(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
05 December 2019 (05.12.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/232006 A1

(51) International Patent Classification:
E21B 17/10 (2006.01) *E21B 44/04* (2006.01)

(21) International Application Number:
PCT/US2019/034325

(22) International Filing Date:
29 May 2019 (29.05.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

62/677,955	30 May 2018 (30.05.2018)	US
62/683,226	11 June 2018 (11.06.2018)	US
62/689,430	25 June 2018 (25.06.2018)	US
62/821,006	20 March 2019 (20.03.2019)	US

(71) Applicant: **KNJB, INC.** [US/US]; 15238 Highsprings Drive, Houston, Texas 77068 (US).

(72) Inventors: **NASH, Kenneth L.**; 15238 Highsprings Drive, Houston, Texas 77068 (US). **KUENZEL, Rainer**; 305 Japonica Road, Hunt, Texas 78024 (US).

(74) Agent: **NASH, Kenneth L.**; PO BOX 680106, Houston, Texas 77268 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

WO 2019/232006 A1

(54) Title: DOWNHOLE RATCHET MECHANISM AND METHOD

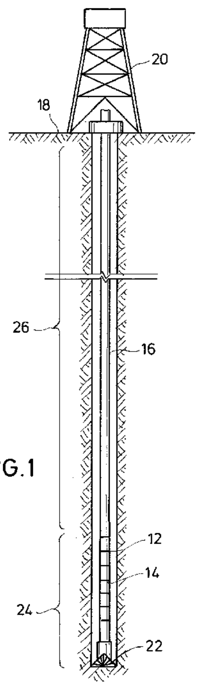


FIG.1

(57) Abstract: A slip mechanism is utilized between tubulars in the drill string to reduce torsion energy in the drill string. The slip mechanism is connected to release when the tubular below the slip mechanism spins faster than the tubular above the slip mechanism. When the tubular below spins more slowly or at the same speed then the slip mechanism firmly secures the upper and lower tubulars together to rotate the bit. The effect is to release torsional energy in the drill string to reduce and eliminate slip stick oscillations. A computer is programmed to determine an optimal position in the drill string to release the torsional energy in the drill string.

[Continued on next page]

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

DOWNHOLE RATCHET MECHANISM AND METHOD

BACKGROUND OF THE INVENTION

[001] Field of the Invention

[002] The present invention relates generally to a downhole slip mechanism for drill string that allows torsion energy in the drill string to be released and more particularly to a slip mechanism with that slip to release torsion in the drill string.

[003] Description of the Background

[004] Slip-stick (stick-slip) occurs when the bit grabs the formation and then releases. Due to the torsional energy in the drilling string during drilling, oscillations of slowing and speeding of the drill bit can occur. Full blown slip-stick results in the bit actually stopping and then when released, the bit begins spinning at high speeds sometimes much higher than the drilling speed. The oscillation can continue indefinitely. Even at much lesser variations below full blown slip-stick, the drill string actually shortens and lengthens, which produces changes in the axial length of the drill string. The shortening and lengthening of the drill string can cause poor cutting and damage to the bits.

[005] Slip-stick is a problem that damages the bits as they are bounced up and down on the bottom of the wellbore (bit bounce), slowing drilling due to poor cutting during Slip-stick, increasing the number of bit trips, damaging the wellbore, causing an irregular well bore, causing circulation problems, decreasing the control of the direction of drilling, decreased cementing reliability due to the presence of one or more elongated troughs, clearance problems for gravel packing screens and other problems discussed below.

[006] In some cases, full blown stick-slip at the lower portion of the drill string miles below the surface especially in higher angle holes or deeper holes is not readily detectable with surface sensors. Therefore surface controls to vary drilling speed to counteract the stick-slip may not be effective.

[007] Because modern PDC cutting elements of bits have a very short length and must be held in constant close contact with the surface to be cut for maximum cutting effects, even small axial changes in the length of the drill string can significantly impede drilling progress. Bit bounce can increase bit wear and require more frequent bit trips. Bit bounce also damages the well bore in ways that become the source for additional torque.

[008] Whenever the drill bit is rotated for drilling into a formation, the drill string has torsional windup or torsional potential energy, just as a torsional spring might have when torque is applied thereto. When drilling, it is highly desirable that this torsional windup or potential energy be a constant value based on the torsional constant of the drill string, and not a varying or oscillating amount, which occurs with slip-stick.

[009] The irregular drilling due to slip-stick damages the drilling string and damages the wellbore. Torsional vibrations may produce a twisted borehole that becomes the source for additional torque. Thus, the problem of torsional vibrations is self-reinforcing. For many reasons, it is desirable to drill a straighter hole with reduced spiraling effects along the desired drilling path and with fewer washed out sections.

[010] For instance, it has been found that tortuosity, or spiraling effects frequently produced in the wellbore during drilling, is associated with degraded bit performance, bit whirl, an increased number of drill string trips, increased likelihood

of losing equipment in the hole, increased circulation and mud problems due to the troughs along the spiraled wellbore, increased stabilizer wear, decreased control of the direction of drilling, decreased cementing reliability due to the presence of one or more elongated troughs, clearance problems for gravel packing screens, decreased ROP (rate or speed of drilling penetration), degraded logging tool response due to hole variations including washouts and invasion, decreased reliability of MWD (measurement while drilling) and LWD (logging while drilling) due to the vibrations generally associated therewith, and many other problems.

[011] It would be desirable to maintain torsional potential energy at a constant value. This maintains the constant close contact of the drill bit with the surface to be cut for maximum cutting effects. It would be desirable to provide a tool that would stabilize torsional potential energy within a few cycles back to a constant level.

[012] While systems that use surface controls to balance torsional potential energy are to some extent effective, they are limited in that energy variations must travel all the way to the surface to even be detected. The deeper the well, the higher the drilling angle, the less likely this is to occur which limits usefulness of surface controls.

[013] Consequently, there remains a need to provide an improved downhole assembly to perform this function and keep the torsional potential energy of the drill string constant. In most cases, it would be desirable to avoid springs and cables to perform this function. It would be desirable to provide a tool that would drain energy from the drill string when the drill bit turns faster than the drilling rate but then immediately apply driving energy to the drill bit when the bit drops back to the drilling driving rate velocity rate. This effect would quickly stabilize the bit drilling speed,

maximize bit life, maximize drill sting life, and improve the hole. It would be desirable that the tool be relatively inexpensive and simple. Those of skill in the art will appreciate the present invention which addresses the above problems.

SUMMARY OF THE INVENTION

[014] Accordingly, it is an objective of the present invention to provide an improved drilling assembly and method.

[015] Another objective of one embodiment of the present invention is to decay torsional pulses going up the drill string to stabilize torsional potential energy in the drill string.

[016] Another possible embodiment is to allow the bit to rotate faster than the drill string whereupon the ratchet or freewheel releases, the bit speeds up and slows down to driving speed whereupon the ratchet or freewheel engages to drive the bit at driving speed.

[017] Another objective of the present invention is to release the lower portion of a drillstring to stabilize torsional potential energy said drillstring.

[018] Another objective of the present invention is to limit axial lengthening/shortening oscillation of the drill string to the point where bit bounce is eliminated – for longer bit life and improved positioning of the PDC cutters to maximize drilling rate.

[019] An objective of another possible embodiment in said drill string is to provide faster drilling ROP (rate of penetration), longer bit life, and reduced stress applied to the drill string.

[020] A non-limiting feature of the present invention is a release/grab mechanism that releases tubulars below the release/grab mechanism.

[021] A non- limiting feature of the present invention is a ratchet that allows rotation of the drill string below the ratchet to spin to release torsional energy and then drives the drill string as soon as it slows down.

[022] Another non-limiting feature of the present invention is to select one or more positions in the drill string for a release/grab or ratchet mechanism, where the positions are used to adjust an amount of damping of the torsional oscillation.

[023] An advantage of use of the present invention in the drillstring is faster drilling ROP (rate of penetration), longer bit life and reduced stress applied to the drill string.

[024] Other examples of advantages include but are not limited to reduced stress on drill string joints, truer gauge borehole, improved circulation, improved cementing, improved lower noise MWD and LWD, improved wireline logging accuracy, improved screen assembly running and installation, fewer bit trips, reduced or elimination of tortuosity, reduced or elimination of drill string buckling, reduced hole washout, improved safety, and/or other benefits.

[025] Another objective of yet another possible embodiment of the present invention may comprise combining one or more or several or all of the above objectives with or without one or more additional objectives, features, and advantages as disclosed hereinafter.

[026] These and other objectives, features, and advantages of the present invention will become apparent from the drawings, the descriptions given herein, and the appended claims. However, it will be understood that the above-listed objectives, features, and advantages of the invention are intended only as an aid in understanding aspects of the invention, and are not intended to limit the invention in

any way, and therefore do not form a comprehensive or restrictive list of objectives, and/or features, definitions, and/or advantages of the invention.

[027] One general aspect includes a slip apparatus connectable in a drilling string to release torsional energy from said drilling string when drilling a wellbore, said drilling string extending from the surface to a drill bit, said slip apparatus being connectable between a first tubular and a second tubular in said drilling string, said slip apparatus including: a body; a first threaded connection on said body, said first threaded connection being threadably connectable with said first tubular; a first component mounted for rotation with respect to said body, a second threaded connection on said first component, said second threaded connection being threadably connectable with said second tubular; and a second component, said first component and said second component being mechanically linked to lock said first and second tubulars together when said second tubular rotates at a velocity equal to or less than said first tubular, and permit relative rotation between said first and second tubulars when said second tubular rotates at a velocity greater than said first tubular to thereby release torsional energy from said drilling string.

[028] Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[029] Implementations may include one or more of the following features. The slip apparatus where an amount of torsional energy released by said slip apparatus is selectable by selection of a depth position for connection of said slip apparatus in said drilling string. The slip apparatus where an amount of torsional energy released

by said slip apparatus is selectable by selection of a plurality of different depth positions for connection of said slip apparatus at each said different depth positions in said drilling string. The slip apparatus where said first tubular is an upper tubular and said second tubular is a lower tubular, said upper tubular being closer to the surface along said wellbore than said lower tubular. The slip apparatus further including a biasing member to bias said first component into engagement with said second component. The slip apparatus where said second component includes an axially moveable member, a pivotal member, a gear, or a roller. The slip apparatus where said first component includes a plurality of asymmetrical elements that engage said second component. The slip apparatus where said plurality of asymmetrical elements includes gear teeth. The slip apparatus where said second component is electromagnetically controlled to release or engage by a computer in response to a sensor that measures a rotational velocity of said first tubular or of said first tubular compared to said second tubular. Implementations of the described techniques may include hardware, a method or process or computer software on a computer-accessible medium.

