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(54) DIRECTABLE NOZZLE FOR ROCK DRILLING BITS

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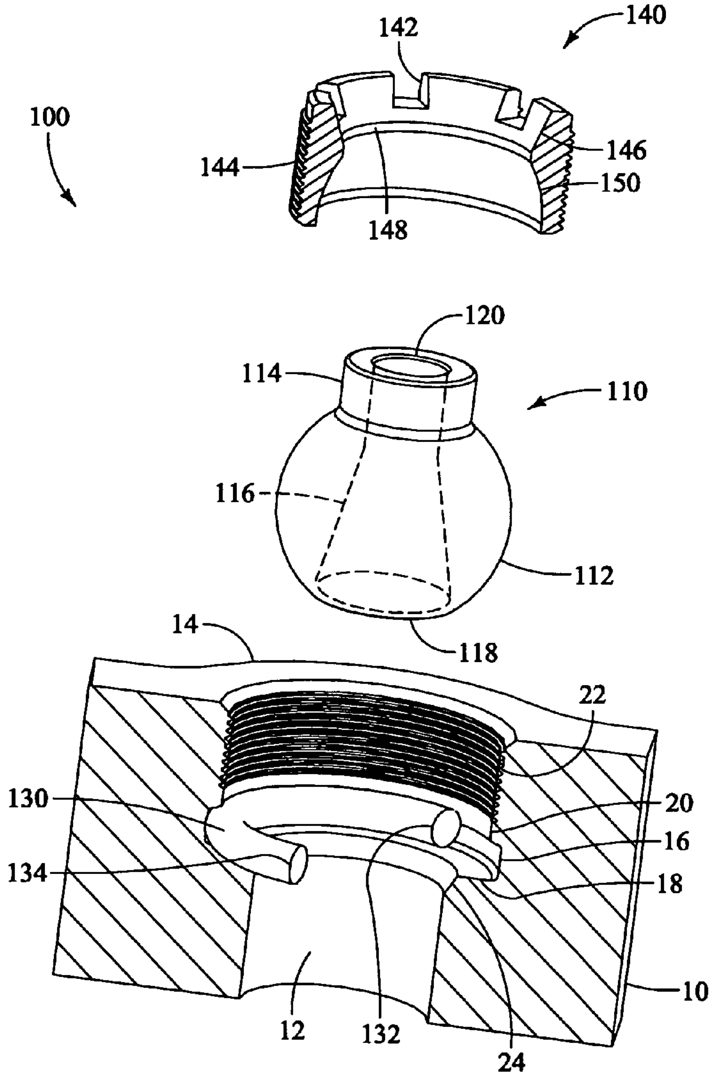
(57) ABSTRACT

A directable nozzle assembly **100** for a rotary drill bit **10** is disclosed, having a nozzle **110** comprising a generally spherical body **112**, and having an extension **114** extending from the body **112**. A passage **116** extends through the body **112** and extension **114** portions. A seal **130** is provided for sealing the nozzle **110** to the nozzle boss area **14** of the rotary drill bit **10**. A removable retainer **140** is provided having a hollow interior, an angle limiter surface **146**, and an interior compression surface **150**. In another embodiment is a wear resistant sleeve **160**, having a collar **162** with a nozzle seat **164** and a body **170**, inserted into a flow port **12** of rotary drill bit **10**.



