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**PATENT SEARCH AND REVIEW ON ROLLER-BIT
BEARINGS SEALS AND LUBRICATION SYSTEMS**

Topical Report

By
William C. Maurer

October 14, 1975

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U. S. DEPARTMENT OF ENERGY
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SEALS AND LUBRICATION SYSTEMS

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INTRODUCTION

Over 300 patents on bit design have been reviewed and the more important ones have been abstracted. These patents have been divided into three groups dealing with roller bit bearings, seals and lubrication systems.

Review of these patents helps identify the problems encountered by previous bit designers and establishes the current state-of-the-art of roller bit design.

This report can be used as a reference for designing improved bits both for the petroleum and the geothermal industries.

BEARING DEVELOPMENT

The first roller bit patent was issued to Howard Hughes in 1909. This bit contained two rolling cutters with oil lubricated journal bearings as shown in Figure 1.

Figure 1. Hughes Roller Bearing Bit (1909) (Patent #930,759)

In 1919, Howard Hughes patented the roller bearing bit shown in Figure 2.

Figure 2. Hughes Roller Bearing Bit (1919) (1,306,694)

Scott (Hughes) patented the Stellite hard faced journal bearing shown in Figure 3 in 1930. In this patent, he stated that temperatures in excess of 750°F are produced in journal bearings.

Figure 3. Scott Hard Faced Journal Bearing (1930) (1,747,394)

Wellensiek (Hughes) patented the ball retainer system shown in Figure 4 for holding cones onto the bit journals.

Figure 4. Wellensiek Ball Retainer System (1933) (1,905,079)

In 1933, Behnke (Reed) patented the roller-ball bearing shown in Figure 5.

Figure 5. Behnke Roller-Ball Bearing (1933) (1,940,839)

In 1934, Flynn patented the tapered roller bearing shown in Figure 6.

Figure 6. Flynn Tapered Roller Bearing (1934) (1,957,532)

Carlson patented the ball locking device shown in Figure 7 which utilizes a pin (96) to hold the balls in the core.

Figure 7. Carlson Ball Locking Pin (1934) (1,973,975)

In 1934, Garfield (Hughes) patented the Stellite coated pilot roller bearing (9) shown in Figure 8.

Figure 8. Garfield Stellite Coated Pilot Roller Bearing (1934) (1,983,283)

Reed patented the combination bearing shown in Figure 9 where the balls (2) and rollers (2a) are alternated in the bearing race.

Figure 9. Reed Ball-Roller Bearing (1935) (2,004,013)

In 1935, Scott (Hughes) patented the ball bearing shown in Figure 10.

Figure 10. Scott Ball Bearing (1935) (2,011,084)

Reed patented the bit shown in Figure 11 which utilizes a filler strip (8) to hold the balls in the bit cone.

Figure 11. Reed Filler Strip Locking Mechanism (1936) (2,065,740)

The combined cylindrical roller-tapered roller bearing assembly shown in Figure 12 was patented by Reed in 1937.

Figure 12. Reed Cylindrical Roller-Tapered Roller Bearing Assembly (1937) (2,075,997)

In 1937, Reed also patented the bearing shown in Figure 13 which utilized a threaded ring (12) to hold the cutter onto the lug.

Figure 13. Reed Threaded Locking Ring (1937) (2,076,000)

Reed patented the roller locking mechanism (5) shown in Figure 14 in 1937.

Figure 14. Reed Roller Locking Mechanism (1937) (2,076,003)

In 1937, Scott (Hughes) patented nose pins utilizing hard metal coatings as shown in Figure 15.

Figure 15. Scott Hard Metal Nose Pins (1937) (2,086,681 and 2,086,682)

Schlumpf (Hughes) patented the journal bearing sleeve (12) shown in Figure 16 in 1938.

Figure 16. Schlumpf Journal Bearing Sleeve (1938) (2,104,819)

In 1938, Reed patented the tapered roller locking mechanism shown in Figure 17.

Figure 17. Reed Tapered Roller Locking Mechanism (1938) (2,126,035)

Scott (Hughes) patented the four cone offset bit shown in Figure 18. The cone offset increased the dragging action of the teeth as they removed the rock.

Figure 18. Scott Offset Four Cone Bit (1939) (2,147,926)

In 1940, Scott (Hughes) patented the split ring cone locking mechanism shown in Figure 19.

Figure 19. Scott Split Ring Cone Locking Mechanism (1940) (2,192,697)

Boice (Reed) patented the combination ball-roller bearing shown in Figure 20.

Figure 20. Boice Combination Ball-Roller Bearing (1942)
(2,283,312)

In 1944, Fermier (Reed) patented the bearing shown in Figure 21 which utilizes a reservoir (18) filled with hard granular material. As the bearing wears, the granular material fills the space behind plunger 19 and prevents the cone from becoming loose on the journal as the bearing wears.

Figure 21. Fermier Granular Bearing Wear Compensator (1944)
(2,339,161)

Miller (Chicago Pneumatic) patented the roller bearing shown in Figure 22. The rollers (32a) contain enlarged heads (32b) which prevents axial thrust from being applied to the rollers when the balls wear.

Figure 22. Miller Roller Bearing (1944) (2,351,357)

In 1949, Noble (Reed) patented a bit bearing using the threaded locking ring (14) shown in Figure 23.

Figure 23. Noble Roller Bearing (1949) (2,490,151)

In 1950, Francis (Reed) patented a system for introducing the ball bearings into the cone through an opening in the nose of the cone as shown in Figure 24.

Figure 24. Francis Ball Locking System (1950) (2,507,776)

Francis (Reed) also patented a bearing utilizing the threaded locking ring (15) shown in Figure 25.

Figure 25. Francis Threaded Locking Mechanism (1950) (2,513,634)

In 1952, Hammer (Security) patented a journal bearing which contained grooves filled with hard metal (23 and 24) as shown in Figure 26.

Figure 26. Hammer Hard Metal Journal Bearing (1952) (2,592,277)

Peter (Reed) patented a technique for locking cones onto bit journals by selectively heating a region (B) of the journal, applying axial force to the journal and thereby producing an upset rib (20) which locks the cone onto the journal as shown in Figure 27.