[030] One general aspect includes a method for controlling an amount of damping of torsional oscillations in a drill string utilizing a slip system, said method including the steps of: utilizing a processor to make torque and drag calculations on said drillstring, said drillstring including a BHA (bottom hole assembly) and a drill pipe portion; said BHA being at a lowermost position in said drillstring, said BHA including a bit and components including one or more of a bit sub, drill collar, heavyweight drill collar, heavy weight drill pipe, stabilizer, reamer, shock, hole opener, downhole

motor, rotary steerable system, directional equipment, drilling while measurement equipment, steering unit, near bit inclination, non-magnetic drill collar, said BHA being connected to said drill pipe portion of said drillstring. The method also includes said drill pipe portion including additional of said components including one or more of a drill pipe, coiled tubing, heavyweight drill pipe, stabilizer; and utilizing said torque and drag calculations on said drillstring for determining one or more positions for one or more slip systems from a plurality of different positions in said drillstring to control said amount of damping of torsional oscillations in said drillstring.

[031] Accordingly, the present invention provides a method for controlling rotational oscillations of a drill bit while drilling. The drill bit is mounted to a drilling string which comprises a plurality of interconnected tubulars. The present invention may comprise one or more steps such as, for instance, installing a locking mechanism in the drilling string between a lower tubular of the drilling string and an upper tubular of the drilling string. The lower and/or upper tubulars could be any type of tubular connection as may be found on a drill bit, mud motor, drill pipe, bottom hole assembly, heavy weight tubular, drill stream, a few tubulars up the wellbore after the connection of the heavy weight casing to the drillstring, or the like. In one possible embodiment, the method utilizes a ratchet or freewheel assembly to transfer torque between the lower tubular portion of the drilling string and the upper tubular of the drilling string during a drilling operation.

[032] The method further comprises the step of permitting slippage between the upper tubular of the drilling string and the lower tubular of the drilling string during the drilling operation to thereby dampen the rotational oscillations. The method may

further comprise reconnecting the upper tubular to the lower tubular at least by when the lower tubular rotational velocity is greater than the upper tubular rotational velocity.

[033] The present invention may also comprise a computer simulation of the damping effect of activating a slip mechanism, which could be of different types, depending on where the mounted in a drilling string where the rotational control may be operable for selectively transferring torque between tubulars in the drilling string, such as with an on-off type mechanism or a variable control. The method of the computer simulation may comprise one or more steps such as, for instance, providing parameter inputs for inputting drill string parameters describing the drilling string, providing one or more rotational control activation parameter for inputting conditions under which the rotational control is activated, and providing one or more outputs related to torsional oscillations of a drill bit (ratchet or drill string below ratchet) of the drilling string. The method may also comprise plotting drill bit (ratchet or drill string below ratchet) movement versus time wherein the rotational control is activated to permit slippage between the tubulars in the drilling string to dampen the torsional oscillations. For instance, the drill string length, weight, and so forth may be entered. The particular timing for activating the rotational control, e.g., on-off, may be tested in any desired way for any acceleration, rotational speed, or any combination of such parameters for the drill string below the ratchet. In another embodiment, a method is provided which may comprise one or more steps such as, for instance, installing a slip assembly in the drilling string between a lower tubular of the drilling string and an upper tubular of the drilling string and/or selectively engaging the slip

assembly to transfer torque between the lower tubular portion of the drilling string and the upper tubular of the drilling string during a drilling operation and/or selectively disengaging the slip assembly to permit slippage between the upper tubular of the drilling string and the lower tubular of the drilling string during the drilling operation to thereby dampen the drill bit (ratchet or drill string below ratchet) oscillations.

BRIEF DESCRIPTION OF THE FIGURES

[034] FIG. 1 discloses a drill string and one or more slip mechanisms located at selected positions in the drill string in accord with one possible embodiment of the invention;

[035] FIG 2 discloses a downhole motor with a slip mechanism mounted between the downhole motor and the drill bit in accord with one possible embodiment of the invention;

[036] FIG. 3 discloses a slip mechanism mounted in the drill string between a first tubular, which may be an upper tubular, and a second tubular, which may be a lower tubular in the drill string in accord with one possible embodiment of the invention;

[037] FIG. 4 is an elevational view, partially in cross-section of a slip mechanism of a ratchet device showing a vertical extent thereof in accord with one possible embodiment of the present invention;

[038] FIG. 5 is an elevational view, partially in cross-section of a slip mechanism showing a vertical extent of the plurality of locking members within a cylindrical cavity in accord with one possible embodiment of the present invention;

[039] FIG. 6 is a top view partially in section along lines 6-6 of FIG. 5, which shows bearing sections that rotatably secure the inner tube to the outer tube in accord with one possible embodiment of the present invention;

[040] FIG. 7 is a top view in section, taken along lines 7-7 of FIG. 5, showing on one side splines rotationally secure the inner tubular with the bottom connector, and on the other side show springs that pre-load the locking members in accord with one possible embodiment of the present invention;

[041] FIG. 8 is a top view, partially in cross-section, along lines 8-8 of FIG. 5 showing a cross-section of the locking members in the locked position so that the outer tube drives the inner tube in accord with one possible embodiment of the present invention;

[042] FIG. 9 is a top view, partially in cross-section, along lines 8-8 of FIG. 5 showing a cross-section of the locking members in the unlocked position so that the outer tube is free to rotate with respect to the inner tube in accord with one possible embodiment of the present invention;

[043] FIG. 10 FIG. is a top view in section which is enlarged from the box of FIG. 8 showing details of the locking members in the locked position in accord with one possible embodiment of the present invention;

[044] FIG. 11 is a top view in section which is enlarged from the box of FIG. 9 showing details of the locking members in the unlocked position in accord with one possible embodiment of the present invention;

[045] FIG. 12 is an elevational view, partially in cross-section of a slip mechanism showing a vertical extent of the plurality of discs or plates that form a clutch used to

drive the bottom connector sub with the driven outer cylinder on the upper side of the tool in the drawing that connects to the drill string in accord with one possible embodiment of the present invention;

[046] FIG. 13 is a top view, partially in cross-section along lines 13-13 of discs that form a clutch on the right side and a key that locks to allow activation of the clutch mechanism on the left side;

[047] FIG. 14 is a top view, in cross-section along lines 14-14 that show a key on the left side and a spline on the right side that operates to activate the clutch mechanism on the right side;

[048] FIG. 15A shows damping of torsional oscillations resulting from placement of a slip mechanism at a first position in a drill string;

[049] FIG. 15B shows damping of torsional oscillations resulting from placement of a slip mechanism at a second position in a drill string;

[050] FIG. 16A is an elevational view showing use of one or more slip mechanisms in a medium angle building bottom hole assembly;

[051] FIG. 16B is an elevational view showing use of one or more slip mechanisms in a horizontal BHA in accord with one embodiment of the present invention.

DETAILED DESCRIPTION

[001] FIG. 1 shows one or more slip mechanisms 10 as described below mounted at various positions 12, 14 in the drill string 16. In other words, the present invention may use a plurality of slip mechanisms inserted at strategic positions or may use a single slip mechanism 10 for insertion at a strategic position as discussed herein. Slip mechanisms may also be referred to herein as ratchet mechanisms, clutches, or the like. There may be only one slip mechanism, but due to the low cost of some embodiments, it would also be possible to use more than one. The drill string 16 extends from an earth surface 18 to the drill bit 22. Surface drive 20 applies torque to rotate the drill sting to rotate the bit. Alternatively, the bit 22 may be driven by a downhole motor.

[002] Various embodiments of a slip mechanism are shown in FIG. 4, 5, and 12. The slip mechanisms allow rotation of an inner member with respect to an outer member when the inner member spins faster than the outer member. Otherwise the outer member drives the inner member. The ratchet of FIG. 5 has only two moving ratchet components. The embodiment of FIG. 5 uses irregular shaped members to grab cylindrical surfaces. The embodiment of FIG. 12 uses plates that engage/release the inner and outer members.

[003] In more detail, a slip mechanism 10 applies driving force from the surface drive 20 through the drill string 16 to the bit 22 but allows slippage if the bit 22 should rotate faster than the drill string above the slip mechanism. For example, a ratchet or freewheel allows a driveshaft to engage a driven gear, but then disengages with the driveshaft to allow the driven gear to rotate faster than the driveshaft.

[004] The drill string 16 comprises a bottom hole assembly (BHA) 24 and a pipe string 26. The pipe string may also be referred to as a drill pipe portion or other related terminology. The BHA 24 is at a lowermost position in the drill string 16. The BHA 24 comprises a bit and components such as a bit sub, drill collar, heavyweight drill collar, heavy weight drill pipe, stabilizer, reamer, shock, hole opener, downhole motor, rotary steerable system, directional equipment, drilling while measurement equipment, steering unit, near bit inclination, and/or non-magnetic drill collar. While in FIG. 1 a top drive or rotary table drive on the surface is utilized to rotate the drill string, many wells are drilled with a downhole motor 28, as indicated in FIG. 2.

[005] The BHA is connected to the drill pipe portion 26 of the drillstring. The drill pipe portion 26 comprises additional components such as drill pipe, coiled tubing, heavyweight drill pipe, and/or stabilizer. The drill pipe portion 26 of the drill string is typically much longer than the BHA. Where the BHA may typically be in the range of 100 to 400 feet, the drill pipe portion 26 of the drill string may be several miles long.

[006] Although the slip mechanism is normally utilized in the BHA and/or pipe portion of the drill string, FIG. 2 shows placement of slip mechanism 10 at a position between the downhole motor 28 and the drill bit 22. However, the slip mechanism may be placed above the downhole motor 28 at a position where it is desirable to bleed off excess torsion created by the drill bit stopping.

[007] FIG. 3 shows placement of a slip mechanism 10 between a first tubular 30, which may be an upper tubular as shown, and a second tubular 32, which may be a lower tubular as shown. A purely mechanical slip system, such as slip mechanisms 10A-10C, discussed hereinafter, locks the upper and lower tubulars together when the

lower tubular rotates at a velocity equal to or less than the upper tubular. The purely mechanical slip system permits relative rotation between the upper and lower tubulars when said lower tubular rotates at a velocity greater than said upper tubular to thereby release torsional energy from said drilling string. As used herein the term tubular and tube are used interchangeably. Drill pipe, heavy weight pipe and the like are referred to as tubulars although they could also be described as tubes.

[008] During normal drilling, the slip mechanism 10 operates the same as other tubulars in the drill string to convey power from the top drive to the drill bit. When Slip-stick occurs so that the drill bit sticks and then comes loose, the bit accelerates to a higher rotation velocity than the drill string velocity driven by the top drive, rotary table or downhole motor. At this time, the slip mechanism 10 allows the tubulars below to rotate independently with respect to the tubular above.

[009] FIG. 4 shows slip mechanism 10A, a type of ratchet, that comprises slidably mounted upper gear 102, 103 and lower gear 104 that grip upper tubular 30 (FIG. 3) and lower tubular 32 (FIG. 3) and allow/prevent rotation. As explained previously, slippage depends on the relative velocity of outer body 34 and inner body 36 and lower portion 62 thereof as indicated by rotational arrows 50, 52. A flow path 38 is provided that extends through 10A Ball type bearings 51 are utilized to connect upper tubular to outer body 34 to inner body 36. Thrust bearing 69 provides a bearing for downward weight. When the velocity of lower tubular 32 (secured to threaded connection 64) is faster than upper tubular (secured to threaded connection 60) then upper gear 102 is pushed upwardly as indicated by arrow 108 against the bias provided by springs 110. Springs are mounted in pockets such as

pocket 112 in outer body 34 and in pocket 114 in moveable gear 103. Note that connectors 60 and 64 may be male or female and more typically connector 60 is female and connector 64 is male. When the velocity of lower tubular 32 is less than or equal to upper tubular 30 then upper gear 102 moves downward due to the bias as indicated by arrow 109. Upper gear 102 cannot rotate with respect to outer body 34 due to splines 116 that engage corresponding grooves 118 shown in dash.