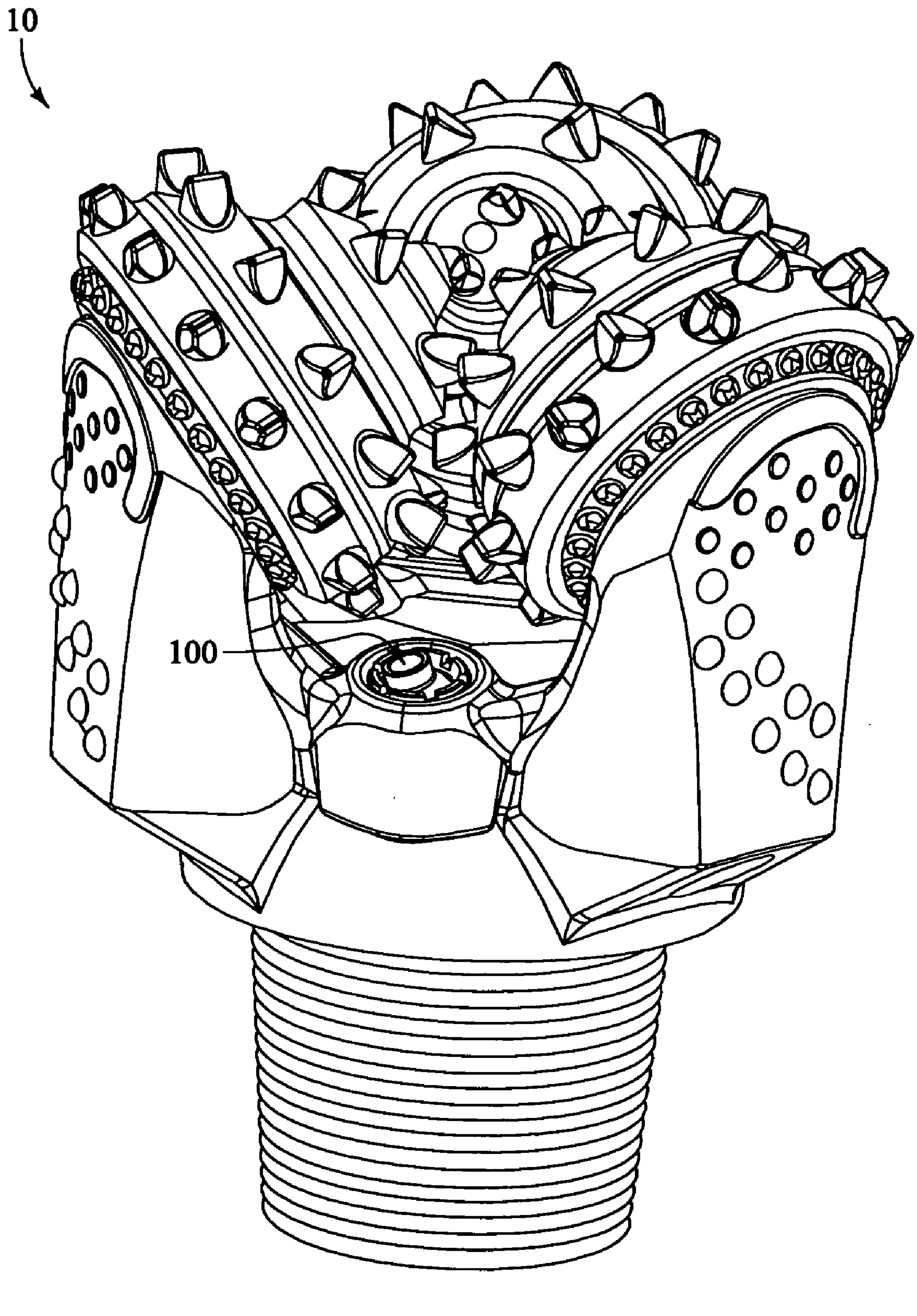



FIG. 1

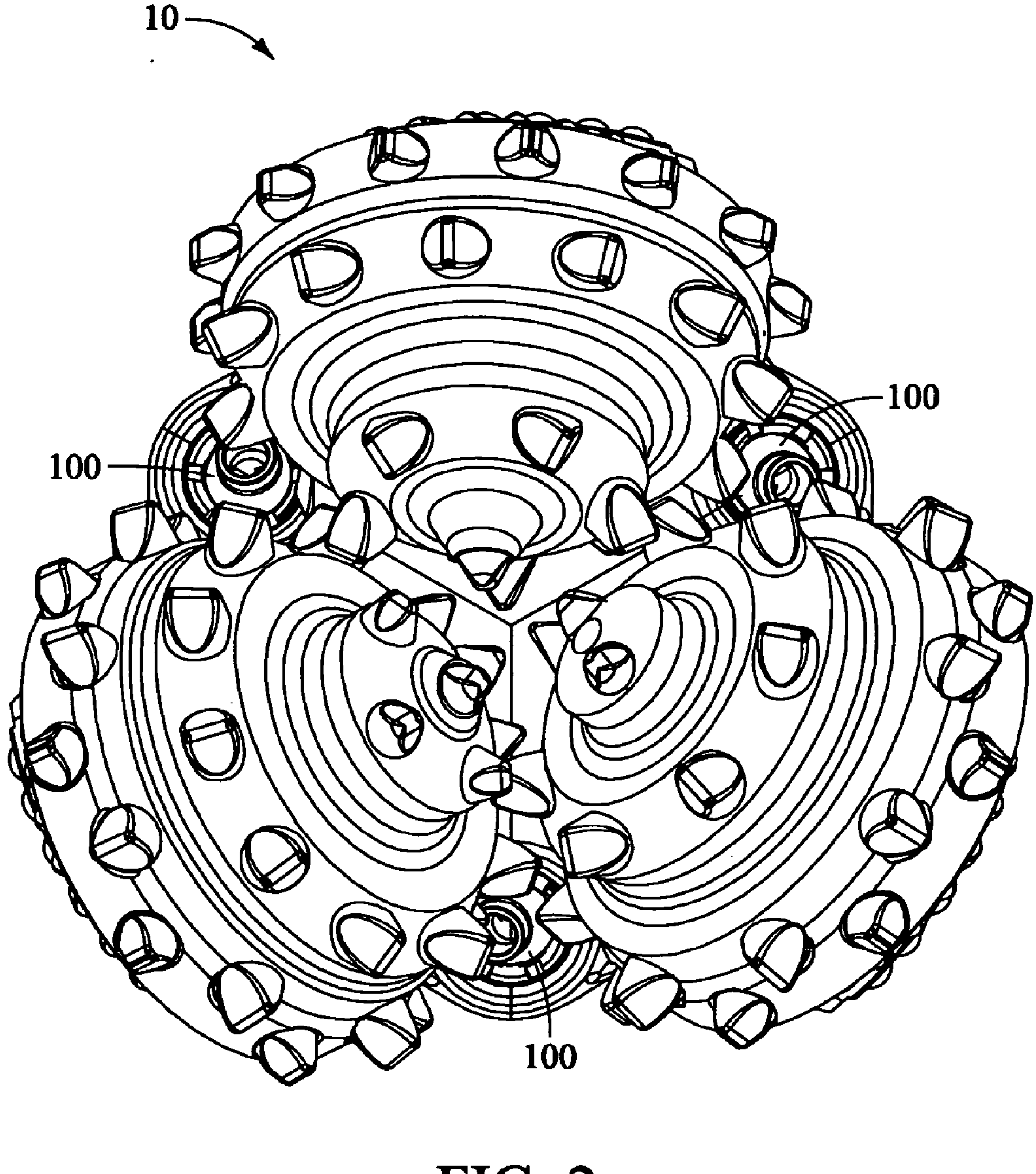



FIG. 2

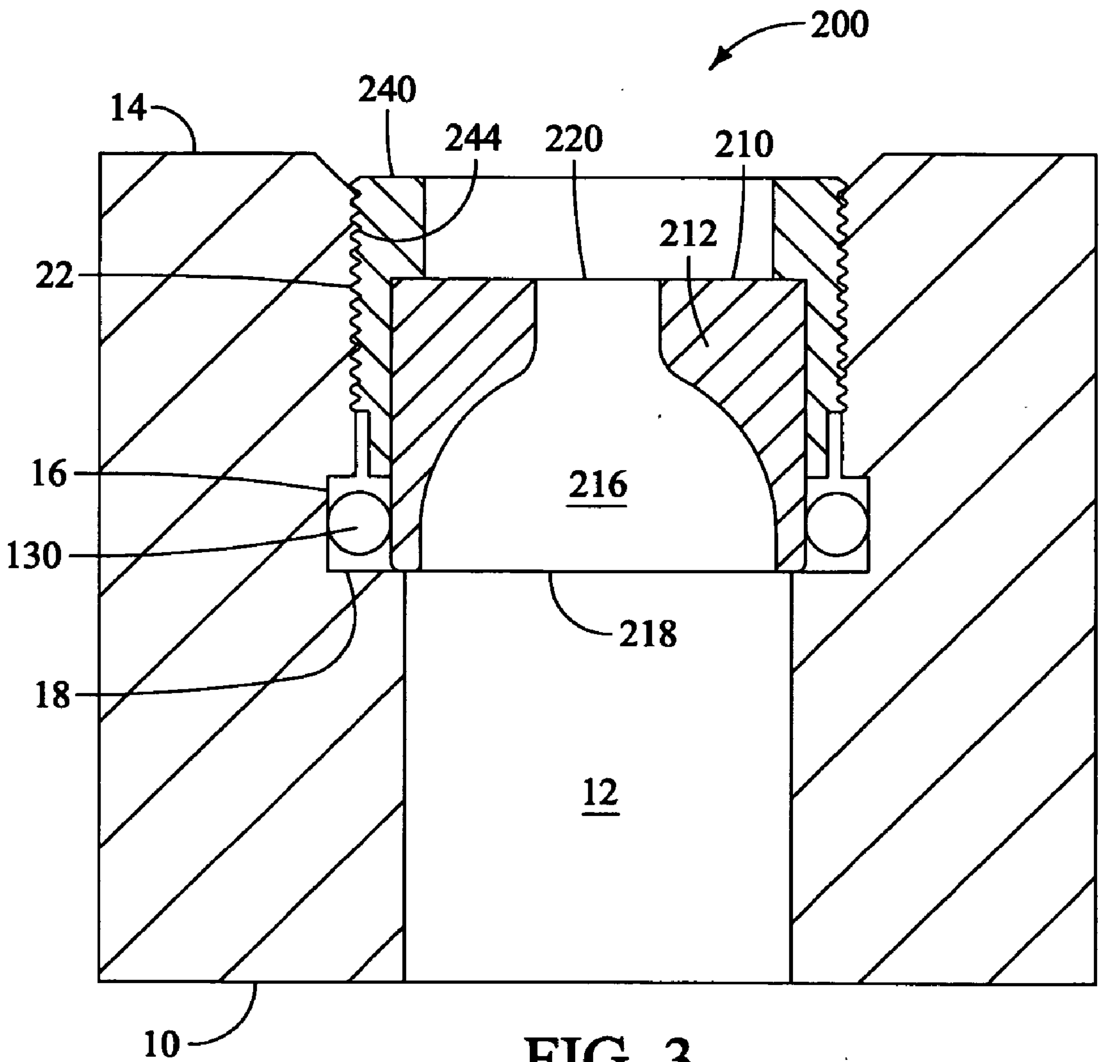
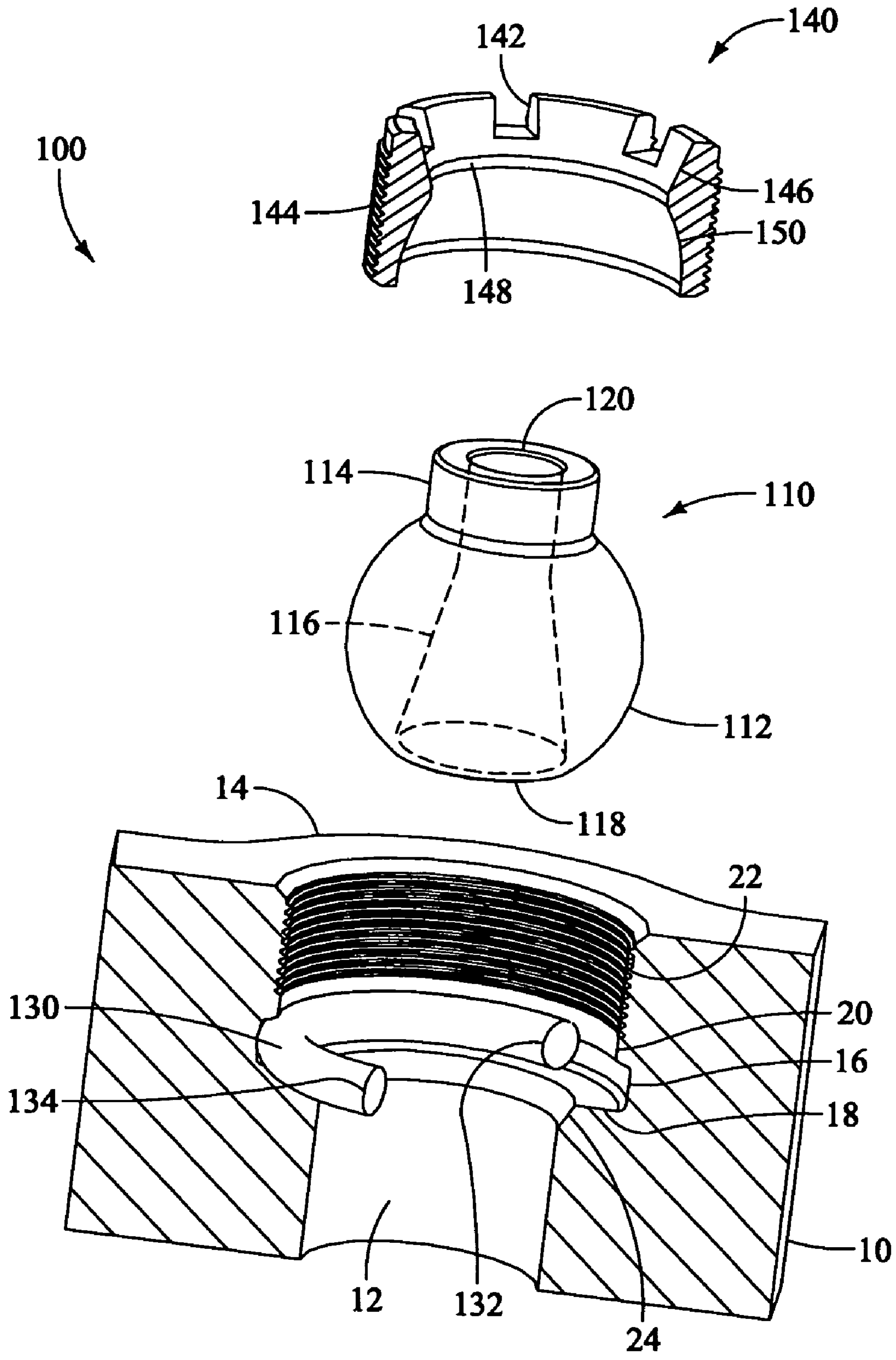



