGURE 6 is an exploded view of an alternative embodiment illustrating a rock bit leg 114 having a journal bearing 132 projecting from the leg. The journal has a radial bearing surface 138 and a ball race 133 and a radially disposed axial thrust bearing surface 140 formed on the end of the journal. A pin 131 extends from the thrust bearing surface 140. An O-ring 130 provides a seal for the bearing surfaces defined between the journal bearing 132 and the cone 128. A thrust washer 129 floats between thrust bearing surface 140 and on the journal 132 and the thrust bearing surface 142 defined within cone 128.

The primary thrust bearing surface 140 has a series of equidistantly spaced grooves 141, each groove 141 having a leading edge 137, a trailing edge 139, a ramp 146 and a tangent or intersection point 147. The intersecting edge 147 is about half way between the grooves 141. Similar grooves and ramps are formed in the cone 128. The groove 144 in the cone is formed in the axial thrust bearing surface 142.

With reference now to FIGURE 7, the grooves 144 formed in axial thrust bearing surface 142 each have a leading edge 149 and a trailing edge 150, the trailing edge 150 being below the planar surface 154 formed in axial thrust surface 142. A ramp 151 is initiated adjacent the trailing edge 150, the ramp exiting at a tangent or intersection point 153 at the planar surface 154. Again the intersecting edge 153 is about half way between the grooves 144 in the example shown. The grooves are approximately 90° apart around the circumference of the axial surface 142. If desired, the intersecting edge may be at any location between adjacent grooves.

FIGURE 8 illustrates the groove 144 preferably stamped into the bearing material of the cone 128 by a stamp or die process. The grooves are typically about 50 micrometers deep and the trailing edge 149 is angled such that it does not provide a sharp edge to wipe lubricant from the axial thrust surfaces, as previously described. The leading edge 150 is about 13 micrometers below the planar surface 154, the ramp angle being between 0.2° and 3°, exiting the groove at intersecting edge 153. Again the groove and ramp takes up about half the distance between grooves. The distance between the leading edge 150 and the intersection 153 is about the same as from intersection point 153 to the trailing edge of the adjacent edge of the groove 149.

The floating washer 129 has flat planar surfaces 159 and 160 on either side of the washer. The grooves and ramps in the thrust bearing surface 140 of journal bearing 142 and the grooves and ramps in the thrust bearing surface 142 of the cone 128 both ride on the flat surfaces of the floating thrust washer 129. Lubricant will be evenly distributed between each of the coined surfaces and the thrust washer, thus providing a superior means for providing a film of lubricant to these axial thrust bearing surfaces 140 and 142.

It is apparent that the grooves and ramps may be placed in the washer in place of the leg and cone.

Turning now to yet another alternative embodiment as illustrated in FIGURES 9 and 10, the cone 228 has shallow grooves 244 formed in a flat thrust bearing surface 242. The grooves are, for example, stamped by a die (not shown) to form a shallow depression with rounded leading and trailing edges 248 and 249. The angle formed between the groove walls and surface 242 is radiused by rounded corners 248 and 249. The groove is shallow with a large radius forming low ramp angles at the point of tangency to the flat surface to encourage hydrodynamic transportation of the lubricant contained within the grooves 244.

Claims

1. A thrust bearing lubrication means for a rotary cone rock bit comprising:

a rock bit body having a first pin end and a second cutting end, and at least one leg having a main journal bearing cantilevered from the cutting end of the leg, said bearing forming at least a cylindrical radial bearing surface and an axial thrust bearing surface,

a rotary cone mounted for rotation on the bearing, said cone having at least a radial bearing surface and an axial thrust bearing surface,

a lubricant reservoir formed in the leg,

a lubrication orifice formed in the leg serving as a conduit for lubricant between the lubricant reservoir and the bearing surfaces, and characterized by:

at least one groove formed in one of the axial thrust bearing surfaces formed on the journal bearing and the rotary cone, the intersection between the wall of the groove and the thrust bearing surface at the trailing edge of the groove being at a sufficiently low angle for developing hydrodynamic pressure between the thrust bearing surfaces when the cone is rotated on the main bearing, thereby distributing a film of lubricant between the axial thrust bearing surfaces.