Figure 27. Peter Cone Locking Mechanism (1952) (2,620,686)

In 1952, Noble (Reed) patented the bearing assembly shown in Figure 28 which utilizes small thrust roller bearings (15) in the cones.

Figure 28. Noble Roller Bearing (1952) (2,647,084)

Noble (Reed) also patented the bearing shown in Figure 29 which utilizes a coiled spring (17) to hold the thrust bearing rollers (29) in place.

Figure 29. Noble Spring Loaded Thrust Bearing (1953) (2,664,321)

Welton (Chicago Pneumatic) patented the criss-cross roller bearing shown in Figure 30 which distributes the bearing loads over a larger area, thereby reducing the contact stresses.

Figure 30. Welton Criss-Cross Roller Bearing (1958) (2,823,083)

Boice (Reed) patented the concept of placing a tungsten carbide bearing element (9) in the nose pin of the bit journal as shown in Figure 31.

Figure 31. Boice Hard Metal Nose Bearing (1959) (2,904,374)

In 1961, Kucera (Reed) patented the concept of placing a detritus trap (20) in the ball retaining plug (17) as shown in Figure 32. This trap is designed to collect detritus which is introduced into the bearing during manufacture or which is produced by spalling or breakage as the bearing wears.

Figure 32. Kucera Bearing Detritus Trap (1961) (2,982,367)

In 1962, Gros (Neyrpic) patented the journal bearing shown in Figure 33 for use in high speed turbodrill bits. This bearing contains a cap (16) composed of a self-lubricating material consisting primarily of graphite, molybdenum disulphide or other solid lubricants.

Figure 33. Gros Turbodrill Journal Bearing (1962) (3,047,344)

Bit bearings and bit lugs are often damaged when reaming tight holes and when drilling due to high inward forces exerted on the cutters. Galle (Hughes) patented the bearing support systems shown in Figure 34 to overcome this problem.

Figure 34. Galle Bearing Support Systems (1963) (3,086,601)

Figure 36. Radzimovsky Angular Contact Bearings (1965)
(3,193,028)

In 1966, Whanger (Hughes) patented the concept of inlaying strips of silver in journal bearings as shown in Figures 37 and 38. This concept is currently being used by Hughes Tool Co. in their journal bearing bits.

Figure 37. Whanger Silver Inlays In Journal (1966) (3,235,316)

Figure 38. Whanger Silver Inlay In Cutter (1966) (3,235,316)

Carburization is used on bit journals and cones to provide hard wear surfaces. In 1966, Neilson (Smith) patented the concept of using deep carburizing in the roller race and thin carburizing in the ball race as shown in Figure 39. Neilson also patented the concept of using deep carburization only at the bottom of the journal since the load is applied in that area.

Figure 39. Neilson Deep Carburization In Roller Race And Shallow Carburization In Ball Race (1966) (3,275,389)

Hildebrandt (Esso) patented the reverse bit bearing shown in Figure 40. Hildebrandt claims that the life of this bearing may be as much as 40 percent greater than that of a conventional bearing.

Figure 40. Hildebrandt Reverse Bearing (1967) (3,307,645)

In 1968, Galle (Hughes) patented a system for locking cones onto bit journals using a plug (12) as shown in Figure 41. Galle also patented the system shown in Figure 42 where a pusher plug (66) forces a round plug (65) forward. The round plug (65) which locks the cone to the journal is prevented from rotating by the eccentric disposition of the pusher plug (66).

Figure 41. Galle Plug Locking Mechanism (1968) (3,361,494)

Figure 42. Galle Plug Locking Mechanism (1968) (3,361,494)

Ferrand (SNPA) patented the concept of using nylon seals (17) instead of ball bearings to lock the cones to the journal as shown in Figure 43. The seal material is introduced into the seal cavity in a liquid state (150°C) and allowed to solidify in place. This bit utilizes a floating piston (14) to supply lubricant to the bearing.

Figure 43. Ferrand Seal Locking Mechanism (1968) (3,365,247)

In 1968, Schumacher (Reed) patented the concept of using a contoured bearing race which allows the load to be distributed over a larger number of rollers, thereby reducing the contact stresses (Figure 44).

Figure 44. Schumacher Contoured Bearing Race (1968) (3,384,426)

Neilson (Smith) patented the concept of putting longitudinal grooves (26 and 30) in the floating journal bearing bushing (22) as shown in Figure 45. The outer grooves (26) are larger than the inner grooves (30) in order to balance the friction forces on the inner and outer surfaces so that the free floating bushing will index randomly.

Figure 45. Neilson Friction Balanced Bushing (1969) (3,476,446)

Neilson (Smith) patented the segmented journal bearing bushing shown in Figure 46 which allows the thrust to be applied over a larger contact area, thereby reducing the contact stresses. The segmented bearings also provide better lubrication. The outer surfaces (32) of the segments are shorter than the inner surfaces (30) to equalize the friction and allow random indexing of the segments. The ball bearings are replaced in this assembly by toric segmented bearings as shown in Figure 47.

Figure 46. Neilson Segmented Journal Bearing (1970) (3,549,214)

Figure 47. Neilson Segmented Toric Bearings (1970) (3,549,214)

One problem with roller bearings is that the rollers often skew in the races and lock the cones as they wear. Becker patented the antiskew bearing shown in Figure 48 which utilizes a rubber roller (42) to align the rollers as they enter the load bearing area in the bearing.

Figure 48. Becker Anti-Skew Roller Bearing (1971) (3,601,456)

High axial loads on bit cutters often cause spalling of the ball bearing race due to fatigue as shown in Figure 49.

Cunningham (Hughes) patented the concept of relieving the inner side of the ball bearing race so that the inward directed axial loads are carried by the thrust button (17) instead of by the balls. See Figure 50.

Figure 49. Cunningham - Spalling In Conventional Bits (1971) (3,620,580)

Figure 50. Cunningham Relieved Ball Bearing Race (1971) (3,620,580)

Extremely high bit weights are often used on mining bits when drilling taconite, granite and other hard rocks. The resulting high axial thrusts cause premature failure of the ball bearings (46) and the nose thrust pin (48). McCallum (Reed) patented the concept of using an intermediate axial thrust member (54) between the ball bearings and the nose pin to overcome this problem as shown in Figure 51.

