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(54)

Drill bit assembly

(57) Various aspects provide for a drill bit assembly, which may include at least two drill bits (210, 220, 230). An inner drill bit (210) may be removably coupled to an outer drill bit (220), which may be coupled to a casing ring (230). Various apparatus and methods may be used to drill a hole (100) having two or more different diameters. The inner and outer drill bits (210, 220, 230) may be connected to a drive tube (214) to drill a hole (100) having a diameter of the outer drill bit (220) and thereafter a set able fluid (730, e.g. concrete) may be supplied to form a joint composite pillar, leaving the drill bits (210, 220, 230) and drive tube (214) to form reinforcement, preferably also a casing (234). The inner drill bit (210) may be decoupled from the outer drill bit (220) to drill a hole (120) (e.g., an extension of the first hole) having a diameter of the inner bit (e.g., smaller than that of the outer drill bit), prior to supplying the set able fluid (730).

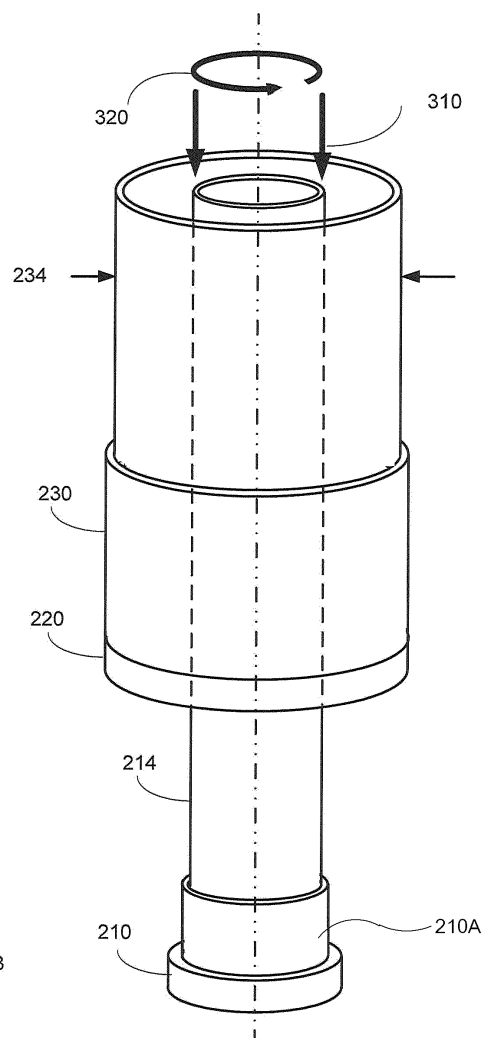


FIG. 3

Description

BACKGROUND

Technical Field

[0001] The present invention relates generally to applying torque and thrust to a shaft, and more specifically to drilling a hole having a varying diameter.

Background

[0002] Various arts require a hole having different diameters at different depths. One portion of a hole may have a diameter larger than that of another portion. Often (e.g., when the lengths of the respective portions are not known) drilling such a hole requires the use of multiple drill bits and sequential steps. Typically, a first portion is drilled with a first bit having a first diameter, and then the next portion is drilled with a second bit having the second diameter. Such a multi-step process may add cost, particularly when the boundary between the two portions is very deep relative to the diameter of the hole (e.g., as in an oil or gas well in the earth). Maintaining concentricity and tolerances using long, narrow tools designed for such holes may be challenging.

[0003] In some applications, a hole may have a first depth (e.g., through soft soil) having a width that is wide enough to accept a casing (e.g. to hinder soft soil from entering into the drill hole). A deeper (and possibly smaller diameter) hole may be drilled through bedrock below the soil. Maintaining concentricity of such a sequentially drilled hole having coaxial and different diameters may be challenging and time consuming.

[0004] From WO9700371 and WO9618798 there are known drilling methods according to the latter principle, wherein by means of reverse rotation an inner drill bit may be disengaged from the drill assembly to continue drilling of a hole with smaller diameter. However, these methods make use of down the hole hammers, which may be undesired, as such. Furthermore, it implies a cumbersome retraction of the drill string to regain the hammer.

SUMMARY OF THE INVENTION

[0005] A drill bit assembly may be configured for use with a drive tube and optionally a casing. The drill bit assembly may include an inner bit and an outer bit. The inner bit may be sized to be bonded to the drive tube, which applies torque and thrust to the inner bit, and thrust applied from a top hammer arrangement. The inner and outer bits may be removably coupled with a drill coupling. The drill coupling may be configured to transmit torque and thrust from the inner bit to the outer bit, to enable drilling with both inner and outer bits. The drill coupling may be configured to disengage the inner bit from the outer bit, such that torque and thrust may be applied to

the inner bit alone, thereby allowing subsequent continued drilling without the need to engage new equipment or to restart the drilling operation from the ground level.

[0006] The outer bit may be coupled to a casing ring.

5 The outer bit and casing ring may be coupled using a thrust ring that provides for the transmission of thrust between the outer bit and the casing ring. In some configurations, the thrust ring is configured to allow rotation of the outer bit while the casing ring does not rotate. The casing ring may be bonded to a casing, and drilling using the inner and outer bits may include rotating the bits while the casing ring and casing do not rotate. In some implementations the casing ring may rotate.

10 **[0007]** A method may comprise drilling a hole having different diameters at different depths. A first portion may be drilled using both an inner and outer bit of a drill bit assembly. The bits may be pulled in reverse a small amount, after which a frictional force on the casing, casing ring, and/or outer bit may hold the outer bit as the inner bit is counter rotated. The inner bit may then be disengaged from the outer bit by counter rotating it a small amount, then the inner bit may be pushed forward to clear the outer bit. Subsequent drilling may use only the inner bit, yielding a deeper portion having a smaller diameter than the first portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

30 FIG. 1 illustrates a cylindrical hole having two different diameters at different depths, according to some embodiments.

FIG. 2 illustrates exemplary components of a drill bit assembly, according to some embodiments.

35 FIG. 3 illustrates a setup for operating a drill bit assembly, according to some embodiments.

FIGS. 4A and 4B illustrate a portion of an exemplary drill coupling, according to some embodiments.

40 FIGS. 5A and 5B illustrate a portion of a drill coupling, according to some embodiments.

FIGS. 6A and 6B are cross section illustrations of engaged and disengaged configurations, according to some embodiments.

45 FIGS. 7A and 7B illustrate a plan view of a coupling in engaged and disengaged configurations (respectively), according to some embodiments.

FIGS. 8A and 8B show a schematic view and a description respectively for drilling a hole having multiple diameters, according to some embodiments.

FIG 9 illustrates a perspective illustration of an exemplary drill bit assembly, seen from above, according to some embodiments, expanded for clarity

50 FIG. 10 illustrates a view from below of a drill bit assembly, according to fig 9, expanded for clarity, and,

FIGS 11A-C show the latter embodiment assembled, in perspective from above, from below and in

cross section respectively.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Various aspects provide for a drill bit assembly, which may include at least two drill bits. An inner bit may be coaxial with and removably coupled to an outer bit having a larger diameter than that of the inner bit. The outer bit may be coaxial with and coupled to a casing ring. The casing ring may attach the drill bit assembly to a casing. A drive tube (hollow or solid) may apply angular and thrust forces to the inner bit, which may, in an engaged configuration, apply similar forces to the outer bit. The outer bit may apply thrust forces to the casing ring, and in some embodiments, the outer bit does not apply substantial torque to (e.g., enough torque to cause rotation of) the casing ring.

[0010] In a disengaged configuration, the inner bit may rotate and/or move forward or backward independently of the outer bit. Various apparatus and methods may be used to drill a hole having two or more different diameters. In some aspects, the inner and outer bits are first driven together, to drill a hole having the diameter of the outer bit. The inner bit may then be disengaged from the outer bit, and be driven by the drive tube to drill a second, deeper portion, having a smaller diameter than that portion drilled by the outer bit.

[0011] FIG. 1 illustrates a cylindrical hole having two different diameters at different depths, according to some embodiments. A cylindrical hole 100 may have an upper portion 110 having a first diameter 112 that descends to a first depth 114, and a lower portion 120 having a second diameter 122 (e.g., 1-90%, including 5-80%, including 10-80%, including 20-70% smaller than first diameter 112) that descends a second depth 124. Hole 100 may be defined by a central axis 130, and upper portion 110 and lower portion 120 may be coaxial. "Coaxial" may be a relatively local term (e.g., as in a hole that gradually curves over a distance through the earth).

[0012] Some holes incorporate a casing (e.g., to prevent collapse when the hole is drilled through soft earth). In FIG. 1, a first casing 116 encases upper portion 110. In some cases, a second casing 126 may encase lower portion 120. Some holes may include only one casing; some holes may include multiple casings. Some holes may not have a casing.

[0013] FIG. 2 illustrates exemplary components of a drill bit assembly, according to some embodiments. Drill bit assembly 200 may include an inner bit 210, coupled to an outer bit 220, which is coupled to a casing ring 230.

[0014] Drill bit assembly 200 may be designed to work with various other drilling apparatus, such as casings, drive shafts, impact hammers, collars, drill rigs, and the like. In some embodiments, inner bit 210 may have a diameter (e.g., inner diameter 212) sized to attach or bond to a hollow drive tube 214. In an exemplary implementation, a drive tube 214 is threaded onto inner bit 210 at a drilling site, and then subsequent drive tubes are

sequentially connected, by use of connectors 214A, as the hole is drilled further and further down with the drill bit 210. In some embodiments, a drive tube may also be used as a casing. Casing ring 230 may have a diameter (e.g., an inner diameter 232) sized to bond or attach to a casing 234. In an exemplary implementation, casing 234 is welded to casing ring 234 at a drilling site, and additional casings may be added sequentially as drilling proceeds. Outer bit 220 may have an outer diameter (not shown) that is substantially the same as that (e.g., within 5%, 1 %, or even 0.1%) of casing ring 230. In some cases, outer bit 220 may have a slightly larger diameter (e.g., 0.1%, 0.5%, 1 %, or even 5% larger) than casing ring 230, which may provide for a "wide open" hole through which casing ring 230 passes. Outer bit 220 may be slightly smaller (e.g., 0.1%, 0.5%, 1 %, or even 5% smaller) than casing ring 230, which may provide for a "tightly fitting" hole for casing ring 230 (e.g., in soft or sandy earth). Outer bit 220 may include a contact height 222, that combines with the outer diameter of outer bit 220 to define a circumferential contact area between outer bit 220 and a material through which outer bit 220 drills.