[010] It will be appreciated for the claims that the terms first component and second component are for convenience and that either of the inner or outer body could be called a first component or second component. The inner body or outer body may also be referred to as an inner tubular or outer tubular.

[011] One advantage of slip mechanism 10A is that very few moving parts are required. The drive force to rotate the bit is transmitted by teeth 106 on the two opposing gears.

[012] Accordingly, the upper gear 102 moves up and down in the pocket 119. However upper gear 102 is biased downwardly. It will be appreciated that many types of springs may be utilized instead of coil springs as shown. Outer body 34 is secured to the upper tubular 30 via threaded connection 60. The upper gear 102 has to rotate with the outer body 34 because the pocket 119 comprises splines 116. Because outer body 34 is threadably secured to the upper tubular 30, upper gear 102 is constrained to rotate with the upper tubular 30.

[013] The lower gear 104 connects to the lower tubular 32 through threaded connection 64. The lower gear 104 cannot move axially up and down. During

normal drilling, the upper gear 102 drives the lower gear 104, which drives the drill string below the slip mechanism 10.

[014] If due to slip stick, lower gear 104 rotates faster than the upper gear 102 then the spring loaded upper gear 102 is pushed up and slipping occurs between upper gear 102 and lower gear 104 until the velocity of lower gear 104 drops to the driving speed of outer body 34.

[015] This releases torque energy in the drill string to dampen out torque oscillations.

[016] In other words, two saw-toothed gears 102, 104 with at least one gear 103 is spring loaded to press against each other with the toothed sides together. Rotating in one direction, the saw teeth of the drive disc lock with the teeth of the driven disc, making it rotate at the same speed. If the drive disc slows down or stops rotating, the teeth of the driven disc slip over the drive disc teeth and continue rotating.

[017] Another type of slip mechanism is shown in FIG. 5. Slip stick design 10B comprises outer body or tube 212 and inner tube or body or mandrel 214. Inner tube may also be referred to as an inner tubular. Inner tube 214 may be referred to as an inner body, inner tube, inner tubular, inner member, or the like. Outer tube 212 has a constant outer diameter and has smooth tubular surfaces of different diameter on the interior. In other words, the surfaces are continuous with openings. The inner tube 214 and outer tube 212 are connected by locking members 216, which allow relative rotation between inner tube 214 and outer tube 212 in one direction, but prevent relative rotation in the opposite direction. The inner tube 214 is connected to a lower tubular connector 220 by splines 218. The lower tubular connector 220 can then be secured to lower tubular 32 (See FIG. 3). The outer tube

212 is connected to upper tubular 30 (FIG. 3). When the drill bit slips forward relative to the drill pipe at drilling speed, the inner tube 214 is able to follow because the locking members 216 are released in this situation, as will be explained below. As soon as the drill bit slows down to the drilling speed, the drill pipe or specifically upper tubular 30 will again transmit torque to lower tubular 32 and the drill bit (See FIG. 3). This is because locking members 216 will be placed in a locking mode.

[018] As shown in FIG. 8, 9, locking members 216 are constantly in touch with the outer tube 212 on one side and the inner tube 214 on the other side, because they are urged into a clockwise direction by individual torque springs 222 (see Fig. 7).

[019] In FIG. 8, when outer tube or member 212 rotates clockwise as fast as inner tube 214, locking members 216 jam against the inner diameter of 212 and outer diameter of 214 to lock the inner tube with respect to the outer tube. This is indicated visually by the inner arrow velocity length being less than or the same as the outer arrow velocity length.

[020] In FIG. 9, when the outer tube or member 212 rotates clockwise at a velocity less than the inner tube 214, then the locking members rotate slightly to allow slippage. This is indicated visually by the inner arrow velocity arrow length being greater than the length of the outer arrow velocity.

[021] In other words, the locking members rotate between a locking position and a released position. In the locked position shown in FIG. 8 and 10, the outer tube drives the inner tube. In the released position, the inner tube is free to rotate faster than the outer tube. As shown in FIG. 8-11, the plurality of locking members may form a ring around the cylindrical opening between the inner and outer tubes. In

this example, each locking member engages two neighboring locking members. This allows for a maximum number of locking members. Prior art locking members are formed in pockets that severely limit the number of locking members.

[022] In more detail, when outer tube 212 rotates clockwise as fast as inner tube 214, then members 216 jam against the inner surface 224 of outer tube 212 (see enlargement of FIG. 8 shown in FIG. 10) and the outer surface 226 of inner tube 214 on the other side, because width or thickness 228 is larger than width or thickness 230. It will be seen that the inner surface 224 is a smooth inner cylindrical wall of outer tube 212. Likewise, surface 226 is a smooth outer cylindrical wall of inner tube 214.

[023] In the enlargement of FIG. 10, the tangential angle alfa (α) between the contact surfaces of inner wall 224 and locking member outermost surface 232, and between outer wall 226 and locking member innermost surface 236 is 10 degrees or smaller to guarantee locking and avoiding slipping. The inner velocity arrow and outer velocity arrow are the same. The centrally located outer surface of members 216 is circular (as indicated by the circle in Fig. 10), to maintain contact between the locking members when they slightly rotate from locked to unlocked position. This allows all locking members 216 to maintain position as they fill out the ring space between outer tube 212 and inner tube 214. It will be seen in this embodiment that the cross-section of the plurality of locking members 216 comprise six sides. At least the two outermost surface 232 and innermost surface 236 comprise a rounded section.

[024] As indicated in FIG. 11, the rounded surfaces of locking the locking members allow slipping when the inner member rotates faster than the outer member. In this case, the inner velocity arrow is longer than the outer velocity arrow to visually show the inner body rotates faster than the outer body.

[025] It will be seen that the plurality of locking members 216 are positioned between a smooth tubular inner cylindrical wall of 212 and the smooth tubular outer wall of 214. A cylindrical housing or chamber is formed into which the plurality of members are positioned. There is no need for pockets in which to place the locking members as is done in the prior art.

[026] The most important advantages of this kind of locking members are as follows:

[027] There are no “pockets” or spring to urge circular rods or spherical balls into locking position, which saves space for a larger number of locking members, which makes the transmission of a much higher torque possible, and all this is possible without sacrificing more of the available wall thicknesses.

[028] The contact surface of the locking members 216 are of a much larger radius than those of circular rods of the prior art freewheeling designs, which reduces contact pressure per square inch so as to reduce wear.

[029] Manufacturing is much easier than designs with circular members, which require machining pockets, springs that push these members into contact with the pocket surfaces, and contact members between the rods or ball and springs. Surface 624 and 626 can simply be left entirely cylindrical.

[030] In the prior art, balls or circular rods are used as locking members, which act as ball bearings or needle bearings to allow forward slipping of the drill bit unrestrained.

Locking members of the present invention will rub against the interior wall 224 of the outer tube 212 in the unlocked mode and thus provide dampening of the slippage as per FIG. 9 and Fig. 12.

[031] Locking members 216 are equipped with axial extensions 240 and 242 (see Fig 5, Fig. 7), which allow rotating inside holes of upper and lower rings 244 and 246. Rings 244 and 246 are keyed to inner tube 214 by keys 248 and 250. Faster rotation of lower tubular 36 causes the locking members to move around with the inner tube in the slipping mode, rubbing against the inner wall 224 of the tube 212. However, rings 244 and 246 could also be keyed to the outer tube 212, which would cause the locking members to stay in place during slipping and rub instead against the inner tube to produce dampening of the slip. This might be preferable for manufacturing purposes.

[032] As shown in FIG. 5 and FIG. 6, the inner tube 214 is held in vertical position between shoulder 254 of outer tube 212 and shoulder 256 of connector 220 by upper and lower split rings 258 and slip rings 260. Thrust bearing 270 is provided to support downward weight between outer tube 212 and inner tube inner tube 214 Segments of rings 258 (see Fig. 6) are inserted into grooves 262 of inner tube 214 and bolted to the slip rings 260. The thickness of split rings 258 may be increased to increase the tension that may be applied to the slip mechanism 10C (See FIG. 12). It will be appreciated that slip mechanism may also be referred to as a slip system or other related term.

[033] To maintain smooth operation and keep out dirt, the inner cavity containing the locking members 216 and rings 244 and 246, is sealed by O-rings 272, 274, and 276

and is filled with a lubricant like, for example, transmission fluid though grease nipple 278.

[034] Another embodiment of a slip mechanism is shown in Fig. 12. Slip stick design 10C comprises outer tube 312 and inner tube 314, which is connected to a drill bit or lower tubular connector 316 via splines 318. The torque of outer tube 312 is transmitted to inner tube 314 by a stack of splined discs 320 and 322, similar to an automobile clutch. Discs may also be referred to as plates herein. Discs 320 are driving by outer tube 312 while discs 322 are connected to inner tube 314. The transmission of torque occurs when the stack of discs is compressed to a point where no slipping occurs between the discs. The upper end of the stack of discs rests against the shoulder 324 of tube 312, while the lower end is in contact with upper ring 326. The opposite lower side of ring 326 is in contact with a second ring 328. Both rings contact each other by angled surfaces 330 and 332. The upper ring 326 is keyed to outer tube 312 by key 334. (FIG. 12 and FIG. 13). The lower ring 328 is keyed to the inner tube by key 336. (FIG. 12 and FIG. 14) In other words, a first group of discs 320 and a second group of discs 322 are shown. The first group of discs is keyed to outer tube 312. The second group of discs is keyed to inner tube 314. The inner tube and outer tube may be referred to as first and second components herein.

[035] FIG. 13 shows a cross-sectional view of the spline generally indicated at cross sectional lines 13 in FIG. 12. The spline grooves 338 in connector 316 may be about twice as wide as the spline teeth 340 of inner tube 314, which allows the inner

tube, including ring 328, to rotate slightly ahead of outer tube 312, including driven lower tube connector 316.

[036] Under normal drilling, outer tube 312 together with upper ring 326 rotate clockwise, while the drill bit provide sufficient friction to cause the angled surfaces 330 (FIG. 12) to ride up on the angled surfaces 332 of lower ring 328, thus causing the stack of clutch discs 320 and 322 to be compressed and form a gripping or engaged connection between driving or outer tube 312 and driven lower connector 316.

[037] With the occurrence of stick slip, the inner mandrel slips clockwise forward as much as spline groove tooth 340 in groove 338 (Fig. 14) is allowed to, which rotates ring 328 to rotate clockwise to close gap 341 (Fig. 12), which releases the compression of the clutch stack, so that torsion can be released from the drill string as outer tube 312 slips with respect to inner tube 314 and lower connector tube 316. During this time discs 322 rotate with inner tube 314 and discs 320 rotate with the slower speed of tube 312. Once the speed of inner tube 314 and lower connector tube 316 is reduced, the gap 341 is opened again and the clutch stack continues to drive inner tube 314 and lower connector tube 316 at the drilling speed of outer tube 312.

