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(31) **11000372**	(32) **01.03.2011**	(33) **US**
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(31) **1111482**	(32) **05.07.2011**	(33) **GB**
(31) **1116098**	(32) **19.09.2011**	(33) **GB**

(71) Applicant(s):
Bruce Arnold Tunget
35 Eastside Drive, WESTHILL, Aberdeenshire, AB32 6QN, United Kingdom

(72) Inventor(s):
Bruce Arnold Tunget

(74) Agent and/or Address for Service:
Bruce Arnold Tunget
35 Eastside Drive, WESTHILL, Aberdeenshire, AB32 6QN, United Kingdom

(51) INT CL:
E21B 17/10 (2006.01)

(56) Documents Cited:
WO 2010/022755 A1 **WO 2000/040833 A1**
US 6837621 B1 **US 20090242276 A1**

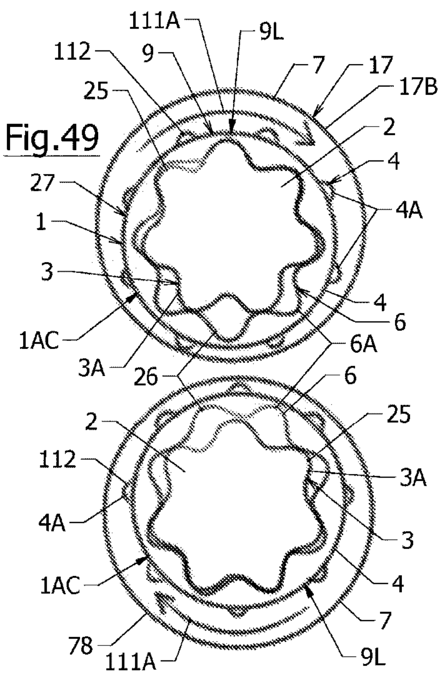
(58) Field of Search:
INT CL **E21B**
Other: **Online : WPI, EPODOC**

(54) Title of the Invention: **Rotary stick, slip and vibration reduction drilling stabilize s with hydrodynamic fluid bearings and homogenizers**

Abstract Title: **Hydrodynamic stabilising device for a down-hole rotating shaft**

(57) A device for reducing friction and vibrations in a down-hole rotating shaft comprising a hydrodynamic bearing 1 surrounding the shaft 2 within the bore, an arced wall 4 radially extending from a conduit shaft housing, a hydrodynamic profiled wall 3 rotatable by or about the shaft which displaces fluid axially along the inner wall forcing fluid between two adjacent walls. The fluid creating a pressurised cushion between the walls lubricating the bearing and dampening vibrations and stabilising the shaft. The hydrodynamic profiles comprising impellors, stators or rotors to displace the fluid.