[0015] FIG. 3 illustrates a setup for operating a drill bit assembly, according to some embodiments. Drilling may be described as a combination of thrust force 310 and torque 320 applied to a drill bit. A forward thrust force applied to inner bit 210 via drive tube 214 may push inner bit 210 in a "downward" direction, and a reverse thrust force may pull inner bit 210 in an "upward" direction. A torque may spin drive tube 214 and inner bit 210 about axis 130 (e.g., clockwise or counterclockwise, per the design of the drill bit assembly). The thrust 310 and torque is preferably applied by means of a top hammer assembly 99 (known per se, see FIG. 8A).

[0016] Inner bit 210 and outer bit 220 may be removably coupled. In an engaged configuration (not shown), a torque applied to inner bit 210 may be transmitted to outer bit 220, and a thrust force applied to inner bit 210 may be transmitted to outer bit 220. When disengaged from outer bit 220, inner bit 210 may rotate, move forward, or move in reverse independently of outer bit 220.

[0017] Outer bit 220 and casing ring 230 may be coupled in a manner that transmits certain forces while minimizing the transmission of other forces. Outer bit 220 and casing ring 230 may be coupled by a thrust bearing (e.g., a journal bearing), such that outer bit 220 does not apply torque (or only applies a small amount of torque) to casing ring 230. In an exemplary embodiment, a thrust force applied by inner bit 210 to outer bit 220 is transmitted to casing ring 230 by outer bit 220, which may result in outer bit 220 "pulling" a casing 234 down the hole (and/or outer bit 220 may be "pushed" downward by an apparatus, e.g. top hammer assembly, pushing on casing 234 at the surface). A torque may be minimally transmitted between outer bit 220 and casing ring 230, such that friction between the casing 234 and the ground does not impede the rotation of the drill bits. In such cases, outer bit 220 may rotate while casing ring 230 (and casing 234,

if bonded to casing ring 230) does not rotate, and casing ring 230 and outer bit 220 move together in forward and reverse. A lubricant (e.g., graphite, MoS_2) may reduce friction (e.g., in a thrust bearing) and may ease disengagement of an inner bit from an outer bit. In some cases, outer bit 220 may be bonded to casing ring 230.

[0018] FIGS. 4A and 4B illustrate a portion of an exemplary drill coupling, according to some embodiments. A drill coupling may removably couple an inner bit to an outer bit. In exemplary FIGS. 4A and 4B, drill coupling 400 may removably couple inner bit 210 to outer bit 220 via one or more male teeth on one bit (in this case, the outer bit) that engage with corresponding female teeth on the other bit (in this case, the inner bit). FIG. 4A illustrates drill coupling 400 in a disengaged configuration, in which inner bit 210 may move vertically independent of outer bit 220. FIG. 4B illustrates drill coupling 400 in an engaged configuration, in which thrust and a torque (in this case, counterclockwise as viewed from above) may be transmitted from inner bit 210 to outer bit 220. When inner bit 210 and outer bit 220 are engaged, drilling forces may be transmitted from a drive tube to outer bit 210 via inner bit 210, causing both inner bit 210 and outer bit 220 to rotate and drill downward. In the configuration shown in FIG. 4B, forward, reverse, and counterclockwise rotation forces may be transmitted from inner bit 210 to outer bit 220.

[0019] A drill coupling may include one or more male teeth 410 and a corresponding number of female teeth 422. A drill coupling may include 1, 2, 3, 4, 6, 8, 10, or even more pairs of teeth. In some applications, a drill coupling includes at least 3 pairs of teeth and at most 12, including 8, and preferably 6 pairs of teeth. Male teeth 410 may be sized to fit within corresponding cavities 420 in female teeth 422. Male teeth 410 and female teeth 422 may be disposed periodically around the facing circumferences of outer bit 220 and inner bit 210. In some cases, a first pair of male and female teeth is sized differently than another pair (e.g., the other pairs) to control of rotational alignment between the inner and outer bits. In some cases, the pairs of male and female teeth are interchangeable.

[0020] An inner bit may include male teeth that engage with the corresponding female teeth of an outer bit. An inner bit may include female teeth that engage with the corresponding male teeth of an outer bit. In exemplary drill coupling 400, male teeth 410 extend radially inward from an inside circumference of outer bit 220, and inner bit 210 includes corresponding female teeth 422 extending radially outward. Each cavity 420 and its corresponding male tooth 410 is sized such that the male tooth 410 may move into or out of its corresponding cavity 420 as inner bit 210 rotates with respect to outer bit 220. A tooth need not be explicitly defined. For example, a male tooth may move into a cavity within a corresponding bit in which the cavity is not disposed in a female "tooth" *per se*.

[0021] Male tooth 410 may have a male tooth width 412 (e.g., an angular width) that is smaller than a gap

460 between adjacent female teeth 422 (of which only one is shown in FIGS. 4A and 4B). Similarly, a female tooth 422 may have a female tooth width 424 that is smaller than the gap between two adjacent male teeth 410 (only one of which is shown). As a result, inner bit 210 may be rotated with respect to outer bit 220 (or *vice versa*) to a point at which male teeth 410 exit the cavities 420 of female teeth 422, allowing inner bit 210 to move forward or reverse (e.g., up or down) with respect to outer bit 220 (e.g., as in FIG. 4A). Subsequently, inner bit 410 may be moved forward or reverse, to a distance at which male teeth 410 and female teeth 422 do not engage with each other, and inner bit 210 may rotate independently of outer bit 220.

[0022] Male teeth 410 may engage with female teeth 422 when the male teeth are positioned within their corresponding cavities. FIG. 4B illustrates drill coupling 400 configured to engage inner bit 210 with outer bit 220, and to transmit thrust and torque between inner bit 210 and outer bit 220. Torque may be transmitted from inner bit 210 to outer bit 220 via an application of angular force from torque face 450 (of cavity 420 in female tooth 422, FIG. 4A) to corresponding torque face 452 of male tooth 410 (FIG. 4A). As shown in FIG. 4B, an overlap between the matching torque faces may define a torque area 454, through which inner bit 210 (when rotated counterclockwise as viewed from above) may apply a torque to outer bit 220.

[0023] As shown in FIG. 4A, cavity 420 in female tooth 422 includes a forward face 430, which transmits a forward thrust force to a corresponding forward face 432 of tooth 410 when tooth 410 is within cavity 420 (e.g., as in FIG. 4B). An overlap between these faces may define a thrust area 434 (FIG. 4B), which describes a surface through which (in this case, forward) thrust is transmitted from inner bit 210 to outer bit 220. A reverse face 440 in cavity 420 (FIG. 4A) may transmit a reverse thrust from inner bit 210 to outer bit 220 via a corresponding reverse face 442 on tooth 410, and an overlap between these faces may define a thrust area (not shown) associated with reverse thrust.

[0024] In some embodiments, forces may be transmitted between inner bit 210 and outer bit 220 (via engaged teeth) using substantially (e.g., greater than 95%, 99%, or even 99.9%) normal forces across matching faces, without appreciable shear forces across these faces. A vector that defines a thrust face may be within 5%, 1 % or even 0.1 % of an expected drilling direction (e.g., downward). A torque face may be within 5%, 1 % or even 0.1 % of coplanar with the expected drilling direction. A vector that defines a torque face may be orthogonal to an axis 130 that defines an expected drilling direction. Shear forces may be additionally reduced using a lubricant. By transmitting force from inner bit 210 to outer bit 220 using normal forces, residual deformations that tend to attach the bits to each other (when unloaded) may be minimized. As a result, large forces may be applied during drilling, yet the inner and outer bits do not "wedge together," and

removal of these forces may yield easy disengagement of the inner and outer bits. In some embodiments, the engagement of inner bit 210 and outer bit 220 by normal forces (e.g., without shear stresses across the interfaces between the bits) results in an engagement that is easily loosened (e.g., inner bit 210 may be angularly reversed while outer bit 220 remains stationary) even when frictional forces holding outer bit 220 are small. In some embodiments, a lifting force is applied to the inner bit 210, which may transmit the lifting force to the casing 234 via casing ring 230 to create a counter acting frictional force, facilitating loosening of the inner bit 210. A contact height 222 of outer bit 220 (FIG. 2) may be chosen according to an expected friction between the outside surface of outer bit 220 and the material through which outer bit 220 drills. For lower friction or a weak material (e.g., soil), and/or if a short casing is expected, contact height 222 may be increased enough to ensure that friction between the material and outer bit 220 is sufficient to hold outer bit 220 as inner bit 210 is rotated to disengage from outer bit 220. In an application in which a wider hole is drilled through a weak material (e.g., soil), followed by a more narrow hole drilled through a stronger (or more tightly gripping) material (e.g., rock), outer bit 220 may be operated to drill a short distance into the stronger material. Drilling outer bit 220 into the rock may make it easier to disengage inner bit 210 from outer bit 220, and may improve sealing between a casing and the weak material.

[0025] A hole having a diameter defined by the diameter of outer bit 220 may be drilled using both inner bit 210 and outer bit 220. By disengaging inner bit 210 from outer bit 220, the hole may be extended deeper to create a lower portion having a diameter defined by the diameter of inner bit 210.

[0026] Engaged bits may be disengaged via a series of steps. Having drilled a hole to a first depth with both (engaged) bits, a reverse thrust may be applied to the engaged inner and outer bits (e.g., disposed as in FIG. 4B). The drill bit assembly (incorporating drill coupling 400 and casing 234) may then be moved in reverse (e.g., pulled upward) to a distance that is greater than the sum of height 470 of female bit 422 above forward face 432 (FIG. 4A) and height 414 of male tooth 410. Subsequently, inner bit 210 may be rotated in reverse, an angular distance greater than the depth to which male teeth 410 engage with cavities 420, and less than a distance 460 at which male teeth 410 would contact adjacent female teeth 422 (e.g., until male teeth 410 exit their corresponding cavities 420). Rotation may then be stopped, and inner bit 210 may be thrust forward (while outer bit 220 remains stationary) a distance greater than the sum of height 414 of male tooth 410 and height 470 of female tooth 422, so that the female teeth 422 are "below" or "past" male teeth 410. Inner bit 210 may then be rotated independently of outer bit 220, and drilling may continue using inner bit 210. In some embodiments the casing 234 (with the casing ring 230 and outer bit 220) may be subsequently pushed downward (from an apparatus above)

to abut and seal against the bottom of the outer hole.