[038] The cavity between inner tube 312 and inner tube 314 that contains clutch discs 320 and 322, and rings 326 and 328, is sealed by O-rings 350, 352, 354, and can be filled with a lubricant like transmission oil through grease nipple 356 to insure smooth operation and keep out dirt. O-rings 350 and 352 are mounted in section 329. Nevertheless, during slipping of the drill bit and drill string below 10C, there is

still providing some drag for dampening of the slipping process. Openings 331 and 333 are utilized to allow the transmission fluid to flow freely throughout the inner and outer rings

[039] FIG. 15A and FIG. 15B show the effect of damping of torsional vibrations as represented in FIG. 16A by the bit speed 174 (which may be closely related to the speed measured at lower tubular 32 or speed of inner body 36) or in FIG. 15B by bit speed 180. Drilling speed 172 may be in the range of 120 RPM or so. The speed at which damage occurs in the drill string is shown at 170, which may be in the range of 240 RPM. Speed indicted at 176 could be in the range of zero RPM if full blown slip-stick is occurring.

[040] Another method for controlling the damping for a purely mechanical slip system is by selecting the placement within the drill string. The slip mechanism 10 may be used in different positions in the drill string 16 to effect changes in the damping. As well different numbers of slip mechanisms may be used at selected positions in the drill string to

[041] FIG. 15B shows the torsional damping 182 by placement of slip mechanism 10 at one position in the drill string. Improved torsional damping 178 as shown in FIG. 15A is the result of placement of slip mechanism 10 at another position in the drill string.

[042] Location of the slip mechanism 10 can be accomplished in different ways. Torque and drag programs, which are commonly used in calculating dynamics of drill strings, can be used to determine how best to locate the one or more slip mechanisms to control the amount of damping. Torque and drag problems are very

common during drilling, completion and workover operations. Torque and Drag module can be used to calculate torque and drag of the drill string during planning, drilling and post-drilling. Various models for the drill string may be utilized. 3D visualization may be provided. The wellbore friction, torque and drag, between drill string and the wellbore wall is the most critical issue which limits the drilling industry to go beyond a certain measured depth. Surface torque is defined as the moment required rotating the entire drill string and the bit on the bottom of the hole. Torque and drag software can be utilized to model slip stick with simulated sticking loads. In this way, software can be used to determine where to utilize one or more slip mechanisms to utilize in the drill string. The software can determine how much torsional energy will be released in a purely mechanical slip system.

[043] In another embodiment, it may be desirable to simply place several slip mechanisms at various locations in the drill string.

[044] FIG 16A shows a medium angle building BHA. FIG. 16B shows a horizontal drilling BHA. In both drilling assemblies, bit 200 is driven by motor system 198. Directional instruments are located in non-magnetic tubulars 196. The kick off point is indicated by 194. The vertical section is shown. In this example, the vertical section is also the heavyweight pipe. In 16A, the top 202 of the BHA is shown. In this example, two slip assemblies 10 are utilized. However, this would be determined based on the particular well dynamics. Because the motor 198 is at the bottom of the drilling string, slip mechanism 10 may utilize reversed teeth arrangements from that shown previously but otherwise operate the same. If slip system 10 is placed beneath the motor system, then this is not necessary.

[045] A slip system is used herein to release torsional energy from the drilling string when drilling a wellbore. As a further refinement, the position or positions of placement of the slip system(s) within the drilling string is utilized to control the amount of damping of torsional oscillations.

[046] One or more slip systems may be utilized to release torsional energy from the drilling string in order to dampen torsional oscillations due to slip stick.

[047] As discussed below, one type of slip system utilized herein is purely mechanical and may be referred to herein as purely mechanical slip systems, ratchet, or the like. This slip apparatus is connectable between an upper tubular and a lower tubular in the drilling string. This slip system utilizes components that are mechanically linked to lock upper and lower tubulars together when said lower tubular rotates at a velocity equal to or less than said upper tubular, and permit relative rotation between said upper and lower tubulars when said lower tubular rotates at a velocity greater than said upper tubular to thereby release torsional energy from said drilling string.

[048] Many additional changes in the details, components, steps, and organization of the system, herein described and illustrated to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention. It is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

CLAIMS

1. A slip apparatus connectable in a drilling string to release torsional energy from said drilling string when drilling a wellbore, said drilling string extending from the surface to a drill bit, said slip apparatus being connectable between a first tubular and a second tubular in said drilling string, said slip apparatus comprising:

a first component, a first threaded connection on said first component, said first threaded connection being threadably connectable with said first tubular;

a second component mounted for rotation with respect to said first component, a second threaded connection on said second component, said second threaded connection being threadably connectable with said second tubular;

said first component and said component being mechanically linked to lock said first tubular and said second tubular together when said second tubular rotates at a velocity equal to or less than said first tubular, and permit relative rotation between said first tubular and said second tubular when said second tubular rotates at a velocity greater than said first tubular to thereby release torsional energy from said drilling string; and

a computer programmed to make calculations on said drill string for determining a position for said slip apparatus in said drill string from a plurality of different positions in said drill string to control an amount of damping of torsional oscillations in said drill string.

2. The slip apparatus of claim 1, wherein an amount of torsional energy released by said slip apparatus is selectable by selection of a plurality of different depth positions for connection of said slip apparatus at said different depth positions in said drilling string.

3. The slip apparatus of claim 1, further comprising a plurality of discs stacked upon each other between said first component and said second component.

4. The slip apparatus of claim 1, wherein said second component comprises an axially moveable member, a pivotal member, a gear, or a roller.

5. The slip apparatus of claim 1, wherein said second component comprises a first group of discs and a second group of discs, said first group of discs being keyed to said first component, said second group of discs being keyed to said second component.

6. A method for controlling an amount of damping of torsional oscillations in a drill string utilizing a slip system, said method comprising the steps of:

providing that said slip system is operable to drive said drill string or to release torsional energy;

utilizing a processor to make torque and drag calculations on said drill string, said drill string comprising a BHA (bottom hole assembly) and a drill pipe portion;

said BHA being at a lowermost position in said drill string, said BHA comprising a bit and components comprising one or more of a bit sub, drill collar, heavyweight drill collar, heavy weight drill pipe, stabilizer, reamer, shock, hole opener, downhole motor, rotary steerable system, directional equipment, drilling while measurement equipment, steering unit, near bit inclination, non-magnetic drill collar, said BHA being connected to said drill pipe portion of said drill string;

said drill pipe portion comprising additional of said components comprising one or more of a drill pipe, coiled tubing, heavyweight drill pipe, stabilizer; and

utilizing said torque and drag calculations on said drill string for determining a position for said slip system from a plurality of different positions in said drill string to control said amount of damping of torsional oscillations in said drill string.

7. The method of claim 6, further comprising providing that said slip system locks a first tubular and a second tubular together when said second tubular rotates at a velocity equal to or less than said first tubular, and permits relative rotation between said first tubular and second tubular when said second tubular rotates at a velocity greater than said first tubular to thereby release torsional energy from said drill string.

8. The method of claim 7, providing said slip system comprises a first gear slidably mounted to said first tubular and a second gear secured to said second tubular, said first gear and said second gear engaging each other to drive said drilling string.

9. The method of claim 7, providing said slip system comprises a plurality of locking members positioned in a chamber between a smooth inner cylindrical wall and a smooth outer cylindrical wall of said first tubular and said second tubular.

10. The method of claim 9, wherein a cross-section of each locking member comprises six sides.

11. The method of claim 7, wherein said slip system comprises a plurality of plates positioned between said first tubular and said second tubular.

12. The method of claim 11, wherein a portion of said plurality of plates are keyed to said first tubular and another portion of said plurality of plates are keyed to said second tubular.

13. A method for controlling an amount of damping of torsional oscillations in a drillstring utilizing one or more positions in said drill string, said drillstring extending

from the surface to a drill bit, said drill string being movable in a wellbore, said method comprising the steps of:

providing a plurality of slip systems for insertion at a plurality of positions in said drill string, each slip system being connectable between a first tubular and a second tubular, each of said plurality of slip systems being operable for transferring torque between said first tubular and said second tubular or allowing slippage between said first tubular and said second tubular;

said drillstring comprising a BHA (bottom hole assembly) and a drill pipe portion;

said BHA being at a lowermost position in said drillstring, said BHA comprising a bit and components comprising one or more of a bit sub, drill collar, heavyweight drill collar, heavy weight drill pipe, stabilizer, reamer, shock, hole opener, downhole motor, rotary steerable system, directional equipment, drilling while measurement equipment, steering unit, near bit inclination, non-magnetic drill collar, said BHA being connected to said drill pipe portion of said drillstring; and

said drill pipe portion comprising additional of said components comprising one or more of a drill pipe, coiled tubing, heavyweight drill pipe, stabilizer.

14. The method of claim 13, further comprising providing that said slip system locks said first tubular and said second tubular together when said second tubular rotates at a velocity equal to or less than said first tubular, and permits relative rotation between said first tubular and said second tubular when said second tubular rotates at a

velocity greater than said first tubular to thereby release torsional energy from said drilling string.

15. A slip apparatus connectable in a drilling string to release torsional energy from said drilling string when drilling a wellbore, said drilling string extending from the surface to a drill bit, said slip apparatus being connectable between a first tubular and a second tubular in said drilling string, said slip apparatus comprising:

a first component, a first threaded connection on said first component, said first threaded connection being threadably connectable with said first tubular;

a second component mounted for rotation with respect to said first component, a second threaded connection on said second component, said second threaded connection being threadably connectable with said second tubular; and

a plurality of plates positioned between said first component and said second component, said plurality of plates being urged to lock said first and second tubulars together when said second tubular rotates at a velocity equal to or less than said first tubular, and permit relative rotation between said first and second tubulars when said second tubular rotates at a velocity greater than said first tubular.

16. The slip apparatus of claim 15, wherein said plurality of plates are mechanically linked to compress against one another to lock said first tubular and said second tubular together and to move apart from each other to permit relative rotation

between said first tubular and said second tubular when said second tubular rotates at a velocity greater than said first tubular.

17. A slip apparatus connectable in a drilling string to release torsional energy from said drilling string when drilling a wellbore, said drilling string extending from the surface to a drill bit, said slip apparatus being connectable between a first tubular and a second tubular in said drilling string, said slip apparatus comprising:

a first component, a first threaded connection on said first component, said first threaded connection being threadably connectable with said first tubular;

a second component mounted for rotation with respect to said first component, a second threaded connection on said second component, said second threaded connection being threadably connectable with said second tubular; and

a plurality of locking members positioned between said first component and said second component, said plurality of locking members comprising a cross-section comprising a plurality of sides, said plurality of locking members being rotatable to a locking position that lockingly engages said first and second components to lock said first and second tubulars together when said second tubular rotates at a velocity equal to or less than said first tubular, and said plurality of locking members being rotatable to a released position that slidingly engage said first and second components when said second tubular rotates at a velocity greater than said first tubular.