Fig.49



GB 2486591 A

Fig.1

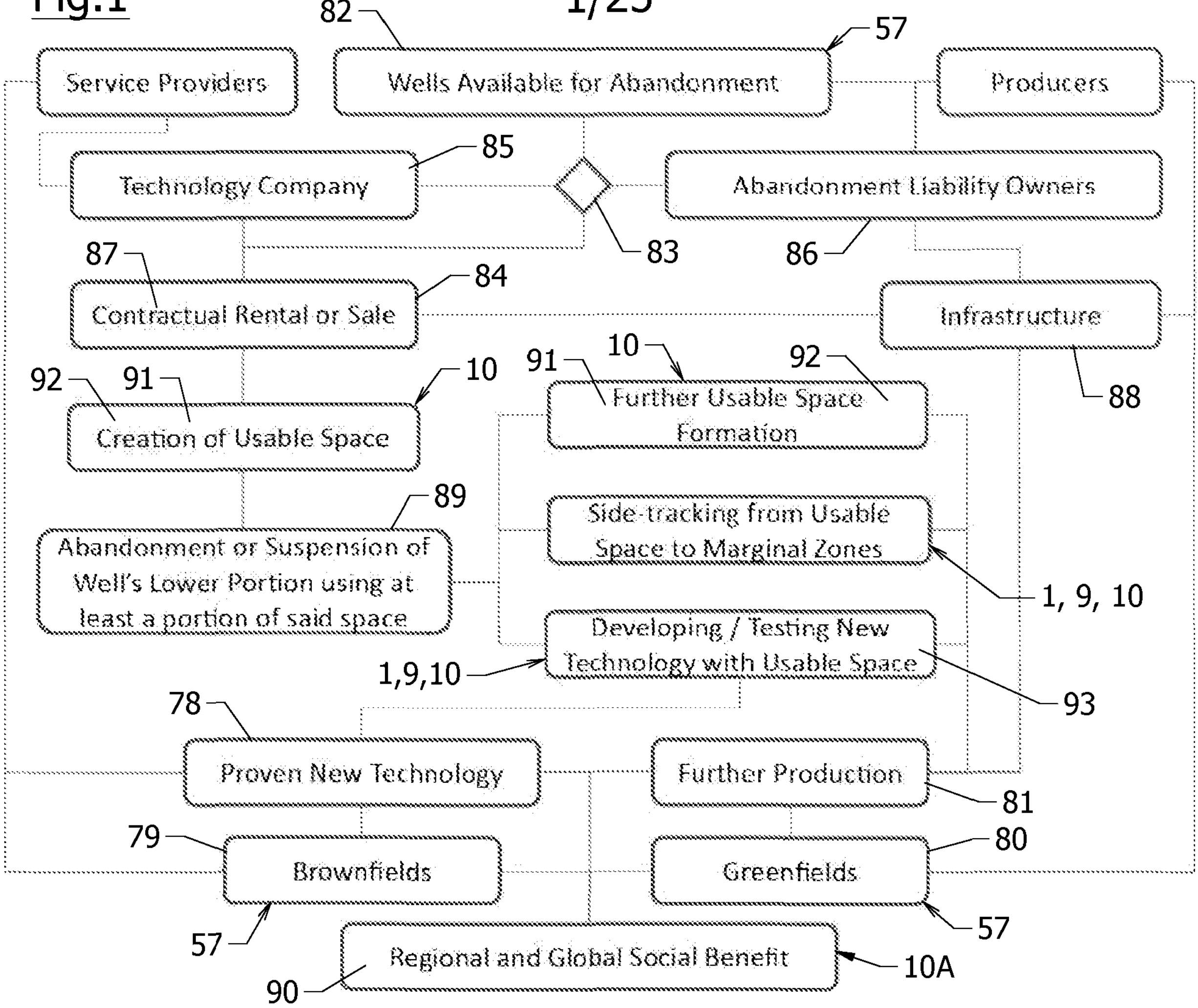


Fig.22
Prior Art

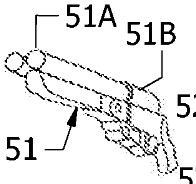


Fig.23
Prior Art

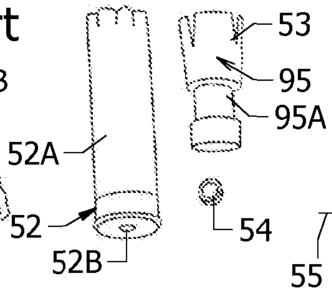
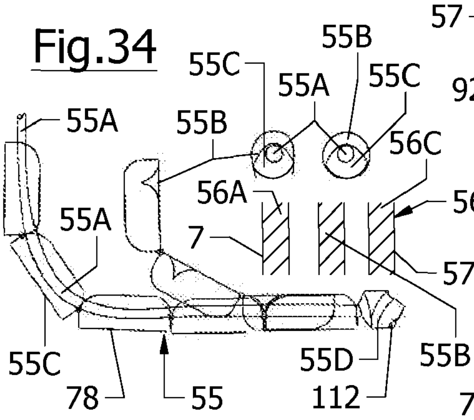
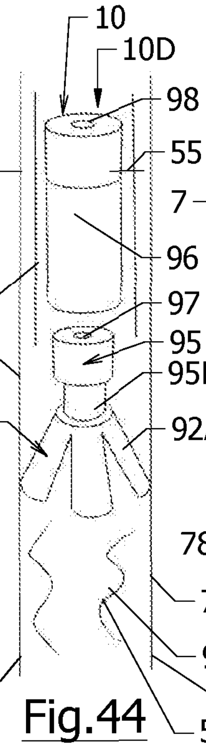


Fig.34