2. The thrust bearing lubrication means for a rotary cone rock bit as set forth in claim 1 wherein the intersection between the wall of the groove and the thrust bearing surface comprises a ramp formed in the axial thrust bearing surface, said ramp extending from a trailing edge of the groove and gradually converging with a planar bearing surface of the axial thrust bearing surface.

3. The thrust bearing lubrication means for a rotary cone rock bit as set forth in claim 2 wherein the ramp in the axial thrust bearing surface is formed in the rotary cone.

4. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein the ramp is formed by stamping the ramp with a die thereby forming the ramp in the cone through plastic deformation.

5. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein there are at least a pair of radially disposed grooves and ramps formed in the axial bearing surface formed in the cone, each said ramp beginning at a trailing edge of the groove and gradually sloping up to the planar surface of the axial bearing.

6. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein there are four equidistantly spaced radially disposed grooves formed in the axial thrust bearing surface formed in the cone with ramps formed on the trailing edge of each of the grooves.

7. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein each ramp extends from the trailing edge of one groove half way toward the leading edge of an adjacent groove.

8. The thrust bearing lubrication means for a rotary cone rock bit as set forth in claim 1 wherein such a groove is formed in the axial thrust bearing surface on the main journal bearing, said groove having the ramp formed on the trailing edge of the groove.

9. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein the thrust bearing lubrication means further comprises:

a floating axial thrust bearing washer positioned between the main journal bearing axial thrust bearing surface and the axial thrust bearing surface formed in the rotary cone; and

at least one groove formed in the main journal bearing axial thrust bearing surface and at least one groove formed in the axial thrust surface formed in the cone,

the grooves having ramped surfaces formed on a trailing edge of each of the grooves and gradually converging with the respective planar axial thrust bearing surfaces, and

the thrust washer and the axial thrust bearing surfaces communicating with the source of lubricant whereby the lubricant is hydrodynamically distributed on all of the thrust bearing surfaces formed by the thrust washer when the cone is rotated on the main bearing.

10. The thrust bearing lubrication means for a rotary cone rock bit as set forth in any of the preceding claims wherein the groove is substantially radially disposed.

11. A method of distributing lubricant to an axial thrust bearing surface formed on a main journal bearing of a sealed bearing rotary cone rock bit and an axial thrust bearing surface formed on a rotary cone comprising delivering lubricant to the thrust bearing surfaces from a pressure compensated lubricant reservoir and characterized by the steps of:

forming at least one substantially radially disposed groove in one of the axial thrust bearing surfaces formed by the main journal bearing and the cone, and

forming a ramp in the thrust bearing surface at a trailing edge of the groove, the ramp gradually converging with a planar surface of the thrust bearing surface for developing hydrodynamic pressure, thereby spreading a film of lubricant along the axial thrust bearing surfaces when the cone is rotated on the main bearing.

12. A method as set forth in claim 11 comprising the step of forming the groove and the ramp in the axial thrust bearing surface in the cone.

13. The method as set forth in either of claims 11 or 12 further comprising the steps of forming four equidistantly spaced grooves and ramps in the axial thrust bearing surface in the cone.

14. The method as set forth in any of claims 11 to 13 further comprising the step of forming a ramp on the trailing edge of such a groove by stamping the thrust bearing surface with a die, thereby plastically deforming the bearing surface.

15. The thrust bearing lubrication means for a rotary cone rock bit as set forth in claim 1 wherein the intersection between the wall of the groove and the thrust bearing surface comprises rounded leading and trailing edges on the groove so that the groove walls have low ramp angles adjacent to the axial thrust bearing surface.

16. The thrust bearing lubrication means for a rotary cone rock bit as set forth in claim 15 wherein the groove in the axial thrust bearing surface is formed in the rotary cone.