FIG. 3

Mayo (Reed) patented the concept of making floating bushings (24) in journal bearing bits out of beryllium copper alloys as shown in Figure 52. Beryllium copper alloys have good fatigue properties, have low coefficients of friction and dissipate the heat readily from the highly loaded sliding surfaces. Reed Tool Company is using these beryllium copper alloy bushings in their premium journal bearing bits.

Figure 52. Mayo Beryllium Copper Alloy Bushing (1973) (3,721,307)

Jackson (Dresser) patented the concept of pitting one of the journal bearing surfaces (49) so that the pits can serve as reservoirs for anti-galling materials (44) as shown in Figure 53. He recommends using a lithium soap grease containing 5 percent silver particles (45). In a later patent (3,839,774) Jackson recommends pitting the surface by grit blasting to give it a 50 to 200 RMS finish.

Figure 53. Jackson Pitted Journal Bearing Surface (1974)
(3,784,264)

Hudson (Dresser) patented a tungsten carbide journal bearing where sintered tungsten carbide particles (24) are placed in a recess (25) in the journal by a Stellite type welding rod as shown in Figure 54.

Figure 54. Hudson Tungsten Carbide Journal Bearing (1974)
(3,823,030)

Trey (Creusot-Loire) patented a journal bearing which contains grooves, the rear sides of which are substantially perpendicular to the rubbing surface as shown in Figure 55. Trey reports tests where greases containing 5 to 50 percent silver produced equal wear whereas the wear rate was double when only 2 percent silver was used. Trey recommends using at least 15 percent of one of the following metals: germanium, silver, indium, tin, antimony, thallium, lead, bismuth, cadmium, or copper.

Figure 55. Trey Grooved Journal Bearing (1974) (3,845,994)

Goodfellow (Kennametal) patented the threaded cone locking mechanism shown in Figure 56. Once the threaded ring (54) is tightened, hole 56 is sealed with a plug or by welding it closed.

Figure 56. Goodfellow Threaded Locking Ring (1974) (3,847,235)

Garner (Smith) patented the laminated journal bearing shown in Figure 57. The different bearing rings (36, 38, 40 and 42) have different coefficients of friction so that they will all rotate at different speeds. This keeps the relative velocities low between adjacent rings and thereby increases bearing life. The same concept can be used by using holes (46) filled with solid lubricants as shown in Figure 58.

Figure 57. Garner Laminated Journal Bearing (1975) (3,866,987)

Figure 58. Garner Laminated Journal Bearing (1975) (3,866,987)

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BEARING SEAL DEVELOPMENT

Earlier rock bits were often lubricated with oil or grease, but they contained no bearing seals, so the lubricants leaked continuously through the bearings. An example of this is the first roller bit ever patented (Figure 1).

Figure 1. Hughes Original Roller Bit (1909) (930,759)

In 1931, Behnke (Reed) patented the concept of circulating mud through the bearings to cool and lubricate them as shown in Figure 2. This system which eliminated the need for a bearing seal was subsequently used for many years.

Figure 2. Behnke Mud Lubricated Bearings (1931) (1,816,203)

The first bit bearing seal patent was issued to Baggett (Hughes) in 1932 (see Figure 3). This seal consists of a rubber ring (17), an outer steel ring (15), and an inner leather washer (14) which prevents leakage through the bearing.

Figure 3. Baggett Bearing Seal (1932) (1,884,965)

In 1940, Kirkpatrick patented a roller bit which utilized the rubber bearing seal (160) shown in Figure 4. When subjected to high internal pressure, annular rib 170 acts like a fulcrum bending the rubber seal outward into tighter contact with the sealing surfaces.

Figure 4. Kirkpatrick Bit Bearing Seal (1940) (2,187,037)

The turbulent action of the abrasive drilling mud issuing from the bit nozzles accelerates wear of the bearings and bearing seals. Scott (Hughes) patented the fluid deflector (19) shown in Figure 5 which reduces the erosive effect of the drilling mud.

Figure 5. Scott Bearing Seal Fluid Deflector (1941) (2,260,487)

In 1957, Fisher (Garloc) patented the shielded bearing seal shown in Figure 6. The rubber seal ring (48) is shielded by the flexible stainless steel ring (50) which is similar to a Belleville spring. The rings are held in place by a steel clamping ring (52).

Figure 6. Fisher Shielded Bearing Seal (1957) (2,797,067)

Atkinson (Hughes) patented the bearing seal shown in Figure 7. This seal consists of a rubber outer seal member (21) which contains an inner steel spring member (30 or 30'). Steel ring 30 is provided with radial slots 31 to allow limited axial movement of steel fingers 33. Steel ring 30' is formed with alternate ridges and grooves to allow axial movement of the ring.

Figure 7. Atkinson Bearing Seal Ring (1963) (3,075,781)

Neilson (Smith) patented the bearing seal assembly shown in Figure 8 where the seal surfaces (29 and 30) are inclined approximately 10 degrees to the perpendicular to the journal axis. This design allows the rollers (18) to be longer thereby increasing their load carrying capacity. (See also patent # 3,199,878 which is a continuation of this patent.)

Figure 8. Neilson Inclined Bearing Seal (1963) (3,096,835)

Neilson (Smith) also patented the O-ring bearing face seal shown in Figure 9. This seal utilizes a lubricant inlet (28) and an air bleed hole (36). The bleed hole (36) is plugged after the bearing cavity is filled with lubricant whereas the inlet hole (28) is left open in order to equalize the hydrostatic pressure across the O-ring seal.

Figure 9. Neilson O-Ring Bearing Seal (1964) (3,127,942)

Cunningham (Hughes) patented the seal ring shown in Figure 10 which consists of a steel spring core (32) encapsulated in rubber or plastic sealing element (33). The seal ring is held firmly to the journal (6) by an interference fit (39 and 40) and thereby rotates with respect to the cutter (7). The rotating seal occurs at point B between the seal ring and the cutter. This design was found to eliminate the problem of having abrasive drill cuttings get beneath the seal ring and score the seal surfaces. The seal ring can also be made with a seal pocket (51) which will trap low pressure air and thereby help hold the seal ring in position due to the differential pressure effect.