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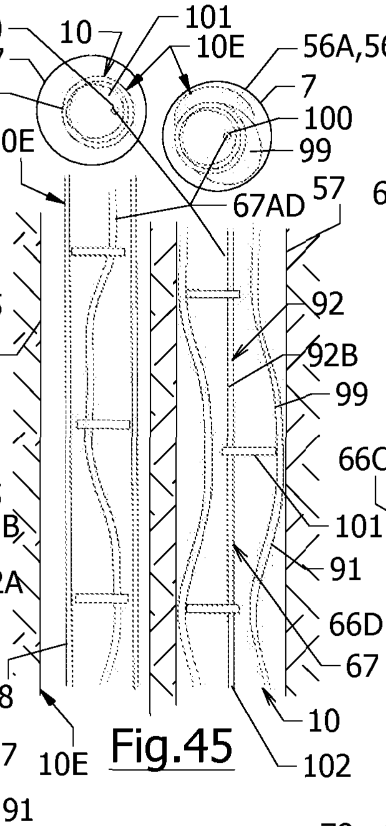
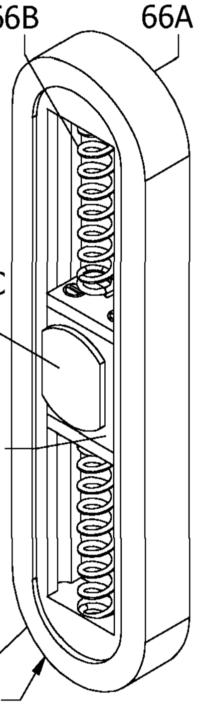


Fig.45

Fig.33



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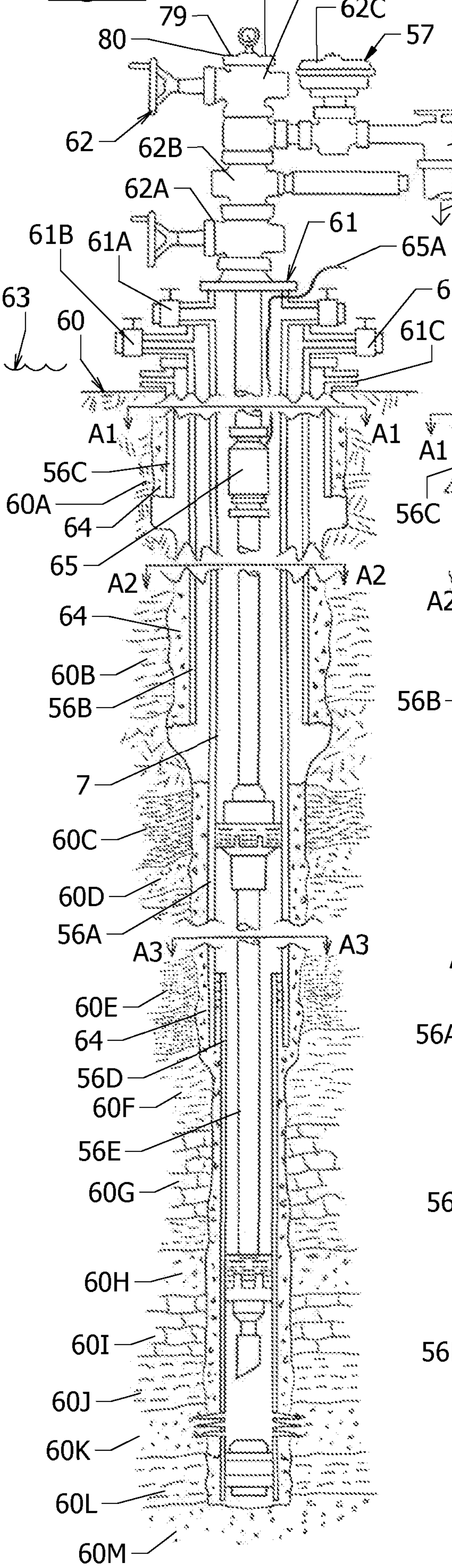
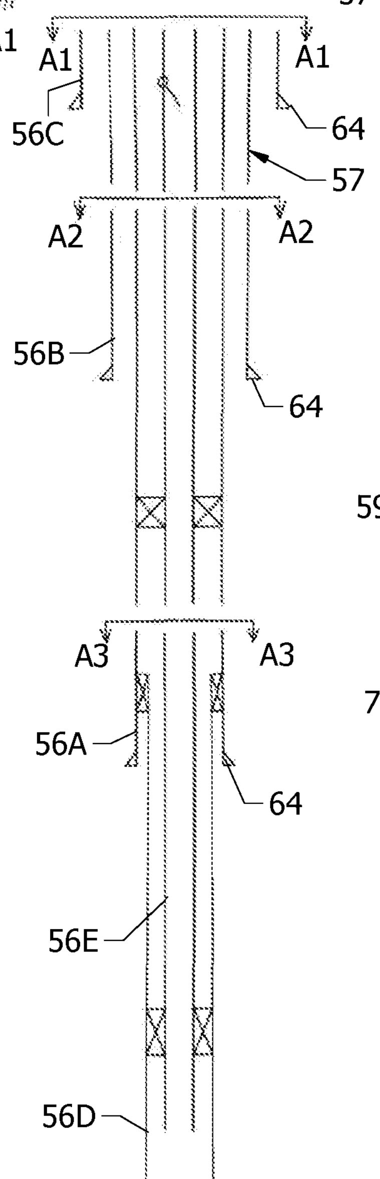