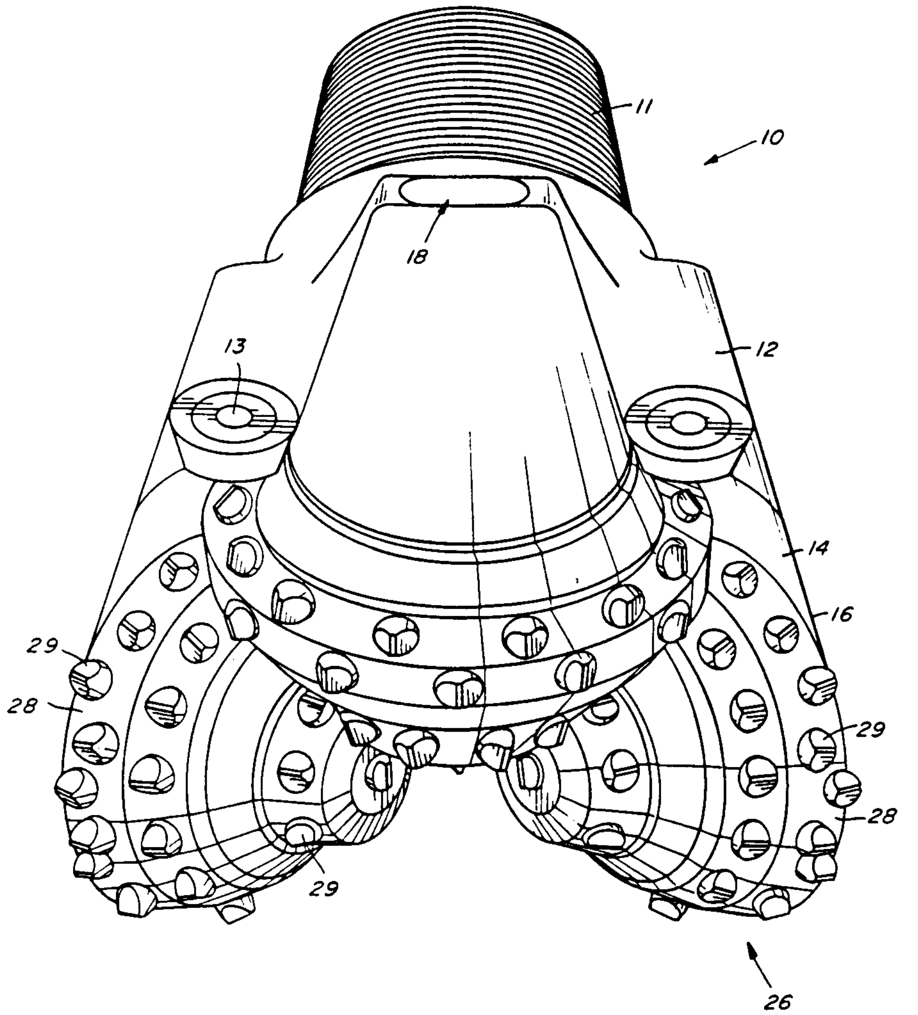