Figure 10. Cunningham Bearing Seal (1964) (3,137,508)

Goodwin (Globe) patented the bearing seal shown in Figure 11 which utilizes a spring (37) to load the rubber seal ring (38) which seals between the journal (13) and the cutter (15). The pressure across this seal is equalized through a hole drilled through the trailing side of the leg.

Figure 11. Goodwin Bearing Seal (1964) (3,151,691)

Swart (Smith) patented the O-ring bearing seal shown in Figure 12 where the O-ring seals between a tapered shoulder (22) on the journal (12) and the cutter (13). The seal is designed so that it can absorb angular, radial and axial displacement of the cutter on the journal.

Figure 12. Swart O-Ring Bearing Seal (1967) (3,299,973)

Bercaru patented the U-shaped rubber seal shown in Figure 13. The seal ring is vulcanized to a brass ring (35) which gives the seal more rigidity and allows it to operate at higher pressures. The outer surface of the seal ring (16) is coated with a thin layer of graphite rubber (36) to reduce the sliding friction between the stationary seal and the rotating cutter (3). Bercaru also patented the seal rings shown in Figure 14 which utilize metal sealing elements (37a and 41a) to provide dynamic seals against rubber rings 39 which are vulcanized to the cutters (3). The grooves (40) in the corrugated seal (37a) provide passages for the lubricant, thereby reducing the sliding friction.

Figure 13. Bercaru Bearing Seal (1967) (3,303,898)

Figure 14. Bercaru Bearing Seals (1967) (3,303,898)

Cason (Dresser) patented the bearing seal shown in Figure 15 which consists of an inner steel spring (32), a rubber outer body (34) and a metal sliding seal (30) which seals against the rotating cutter (12). The metal seal is made of a "hard, brittle, abrasion resistant metallic alloy of non-galling compatibility with the cutter" such as Stellite. Materials such as Teflon or some of the plastics with wear resisting qualities can also be used for this seal ring.

Figure 15. Cason Bearing Seal (1968) (3,370,895)

Neilson (Smith) patented the bearing seal shown in Figure 16 which consists of several thin laminated Belleville springs (28, 29 and 30) separated by Teflon strips (31 and 32) inside of a rubber sealing element (35). The thin springs have greater resistance to fatigue, thereby overcoming a problem of fatigue failures with seals containing single springs.

Figure 16. Neilson Bearing Seal (1968) (3,381,968)

Galle (Hughes) patented the concept of using more than 10 percent compression on the bearing seals as shown in Figure 17. This is much more than is normally used on this type of seal, but Galle found that this high compression was advantageous with rock bit bearing seals.

Figure 17. Galle High Compression Bearing Seals (1968) (3,397,928)

Engelking (Caterpillar) patented the rotating seal shown in Figure 18 which may have application in rock bits. An O-ring (32) provides load on two metal-to-metal sealing elements (12 and 14).

Figure 18. Engelking Rotating Seal (1969) (3,452,995)

Galle (Hughes) patented the bearing seal shown in Figure 19 which utilizes an O-ring (23) to seal against an annular body (21) consisting of an outer retainer ring (27) and an inner wear ring (31) separated by a rubber core (29). The outer steel retainer ring has an interference fit in the cutter thereby forcing the wear ring into intimate contact with the journal (13) and the O-ring seal. The inside diameter of the steel wear ring (31), which seals against the O-ring, is chrome plated to increase its wear resistance.

Figure 19. Galle O-Ring Bearing Seal (1969) (3,467,448)

Neilson (Smith) patented the concept of using a metal retainer ring (54) with an interference fit in the leg to prevent the bearing seal (38) from rotating with the cutter (12) as shown in Figure 20. The seal is designed with initial clearance between the back side of the seal and the journal (8) to allow for axial cutter movement as the bearing wears. Neilson also patented the concept of placing the retainer ring (72) in a groove (74) in the leg (18) or in the cutter (12) as shown in Figure 21.

Figure 20. Neilson Retained Bearing Seal (1970) (3,489,421)

Figure 21. Neilson Retained Bearing Seal (1970) (3,489,421)

Durham (Caterpillar) patented a variety of seals consisting of metal Belleville seal rings bonded to resilient backup members as shown in Figure 22. The resilient backup members (42, 49, 58, 66 and 72) provide a static seal while the metal seal rings (40, 47, 54, 67 and 74) provide dynamic seals against the bit legs (12 and 68) or against the cutters (15 and 70).

Figure 22. Durham Bearing Seals (1970) (3,529,840)

Winberg patented the bearing seal shown in Figure 23 for use in large tunnel boring machine cutters. The seal consists of a static O-ring seal (422) and a spring loaded graphite seal (410) which seals against the steel journal (302). A soft, flexible material (418) such as rubber or plastic is bonded to the seal ring (410). A hard protective ring (420) is located between the spring and this yieldable material. Winberg also patented the seal shown in Figure 24 which utilizes two graphite seal rings with sealing surfaces (222) held by retainer rings (232) and loaded by O-rings (202).

Figure 23. Winberg Bearing Seal (1971) (3,572,452)

Figure 24. Winberg Bearing Seal (1971) (3,572,452)

Lichte (Dresser) patented the tunnel cutter bearing seal shown in Figure 25 which utilizes O-rings (19 and 20) to provide static seals and to load seal rings 17 and 18. These seal rings which rotate with the cutter are fabricated of graphite and coated with dense, fluid impervious, betacrystalline, silicone carbide. Figure 26 shows this seal ring in a roller bit cone. Lichte also patented the seal assembly shown in Figure 27 which utilizes two silicone carbide coated graphite seal rings (30 & 34 and 31 & 35).