18. The slip apparatus of claim 17, wherein said first and second components form a chamber therebetween comprising a smooth tubular inner wall and a smooth

tubular outer wall, two of said plurality of sides of said locking members engaging said smooth tubular inner wall and said smooth tubular outer wall.

19. The slip apparatus of claim 17, further comprising said plurality of locking members forming a ring with each locking member engaging two neighboring locking members.

20. The slip apparatus of claim 17, further comprising two of said plurality of sides being rounded.

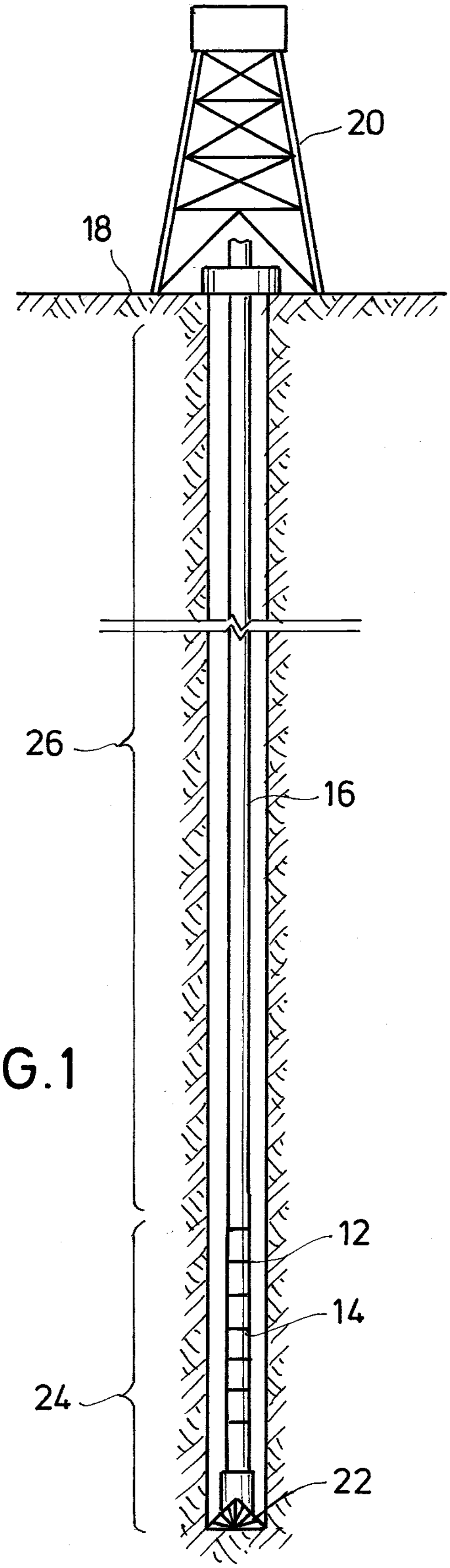


FIG.1

FIG.2

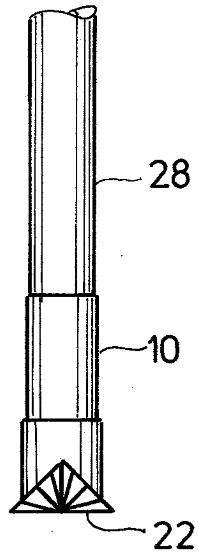
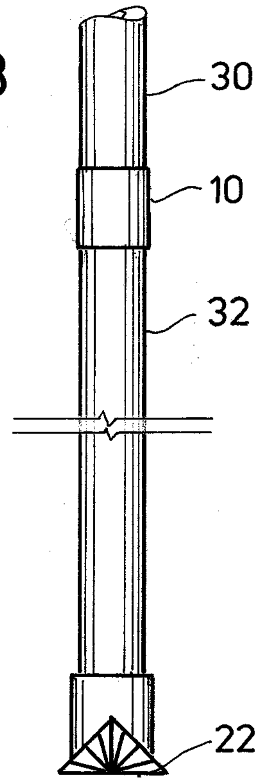


FIG.3



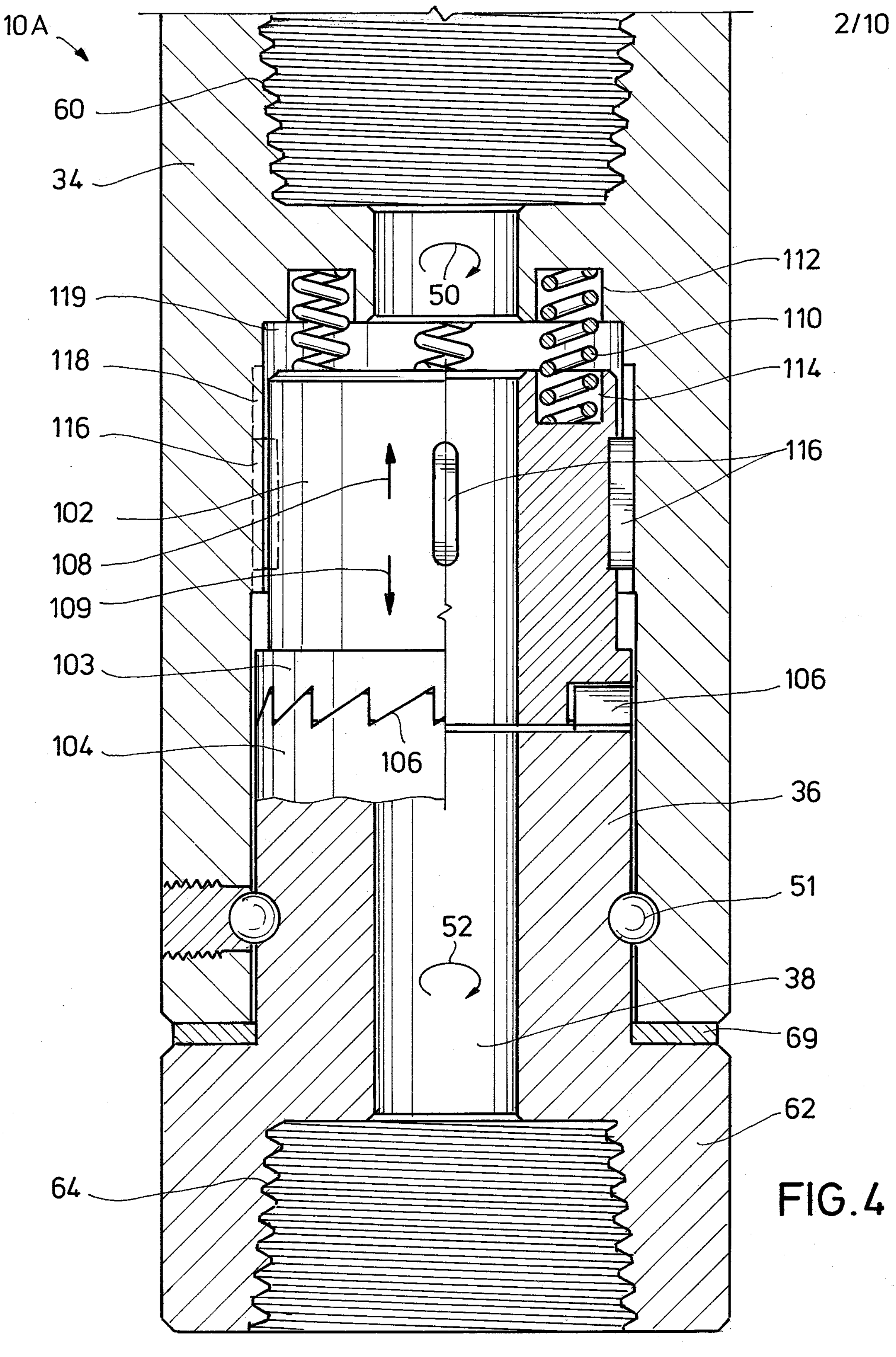
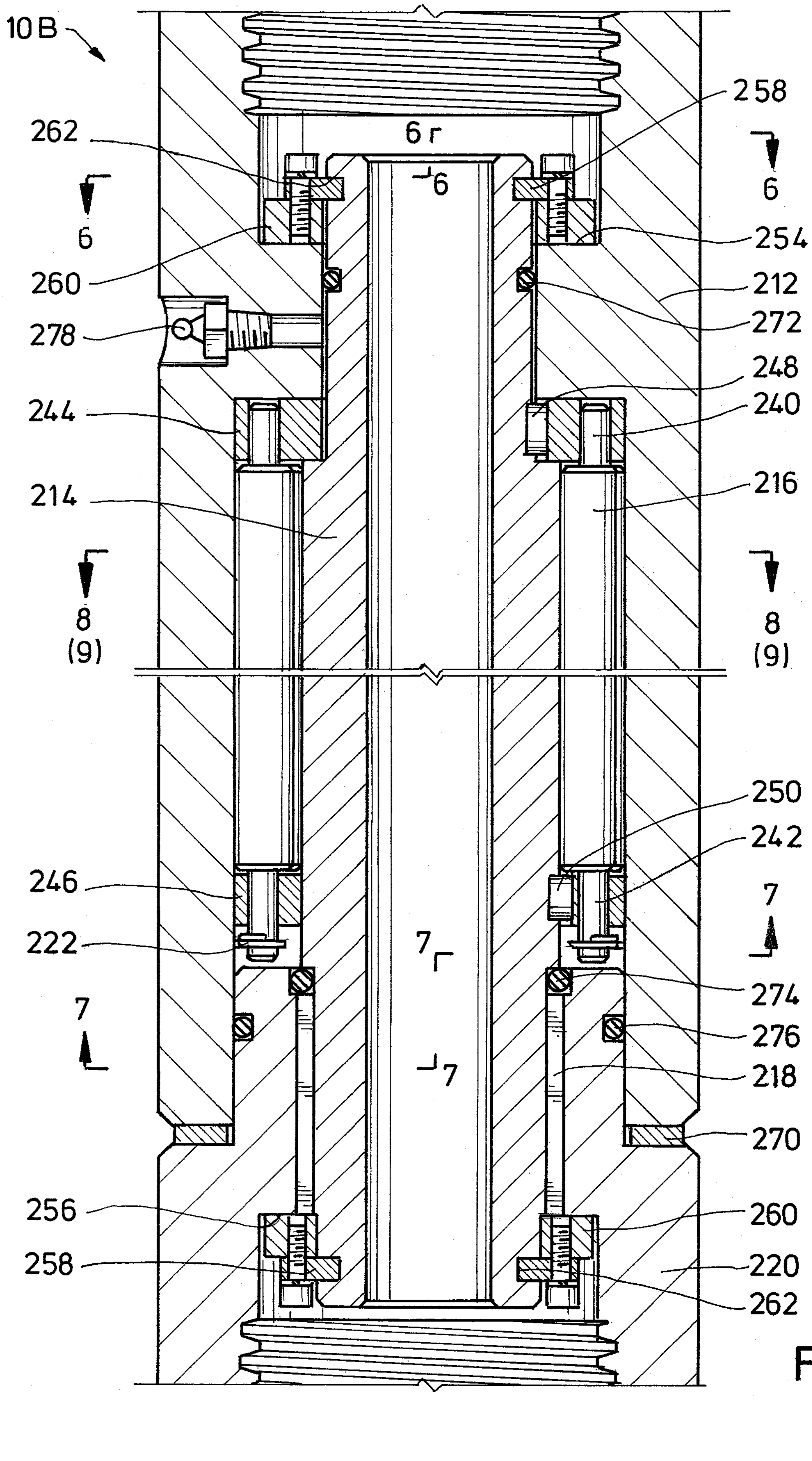