[0027] FIGS. 5A and 5B illustrate a portion of a drill coupling, according to some embodiments. Drill coupling 500 illustrates an example in which male teeth 510 extend radially outward from an outer circumference of inner bit 210 (not shown). Male teeth 510 removably disengage with corresponding cavities 520 in female teeth 522, that may extend radially inward from outer bit 220. Inner bit 210 may be rotated to cause engagement between male teeth 510 and female teeth 520 (clockwise from above as shown in FIG. 5A). Inner bit 210 may be rotated to disengage male teeth 510 from female teeth 520 (as shown in FIG. 5B), allowing for upward or downward motion of inner bit 210 with respect to outer bit 220. When engaged (as in FIG. 5A) drill coupling 500 may transmit thrust and (in this case, clockwise) torque from inner bit 210 to outer bit 220. After reaching a desired depth, inner bit 210 may be rotated counterclockwise to disengage male teeth 510 from cavities 520 (e.g., as in FIG. 5B). Inner bit 210 and teeth 510 may then be thrust forward without rotation, until male teeth 510 clear female teeth 522 (e.g., by moving inner bit 510 forward a distance greater than the sum of a lower height 570 of female tooth 522 and the height 572 of male tooth 510). Rotation of inner bit 210 may then resume without causing rotation of outer bit 220.

[0028] FIGS. 6A and 6B are cross section illustrations of engaged and disengaged configurations, according to some embodiments. In FIG. 6A, drill bit assembly 600 may have drill coupling 400 configured to engage inner bit 210 and outer bit 220. In FIG. 6B, drill bit assembly 600 may have drill coupling 400 configured to disengage inner bit 210 from outer bit 220 (e.g., to allow inner bit 210 to move downward independent of outer bit 220).

[0029] Outer bit 220 may be coupled to casing ring 230 via a thrust ring 610. Thrust ring 610 may include a ring extending radially from one of outer bit 220 and casing ring 230, sized to fit within an annular groove in the other of outer bit 220 and casing ring 230. In some embodiments, an outer surface of inner bit 210 and an inner surface of outer bit 220 may have facing grooves, and a thrust ring may be disposed within the grooves to transmit thrust between the bits (e.g., as a piston ring is disposed within a piston).

[0030] Thrust ring 610 may provide for the transmission of a forward and/or reverse thrust force between outer bit 220 and casing ring 230. Thrust ring 610 may be shaped to minimize the transmission of torque from outer bit 220 to casing ring 230, such that outer bit 220 may rotate while casing ring 230 does not rotate. A thrust ring may include a "male" feature (e.g., a ring extending from a surface) and a corresponding "female" feature (e.g., a race within which the ring slides). In some implementations, a thrust ring and/or casing ring may be cut or split longitudinally and stretched to fit around outer bit 220; it may then be welded along the cut.

[0031] In some implementations, casing ring 230 may be connected to a casing 234 via a bond 620. Drive tube

214 may be connected to inner bit 210 via a bond 622, wherein preferably the inner bit 210 is arranged with an upwardly protruding annular collar 210A having an inner diameter adapted to fit the outer diameter of the front end 214A of the drive tube 214, to enable overlapping introduction of the front end 214A of the drive tube 214 within the annular collar 210A of the inner bit 210. A bond may include a weld, one or more bolts, an adhesive, a threaded fitting, a rivet, and the like. A bond may provide for the transmission of angular (e.g., torque), shear and thrust forces between bound objects. In an exemplary implementation at a drilling site, drive tube 214 may be threaded into inner bit 210, and casing ring 230 may be welded to casing 234.

[0032] FIG. 6A illustrates fittings 630, that may be sized to receive cutting tool inserts 632. An exemplary cutting tool insert may include a tool steel, a carbide, a nitride, a cemented carbide or carbonitride, a diamond or diamond-like-carbon composite, or coatings thereof.

[0033] FIG. 6A illustrates a drilling fluid passage 640 in inner bit 210. Passage 640 may provide for fluid communication between an interior volume (e.g., of inner bit 210 and drive tube 214) and an exterior side (e.g., the drilling face) of inner bit 210. In some cases, an exterior passage 650 provides for fluid communication between the exterior side and a volume between drive tube 214 and casing 234, whereby preferably said exterior passages 650 include outlet openings 650A arranged at the outside of the collar portion 210A of the inner bit 210.

[0034] The engaged configuration shown in FIG. 6A may be operated to rotate both inner bit 210 and outer bit 220 while casing ring 230 and casing 234 do not rotate (e.g., if they are held by friction with the earth). FIG. 6B illustrates a disengaged configuration of drill bit assembly 600, in which inner bit 210 has been disengaged from outer bit 220. Inner bit 210 may continue to drill while outer bit 220 remains stationary. A difference in diameter between that of inner bit 210 and that of outer bit 220 may yield a corresponding difference in hole diameter as inner bit 210 descends past outer bit 220.

[0035] FIGS. 7A and 7B illustrate plan views (from above) of a coupling in engaged and disengaged configurations (respectively), according to some embodiments. Female teeth 422 (of which only one is shown) have cavities 420 shaped to engage with male teeth 410. A total thrust area may describe the sum of the thrust areas 434 between the thrust surfaces of corresponding male and female teeth. A total torque area may describe the sum of the torque areas between the torque faces of corresponding male and female teeth (not shown). Increasing the number of teeth (at constant height) may increase the torque area. Decreasing the number of teeth (and increasing tooth width) may increase the thrust area. The relative ratio of thrust area to torque area may be chosen according to the requirements of the site to be drilled. A configuration having more teeth may have higher torque area and lower thrust area. A configuration having fewer teeth may have lower torque area and higher thrust area.

Tooth and cavity height may be increased to increase torque area.

[0036] In FIG. 7A, female teeth 422 are disengaged from male teeth 410, and inner bit 210 may move forward or reverse (in/out of the page) with respect to outer bit 220. In FIG. 7B, male teeth 410 are disposed within cavities 420 of female teeth 422, and thrust and (in this case, clockwise) torque may be transmitted from inner bit 210 to outer bit 220.

[0037] An outer passage 650 may provide for fluid communication between inner passage 640 and a gap 710 between adjacent pairs of engaged teeth. Gap 710 may be defined by a distance 712 between a side of a female tooth 422 and the facing side of an adjacent male tooth 410 when the drill coupling is engaged, and a distance between the outside of inner bit 210 and inside of outer bit 220.

[0038] Passage 640 may be in fluid communication with a volume within drive tube 214 (FIG. 3), and passage 650 may provide fluid communication from passage 640 to gap 710. Gap 710 may be in fluid communication with the volume between drive tube 214 and casing 234 (FIG. 6) which may extend to the surface of the material being drilled. Gap 710 may form at least a portion of a passage (e.g., passage 650). In some applications, a drilling fluid (e.g., air, water, mud, and the like) is pumped down through an interior of the drive tube, through passage 640 to the drilling face, then up through a passage 650 comprising gap 710 to the volume between the drive tube and the casing (and if desired, back to the surface). Fluid may be pumped in the opposite direction.

[0039] In certain embodiments, various passages may be filled (e.g., with cement, concrete, and the like) by pumping a settable fluid. As shown in FIG. 8A concrete 730 may be pumped down drive tube 214 as air escapes up through the volume between drive tube 214 and casing 234. Concrete may possibly also be pumped down through the volume between drive tube 214 and casing 234 as air escapes up through drive tube 214 (or vice versa). Concrete 730 may be pumped until it fills both the interior of drive tube 214 and the volume between drive tube 214 and casing 234. The concrete may set, to form a composite pillar having concrete reinforced by (e.g., steel) drive tube 214 and casing 234. In some embodiments, a surface (e.g., an exterior of a drive tube and/or an interior of a casing) may have a pattern or texture (e.g., ridges, grooves, knobs, and the like) that grip or otherwise reinforce the material filling the volume bounded by that surface. Accordingly the drill bits 210, 230 will then also remain as integrated parts of such a pillar.

[0040] FIG. 8A describes a method for drilling a hole having multiple diameters, according to some embodiments, e.g. to make a composite pillar as shown in FIG. 8A. Method 800 includes steps 810, 820, 830, 840, and 850. In step 810, a hole 100 is drilled with a drill bit assembly 201, 230 configured to drill with both inner and outer bits. In step 820, the drill bit assembly is pulled

upward (reverse) a distance large enough that the male teeth on one bit will clear the female teeth on the other bit. In step 830, the inner bit is counter-rotated a short distance (e.g., less than gap 460) to disengage the male teeth from their corresponding female teeth. In step 840, the inner bit is thrust downward (forward) a distance large enough that the male and female teeth clear each other. In step 850, drilling continues with only the inner bit to form a hole 120 of a smaller diameter. A drilling fluid (e.g., air) may be pumped during various steps. In an optional step (not shown), concrete 730 may be pumped (e.g., down the drive tube) to fill a casing bonded to the casing coupling of the drill bit assembly and/or the drive tube driving the inner bit.

[0041] FIG. 9 illustrates a perspective illustration of an exemplary drill bit assembly, according to some embodiments. Drill bit assembly 900 includes an inner bit 210, an outer bit 220, and a casing ring 230. In exemplary drill bit assembly 900, outer bit 220 includes four pairs of male teeth 410 that engage with cavities 420 in corresponding and female teeth 422. FIG. 9 illustrates drill bit assembly 900 as viewed from above, with the various components "expanded" for clarity. In some implementations, a drill bit assembly may be assembled by cutting a casing ring (e.g., longitudinally) and fitting the casing ring around the outer bit (e.g., as a piston ring is fit into a corresponding race in a piston). A casing ring may be subsequently welded or otherwise bonded across the cut, typically in a manner that does not impede the performance of thrust ring 610.