Fig. 2A



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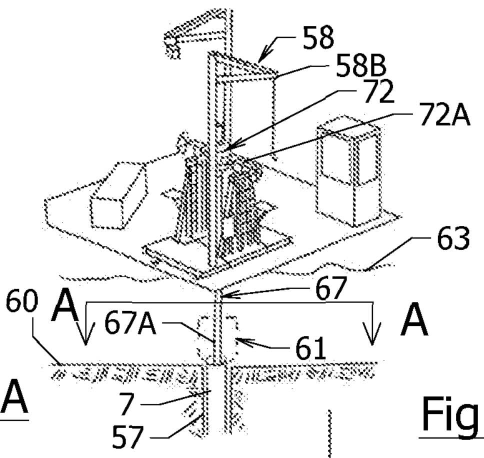

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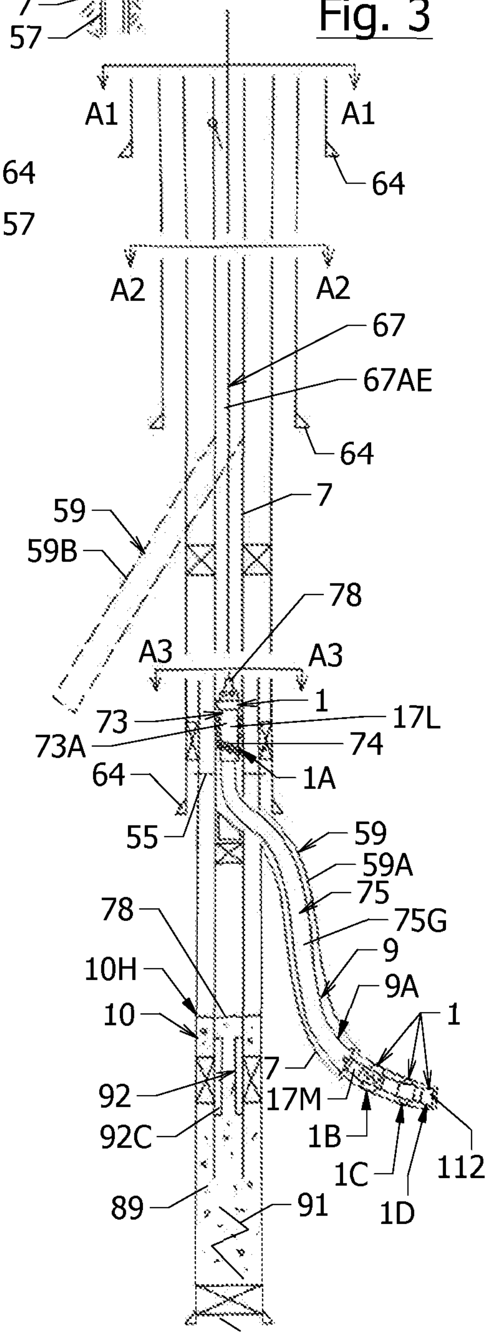
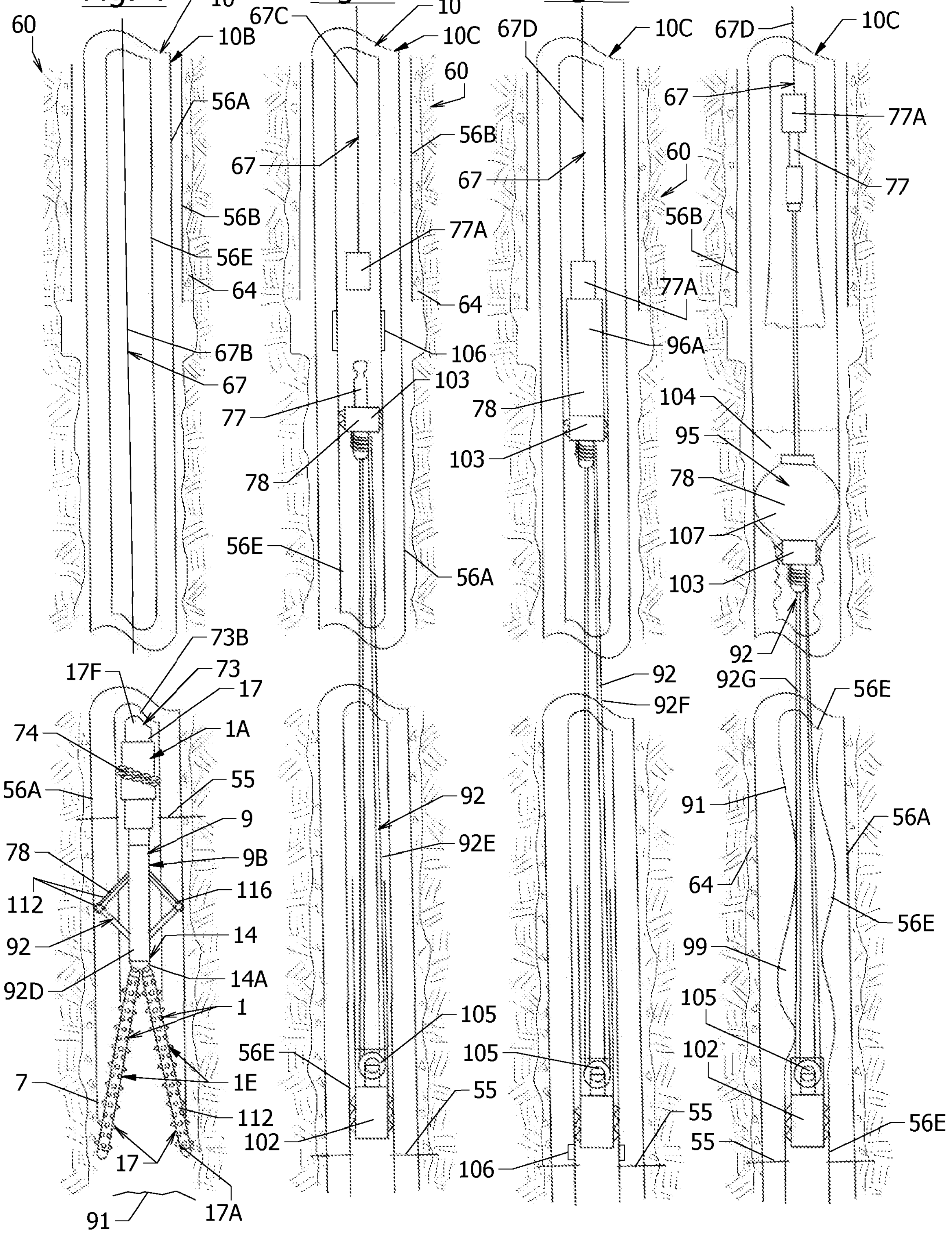
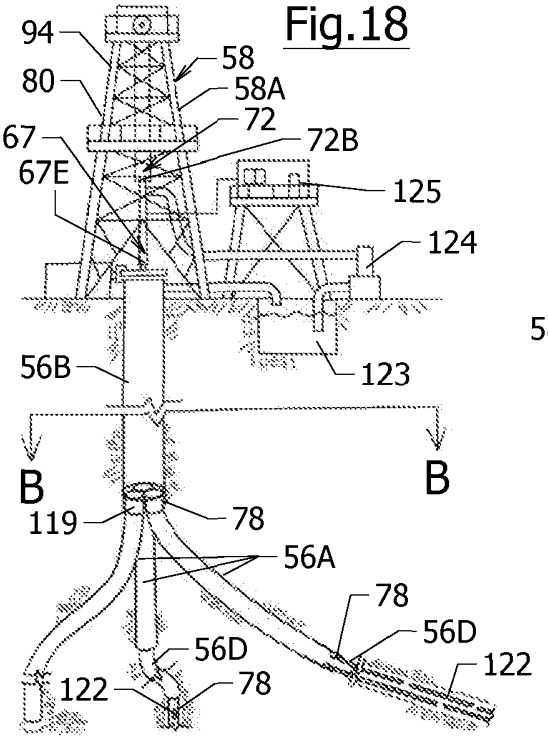


Fig. 4 Fig. 5 Fig. 6 Fig. 7





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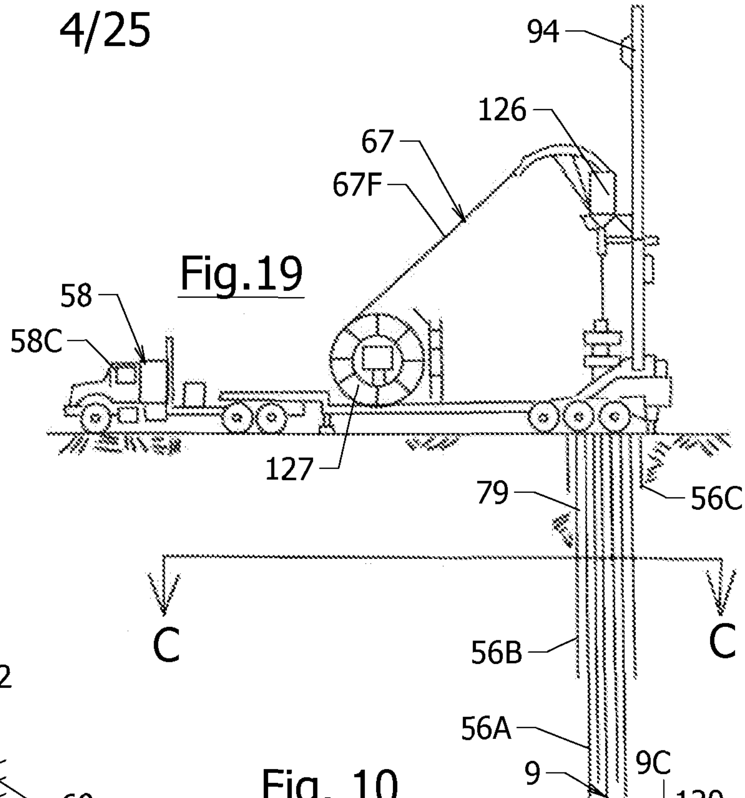