FIG. 3
Prior Art


140
142
100
146
144
150
148
120
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116
112
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22
130
20
16
134
18
10
12
132
24

FIG. 4

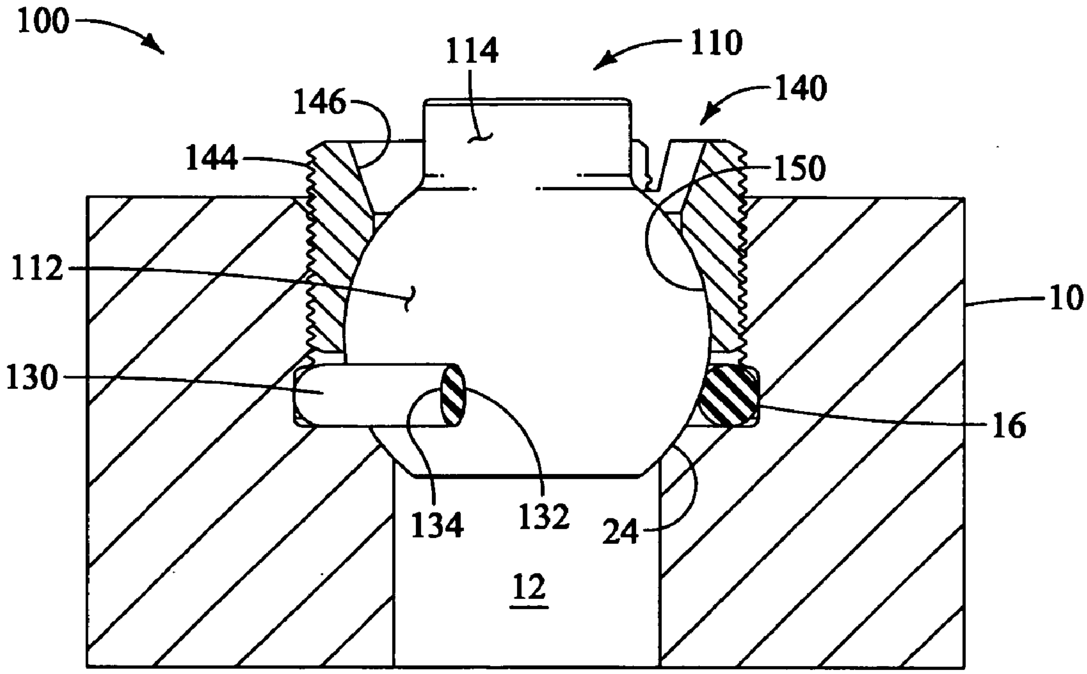
100
114
110
140
146
144
150
112
10
130
16
134
132
24
12

FIG. 5

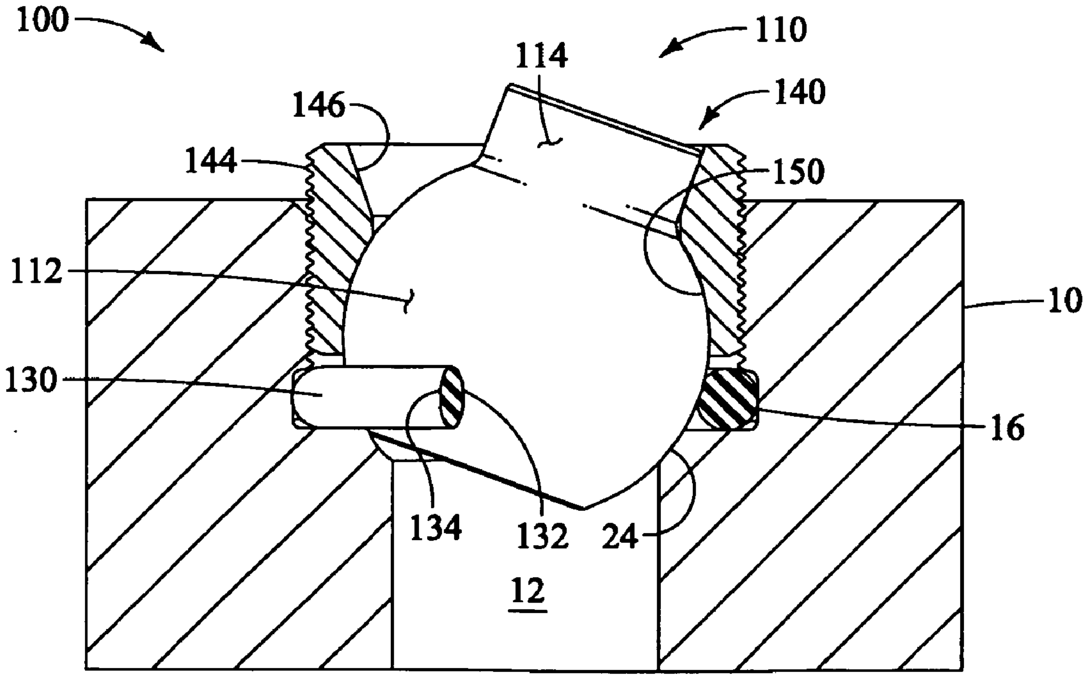
100
110
114
140
146
144
150
112
10
130
16
134
132
24
12

FIG. 6

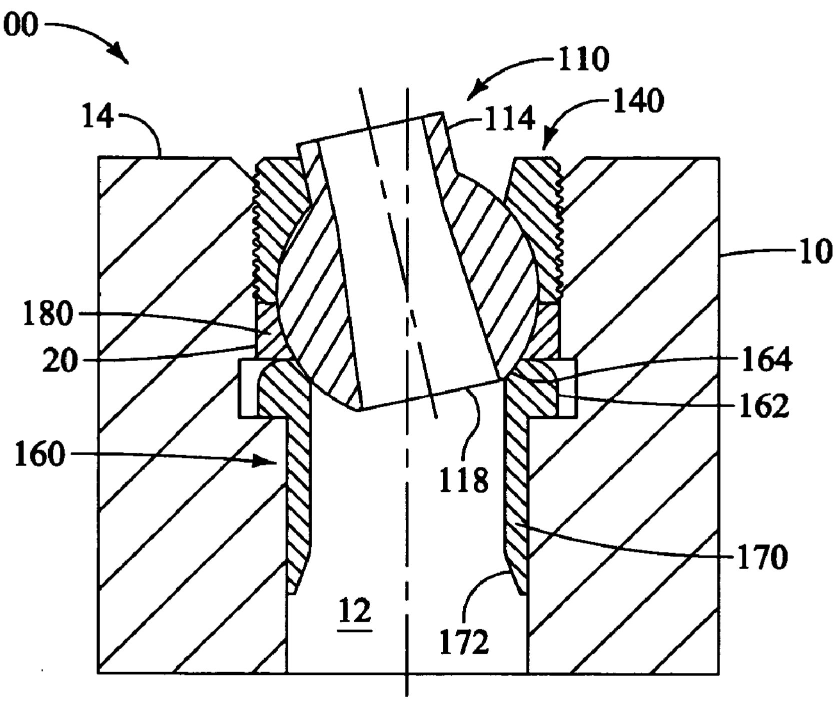
100
110
114
140
14
10
180
20
164
162
160
118
170
12
172