[0042] FIG. 10 illustrates another view of a drill bit assembly, according to some embodiments. FIG. 10 illustrates a view of drill bit assembly 900 as viewed from below, expanded for clarity. In some embodiments, a face of a tooth may include a divot 1010. Divot 1010 may be a machining feature that (inter alia) removes portions of a torque face that would be non-parallel with corresponding portions on a facing tooth or cavity. Divots 1010 may minimize the creation of shear forces between male and female teeth, which may reduce undesired binding or wedging during use. FIG. 10 also illustrates corresponding male and female features of thrust ring 610.

[0043] FIGS. 11A, 11B, and 11C illustrate various views of a drill bit assembly, according to some embodiments. FIG. 11A illustrates drill bit assembly 900 in an "assembled" configuration. At a drilling site, a drive tube may be attached to inner bit 210, and optionally a casing may be attached to casing ring 230. FIG. 11B illustrates a plan view (from below, facing opposite the drilling direction) of drill bit assembly 900. FIG. 11B provides additional illustration for an exemplary embodiment in which passages 640 and 650 provide for fluid communication between the volume within a drive tube and the volume between the drive tube and a casing (see FIG. 3). FIG. 11C illustrates an assembled drill bit assembly 900 as viewed in cross section, according to the section "A" shown in FIG. 11B.

[0044] The above description is illustrative and not re-

strictive. Many variations of the invention will become apparent to those of skill in the art upon review of this disclosure. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.

10 Claims

1. A drill bit assembly (200, 900) comprising:

an inner bit (210, 210);
an outer bit (220, 220) coupled to the inner bit (210, 210) via a drill coupling (400, 500); and
a casing ring (230, 230) coupled to the outer bit (220, 220) via a thrust ring (610),
wherein the drill coupling (400, 500) may be operable to engage the inner bit (210,210) with the outer bit (220, 220) or disengage the inner bit (210,210) from the outer bit (220, 220) and the drill coupling (400, 500) comprises a pair of teeth,
preferably a plurality of pairs, the pair comprising:

a male tooth (410, 510) extending radially from one of the inner and outer bits (210, 220) toward the other of the inner and outer bits (210, 220), the male tooth (410, 510) having a male thrust face (432) and a male torque face (452);
a female tooth (422, 522) extending radially from the other of the inner and outer bits (210, 220) toward the bit (210, 220) having the male tooth (410, 510); and
a cavity (420, 520) in the female tooth (422, 522), the cavity (420, 520) defined at least in part by a female thrust face (430) and a female torque face (450), the cavity (420, 520) sized to receive the male tooth (410, 510) and create a thrust area (434) to transmit a thrust (310) from the inner bit (210,210) to the outer bit (220, 220), and a torque area (454) to transmit a torque (320) from the inner bit (210,210) to the outer bit (220, 220), **characterized in that** the inner bit (210,210) is sized to be bonded to a drive tube (214), and the casing ring (230, 230) is sized to be bonded to a casing (234), wherein the drive tube (214) is arranged to transmit torque and thrust to the drill assembly (200,900) by means of a top hammer.

2. The assembly of claim 1, wherein the female teeth (422, 522) are separated by a gap (460) that is larger

than a width (412) of the male teeth (410, 510).

3. The assembly of claim 2, wherein the gap (460) extends past a height (470) of the female teeth (422, 522) above the thrust face (432).
4. The assembly of any of the preceding claims, wherein the thrust ring (610) transmits a thrust (310) between the outer bit (220, 220) and the casing ring (230, 230).
5. The assembly of any of the preceding claims, further comprising a drilling fluid passage (640) in the inner bit (210,210) that provides for fluid communication with the inner space of the drive tube (214) through a drilling face of the inner bit (210,210) and an exterior passage (650) that provides for fluid communication between drilling fluid passage (640) and a volume between inner bit (210,210) and outer bit (220, 220).
6. The assembly of any of the preceding claims, further comprising a gap (710) between the inner bit (210,210) and the outer bit (220, 220), the gap (710) defined at least in part by a first distance (714) between inner bit (210,210) and outer bit (200) and a second distance (712) between a first side of a female tooth (422, 522) and a second side of a male tooth (410, 510) that is facing the first side.
7. The assembly of any of the preceding claims, wherein:

a first volume is defined at least in part by an interior surface of the inner bit (210,210);

a second volume is defined at least in part by an exterior surface of the inner bit (210,210) and an interior surface of the outer bit (220, 220); and the first and second volumes are in fluid communication via one or more passages and gaps in at least one of the inner bit (210,210) and outer bit (220, 220).
8. The assembly of any of the preceding claims, further comprising a divot (1010) associated with at least one of the male or female teeth.
9. A method for producing a composite pillar, using an assembly defined in any preceding claim, the method comprising:

drilling a hole (100) using a drive tube (214) bonded to a drill bit assembly (210, 220, 230) according to any of the preceding claims;

supplying a set able fluid (730) down into the hole (100), and filling at least one annular space outside of the drive tube (214) from the drill bit assembly up to the ground level,

allowing the fluid (730) to settle to form a composite pillar together with the drill bit assembly (210, 220, 230) and the drive tube (214).

10. A method according to claim 9, wherein further:

prior to supplying a set able fluid (730), disengaging the inner bit (210,210) from the outer bit (220, 220) using the drive tube (214); and drilling a lower hole portion (120) having a smaller diameter (122) than the upper portion (110) of the hole (100) using the inner bit (210,210).
11. A method according to claim 10, wherein disengaging comprises:

pulling the drill bit assembly (210, 220, 230) a first distance in reverse;

counter-rotating the inner bit (210); and pushing the inner bit (210) forward a second distance that is greater than the first distance, wherein the first distance is at least a sum of a first height (414, 572) and a second height (470, 570), the first height (414, 572) of a male tooth (410, 510) associated with the drill coupling (400, 500) and the second height (470, 570) between the male tooth (410, 510) and a surface of a corresponding female tooth (422, 522) associated with the drill coupling (400, 500).
12. A method according to any of claims 9- 11, wherein supplying the set able fluid (730) is achieved first via the inner of the drive tube (214) and then via the drill bit assembly (210, 220, 230) to thereafter achieve a subsequent filling upwardly of the volume outside of the drive tube (214).
13. A method according to claim 12, wherein the set able fluid (730) is supplied via a plurality of outlet holes (640) and passage ways (650) of the inner bit (210), wherein preferably each outlet hole communicates with two passageways (650).
14. A method according to claim 13, wherein the outlets (650A) of said passage ways (650) are arranged at the outside of a collar portion (210A) of the inner bit (210).
15. A method according to claim 12 or 13, wherein a casing tube (234) is used whereby the subsequent filling includes filling a volume between the drive tube (214) and the casing tube (234).