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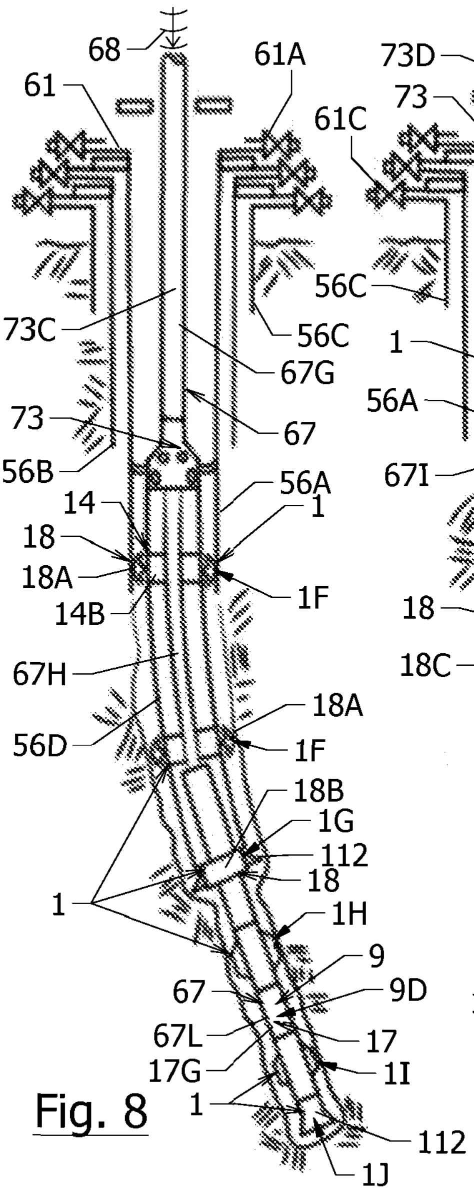

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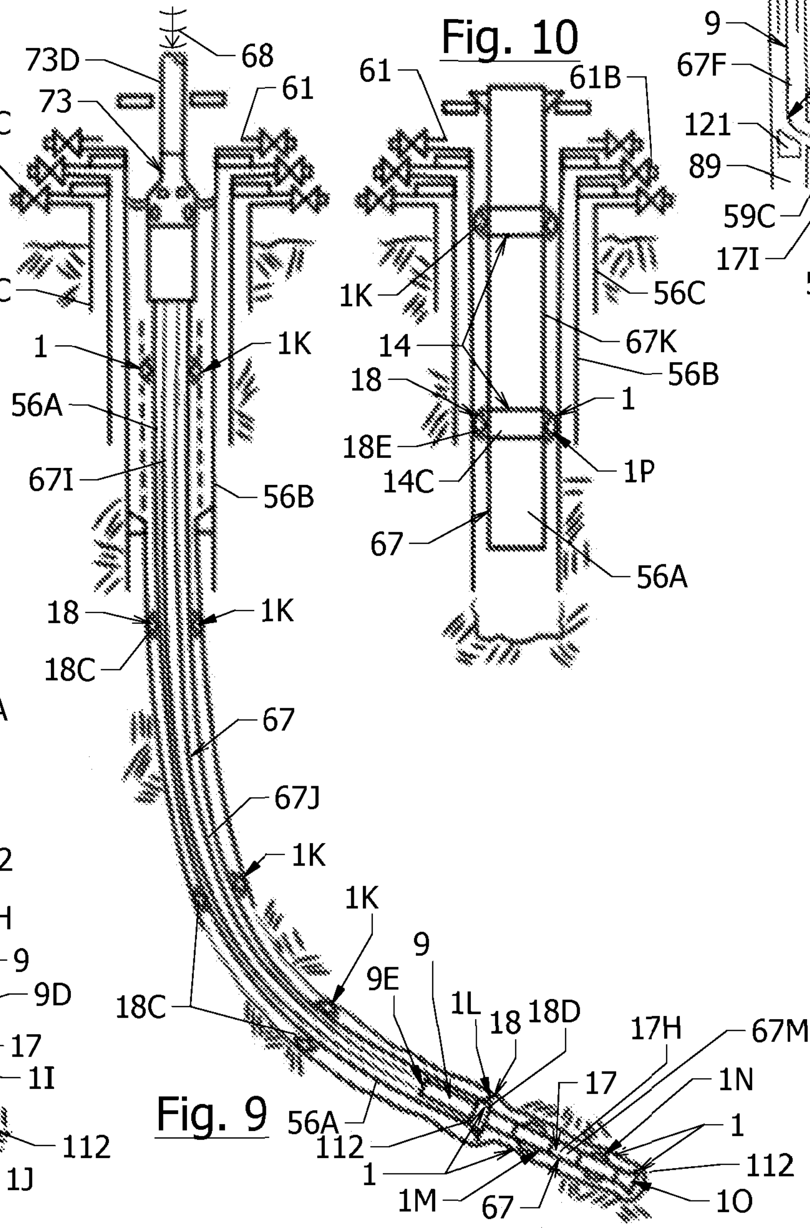
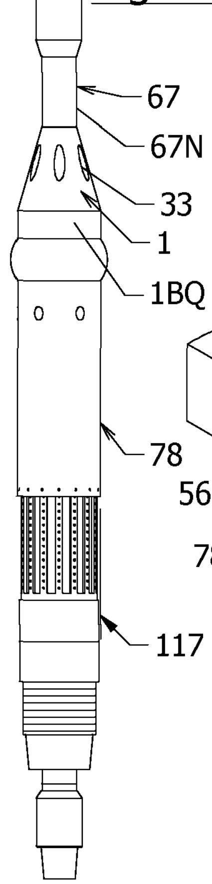