FIG. 7

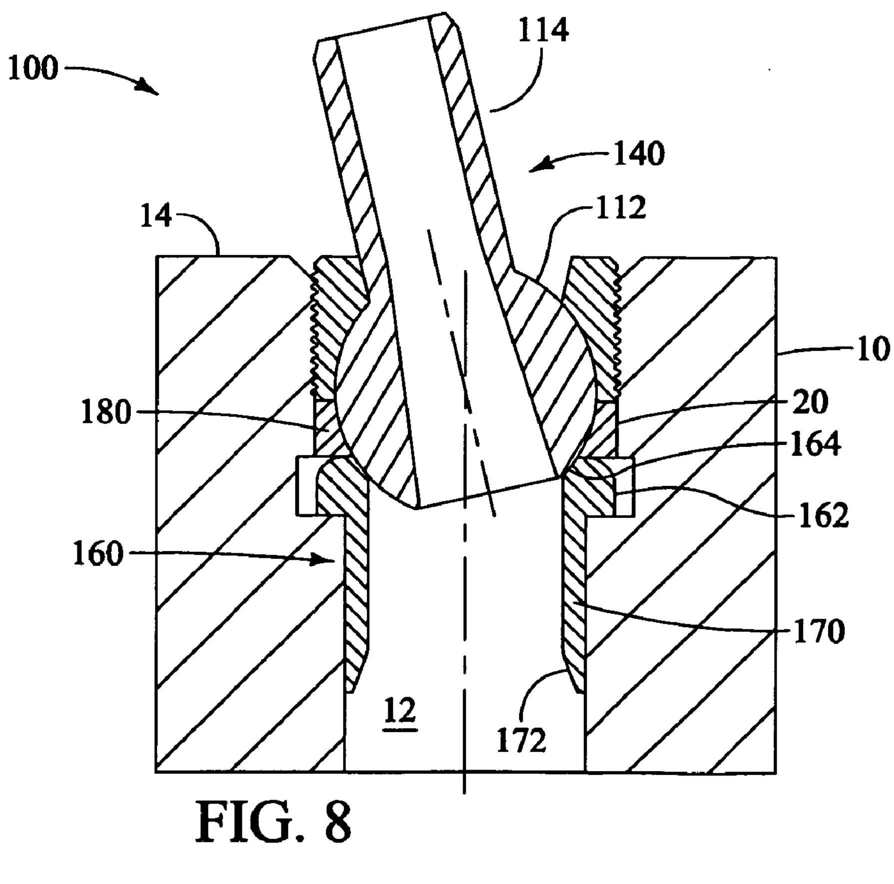
114
100
140
14
112
10
180
20
164
162
160
170
12
172

FIG. 8

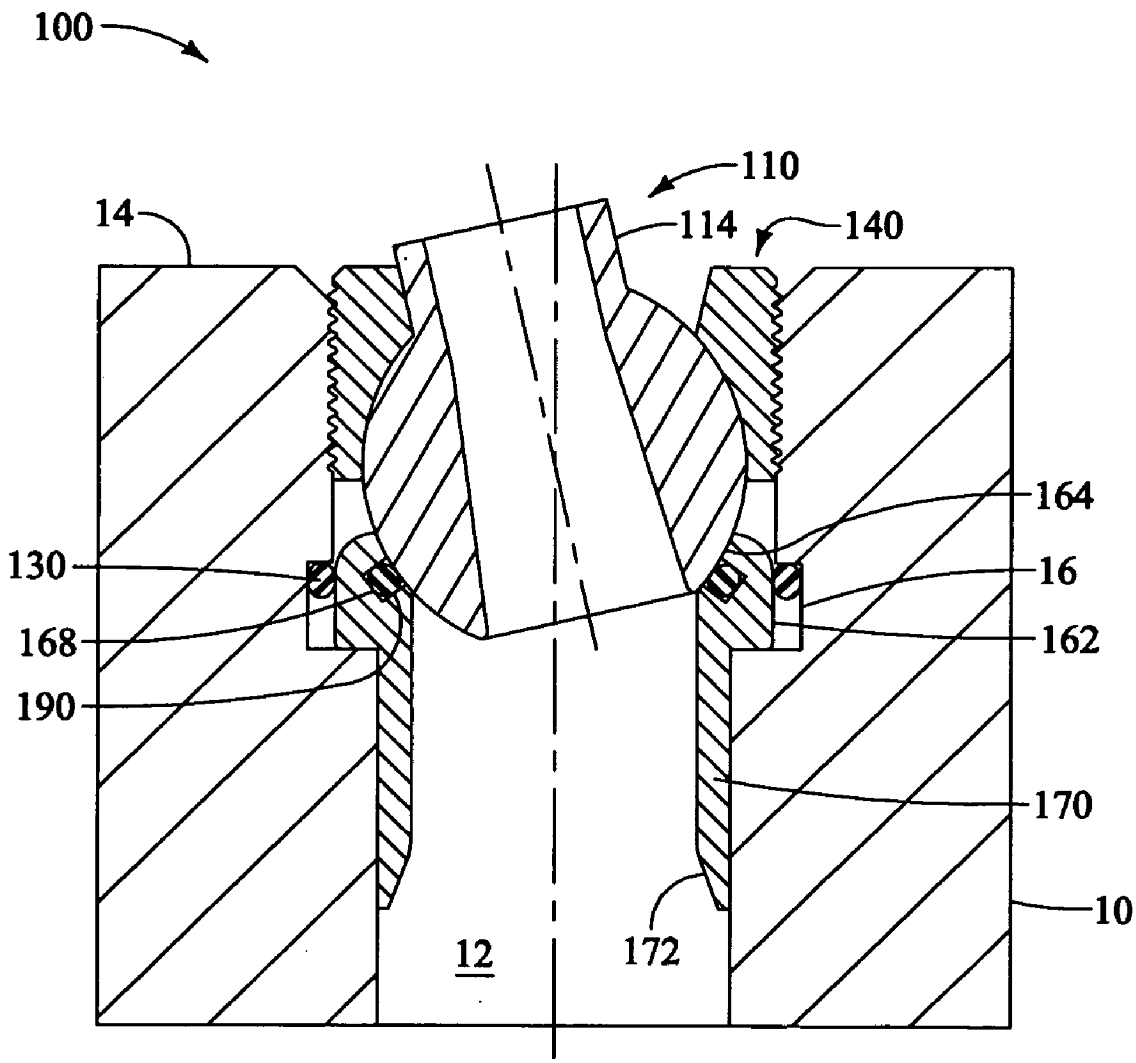


FIG. 9

# DIRECTABLE NOZZLE FOR ROCK DRILLING BITS

## CROSS REFERENCE TO RELATED APPLICATION

[0001] None.

## BACKGROUND OF THE INVENTION

[0002] 1. TECHNICAL FIELD

[0003] The present invention relates generally to drilling bits used for drilling earth formations. More specifically, the present invention relates to a novel design for a directable jet nozzle for rock bits, which works in combination with a retaining system which defines limits of angular orientation.

[0004] 2. DESCRIPTION OF RELATED ART

[0005] In the exploration of oil, gas, and geothermal energy, drilling operations are used to create boreholes, or wells, in the earth. These operations normally employ rotary and percussion drilling techniques. In rotary drilling, the borehole is created by rotating a tubular drill string with a drill bit secured to its lower end. As the drill bit deepens the hole, tubular segments are added to the top of the drill string. While drilling, a drilling fluid is continually pumped into the drilling string from surface pumping equipment. The drilling fluid is transported through the center of the hollow drill string and into the drill bit. The drilling fluid exits the drill bit at an increased velocity through one or more nozzles in the drill bit. The drilling fluid then returns to the surface by traveling up the annular space between the borehole and the drill string. The drilling fluid carries rock cuttings out of the borehole and also serves to cool and lubricate the drill bit.

[0006] One type of rotary rock drill is a drag bit. Early designs for drag bits included hard facing applied to steel cutting edges. Modern designs for drag bits have extremely hard cutting elements, such as natural or synthetic diamonds, mounted to a bit body. As the drag bit is rotated, the hard cutting elements scrape against the bottom and sides of the borehole to cut away rock.

[0007] Another type of rotary rock drill is the roller cone bit. These drill bits have rotatable cones mounted on bearings on the body of the drill bit, which rotate as the drill bit is rotated. Cutting elements, or teeth, protrude from the cones. The angles of the cones and bearing pins on which they are mounted are aligned so that the cones roll on the bottom of the hole with a controlled amount of slippage. One type of roller cone cutter is an integral body of hardened steel with teeth formed on its periphery. Another type has a steel body with a plurality of tungsten carbide or similar inserts of high hardness that protrude from the surface of the body. As the roller cone cutters roll on the bottom of the hole being drilled, the teeth or carbide inserts apply a high compressive load to the rock and fracture it. The cutting action of roller cone cutters is typically a combination of crushing, chipping and scraping. The cuttings from a roller cone cutter are typically a mixture of moderately large chips and fine particles.