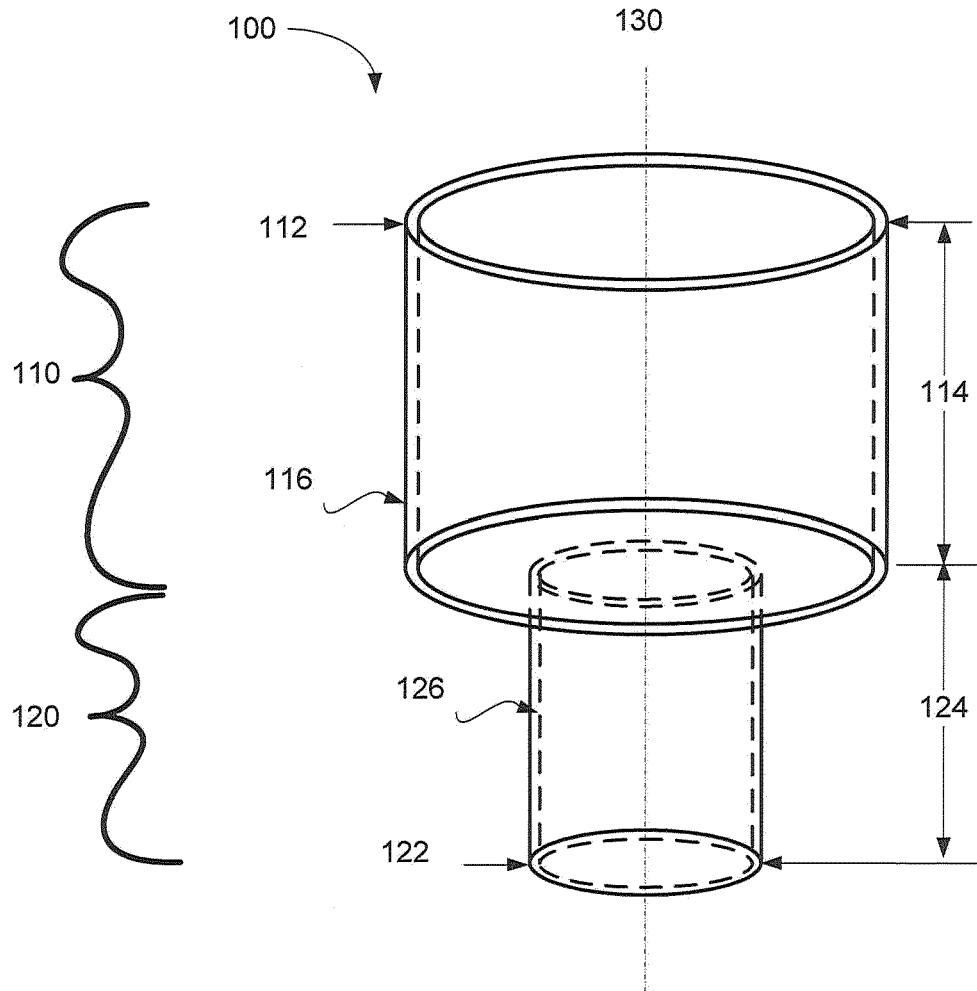
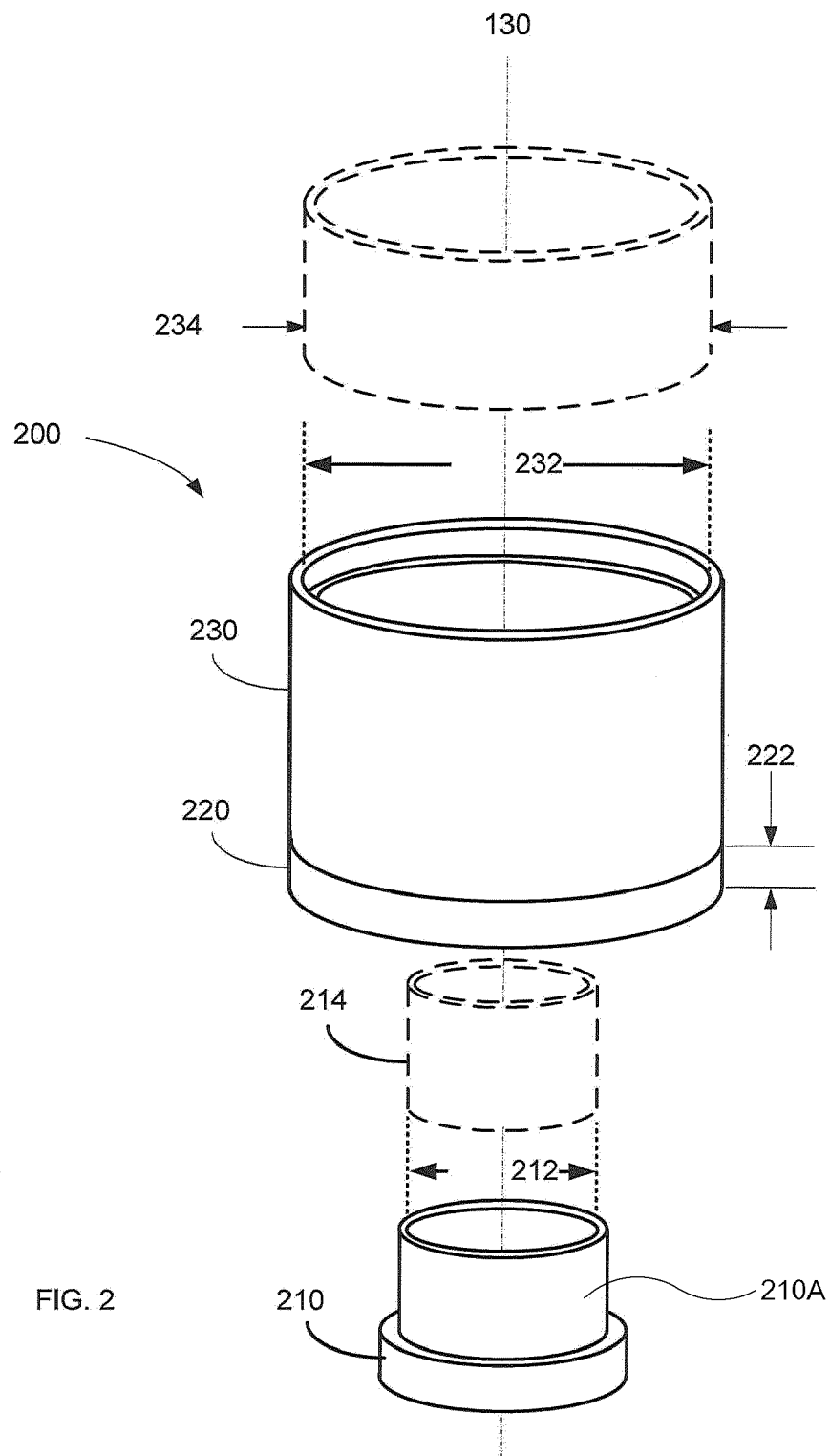
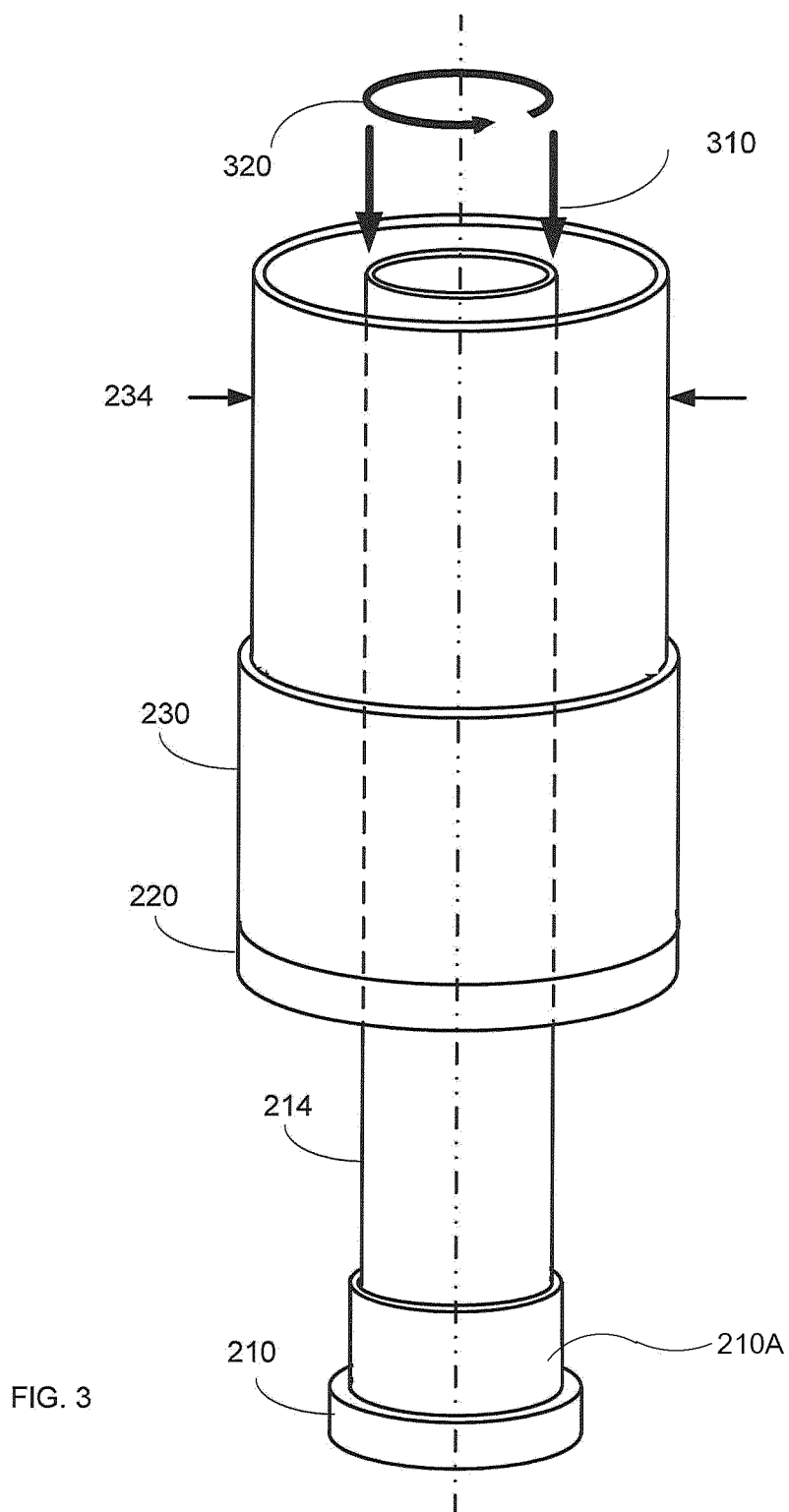