Fig. 9

Fig. 10

Fig.35



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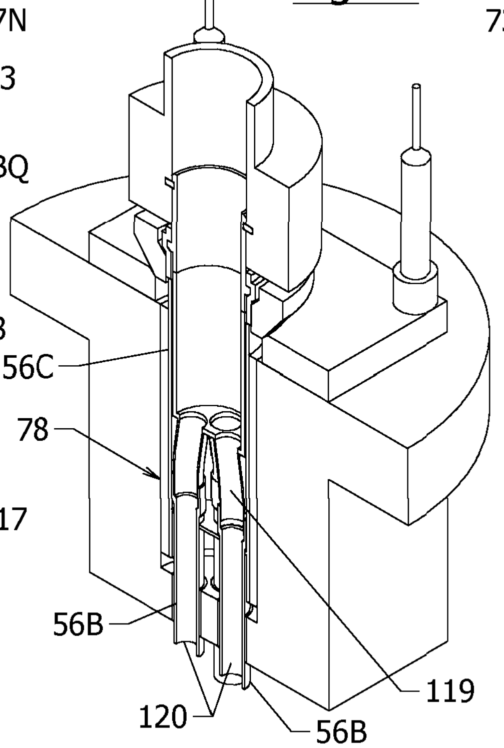
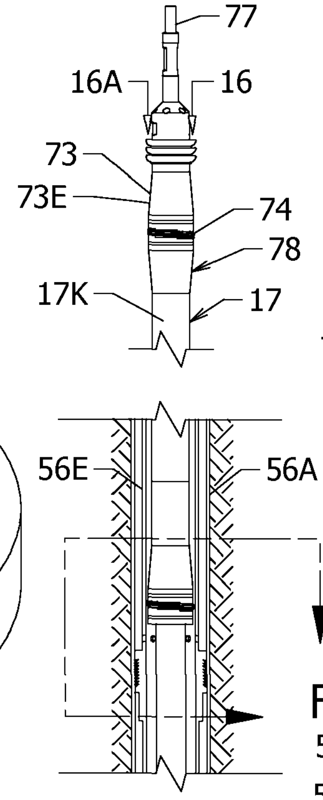




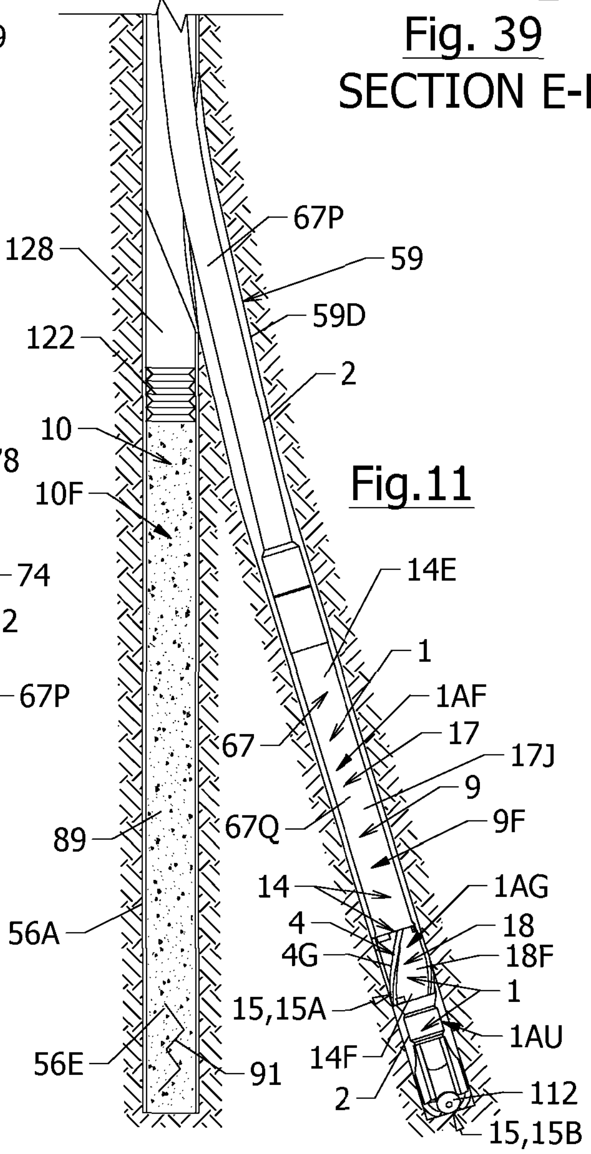
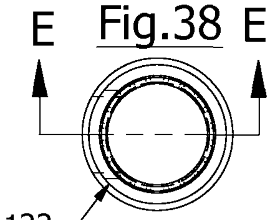


Fig.11

Fig.38



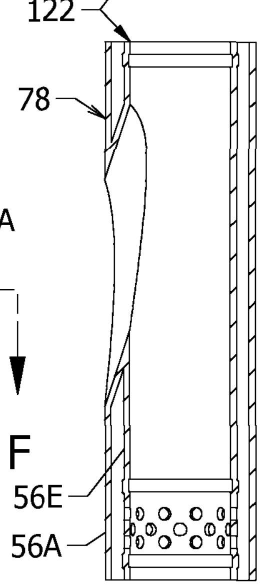
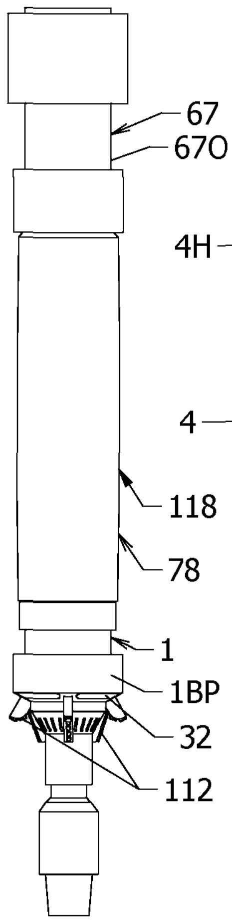