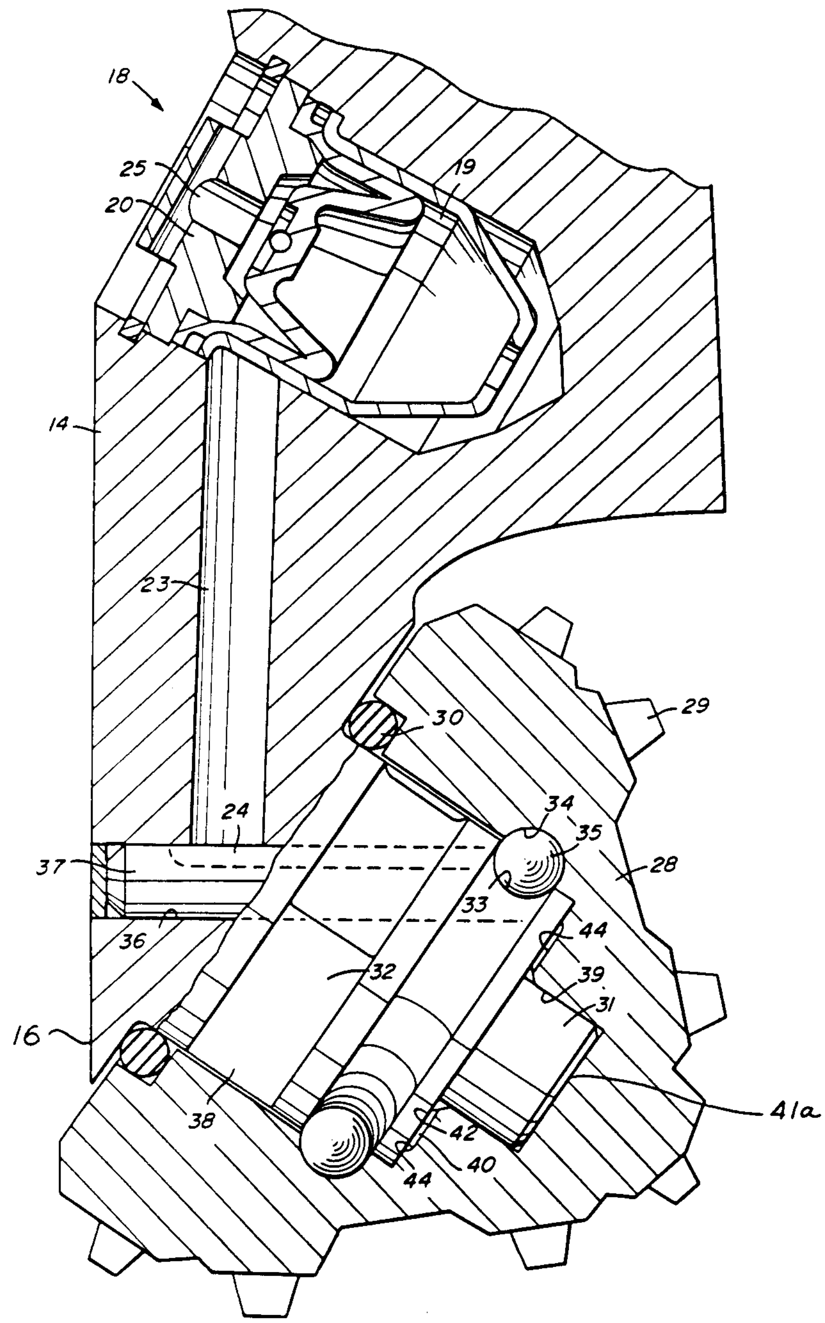