[0008] When drilling rock with a roller cone cutter, it is imperative to remove the cuttings from the bottom of the hole. Failure to remove the cuttings from the hole-face will result in redrilling the cuttings. Redrilling rock cuttings substantially reduces the rate of penetration and causes premature failure of the roller cone drill bit. Roller cone drill bit cutting structures and bearing systems are both susceptible to premature failure when cuttings are not promptly removed from the hole-face when drilling. As an example, cutting structures may begin to track in a pattern that prevents normal progressive drilling. Build-up of cuttings or grindings of rock may quickly erode the metal surrounding the inserts, reducing the area of retention. This may allow inserts to be released in a catastrophic failure of the drill bit. Similarly, cuttings and grinds may build-up behind journal shirttail sections causing erosion and exposure of ball-plugs and seals, also resulting in catastrophic failure of the drill bit.

[0009] The importance of optimizing drilling hydraulics in oil and gas exploration has long been known. Drill bit manufacturers provided plastic slide rules to operators and contractors for many years, allowing them to calculate the various hydraulic components. In the late 1970's, Field Engineers used programmable calculators for the same purpose. In 1980, Reed Rock Bit® introduced an interactive microcomputer program for Field Engineers planning well drilling and hydraulics programs. A goal of these calculations, however made, was the proper selection of nozzles for the drill bits.

[0010] Various theories of hydraulics optimization have been advanced in oil and gas exploration. One popular theory relies upon maximization of a calculated numeric known as Hydraulic Horsepower. Another popular theory relies upon maximization of a calculated numeric known as Jet Impact Force. Both theories depend upon calculation of the pressure losses in the drilling system and allocating the optimum amount of remaining available pressure loss through the nozzles. Utilization of the theoretical optimum available pressure loss is achieved, in part, by increasing or decreasing the velocity through the nozzles. The velocity is adjusted by changing the cross-sectional area of the nozzle through which the fluid flows. Since nozzles in conventional drilling bits are interchangeable, this is easily accomplished.

[0011] Coincident to the practice of optimizing jet nozzle selection, it is known that the distance between the nozzle exit and the hole-face is an important factor in optimizing drilling hydraulics, and thus rate-of penetration. The closer the nozzle exit to the hole-face, the better the bottom hole cleaning properties. As the nozzle exit approaches the hole-face, there is less intervening turbulent flowing drilling fluid to interfere with the cleaning action of the fluid flowing from the nozzle. Conventional drill bits are limited by manufacturing practices as to how far up nozzle bosses can be manufactured, and still allow journals to be turned on machine centers. There is also a counterbalancing constraint requirement to provide sufficient return area across the drill bit for drilling fluid and cuttings to navigate the drill bit geometry in transit to the annulus of the well bore.

[0012] In addition to proximity to the hole-face, it has been determined that the angularity with which the fluid strikes the bottom of the hole can have a substantial impact on the hydraulic cleaning of the hole-face, and thus rate-of penetration. Drill bits and formations have different physical characteristics, leaving the optimum angle of nozzle direction relegated somewhat to experimentation between drill bits and formations. Additionally, the practice of high-speed drilling in which drill bits are rotated in excess of 100 rpm can change the optimum angle of nozzle direction. There is a counterbalancing constraint in which excessive angular disposition of the nozzle may contribute to cone erosion or seal exposure.

[0013] Numerous attempts have been made to provide a commercially practical directable nozzle design, as well as extended nozzle designs. U.S. Pat. No. 6,585,063 issued to Larsen discloses a multi-stage diffuser nozzle for rolling-cutter bits. The nozzle may comprise two or more portions, including a diffuser upstream of the nozzle outlet and a multi-outlet nozzle. The nozzle must be oriented as it is inserted and fixed in a given orientation.

[0014] U.S. Pat. No. 6,571,887 issued to Nguyen et al. discloses a nozzle retention body welded to the bit body between adjacent bit legs. The nozzle retention body may be of differing configuration and orientation, but it retains a generally conventional nozzle.

[0015] U.S. Pat. No. 6,390,211 issued to Tibbitts discloses a ball-mounted nozzle for a fixed-cutter bit or a rolling-cutter bit. The nozzle body is spherical and seats in a spherical receptacle. A retainer ring is used to secure the nozzle against rotation in the seat. U.S. Pat. No. 6,186,251 issued to Butcher discloses modifying the nozzle size or orientation with the intention of modifying the force balance.

[0016] U.S. Pat. No. 5,992,763 issued to Smith et al. discloses a nozzle having an indentation adjacent the nozzle opening or exit to enhance the flow of drilling fluid entrained near the face of the nozzle. U.S. Pat. No. 5,967,244 issued to Arfele discloses an "indexed" nozzle for fixed-cutter bits. The nozzle has a grooved exterior with corresponding grooves in a lock ring.

[0017] A primary disadvantage of several of the known art designs is that they are difficult and expensive to manufacture. Several of the designs are not compatible with the nozzle boss on standard rock bits having interchangeable nozzles. When modifications to the bit itself are required, the several costs associated with non-standard designs, such as tooling and machine set-ups, further increase the cost.

[0018] Another disadvantage of several of the known art designs is the time required for assembly of the drill bits. In the drilling industry, drill bit selection decisions are often made while drilling, in response to the drilling rate achieved and the condition of the dull bit removed from the hole. Several of the known art designs require welding operations which have proven to be an impediment to their acceptance in the drilling industry.

[0019] Another disadvantage of several of the known art designs is that they are not reusable. Sintered tungsten carbide nozzles are expensive, and operators expect to be able to reuse them. When dull drill bits are removed from the well, nozzles are removed and reused or recycled.

[0020] A significant disadvantage of the known art directable nozzle designs is that they are capable of being aligned in a manner that creates excessive turbulence around the nozzle boss and seal areas, resulting in hydraulic erosion of the steel around the nozzle boss, known-as "wash-outs," and premature failure of the drill bit.

[0021] Another significant disadvantage of the known art directable nozzles is that they are capable of being aligned in a manner detrimental to the hydraulic performance of the drill bit. Still another significant disadvantage of the known art directable nozzles is that they are capable of being aligned in a manner which can result in improper alignment and premature bit failure from erosion of cones and/or exposure of journal bearing seals.

[0022] Thus it can be seen that, collectively, the known art fails to resolve the issue of a need for a directable nozzle that is inexpensive to manufacture, that is cost effective, that is easy to install, that is reusable, that has a restricted range of disposition, that avoids wash-outs, and that avoids poor hydraulic performance from misalignment.

## SUMMARY OF THE INVENTION

[0023] The present invention is a significant improvement over that described in the above enumerated known directable nozzle designs. References to the present invention are intended to refer to one of more of the various embodiments disclosed of which can be inferred from the disclosure contained herein.

[0024] A principal advantage of the present invention is that it provides a nozzle system that has a designed restricted directability. As a result of this feature, rig floor assemblies by untrained personnel can be completed without risk of various problems associated with known directable nozzle designs. A benefit of this feature is that the present invention prevents excessive nozzle angularity resulting in internal turbulence around the nozzle boss and seal areas, hydraulic erosion and premature failure of the drill bit. Another benefit of this feature is that the present invention prevents excessive nozzle angularity resulting in inefficient hydraulic performance of the drill bit. Another benefit of this feature is that the present invention prevents excessive nozzle angularity resulting in improper alignment and premature bit failure from erosion of cones and/or erosion of shirttail regions and exposure of journal bearing seals.

[0025] Another advantage of the preferred embodiment of the present invention is that it is inexpensive and easier to manufacture than conventional designs. The design is compatible with the nozzle boss on standard rock bits having interchangeable nozzles. Another advantage of the present invention is the time required for assembly of the drill bits. No welding is required, and nozzle size selections can be made at the rig floor, immediately prior to connecting the drill bit to the drill string. This is critical as optimization of the nozzle selection requires knowledge of the drilling fluid and hydraulic system parameters at the time and depth the previous drill bit is removed from the wellbore.

[0026] Another advantage of the present invention is that it is reusable. Other advantages of the present invention will become apparent from the following descriptions, taken in connection with the accompanying drawings, wherein, by way of illustration and example, an embodiment of the present invention is disclosed.