Figure 25. Lichte Silicone Carbide Coated Graphite Seal Rings
(1971) (3,604,523)

Figure 26. Lichte Silicone Carbide Coated Graphite Seal
(1971) (3,604,523)

Figure 27. Lichte Silicone Carbide Coated Graphite Seal
(1971) (3,604,523)

Robinson patented the bearing seal shown in Figure 28 which consists of two O-rings separated by a floating rigid ring. Figure 29 shows other variations of this design. These designs allow nearly double the O-ring compression without significantly increasing the seal width. In addition, the seal accommodates more axial, radial and angular displacement of the cutter.

Figure 28. Robinson Double O-Ring Bearing Seal (1972) (3,656,764)

Figure 29. Robinson Double O-Ring Bearing Seals (1972) (3,656,764)

Bronson (Varel) patented the Belleville spring seal (50) shown in Figure 30 which has a rubber flange (96) which fits into a tapered groove (74) on the bit journal. The seal remains stationary and seals against the rotating cutter (18) along surface 114.

Figure 30. Bronson Stationary Bearing Seal (1972) (3,663,073)

Garner (Smith) patented the seal retainer ring (46) shown in Figure 31. The two legs of this retainer ring are cut along 62 and 64 to weaken the ring so that it will snap into two parts as it slides past abutment 56 and snaps into place behind this abutment. The ring breaks along surface 50 as it slides past the abutment.

Figure 31. Garner Seal Retainer Ring (1972) (3,680,373)

Bennett (Sun Oil) patented the bearing seal shown in Figure 32. The sealing elements (22 and 28) which are made of heat resistant materials such as Teflon or Viton are attached to heat dissipating elements (20 and 30) made of a highly conductive metal such as beryllium copper. The heat dissipating elements can also be formed in a spring-like manner to provide means for keeping the sealing members in contact. This concept may have application in geothermal bits where heat dissipation from the seals will be important.

Figure 32. Bennett Heat Dissipating Bearing Seal (1973) (3,713,707)

Schumacher (Reed) patented the bearing seal shown in Figure 33 which uses an O-ring (28) to force a stationary plastic or metal seal ring (24) into contact with the rotating cutter (15). The seal is shown in more detail in Figure 34. The tapered shoulder on the journal (14) forces the seal ring against the cutter (15).

Figure 33. Schumacher Bearing Seal (1973) (3,761,145)

Figure 34. Schumacher Bearing Seal (1973) (3,761,145)

Murdock (Reed) patented the elongated rubber seal ring (22) shown in Figure 35 which provides good sealing with less than 10 percent radial compression of the ring. This seal ring is currently used in Reed's premium sealed bearing journal bits.

Figure 35. Murdock Bearing Seal (1973) (3,765,495)

Millsap (Parker - Hannifan) patented the bearing seal assembly shown in Figure 36. The O-ring (28) provides a static seal with the journal (3) and forces the stationary Teflon seal ring (23) into contact with the rotating cutter (4). Figure 37 shows one variation where a rib (25) is used on the Teflon ring to provide the dynamic seal and a second variation where the ring is held in place by retainer ring 32 and rib 31 is used to provide the static seal.

Figure 36. Millsap Teflon Bearing Seal (1975) (3,862,762)

Figure 37. Millsap Teflon Bearing Seals (1975) (3,862,762)

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LUBRICATION SYSTEMS DEVELOPMENT

Howard Hughes utilized a spring (15) loaded piston (10) to supply lubricant to the journal bearings in the first roller cone bit which he patented (Figure 1).

Figure 1. Hughes Roller Bit (1909) (930,759)

Hughes also patented the concept of using a spring (25) loaded piston (24) in each cone as shown in Figure 2.

Figure 2. Hughes Roller Bit (1909) (930,759)

In 1915, Howard Hughes patented the bit lubrication sub shown in Figure 3. Drilling mud passes from the annulus through pipe 16 into the bottom of the oil reservoir, displacing the oil through pipe 11 and into the journal bearings in the bit. Hughes states that pipe 16 can also be connected to the inside of the drillpipe in which case the higher fluid pressure in the drillpipe will force the oil into the bearings.

Figure 3. Hughes Lubrication Sub (1915) (1,136,134)

Gardner patented the lubrication system shown in Figure 4 where weight 18 forces oil (17) into the bit bearings.

Figure 4. Gardner Lubrication System (1917) (1,238,757)

Duda (Reed) patented the downhole lubrication pump shown in Figure 5. As the reamer (6) rotates, it reciprocates plunger 23, pumping mud up through pipe 21 and on top of piston 20. As the piston moves down, it forces oil into the bit bearings.

Figure 5. Duda Downhole Lubrication Pump (1924) (1,487,319)

Behnke (Reed) patented the concept of using a downhole strainer (8) to allow clean mud to cool and lubricate the bearings as shown in Figure 7.

Figure 7.. Behnke Mud Lubricated Bearings (1931) (1,816,203)

Wadsworth patented the downhole lubrication pump shown in Figure 8 where the rotation of the side cutter (14b) rotates screw pump 46b which pumps fluid beneath piston 41b. As the piston moves upward, it forces oil located above the piston through pipe 34b and into the bit bearings.

Figure 8. Wadsworth Downhole Lubrication Pump (1931) (1,838,067)

Fletcher (Hughes) patented the lubrication system shown in Figure 9 where mud pressure acting through hole 20 forces piston 18 down thereby forcing lubricant into the journal bearings. Check valve 23 prevents grease or mud from flowing back into lubricant reservoir 17.

Figure 9. Fletcher Lubrication System (1933) (1,896,231)

Scott (Hughes) patented the lubricator coupling shown in Figure 10 which allows lubricant to flow from the lubricator reservoir (5) to the bit journal bearings.

Figure 10. Scott Lubricator Coupling (1933) (1,896,250)

Scott also patented the lubricator shown in Figure 11 which utilizes a floating piston (17) to force lubricant into the bearings. A U-shaped seal (11) is used to seal the lubricant in the bearings.

Figure 11. Scott Lubrication System (1933) (1,909,078)

Scott also patented the lubrication system shown in Figure 12 where mud pressure acting on piston 17 forces lubricant through the spring-loaded check valve 21 and into the bearings. As the cone rotates, cam 28 forces piston 25 to reciprocate and pump lubricant to the journal bearings. The cones are equipped with U-shaped packing rings (12) to prevent mud from leaking into the lubricated bearings.