FIG. 1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44

FIG. 2

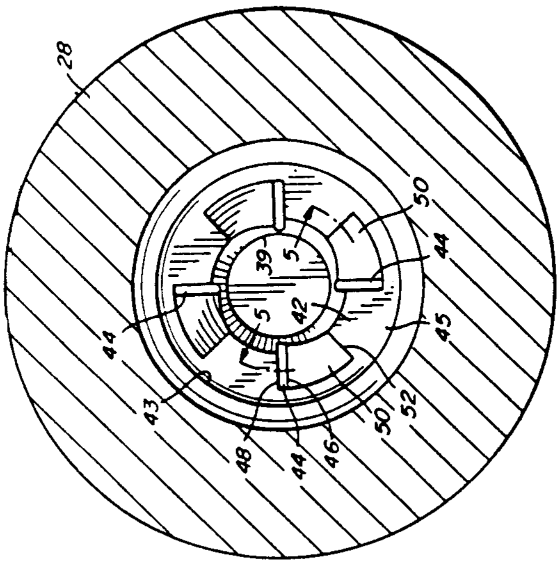

FIG. 4

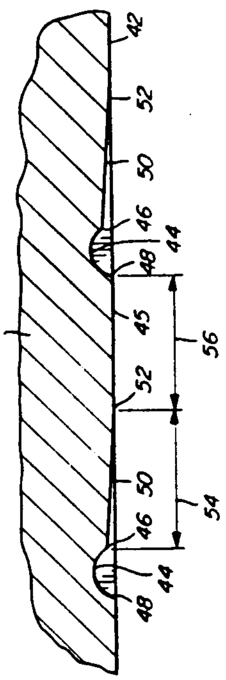

FIG. 5

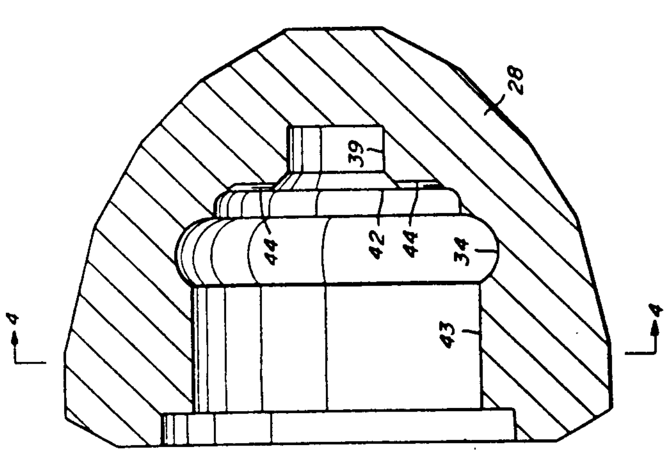

FIG. 3

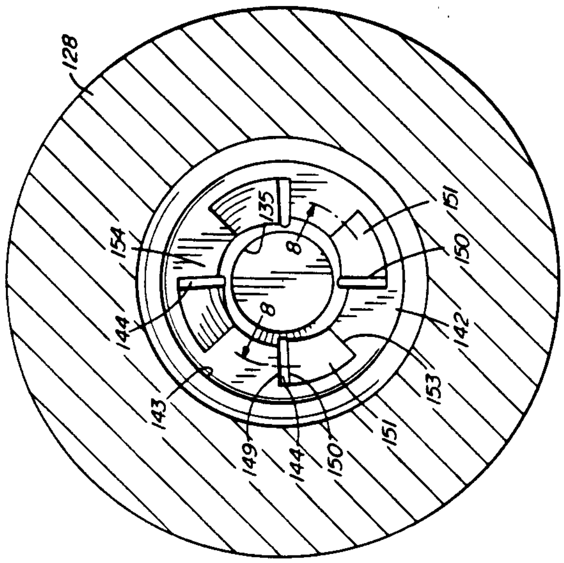

FIG. 7

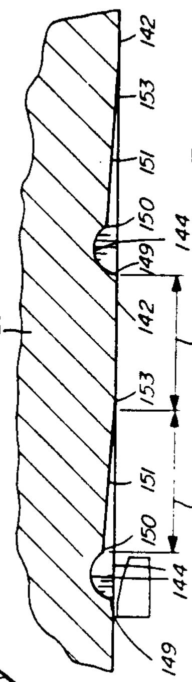

FIG. 8

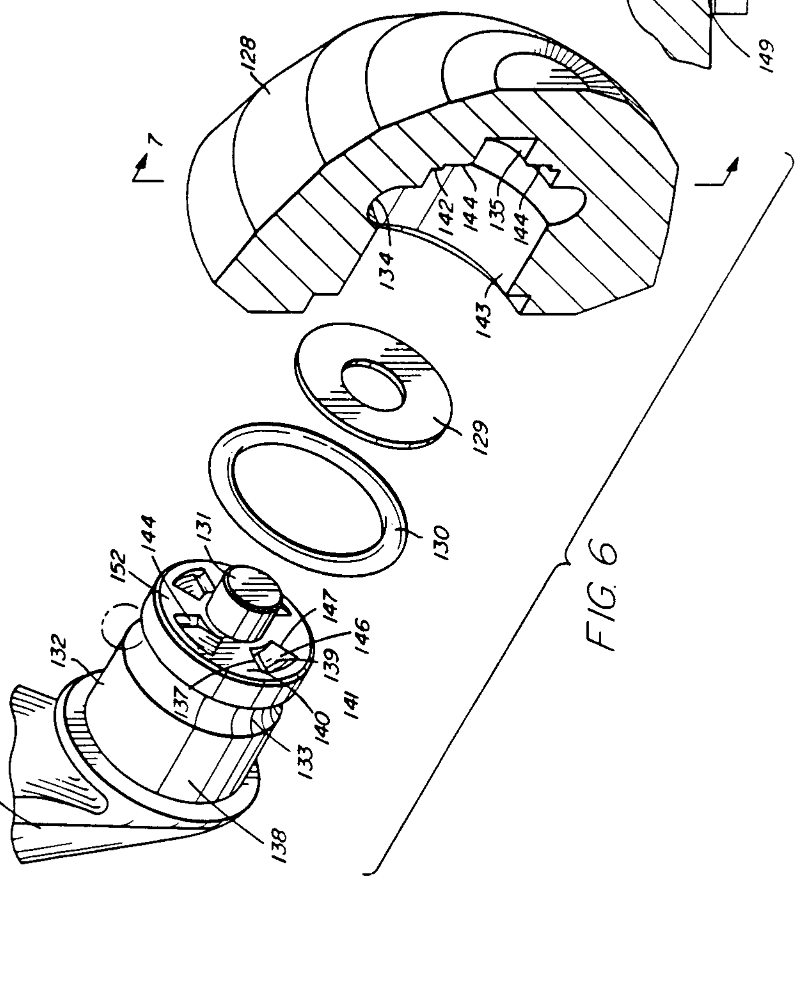

FIG. 6

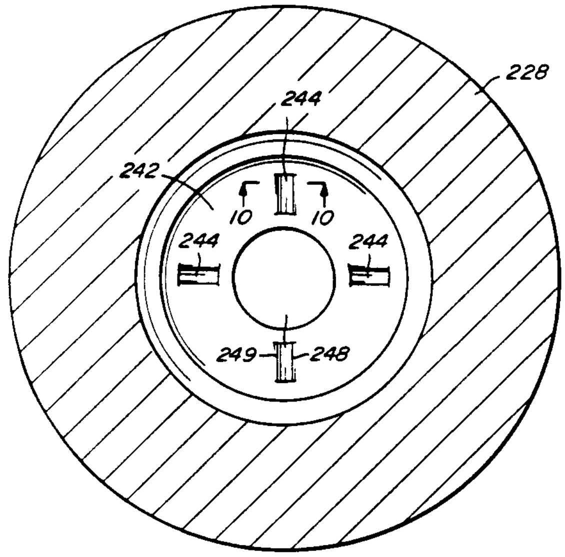

FIG. 9

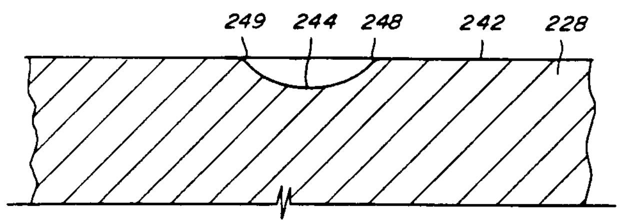

FIG. 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 3057

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4 412 590 (DALY) * Column 4, line 1 - column 5, line 51; figures 1,10,11 * ---	1,5,6,8,10,15,16	E 21 B 10/24
X	US-A-4 181 185 (KELLER) * Column 4, lines 22-66; figure 2 * ---	1,5,6,10,15,16	
A,D	US-A-4 410 284 (HERRICK) * Whole document * ---	1,9	
A	US-A-4 610 319 (KALSI) * Abstract; column 1, lines 2-6; figure 11 * ---	1	
A	US-A-3 890 018 (CLAMON) * Column 4, lines 24-27; figure 4 * ---	1	
A	US-A-4 330 158 (WALTERS) * Column 4, lines 25-48; figure 2 * ---	1	
A	US-A-3 923 108 (WILLIAMS, Jr.) ---		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	US-A-4 193 463 (EVANS) -----		E 21 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-11-1991	FONSECA Y FERNANDEZ H.

CATEGORY OF CITED DOCUMENTS

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