FIG. 1





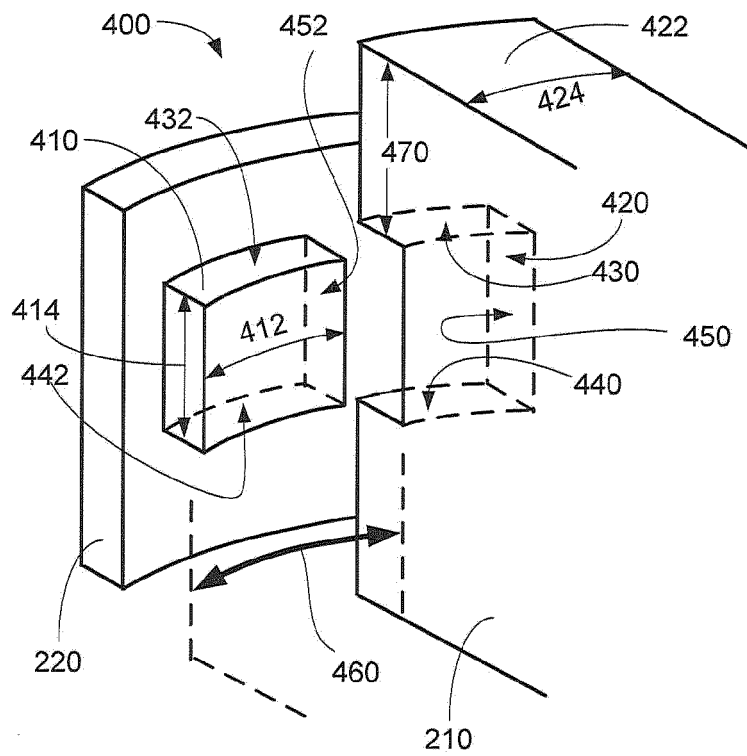


FIG. 4A

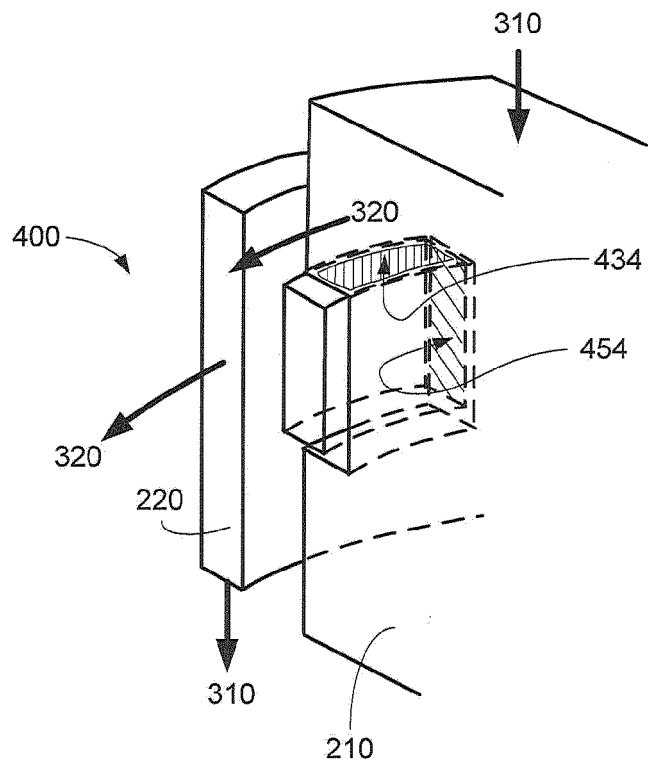


FIG. 4B

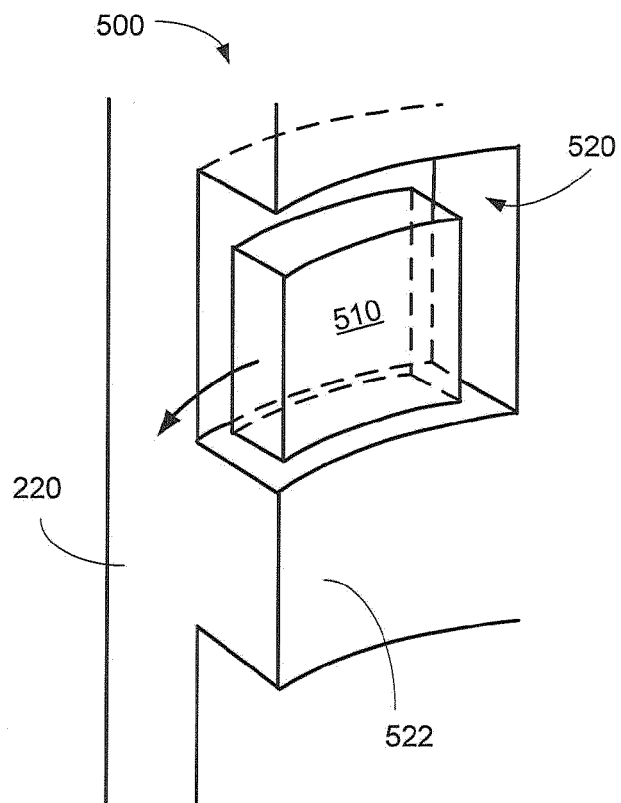
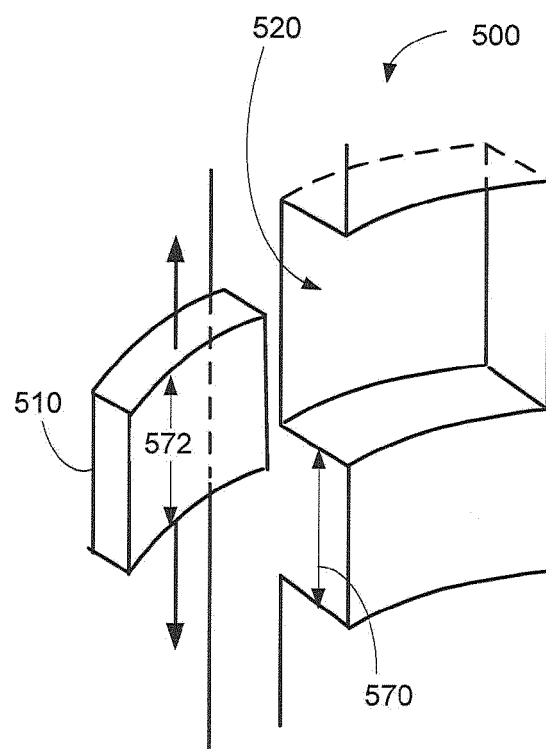
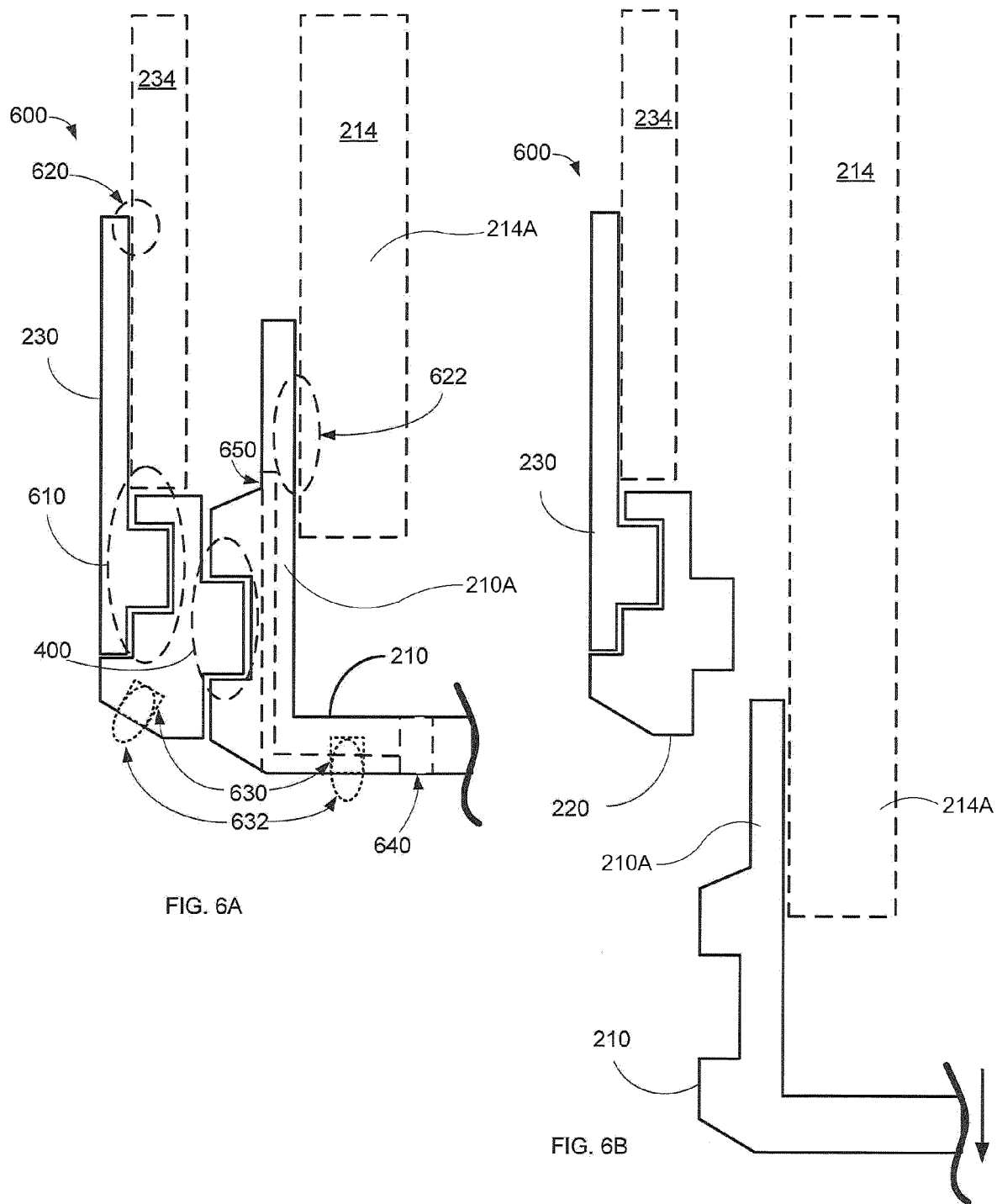