Figure 12. Scott Lubrication System (1933) (1,909,128)

Catland (Globe) patented the lubrication system shown in Figure 13 which utilizes a spring loaded piston (46) in the journal. The lubricant chamber (18) is filled with grease through fitting 28, compressing spring 47. Vent hole 48 allows mud to act on the backside of the piston, so the bearing seals (43 & 45) are subjected only to the differential pressure created by the spring acting on the piston. The cone is equipped with a cam (58) which opens valve 55 each revolution of the cone, thereby allowing lubricant to pass into the bearing.

Figure 13. Catland Lubrication System (1939) (2,174,102)

Crook (Reed) patented the concept of using a spiral vane (30) to throw the abrasive solids in the mud outward and allow relatively clean mud to be diverted through ports 33 and into the bearings as shown in Figure 14.

Figure 14. Crook Mud Cleaning System (1943) (2,329,745)

Green (Engineering Laboratories) patented a bit containing the lubrication system shown in Figure 15. Lubricant is supplied to the bearing by spring loaded piston 53. The cavity above the piston is vented (62) to the wellbore annulus, so the bearing seals (68 & 69) are subjected only to the differential pressure created by the spring acting on the piston. The journal is equipped with a grease fitting (58) to allow easy filling of the lubrication reservoir (55).

Figure 15. Green Lubrication System (1953) (2,654,577)

Woods (Hughes) patented the air cooled bit shown in Figure 16. Part of the air is diverted down passageway 25, past the bearing retainer way (17) and through the bearings. The air is cooled as it expands in the bearing which greatly increases the life of the bearing.

Figure 16. Woods Air Cooled Bearings (1953) (2,661,932)

Turner patented the lubrication system shown in Figure 17 where grease gun 22 is used to lubricate the bearings through fitting 21 in the cone. Once the bearing is full of grease, two prongs (26) on the grease gun are used to rotate the threaded seal plug (24) while under pressure. This plug seals against the ball (31) thereby sealing the lubricant in the bearing under pressure.

Figure 17. Turner Lubrication System (1954) (2,676,790)

Smith patented the oil lubricated air bit shown in Figure 18. Air in the drillpipe acts on the oil in reservoir 29, thereby forcing the oil into the bit bearings.

Figure 18. Smith Oil Lubricated Air Bit (1956) (2,751,196)

Pike (Engineering Laboratories) patented the concept of using inserts (21) to provide continuous passages between the bit shank (2) and the spindles (5) which contains the bit cones as shown in Figure 19.

Figure 19. Pike Air Bit (1957) (2,814,464)

Smiecinski (National Oil Tool) patented the air bit shown in Figure 20. This bit utilizes jet aspirator action to deliver lubricant from reservoir 37 into the air stream which is passing down conduit 35 to the bearings.

Figure 20. Smiecinski Oil Lubricated Air Bit (1958) (2,831,660)

Swart (Smith) patented the bit shown in Figure 21 which utilizes a porous metal filter (27) and graded gravel (29) to filter the abrasive particles out of the mud and provide clean water to cool and lubricate the bearings. The pressure drop present across the bit nozzles (36) is also present across this lubrication system.

Figure 21. Swart Water Cooled Bearings (1959) (2,880,970)

Parks (Esso) patented the bit lubrication system shown in Figure 22 where mud pressure inside of the drillpipe acts on piston 8 forcing lubricant to the bearings. Relief valve 9 prevents excessive pressure from building up in the bearing while piston 15 prevents lubricant from flowing into the bearing when the differential pressure across the seals (3) exceeds a predetermined maximum value.

Figure 22. Parks Lubrication System (1959) (2,906,504)

Cunningham (Hughes) patented the lubrication system shown in Figure 23 where drilling mud acts on flexible member 31 forcing

lubricant down bore 39 and into the bearings. Drilling mud in the wellbore annulus communicates through port 41 and against the membrane, thereby balancing the pressure across the bearing seals (21).

Figure 23. Cunningham Membrane Lubrication System (1961) (3,007,750)

Eenink (Hughes) patented the lubrication system shown in Figure 24 where flexible membrane 36 is held in place by plug 31. Drilling mud acts against the top of this membrane forcing lubricant into the bearings. Drive pin 32 holds the plug in the bit leg (2) and provides a passageway for the mud to act against the membrane. Elastic ring 37 provides a seal to prevent abrasive mud from entering into the lubricant chamber (26).

Figure 24. Eénink Lubricator System (1961) (3,007,751)

Bobo (Phillips) patented the lubrication sub shown in Figure 25 which lubricates the bit each time the mud pumps are stopped and restarted. When the pumps are stopped, fluid flows from the annulus into chamber 74 through check valve 82. When the pumps are restarted, piston 68 moves downward forcing drilling mud through check valve 78 and on to the top of piston 54. As the drilling mud forces piston 54, it forces lubricant beneath the piston into the bit bearings. Lubricant continues to flow until piston 68 comes to rest on top of collapsed spring 76.

Figure 25. Bobo Pump Actuated Lubrication System (1962)
(3,017,937)

Swart (Smith) patented the lubrication system shown in Figure 26 where drilling mud inside the drillpipe expands the flexible diaphragm (30) and forces lubricant from reservoir 29 into the bearings. The lubricant passes through screens 49 & 60 and through metering tube 59 which controls the rate of flow of lubricant to the bearings as shown in Figure 27. The mud pressure drop across the bit nozzles (63) is also present across this lubrication system.

Figure 26. Swart Metering Lubrication System (1962) (3,029,881)

Figure 27. Swart Flow Metering Tube (1962) (3,029,881)

Angel (Phillips) patented the lubrication system shown in Figure 28 where drilling mud inside of the drillpipe acts through holes 58 and against elastic sleeve 16 forcing lubricant into the bearings. A fine screen or permeable plug (62) is used in the lubricant flow line to limit the lubricant flow rate since the pressure drop present across the lubrication system equals the pressure drop across the bit nozzles (54).