Fig. 39

SECTION E-E

Fig.36



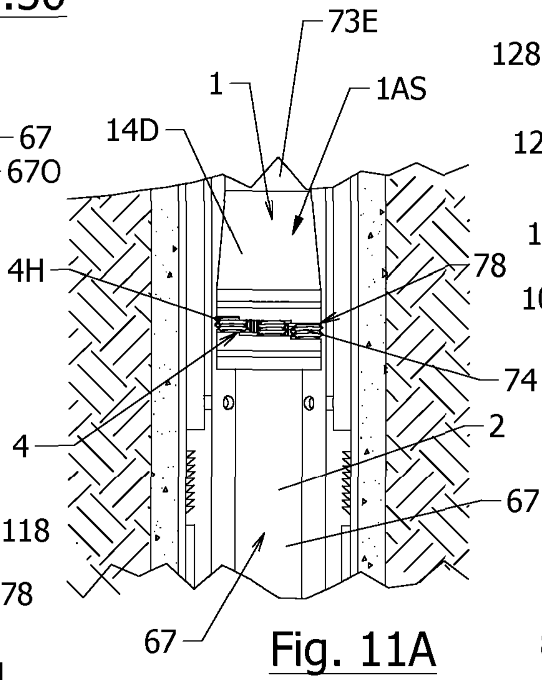


Fig. 11A

DETAIL F

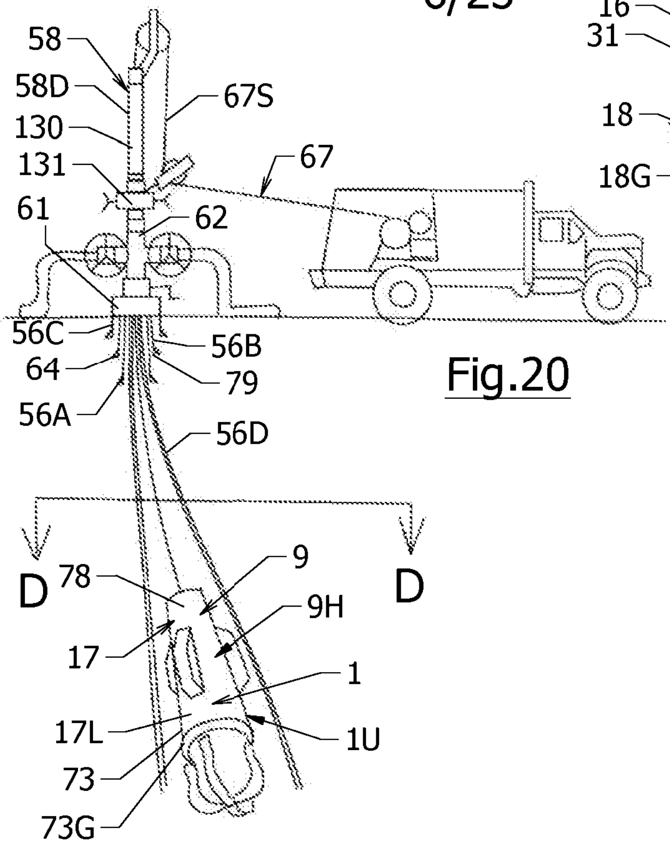


Fig.20

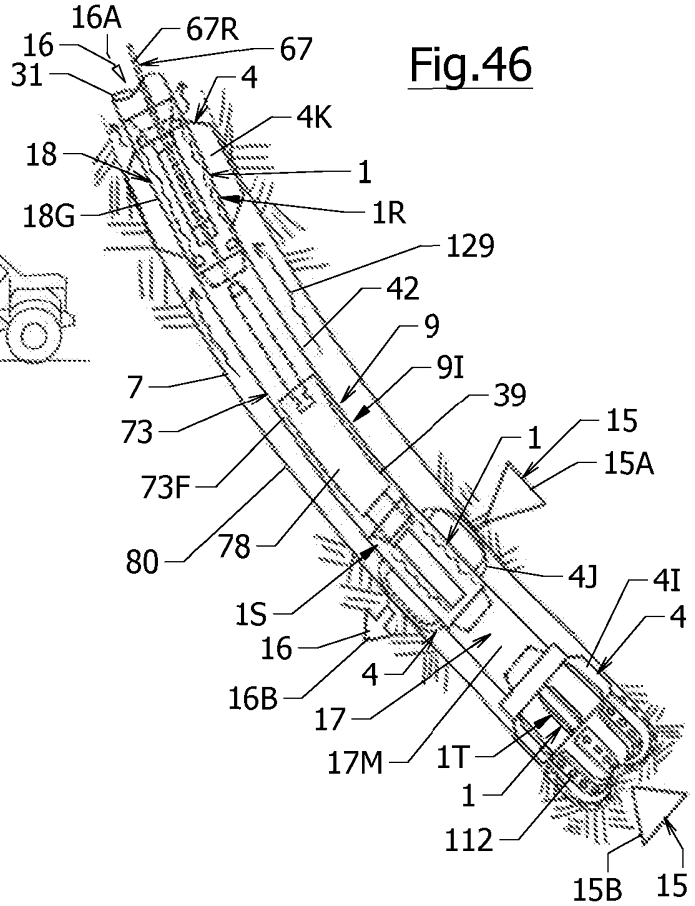
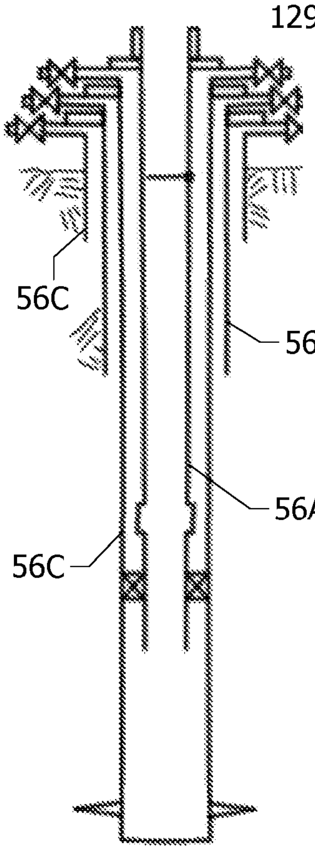