FIG. 5B





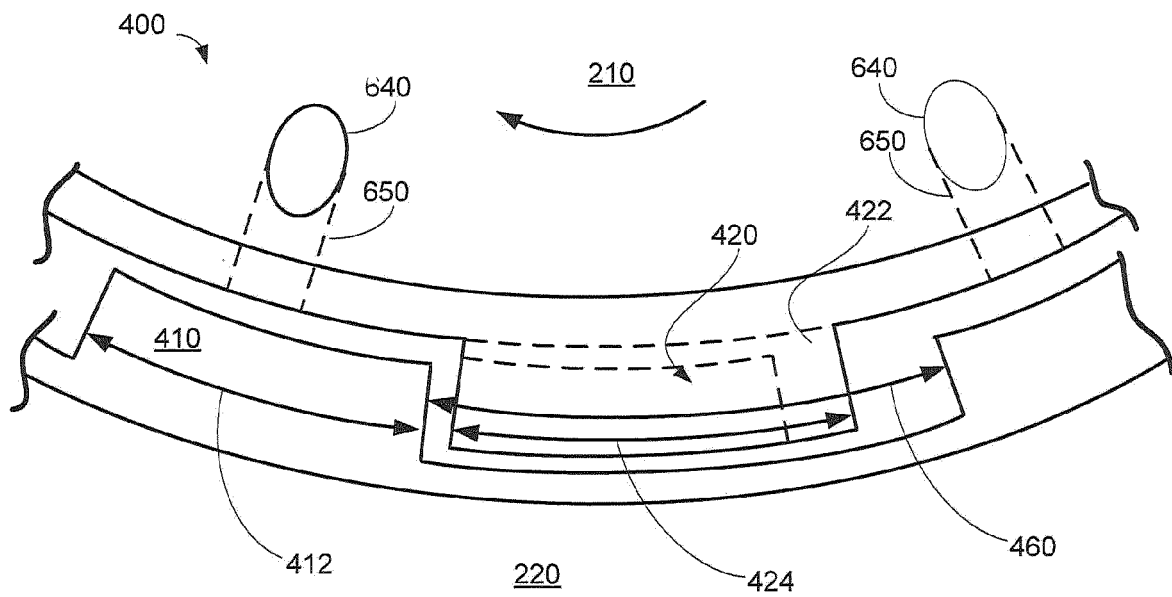


FIG. 7A

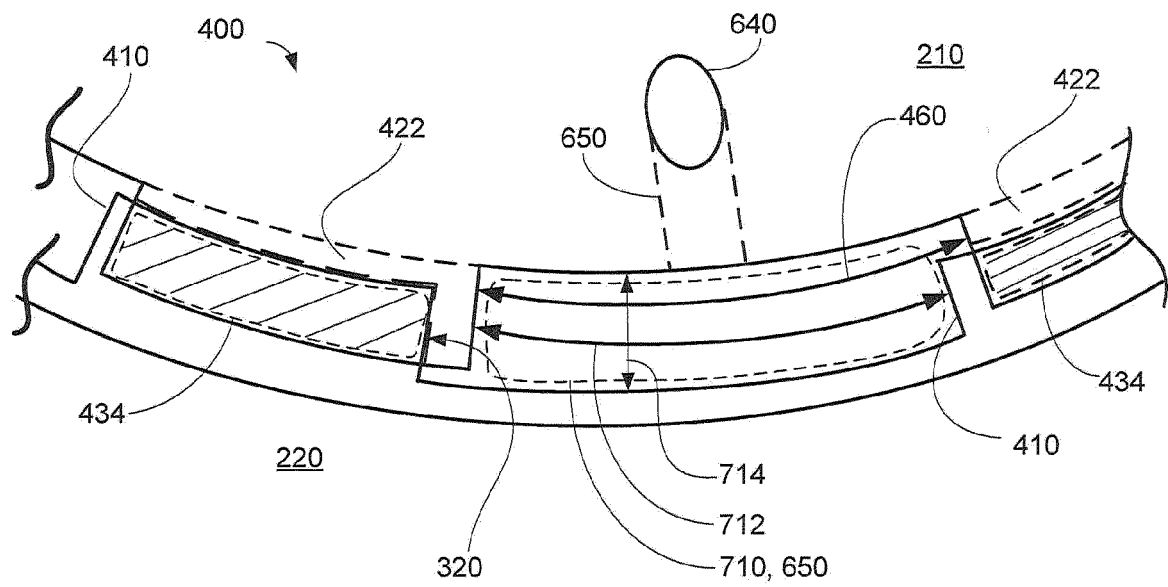


FIG. 7B

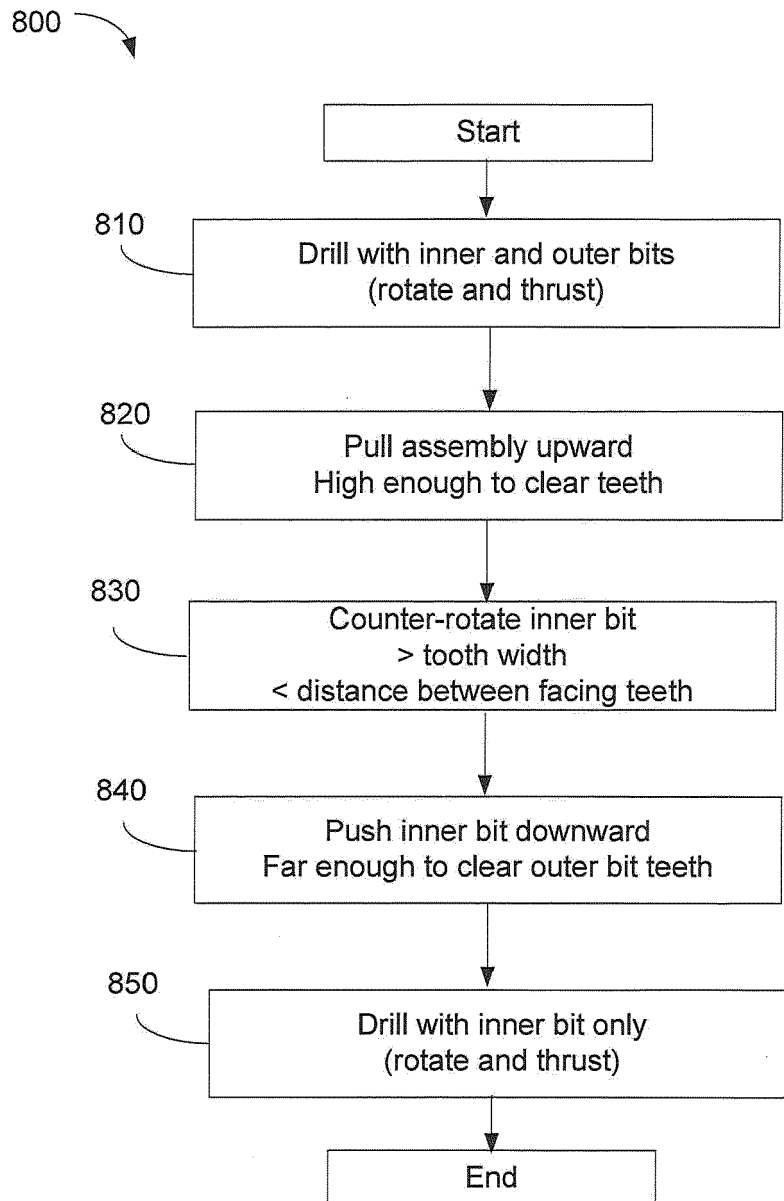


FIG. 8B

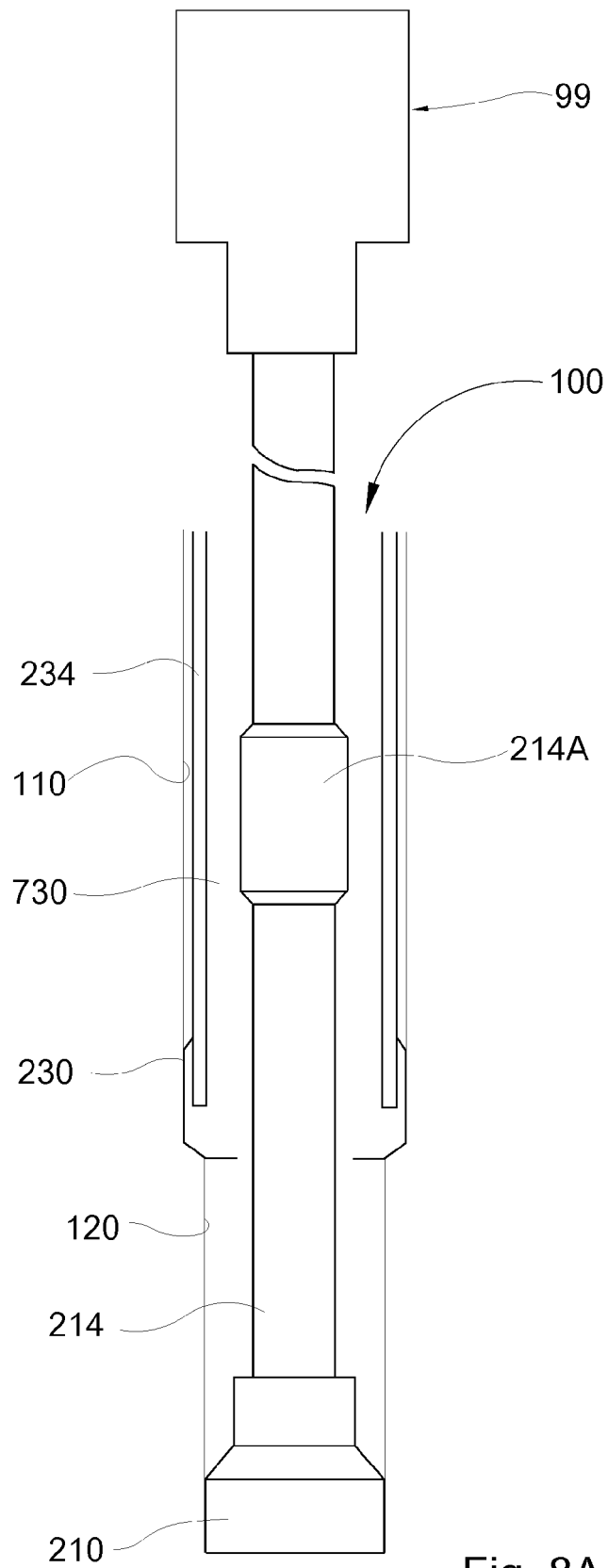


Fig. 8A

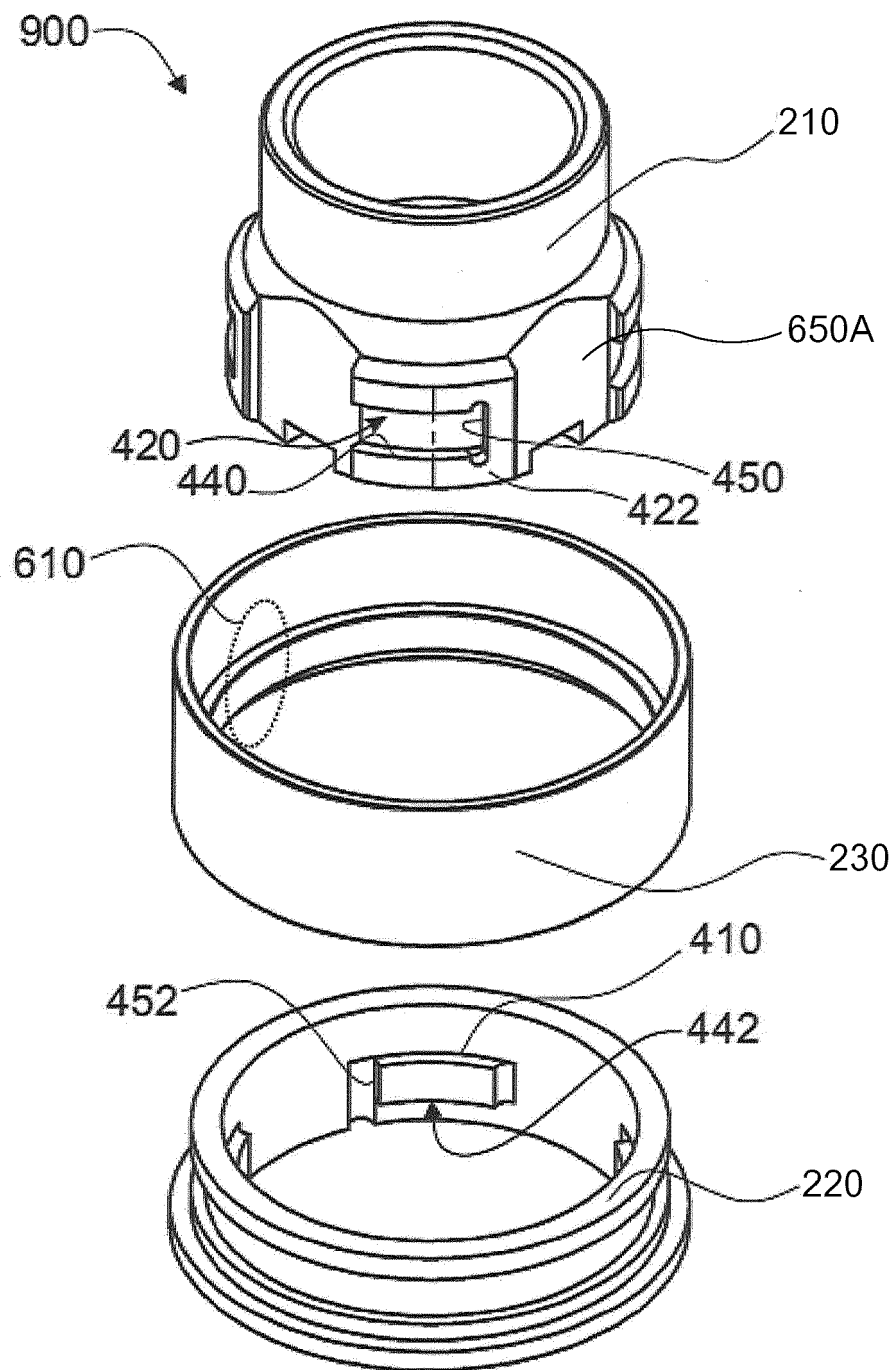


Fig 9