Figure 28. Phillips Lubrication System (1962) (3,048,230)

Goetz (Smith) patented the lubrication system shown in Figure 29 where vent hole 27 is left open after the bearing is filled with grease. Goetz found that this vent hole reduced the problem of "pumping" the lubricant out of the bearing as the cones wobbled and oscillated axially on the journal.

Figure 29. Goetz Lubrication Vent Hole (1963) (3,095,934)

Havenaar (Shell) patented the lubrication sub shown in Figure 30 where a tubular porous metal (or porous ceramic) filter (12) is used to filter part of the mud and allow clean filtrate to flow through the bearings to cool and lubricate them. Havenaar states that the erosive nature of the mud flowing past the filter will prevent plugging of the filter. This system could have application in geothermal bits provided the filter does not plug.

Figure 30. Havenaar Filter Lubrication System (1963) (3,105,563)

Williams patented the bit shown in Figure 31 where drilling mud is circulated through the bit journal in order to improve the bottomhole cleaning action. This concept has potential application in geothermal bits since the drilling mud would help remove heat from the bearings.

Figure 31. Williams Bit Circulation System (1963) (3,113,630)

Medlock (Hughes) patented the air bit shown in Figure 32. This bit utilizes replaceable screens (35, 40 & 56) which filter abrasive particles out of the air diverted through the bearings.

Figure 32. Medlock Air Bit (1964) (3,125,174)

Kotch (Reed) patented the lubrication system shown in Figure 33 where the drilling mud acts on the corrugated flexible diaphragm (24) forcing lubricant in reservoir 16 into the bearings. Metal ring 33 prevents the diaphragm from being damaged if the pressure builds up inside of the lubricant reservoir.

Figure 33. Kotch Lubrication System (1966) (3,230,019)

Gilbert (Reed) patented the lubrication system shown in Figure 34 where drilling mud acting on the outside of flexible bladder 24 forces lubricant into the bearings.

Figure 34. Gilbert Lubrication System (1966) (3,230,020)

Ortloff (Esso) patented the lubrication pump (52) shown in Figure 35. The pump consists of a splined piston (52) which is reciprocated by diagonal face 62 as the cone rotates. The piston pumps lubricant at high pressure between the bearing surfaces producing a hydrodynamical bearing.

Figure 35. Ortloff Hydrodynamical Bearing (1966) (3,244,459)

Dareing (Esso) patented the hydrodynamical bearing shown in Figure 36 which utilizes an electric motor (58A) to drive a high pressure lubricant pump (58). Electrical power is supplied to the motor through electric cables 64 which extend to the surface.

Figure 36. Dareing Hydrodynamical Bearing (1966) (3,251,634)

Neilson (Smith) patented the check valve (26) shown in Figure 37 which prevents water and cuttings from flowing backwards into air bits. The check valve consists of a flexible member (26) which covers ports 25. When air is pumped down through the bits, the outer edge of the flexible member bends down (28) and allows air to flow through the ports.

Figure 37. Neilson Air Bit Check Valve (1966) (3,268,018)

Swart (Smith) patented the lubrication system shown in Figure 38. Drilling mud acting on top of piston 26 forces lubricant into the bearings. The pressure of the lubricant in the bearing is less than the mud pressure around the bit because of the force exerted on the piston by spring 31. This differential pressure is exerted across bearing seal 23.

Figure 38. Swart Lubrication System (1967) (3,299,973)

Bercaru (Rumania) patented the bit lubrication system shown in Figure 39 where drilling mud outside of the bit acts on piston 32 forcing lubricant into the bearing. Spring 31 provides an initial pressure of about 75 psi beneath the piston to ensure that the lubricant is at higher pressure than the drilling mud. The lubricant reservoir 25 beneath the piston is filled through check valve 27 and lubricating pipe 25 and then this outlet is sealed by plug 45.

Figure 39. Bercaru Lubrication System (1967) (3,303,898)

Talbert (Dresser) patented the flow control valve shown in Figure 40 for use in air bits. Air flowing through the bearings passes through screen 56 which removes any large, abrasive particles from the air. Resilient member 64 allows air to flow to nozzles 38, but prevents water and cuttings from flowing backwards into the drillstring.

Figure 40. Talbert Air Flow Control Valve (1968) (3,401,758)

Lundstrom (Sandvikens) patented the lubrication system shown in Figure 41 which utilizes a cam (22) to open a check valve (21) and allow lubricant to flow to the bearing each time the cone rotates one revolution. The cam is mounted on pin 23 which is attached to cone 10.

Figure 41. Lundstrom Cam Operated Lubrication System (1969)
(3,463,270)

Galle (Hughes) patented the valve 35 shown in Figure 42 which relieves the pressure in the lubrication system when it exceeds a predetermined value. Galle states that high pressures are often created in bit lubrication systems because the lubricants undergo partial "cracking" due to the high

temperatures generated in the bearing. This crackling produces both organic liquids and high pressure gases such as methane, ethane and propane. This pressure relief valve, which is similar to ordinary tire valves, is currently used in Hughes sealed bearing bits.

Figure 42. Galle Pressure Relief Valve (1969) (3,476,195)

Bell (Dresser) patented the free breathing lubrication system shown in Figure 43 where drilling mud flows through porous filter 54 and forces lubricant 51 into the bearings. The sintered metal filter, which is located between screens 55 & 56, limits fluid flow and provides a dampening effect. This reduces mixing of the mud with the lubricant. Figure 44 shows one embodiment where the porous filter (92) extends through the flexible diaphragm (86). It also shows a second embodiment where the porous filter (84) communicates with the outside of the bit while a flexible diaphragm (78) communicates with the inner side of the bit leg.

Figure 43. Bell Free Breathing Lubrication System (1972)
(3,719,241)

Figure 44. Bell Free Breathing Lubrication Systems (1972)
(3,719,241)

Sartor (Dresser) patented the lubrication system shown in Figures 45 and 46 where drilling mud acting inside of flexible diaphragm 33 forces lubricant into the bearings. Drilling mud communicates through the hollow metal tube (34) which passes entirely through the leg of the bit. Sartor states that the pressure fluctuations on the diaphragm created by movement of

the bit up and down in the hole are greatly reduced because passageway 30 connects both the high and low pressure areas of the bit.