10A
60
34
112
50
119
110
118
114
116
116
102
108
109
103
106
104
106
36
51
52
38
69
62
64

FIG.4



10B
262
258
6
6
6
6
260
254
212
278
272
248
244
240
214
216
8
(9)
8
(9)
250
242
246
7
222
7
7
274
7
276
7
218
270
256
260
258
220
262

FIG.5

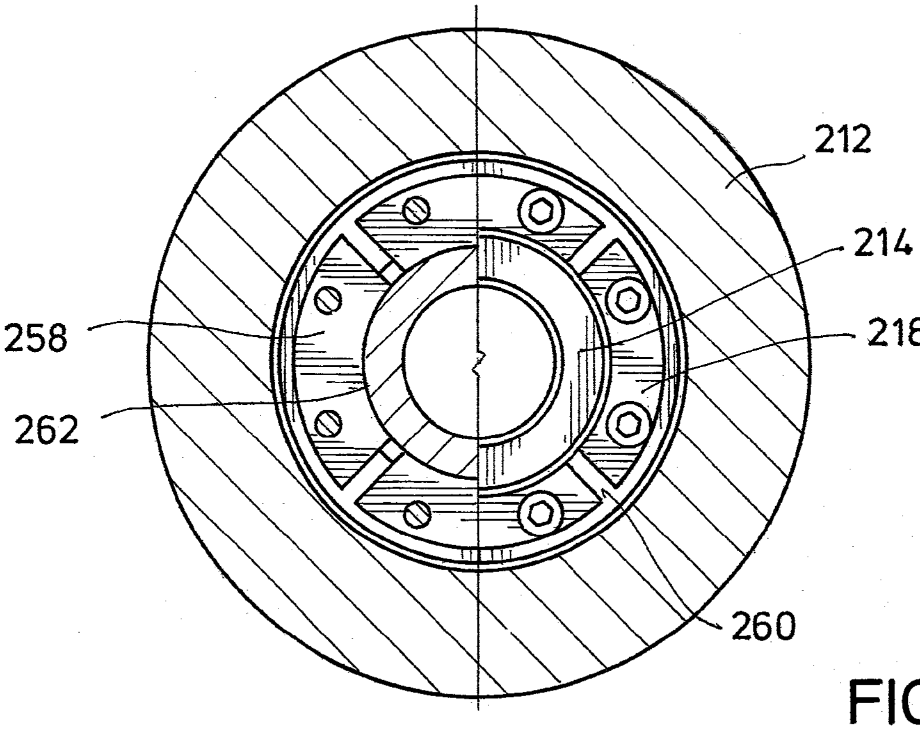


FIG.6

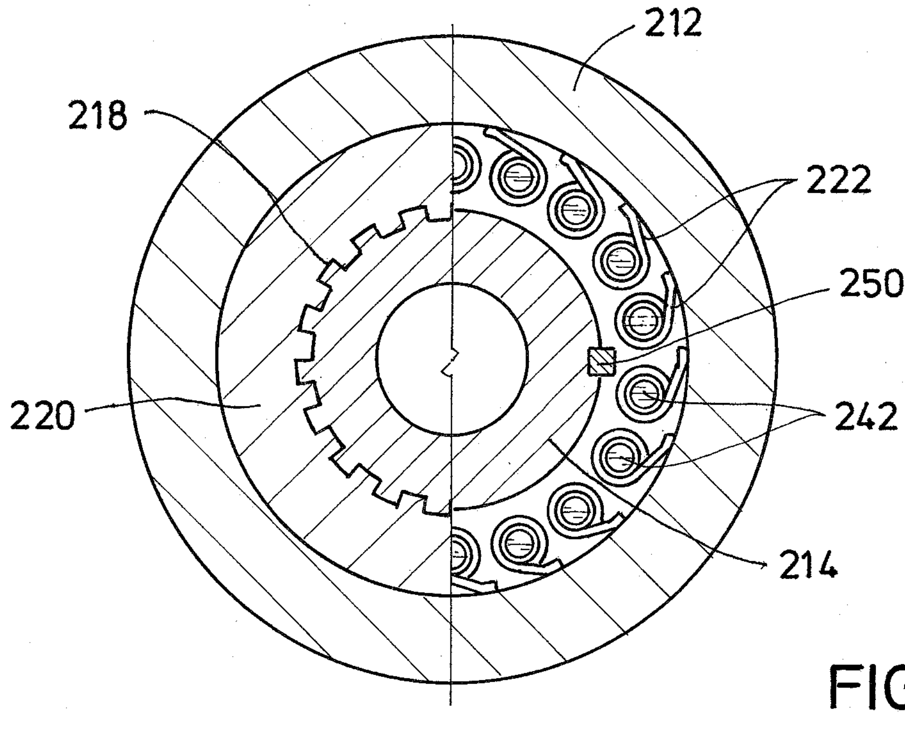


FIG.7

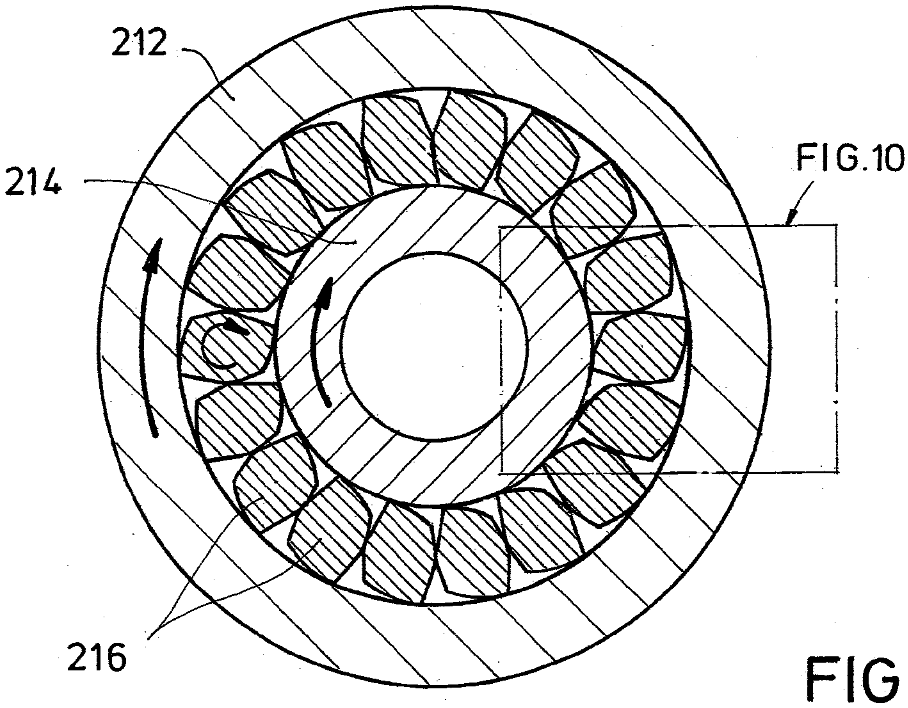


FIG.8

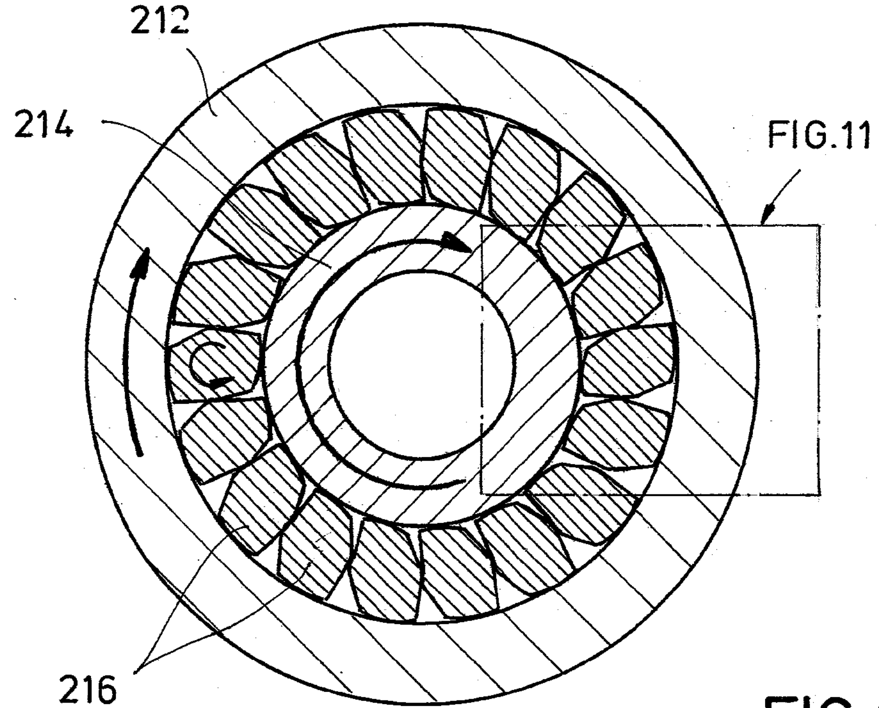


FIG.9

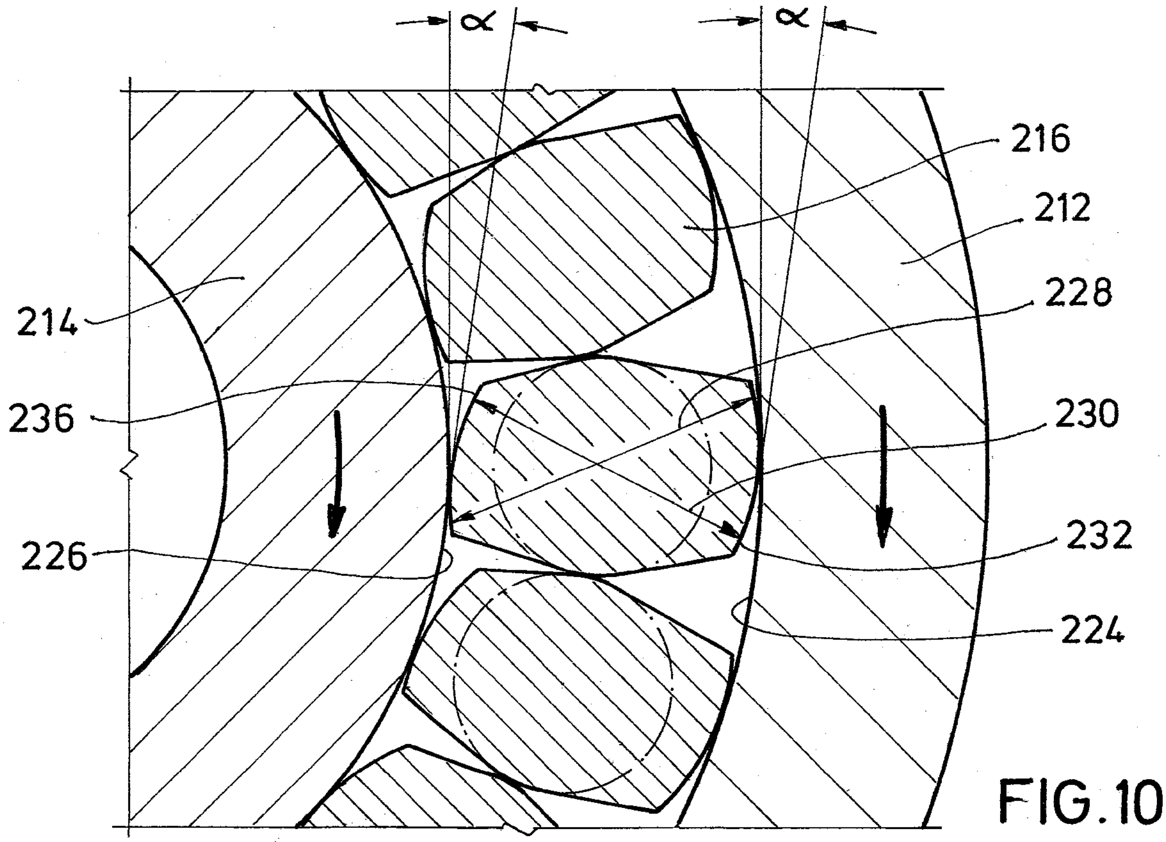

α
α
216
212
228
214
236
230
226
232
224

FIG.10

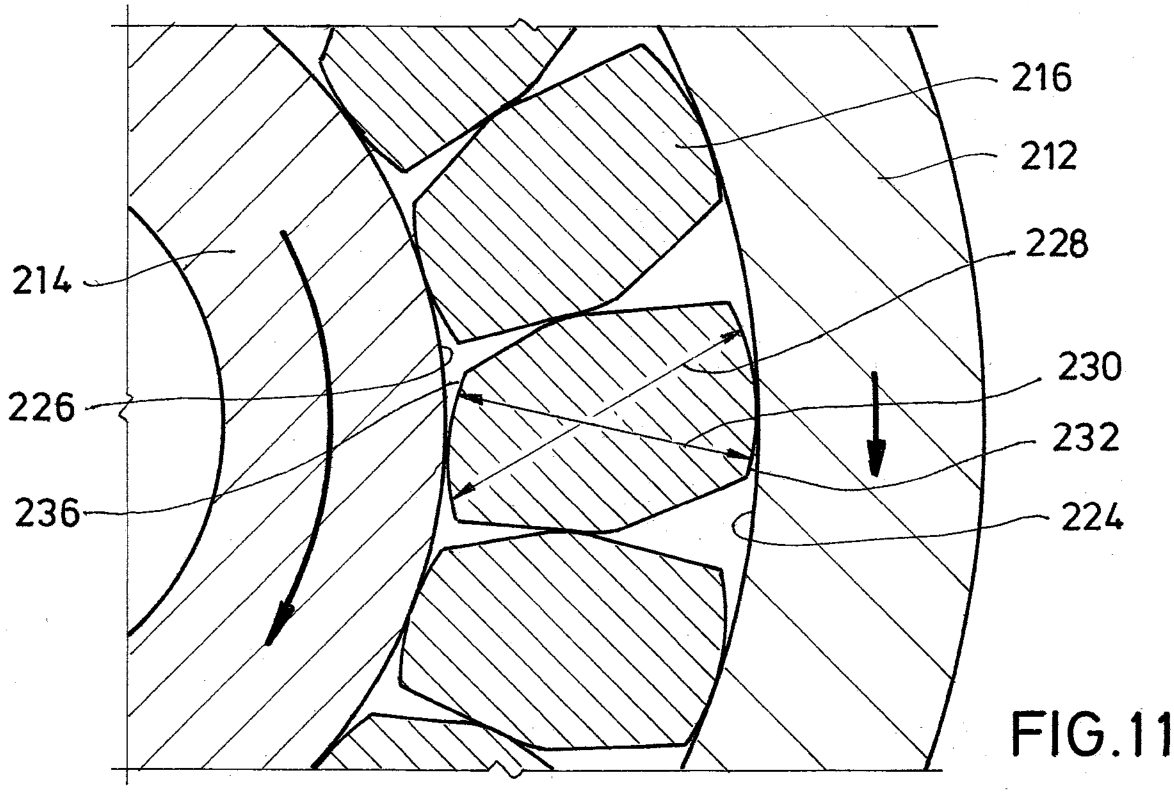

216
212
228
214
230
226
232
236
224

FIG.11

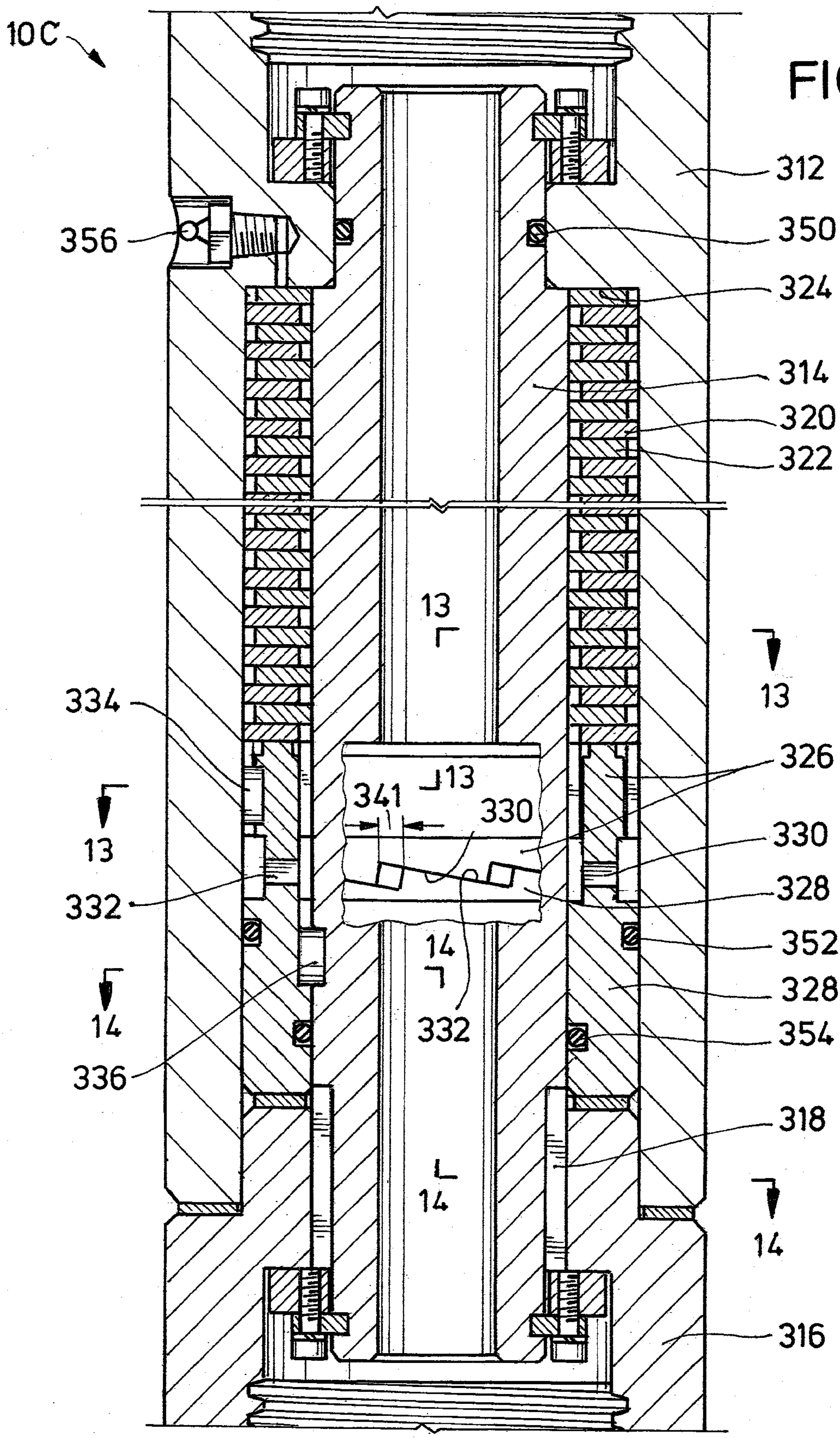

10C
312
356
350
324
314
320
322
13
334
326
13
341
330
330
332
328
352
14
328
14
332
354
336
318
14
14
316

FIG.12