[0027] In carrying out principles of the present invention, in accordance with a preferred embodiment thereof, a directable nozzle assembly for a rotary drill bit is disclosed, having a nozzle comprising a generally spherical body, and having an extension extending from the body. A passage extends through the body and extension portions. A seal is provided for sealing the nozzle to the nozzle boss area of the rotary drill bit. A removable retainer is provided having a hollow interior, a threaded external surface, an angle limiter surface, and an interior compression surface.

[0028] In another preferred embodiment, the angle limiter surface is frustum shaped. In another preferred embodiment, the interior compression surface is spherically shaped. In another preferred embodiment, the retainer has a wrench receptacle on a first end. In still another preferred embodiment, the retainer has a second end seal surface which restricts expansion of a packing seal. In the preferred embodiment, the limiter surface of the retainer prevents misalignment between a first portal of the nozzle body and the flow port of a rotary drill bit.

[0029] In an alternative preferred embodiment, the nozzle has a first portal on the spherical body and a second portal on the extension portion. An erosion resistant hollow sleeve is provided, having a collar portion with a spherical seat for receiving the nozzle body. The sleeve also has a hollow cylindrical body portion. A seal is provided for sealing the sleeve to the nozzle boss area of the rotary drill bit. In a more preferred embodiment, the body has a tapered end. In the preferred embodiment, the angle limiter surface of the retainer prevents misalignment between the first portal of the nozzle body with the hollow center of the sleeve. Additional features are presented in detail herein below.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0030] **FIG. 1** is an isometric view of a rotary drill bit having a directable nozzle assembly installed in accordance with a preferred embodiment of the present invention.

[0031] **FIG. 2** is a top view of the rotary drill bit of **FIG. 1**, illustrating multiple directable nozzle assemblies installed in accordance with a preferred embodiment of the present invention.

[0032] **FIG. 3** is a side-sectional view of a known art interchangeable nozzle assembly installed in a rotary drill bit.

[0033] **FIG. 4** is an exploded side-sectional view of the components of a directable nozzle assembly in accordance with a preferred embodiment of the present invention, as shown in reference to a rotary drill bit.

[0034] **FIG. 5** is a side-sectional view of the preferred embodiment disclosed in **FIG. 4**, illustrating the nozzle directed in an axis parallel to the axis of the flow port of the rotary drill bit.

[0035] **FIG. 6** is a side-sectional view of the preferred embodiment disclosed in **FIGS. 4 and 5**, illustrating the nozzle directed in an axis of maximum angular relation to the axis of the flow port of the rotary drill bit.

[0036] **FIG. 7** is a side-sectional view of a directable nozzle assembly, installed in a rotary drill bit, and utilizing an erosion resistant sleeve in accordance with another preferred embodiment of the present invention.

[0037] **FIG. 8** is a side-sectional view of an extended directable nozzle assembly, installed in a rotary drill bit, utilizing an erosion resistant sleeve in accordance with another preferred embodiment of the present invention.

[0038] **FIG. 9** is a side-sectional view of a directable nozzle assembly, installed in a rotary drill bit, utilizing an erosion resistant sleeve, and having a seal disposed within the sleeve, in accordance with another preferred embodiment of the present invention

## DETAILED DESCRIPTION OF THE INVENTION

[0039] **FIG. 1** is an isometric view of a rotary drill bit **10** having a directable nozzle assembly **100** installed in accordance with a preferred embodiment of the present invention. **FIG. 2** is a top view of rotary drill bit **10** of **FIG. 1**, illustrating multiple directable nozzle assemblies **100** installed in accordance with a preferred embodiment of the present invention.

[0040] **FIG. 3** is a side-sectional view of a known art interchangeable nozzle assembly **200** installed in a nozzle boss **14** of rotary drill bit **10**. In the view, it is seen that a nozzle **210** is non-directable. Nozzle **210** is secured in fixed alignment with a flow port **12** in rotary drill bit **10**. A seal **130** is located in a groove **16** to prevent drilling fluid from bypassing nozzle **210**. Drilling fluid passes through flow port **12** of rotary drill bit **10** and then through a nozzle passage **216** of nozzle **210**. The drilling fluid enters a first portal **218** and exits a second portal **220**, which is significantly smaller in diameter than first portal **218**. Nozzle **210** is secured in position by a retainer **240**. Retainer **240** has a nozzle boss connection means for securing retainer **240** to rotary drill bit **10**. Most conventional nozzle boss connection means incorporate threaded external surfaces **244** which is thread connectable to a threaded portion **22** of nozzle boss **14** to hold nozzle assembly **200** in place.

[0041] **FIG. 4** is an exploded side-sectional view of the components of directable nozzle assembly **100** in accordance with a preferred embodiment of the present invention, as shown in reference to rotary drill bit **10**. A nozzle **110** is provided, having a spherical body portion **112**. An extension portion **114** extends from body **112**. A nozzle passage **116** extends throughout body **112** and extension **114**. Nozzle passage **116** has a first portal **118** located on body **112**. A second portal **120** is located on extension **114**.

[0042] A retainer **140** is provided, having a functionally unique structure. Retainer **140** has a nozzle boss connection means **144**. In the preferred embodiment, nozzle boss connection means **144** is a threaded external surface **144**. Retainer **140** may have a wrench receptacle **142** on its top surface, and a limiter surface **146** extends downward and inward from the top of retainer **140**. In the preferred embodiment, limiter **146** is contoured for complementary engagement with extension **114**. In a more preferred embodiment, limiter **146** forms a frustum, or conic section, for engagement with a generally cylindrical extension **114**.

[0043] A contoured compression surface **150** extends downward from limiter **146**. In a preferred embodiment, compression surface **150** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, compression surface **150** forms a spherical segment. Also in a preferred embodiment, a small chamfer **148** is located between limiter **146** and compression surface **150**.

[0044] As with conventional rotary drill bits previously described, rotary drill bit **10** has a flow port **12**. A nozzle boss **14** is formed on rotary drill bit **10** for receiving nozzle assembly **100**. In the preferred embodiment, nozzle boss **14** has a retainer connection means **22**. In the preferred embodiment, retainer connection means is a threaded portion **22** for threaded coupling to retainer **140**. A groove **16** is receivable of a seal **130**. A bore relief **20** may separate threaded portion **22** from groove **16**. A base **18** is formed at the bottom of groove **16**. A nozzle seat **24** is formed below base **18**. In the preferred embodiment, seat **24** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, seat **24** forms a spherical segment.

[0045] **FIG. 5** is a side-sectional view of nozzle assembly **100** installed in rotary drill bit **10**, illustrating nozzle **110** directed in an axis coincident to the central axis of flow port **12**, in a manner similar to the orientation of conventional nozzle assemblies, as illustrated in **FIG. 3**. **FIG. 6** is a side-sectional view of nozzle assembly **100** installed in rotary drill bit **10**, illustrating nozzle **110** directed in an axis of maximum angular relation to the central axis of flow port **12**.

[0046] **FIG. 7** is a side-sectional view of an alternative preferred embodiment of directable nozzle assembly **100**, shown installed in rotary drill bit **10**. In this embodiment, nozzle assembly **100** further includes an erosion resistant sleeve **160**. As seen in **FIG. 7**, sleeve **160** is insertable into nozzle boss **14** below nozzle **110**. Sleeve **160** has a collar **162**. Collar **162** engages base **18** of nozzle boss **14**, and resides in groove **16** in place of, or in conjunction with, seal **130**. A nozzle seat **164** is formed on collar **162**. In the preferred embodiment, seat **164** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, seat **164** forms a spherical segment.

[0047] Sleeve **160** has a body portion **170** that extends into flow port **12** beyond first portal **118** of nozzle **110**. In a more preferred embodiment, a taper **172** is inscribed on the inside diameter of body **170**. In this embodiment, a seal **180** is located in bore relief **20** of nozzle boss **14** to prevent drilling fluid from bypassing nozzle **110**. In a more preferred embodiment, seal **180** is a packing seal.

[0048] **FIG. 8** is a side-sectional of an alternative preferred embodiment of directable nozzle assembly **100**, shown installed in rotary drill bit **10**. In this embodiment, extension **114** of nozzle **110** is significantly extended. The significant extension of extension **114** is compatible with all embodiments of the present invention.

[0049] **FIG. 9** is a side-sectional view of another preferred embodiment of directable nozzle assembly **100**, shown installed in rotary drill bit **10**. In this embodiment, sleeve **160** further includes a seal groove **168** for accommodation of a seal **190**. In the preferred embodiment, seal **190** is an o-ring seal. As shown in **FIG. 9**, another o-ring seal **130** can be located in groove **16** to seal with collar **162** of sleeve **160**. However, the use of seal **190** is also compatible with the embodiments disclosed in **FIGS. 7 and 8**, in which seal **180** is located in bore relief **20**.