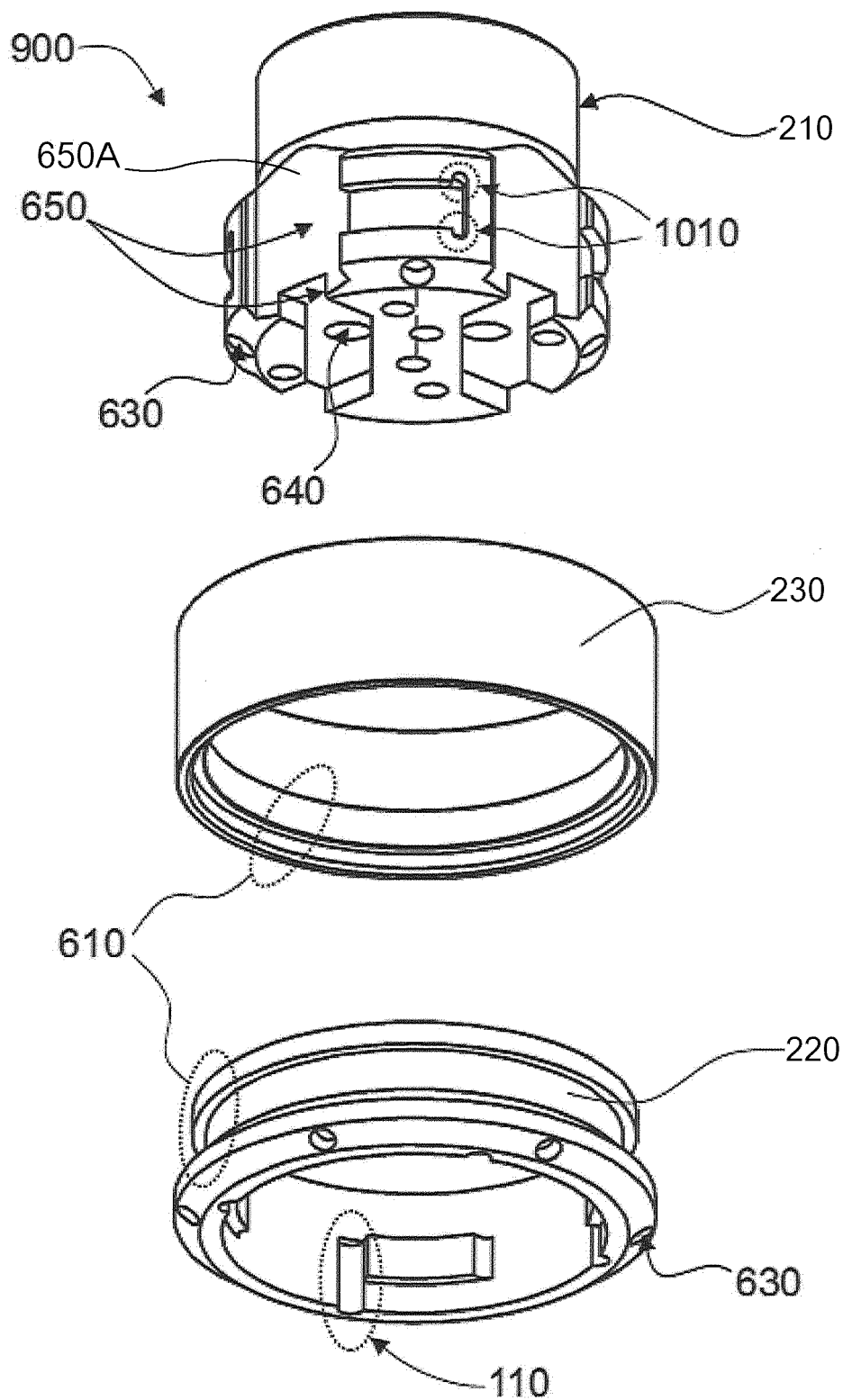
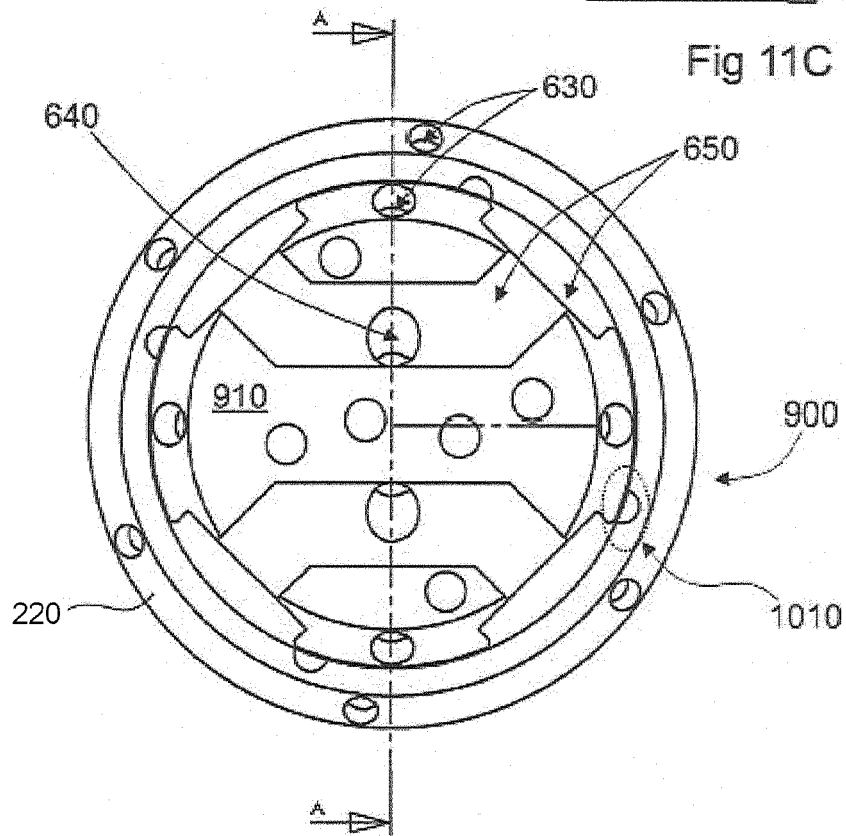
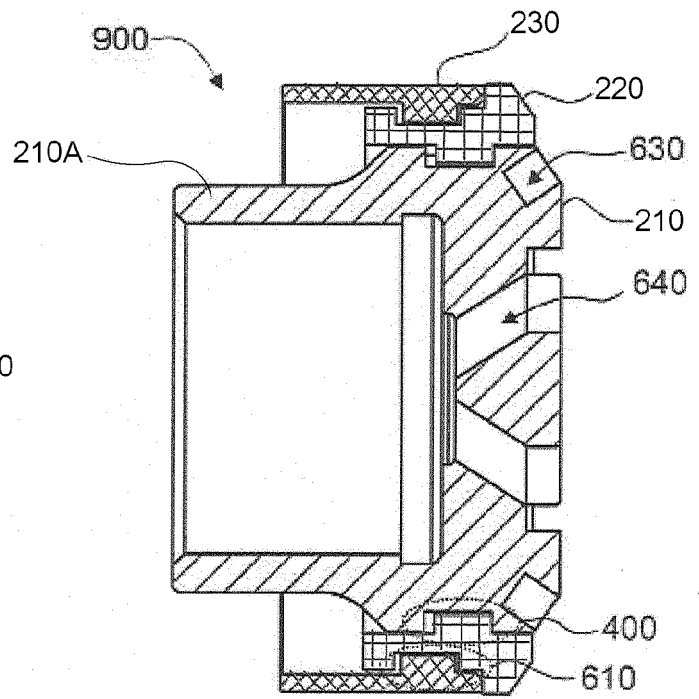
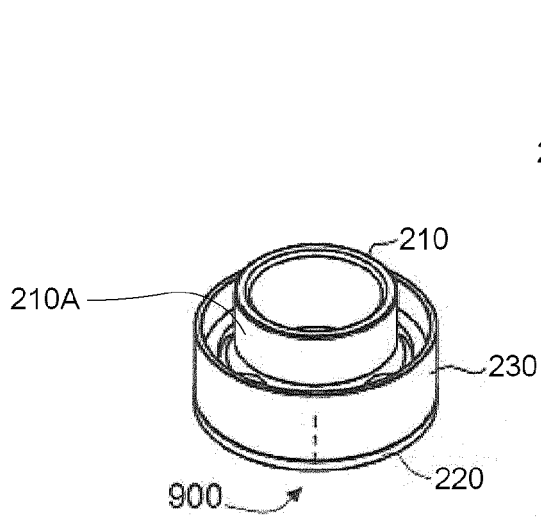


Fig 10



REFERENCES CITED IN THE DESCRIPTION

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