Figure 45. Sartor Lubrication System (1973) (3,721,306)

Figure 46. Sartor Lubrication Diaphragm (1973) (3,721,306)

Keller (Dresser) patented the two-way lubricant pressure relief valve (18) which is mounted in the leg of the bit as shown in Figure 47. The relief valve consists of a flexible rubber ball (44) which acts as a spring loaded check valve and which will pass through the reduced diameter 43 when subjected to excessive pressure. The pressure required to open the two-way valve is controlled by the springs and the diameter of the reduced passageway.

Figure 47. Keller Two-Way Pressure Relief Valve (1973)
(3,735,825)

Keller also patented the two-way pressure relief valve shown in Figure 48 where springs 74 & 75 control the pressure at which piston 72 will move and relieve the pressure through passageway 70.

Figure 48 . Keller Two-Way Pressure Relief Valve (1973)
(3,735,825)

Crow (Dresser) patented the lubrication systems shown in Figure 49 where drilling mud acts against the lubricant in long passageways 30 & 34 to prevent excessive mixing of mud with the lubricant. Passageway 30 consists of a series of helical grooves while passageway 34 is contained in a long spiral tube.

Figure 49. Crow Lubrication System (1973) (3,744,580)

Welton (Globe) patented the journal lubricant recess (34) shown in Figure 50 which is designed to provide better lubrication to the journal bearing.

Figure 50. Welton Journal Lubricant Recess (1973) (3,746,405)

Crow (Dresser) patented the lubrication pumping system shown in Figure 51. Check valves 32 & 36 are designed to allow lubricant flow in one direction through passageways 31 & 35 and through the lubricant reservoir 27. Axial movement of the cutter (14) on the journal (18) produces a pumping action which circulates lubricant through the passageways and reservoir.

This system could have application in geothermal bits, since the circulating lubricant would help remove heat from the bearings.

Figure 51. Crow Lubrication Pumping System (1974) (3,841,422)

Crow (Dresser) patented the bit lubrication system shown in Figure 52. Each time the mud pumps are turned on after a joint of pipe is added to the drill string, mud pressure from inside the bit forces piston 32 down, thereby circulating lubricant through the bearings and into lubricant reservoir 27. Check valves 35 and 37 control the direction of lubricant flow. When the pumps are turned off to make the next connection, spring 38 lifts piston 32 and allows lubricant to fill the reservoir beneath the piston. This process is repeated each time a connection is made. The lubrication system is shown in more detail in Figure 53. These pumping systems could have application in geothermal bits because the lubricant flow would help dissipate heat out of the bit bearings.

Figure 52. Crow Lubrication Pump (1974) (3,844,364)

Figure 53. Crow Lubrication Pump (1974) (3,844,364)

Figure 54 shows a different lubrication pump which utilizes a gas filled reservoir (66) inside of a flexible membrane (65) to pump lubricant through the bit bearings each time the pumps are stopped and started. Check valves 59 and 60 control the direction of lubricant flow.

Figure 54. Crow Lubrication Pump (1974) (3,844,364)

Figure 55 shows a third lubrication pump where gas (97) is trapped below piston 89. When the pumps are started after a connection is made, mud pressure acting on membrane 81 forces lubricant to move piston 89 down and compress spring 91. Lubricant slowly flows through narrow bleed passage 92, equalizing the fluid pressure across piston 89 and allowing compressed spring 91 to displace the piston upward. This forces lubricant through the bit bearings and back to the lubricant reservoir through passage 86. Check valves 94 and 95 control the direction of lubricant flow. This process is repeated each time the pumps are turned off and on.

Figure 55. Crow Lubrication Pump (1924) (3,844,364)

Schumacher (Reed) patented the two-way pressure relief system shown in Figure 56. Pin holes (78 & 82) in the flexible diaphragms (72 & 80) used to force lubricant into the bearings acts as pressure relief valves. These pinholes do not open and relieve the pressure until a predetermined differential pressure is exceeded. This relief pressure is controlled by the type of rubber used in the diaphragms, the thickness of the rubber and the size of the pin hole. Flow passages 76, 86 & 90 in metal plates 74, 84 and 88 limit the flow rate through the diaphragms and prevent the diaphragms from tearing. This concept can also be used in a separate pressure relief valve as shown in Figure 57 where the pin hole (56) is located in diaphragm 44.

Figure 56. Schumacher Pressure Relief Valve (1974) (3,847,234)

Figure 57. Schumacher Pressure Relief Valve (1974) (3,847,234)

Jackson (Dresser) patented the lubrication system shown in Figure 58 containing pressure relief valve 35. Check valve 38 allows lubricant flow into the bearing whereas relief valve 43 allows lubricant to flow back into the reservoir only after a predetermined pressure differential is exceeded. Another valve design which allows free lubricant flow to the bearings and pressure control to the reservoir is shown in Figure 59.

Figure 58. Jackson Lubrication System (1975) (3,866,695)

Figure 59. Jackson Lubrication Valve (1975) (3,866,695)

Clamon (Dresser) patented the friction bearing shown in Figure 60 which contains spring loaded wipers (23) in the rotating friction bearing (16). When a wiper rotates across the top of bearing pin 14 (i.e., the unloaded side), spring 24 pushes the wiper into contact with the pin. This causes the wiper to push lubricant ahead of it as it enters into the load bearing side of bearing pin 14.

Figure 60. Clamon Lubricant Wiper (1975) (3,890,018)

Figure 61 shows a variation where a lubricant reservoir 30 is machined into the top side of bit pin 26. As the cutter rotates, spring-loaded wipers (28) force lubricant from this reservoir into the load bearing part of the bearing (i.e., the bottom of the pin).

Figure 61. Clamon Lubricant Wiper (1975) (3,890,018)

Figure 62 shows a variation where passage 34 is used to supply lubricant from a reservoir in the bit leg to the relieved side of the bearing (i.e., the unloaded side).

Figure 62. Clamon Lubricant Wiper (1975) (3,890,018)