[0050] The foregoing detailed description is to be clearly understood as being given by way of illustration and example, the spirit and scope of the present invention being limited solely by the appended claims. In particular, and by way of example and not limitation, it is well known to use alternative nozzle boss connection means to retain nozzles in rotary drill bits other than retainers with threaded connections. Conventional nozzle assemblies alternatively include nozzles having circumferential grooves and nozzle bosses with holes. In these assemblies, a "nail" is driven into the hole in the nozzle boss, for intersection with the circumferential groove to retain the nozzle. It would be readily apparent to anyone of ordinary skill in the art that the presently disclosed inventive embodiments can be incorporated into such assemblies. For example, the top to nozzle boss **14** can be modified to function as limiter surface **146**, and multiple grooves can be formed on the surface of nozzle body **112** to accept the nail at various positions.

## OPERATION OF THE INVENTION

[0051] **FIG. 2** is a top view of rotary drill bit **10**, illustrating multiple directable nozzle assemblies **100** installed in accordance with a preferred embodiment of the present invention. In this view, it can be seen that second portals **120** are angled toward the leading surface of the cutting structures of rotary drill bit **10**. This capability is a principal objective of the present invention. However, excessive angularity may subject the cutting structure and bearing system to erosion resulting in premature failure. Likewise, excessive angular orientation can result in misalignment of flow ports **12** and first portals **118**, generating turbulence and erosion inside rotary drill bit **10**, resulting in premature failure. For these reasons and others, another principal objective of the present invention is to provide a predetermined, restricted range of angular orientation of directable nozzle assemblies **100**.

[0052] **FIG. 4** is an exploded side-sectional view of the components of directable nozzle assembly **100** in accordance with a preferred embodiment of the present invention, as shown in reference to rotary drill bit **10**. As seen in the preferred embodiment illustrated, nozzle **110** has a spherical body portion **112** that enables multidirectional rotation of nozzle **110**. This capability is best seen in reference to **FIG. 5** and **FIG. 6**.

[0053] Still referring to **FIG. 4**, extension **114** of nozzle **110** serves a dual purpose. First, extension **114** positions second portal **120** closer to the object of delivery of the drilling fluid. This is well known and documented to improve hydraulic cleaning of the bottom of the hole. Secondly, extension **114** provides an index for engaging limiter **146** of retainer **140** to provide a predetermined, restricted range of angular orientation of directable nozzles **110**. This is best seen in **FIG. 6**.

[0054] In the preferred embodiment, retainer **140** may have wrench receptacle **142** on its top surface and threaded external surface **144** for threaded and removable assembly in conventional rotary drill bits **10**. Unique to the present invention, limiter surface **146** extends downward and inward from the top of retainer **140**. In the preferred embodiment, limiter **146** is contoured for complementary engagement with extension **114**. In a more preferred embodiment, limiter **146** forms a frustum, or conic section, for engagement with a generally cylindrical extension **114**. The engagement with extension **114** with limiter **146** defines the maximum obtainable angular orientation of directable nozzles **110**. This relationship is illustrated in **FIG. 6**.

[0055] Nozzle passage **116** extends throughout body **112** and extension **114**, with first portal **118** located on body **112** for entrance of the drilling fluid, and second portal **120** located on extension **114** for exit of the drilling fluid. Second portal **120** is generally smaller in diameter than first portal **118**. The flow of the drilling fluid is thereby accelerated through nozzle passage **116**, obtaining the desired high-velocity necessary to improve the performance of the rotary drill bit **10**.

[0056] Referring again to **FIG. 4**, retainer **140** has a contoured compression surface **150** extending downward from limiter **146**. In a preferred embodiment, compression surface **150** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, compression surface **150** forms a spherical segment.

[0057] Similarly, in the preferred embodiment, rotary drill bit **10** has a nozzle seat **24** formed in nozzle boss **14** below base **18**. In the preferred embodiment, seat **24** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, seat **24** forms a spherical segment.

[0058] The geometric orientation of seat **24** is inverse to that of compression surface **150**. In this configuration, as retainer **140** is progressively threaded into nozzle boss **14** of rotary drill bit **10**, nozzle body **112** is compressed between compression surface **150** of retainer **140** and seat **24** of rotary drill bit **10**. The compressive force on nozzle body **112** maintains nozzle **110** in place, while resisting the high outward force generated in nozzle passage **116** by the flow of the drilling fluid. The force against nozzle **110** is distributed in the threaded engagement between external threads **144** of retainer **140** and threaded portion **22** of nozzle boss **14**.

[0059] As with conventional rotary drill bits previously described, nozzle boss **14** has a threaded portion **22** for threaded coupling to retainer **140**, and a groove **16** for location of a seal **130**, such as an o-ring seal. This advantageously allows convenient interchangeability between directable nozzle assembly **100** and conventional nozzle assembly **200** in rotary drill bit **10**.

[0060] **FIG. 5** illustrates nozzle **110** directed in an axis coincident to the central axis of flow port **12**, in a manner similar to the orientation of conventional nozzle assemblies, as illustrated in **FIG. 3**. **FIG. 6** illustrates nozzle **110** directed in an axis of maximum angular relation to the central axis of flow port **12**. As seen in this view, the maximum angular relation is predefined by interference between limiter **146** and extension **114**.

[0061] A principal advantage of the present invention is that by predefining the range of angular orientation of directable nozzles **110**, catastrophic failure of rotary drill bit **10** can be avoided. This is particularly important because nozzles **110** can be easily assembled on the floor of the drilling rig by persons unfamiliar with the risk of improper orientation. Another advantage of this relationship is that retainers **140** can be provided which have different limiter **146** settings, and whereas retainers **140** are identified by the angle obtained with extension **114** engaging limiter **146**. This can be used to obtain the specific angular orientation desired. The desired angle may be determined by drilling parameters and experimentation. Personnel can then select a retainer **140** identified to provide the angle, without the need for special alignment tools and gauges and training on their use.

[0062] As seen in the preferred embodiment disclosed in **FIG. 6**, limiter **146** restricts angular orientation of nozzle **110**, and contains first portal **118** within alignment of flow port **12**. Additional angularity would position first portal **118** of nozzle **110** substantially out of alignment with flow port **12**, with flow port **12** substantially blocked by nozzle body **112**. This causes at least three significant problems. First, the turbulence generated would subject nozzle boss **14** to rapid erosion from the flow of the drilling fluid. Seals **130** would fail, resulting in retainer **140** erosion, and premature failure of rotary drill bit **10**. Retainers **140** are traditionally made of steel, and are quickly eroded if exposed directly to the drilling fluid flow stream inside rotary drill bits **10**. Second, this configuration effectively reduces the orifice size of first portal **118**, disrupting the designed fluid dynamics of nozzle **110**'s design, and causing an increase in the pressure loss in the system. Third, additional turbulence is generated by the misalignment of first portal **118** and flow port **12**, causing an increase in the pressure loss in the system. These second and third affects result in a possible requirement to reduce the pump speed at the drilling rig floor to manage the pressure in the system, reducing the system flow rate, and resulting in poor performance of rotary drill bit **10**.

[0063] **FIG. 7** is a side-sectional view of an alternative preferred embodiment of directable nozzle assembly **100**. In this embodiment, nozzle assembly **100** further includes an erosion resistant sleeve **160**, designed to prevent erosion from turbulence inside flow port **12** that is unique to directable nozzle assembly **100**. Sleeve **160** is insertable into conventional nozzle boss **14** below nozzle **110**.

[0064] As with conventional rotary drill bits previously described, nozzle boss **14** has a threaded portion **22** for threaded coupling to retainer **140**, and a groove **16** for location of a seal **130**, such as an o-ring seal. This advantageously allows convenient interchangeability between directable nozzle assembly **100** and conventional nozzle assembly **200** in rotary drill bit **10**.

[0065] As seen in **FIG. 6**, as nozzle **110** is directably positioned, first portal **118** increases in proximity to one side of flow port **12**, and decreases in proximity to the opposite side of flow port **12**. Where first portal **118** is in close alignment with flow port **12**, flow is efficient and turbulence is minimized. Where first portal **118** is not in alignment with flow port **12**, a discontinuity in the flow path exists, and turbulence is generated where drilling fluid engages nozzle body **112**, instead of entering first portal **118**. This results in erosion of flow port **12**.

[0066] The above described turbulence will occur even though portal **118** is maintained within flow port **12** by engagement of limiter **146** with extension **114**. Over time, the turbulence will subject nozzle boss **14** to erosion. Seals **130** are therefore at increased risk of failure, as are retainer **140** and rotary drill bit **10**. Sleeve **160** provides an erosion resistant channel that will tolerate the turbulence generated within flow port **12**.