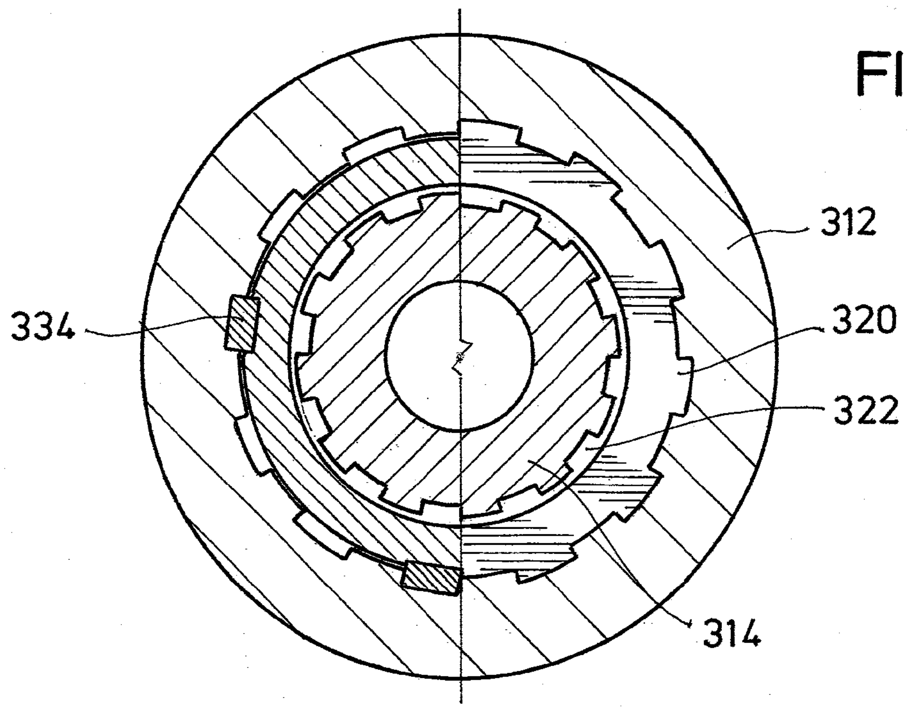


FIG.13

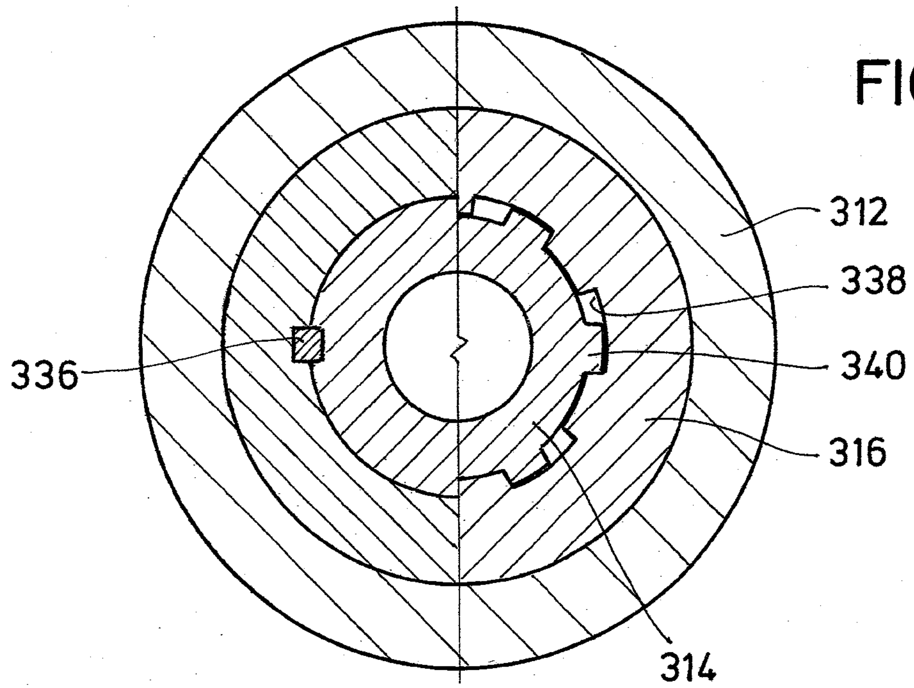


FIG.14

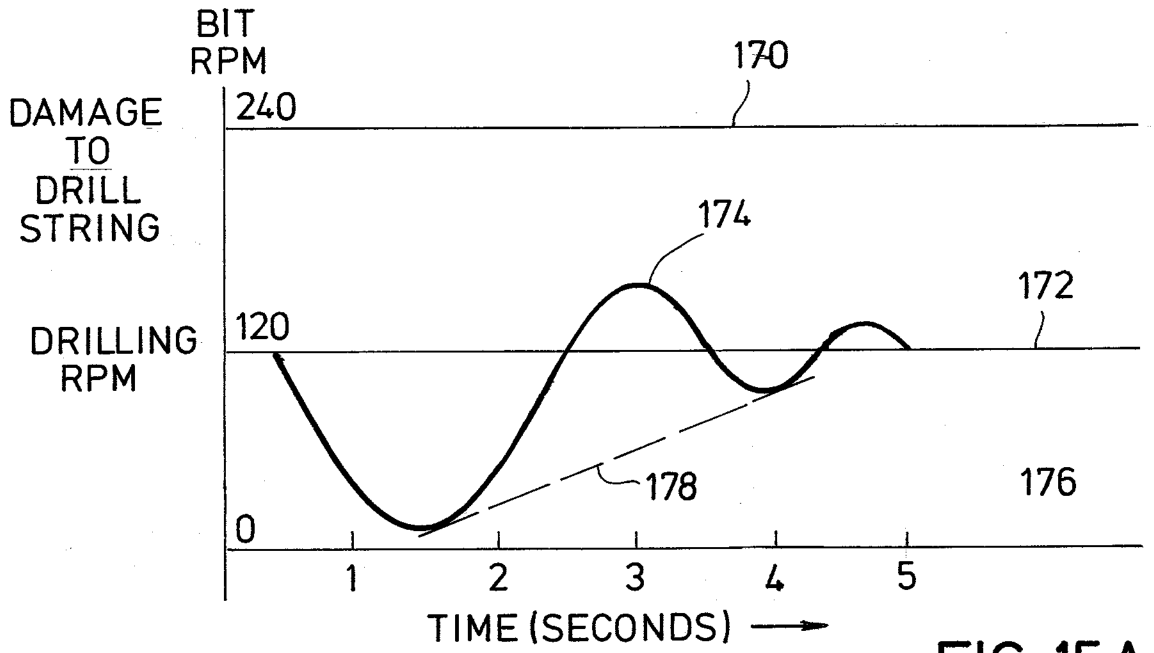


FIG.15A

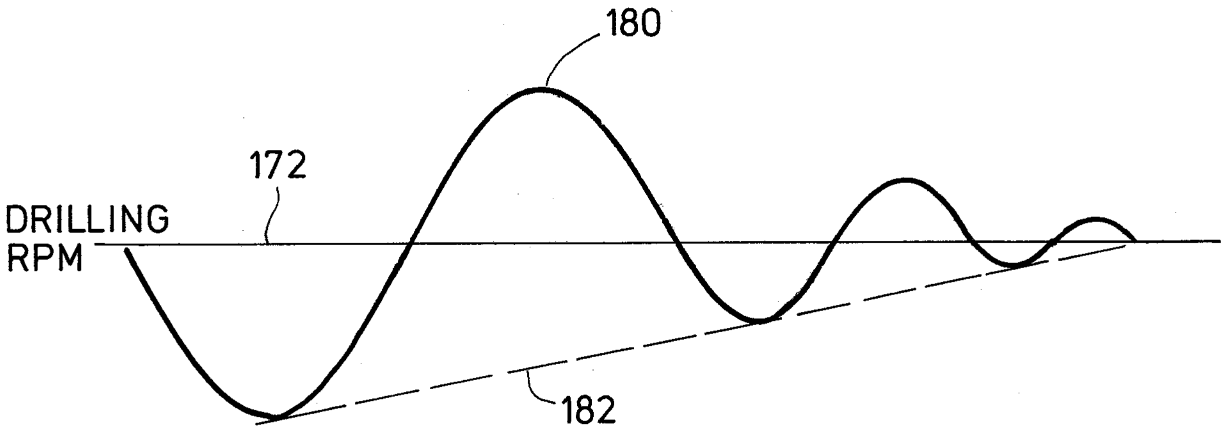


FIG.15B

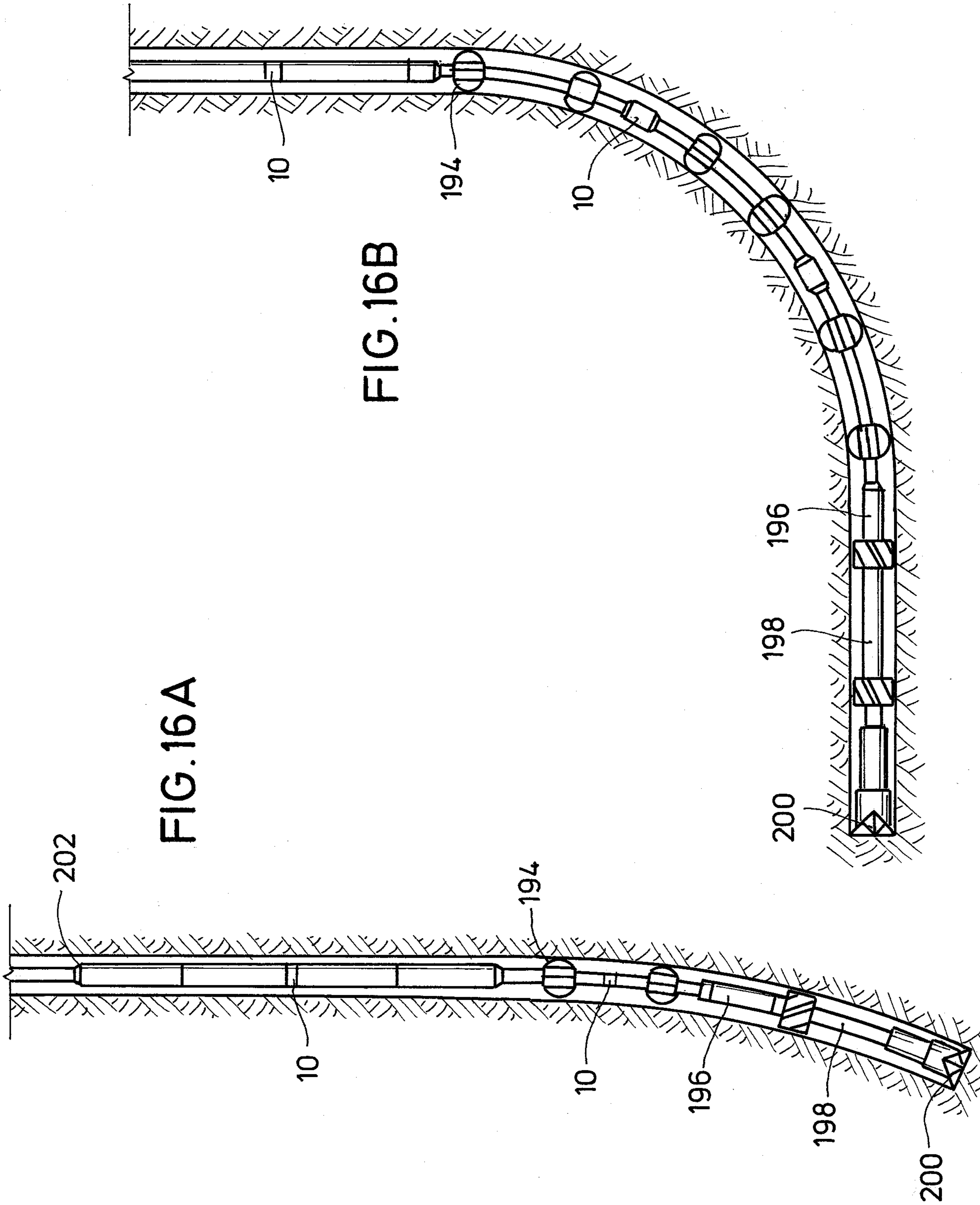


FIG.16B

FIG.16A

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2019/034325

A. CLASSIFICATION OF SUBJECT MATTER

E21B 17/10 *(2006.01)*
E21B 44/04 *(2006.01)*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 7/00, 7/06, 17/00-17/10, 19/00, 19/16, 19/18, 43/00, 44/00-44/04, 47/01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSearch (RUPTO Internal), USPTO, PAJ, Espacenet, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RU 2329376 C2 (STRATELOK TECHNOLOGY PRODACTS LLC) 20.07.2008, p. 12, lines 19-29, line 40 - p. 13, line 16, lines 23-28, 36-46, p. 14, lines 3-5, 19-50, p. 15, lines 8-27, p. 16, lines 18-22, 35-37, p. 17, line 31 - p. 18, line 2, fig. 1, 2, 12	1, 2, 6-9, 13, 14
A		3-5, 10-12, 15-20
A	RU 2625682 C1 (KHALLIBERTON ENERGY SERVICES INC.) 18.07.2017	1-20
A	US 2017/0089149 A1 (ATLAS COPCO SECOROC AB) 30.03.2017	1-20
A	US 9145768 B2 (SCHLUMBERGER TECHNOLOGY CORPORATION) 29.09.2015	1-20

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier document but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2019 (11.09.2019)	26 September 2019 (26.09.2019)

Name and mailing address of the ISA/RU:	Authorized officer
Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993	E. Stopchataya
Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Telephone No. 8(495) 531-64-81