[0067] Referring again to **FIG. 7**, sleeve **160** has a body portion **170** that extends into flow port **12** beyond first portal **118** of nozzle **110**. The outside diameter of body **170** of sleeve **160** fits in close tolerance or slight interference fit with the inside diameter of flow port **12**. In a more preferred embodiment, a taper **172** is inscribed on the inside diameter of body **170**. Taper **172** permits a smooth transition for drilling fluid in flow port **12** entering sleeve **160**.

[0068] Sleeve **160** has a collar **162** that engages base **18** of nozzle boss **14**, and resides in groove **16** in place of, or in conjunction with, o-ring seal **130**. As rotary drill bits **10** are normally inverted for nozzle installation, this configuration allows collar **162** to suspend sleeve **160** in position while nozzle **110** is fitted into place.

[0069] A nozzle seat **164** is provided on collar **162**, providing the function and benefit of nozzle seat **24** inside nozzle boss **14**. In the preferred embodiment, seat **164** is contoured for complementary engagement with nozzle body **112**. In a more preferred embodiment, seat **164** forms a spherical segment.

[0070] The geometric orientation of nozzle seat **164** is inverse to that of compression surface **150**. In this configuration, as retainer **140** is progressively threaded into nozzle boss **14** of rotary drill bit **10**, nozzle body **112** is compressed between compression surface **150** of retainer **140** and nozzle seat **164** of sleeve **160**. The compressive force on nozzle body **112** maintains nozzle **110** in place, while resisting the high outward force generated in nozzle passage **116** by the flow of the drilling fluid. The compressive force on nozzle body **112** further secures sleeve **160** in place, compressed between nozzle **110** and base **18**.

[0071] In the preferred embodiment, nozzles **100** and sleeves **160** are made of a hard metal, such as tungsten carbide, or titanium carbide. The hardness of the hard metal nozzles provides wear resistance to the abrasive forces associated with the high-velocity flow of the drilling fluid through the constricted diameter of nozzles **100**, and the turbulence generated in the vicinity of sleeves **160**.

[0072] In the preferred embodiment disclosed in **FIG. 7**, an alternative seal configuration is also disclosed. In this embodiment, a seal **180** is located in bore relief **20** of nozzle boss **14** to prevent drilling fluid from bypassing nozzle **110**. In a more preferred embodiment, seal **180** is a packing seal.

[0073] **FIG. 9** discloses another seal configuration for use with this embodiment. In this embodiment, sleeve **160** further includes a seal groove **168** for accommodation of a seal **190**. In the preferred embodiment, seal **190** is an o-ring seal. As shown in **FIG. 9**, another o-ring seal **130** can be located in groove **16** to seal with collar **162** of sleeve **160**. However, the use of seal **190** is also compatible with the embodiments disclosed in **FIGS. 7 and 8**, in which seal **180** is located in bore relief **20**.

[0074] **FIG. 8** is a side-sectional view of directable nozzle assembly **100**, in which extension **114** of nozzle **110** is significantly extended. The significant extension of extension **114** is compatible with all of the disclosed embodiments of the present invention.

[0075] The foregoing detailed description is to be clearly understood as being given by way of illustration and example, the spirit and scope of the present invention being limited solely by the appended claims.

I claim:

**1**. A directable nozzle assembly for a rotary drill bit, comprising:

a nozzle comprising:

a generally spherical body;

an extension extending from the body; and,

a passage extending through the body and extension;

a seal; and,

a removable retainer comprising:

a hollow interior;

a nozzle boss connection means;

a limiter surface; and,

an interior compression surface.

**2**. The directable nozzle assembly of claim 1, further comprising:

wherein interference between the limiter surface and the extension limits the angular disposition of the nozzle passage relative to the retainer.

**3**. The directable nozzle assembly of claim 1, the nozzle further comprising:

a first portal formed at the intersection of the passage and the body; and,

a second portal formed at the intersection of the passage and the extension.

**4**. The directable nozzle assembly of claim 2, further comprising:

the limiter surface preventing location of the first portal beyond a flow port in a rotary drill bit.

**5**. The directable nozzle assembly of claim 1, wherein the nozzle boss connection means further comprises a threaded external surface.

**6**. The directable nozzle assembly of claim 1, the retainer further comprising:

the limiter surface being frustum shaped.

**7**. The directable nozzle assembly of claim 1, the retainer further comprising:

the interior compression surface being spherically shaped.

**8**. The directable nozzle assembly of claim 1, the retainer further comprising:

a wrench receptacle on a first end.

**9**. The directable nozzle assembly of claim 1, the retainer further comprising:

a second end seal surface; and,

wherein the seal surface restricts expansion of a packing seal.

**10**. A directable nozzle assembly for a rotary drill bit, comprising:

a nozzle comprising:

a generally spherical body;

an extension extending from the body;

a passage extending through the body and extension;

a first portal formed at the intersection of the passage and the body;

a second portal formed at the intersection of the passage and the extension; and,

a hollow sleeve comprising:

a collar having a seat receivable of the nozzle body;

a body insertable into a flow port of a rotary drill bit; and, a seal; and,

a removable retainer comprising:

a hollow interior;

a nozzle boss connection means;

a limiter surface; and,

an interior compression surface.

**11**. The directable nozzle assembly of claim 10, the sleeve further comprising:

wherein the collar of the sleeve is receivable in a seal groove of a rotary drill bit.

**12**. The directable nozzle assembly of claim 10, further comprising:

wherein the outside diameter of the body is receivable in close tolerance fit within a flow port of a drill bit.

**13**. The directable nozzle assembly of claim 10, further comprising:

wherein the outside diameter of the body is receivable in interference fit within a flow port of a drill bit.

**14**. The directable nozzle assembly of claim 10, the sleeve further comprising:

a taper at the end of the body opposite to the collar.

**15**. The directable nozzle assembly of claim 10, the sleeve further comprising:

a seal slot located in the collar.

**16**. The directable nozzle assembly of claim 10, further comprising:

wherein interference between the limiter surface and the extension limits the angular disposition of the nozzle passage relative to the retainer.

**17**. The directable nozzle assembly of claim 10, further comprising:

the limiter surface preventing location of the first portal beyond a inside diameter of the sleeve body.

**18**. The directable nozzle assembly of claim 1, wherein the nozzle boss connection means further comprises a threaded external surface.

**19**. The directable nozzle assembly of claim 10, further comprising:

wherein the sleeve is made of a material having a hardness greater than the hardness of a flow port of a rotary drill bit in which the sleeve is installed.

**20**. The directable nozzle assembly of claim 10, further comprising:

wherein the sleeve is made of tungsten carbide or titanium carbide.

**21**. A rotary drill bit, adapted for use with a directable nozzle assembly, comprising:

a flow port;

a nozzle boss connected to the flow port;

a retainer connection means;

a groove for receiving a seal; and,

a spherical segment shaped nozzle seat adapted for complementary engagement with a spherical nozzle body.

**22**. The rotary drill bit of claim 22, further comprising:

the nozzle seat being in the shape of a spherical section.

**23**. The rotary drill bit of claim 22, the retainer connection means further comprising:

an internally threaded portion.

**24**. The rotary drill bit of claim 22, further comprising:

a bore relief; and,

a packing seal located in the bore relief.

**25**. A rotary drill bit, comprising:

a flow port;

a nozzle boss connected to the flow port;

a retainer connection means;

a groove for receiving a seal;

a spherical segment shaped nozzle seat;

a seal located in the groove;

a nozzle comprising:

a spherical body complementarily engaged with the nozzle seat;

an extension extending from the body; and,

a passage extending through the body and extension; and

a removable retainer comprising:

a hollow interior;

a nozzle boss connection means connected to the retainer connection means;

a limiter surface through which the extension of the nozzle extends; and,

a spherical segment interior compression surface complementarily engaged with the nozzle body.

**26**. A rotary drill bit, comprising:

a flow port;

a nozzle boss connected to the flow port;

a retainer connection means;

a bore relief;

a groove;

a seal located in the bore relief;

a nozzle comprising:

a generally spherical body;

an extension extending from the body;

a passage extending through the body and extension;

a hollow sleeve made of wear resistant material, comprising:

a collar located in the groove of the nozzle boss;

a spherical segment shaped nozzle seat on the collar;

a body located in the flow port; and,

a hollow interior;

a nozzle boss connection means connected to the retainer connection means;

a limiter surface through which the extension of the nozzle extends; and,

a spherical segment interior compression surface complementarily engaged with the nozzle body.

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