Fig.46

Fig.12



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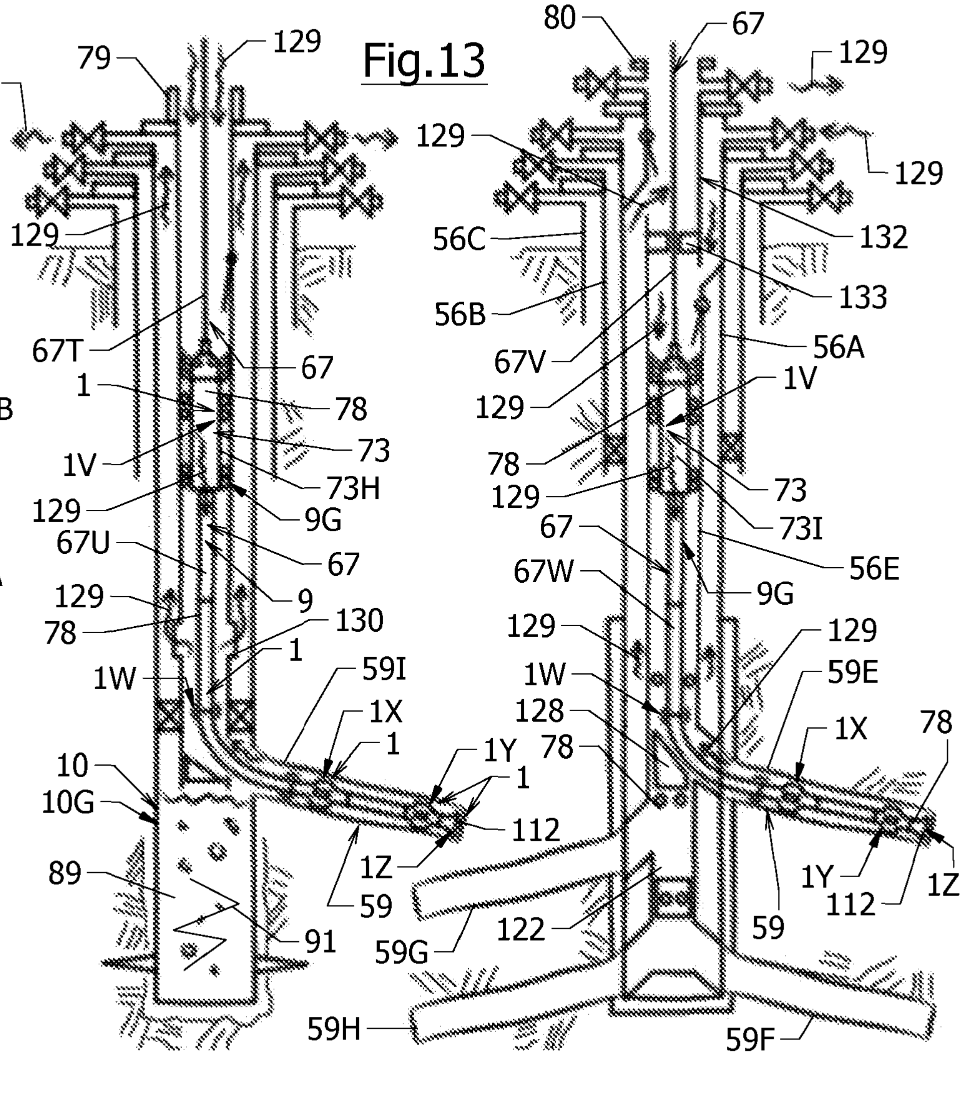

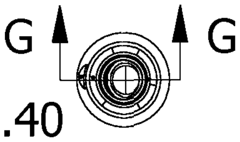

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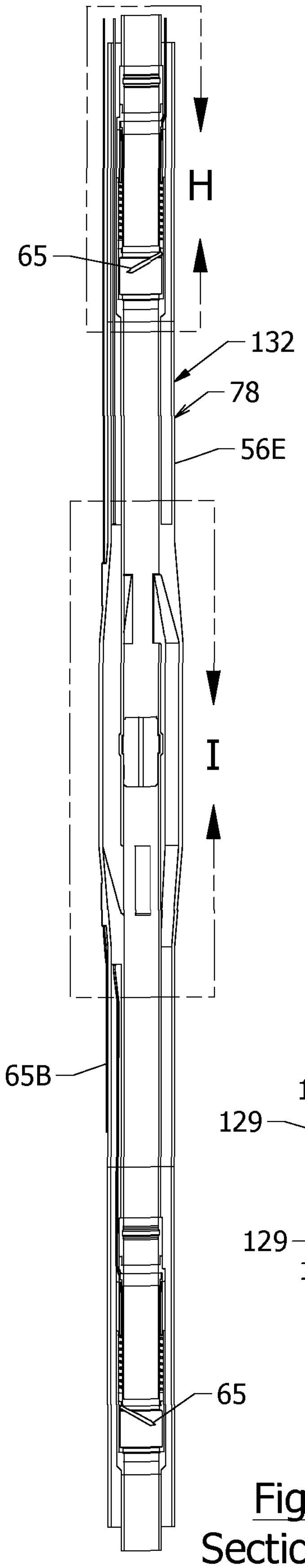
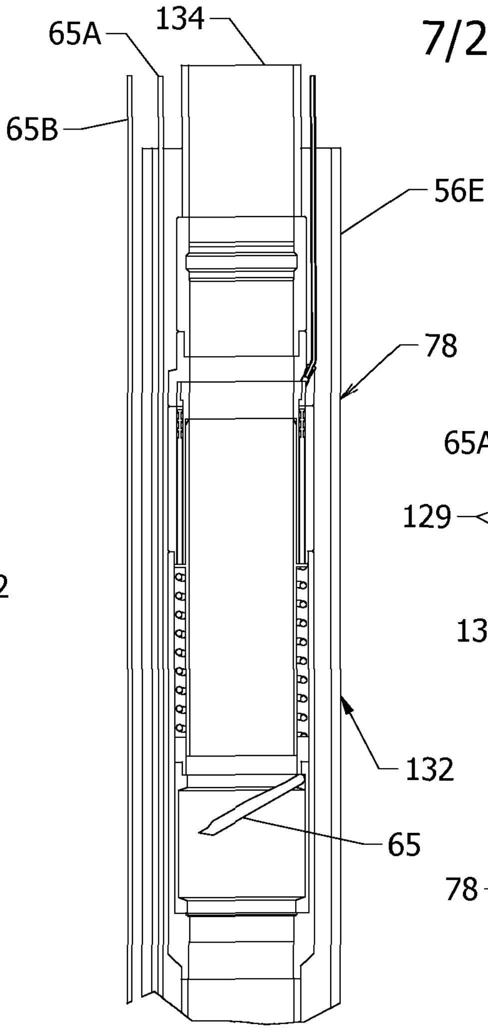


Fig.41
Section G-G



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Detail H

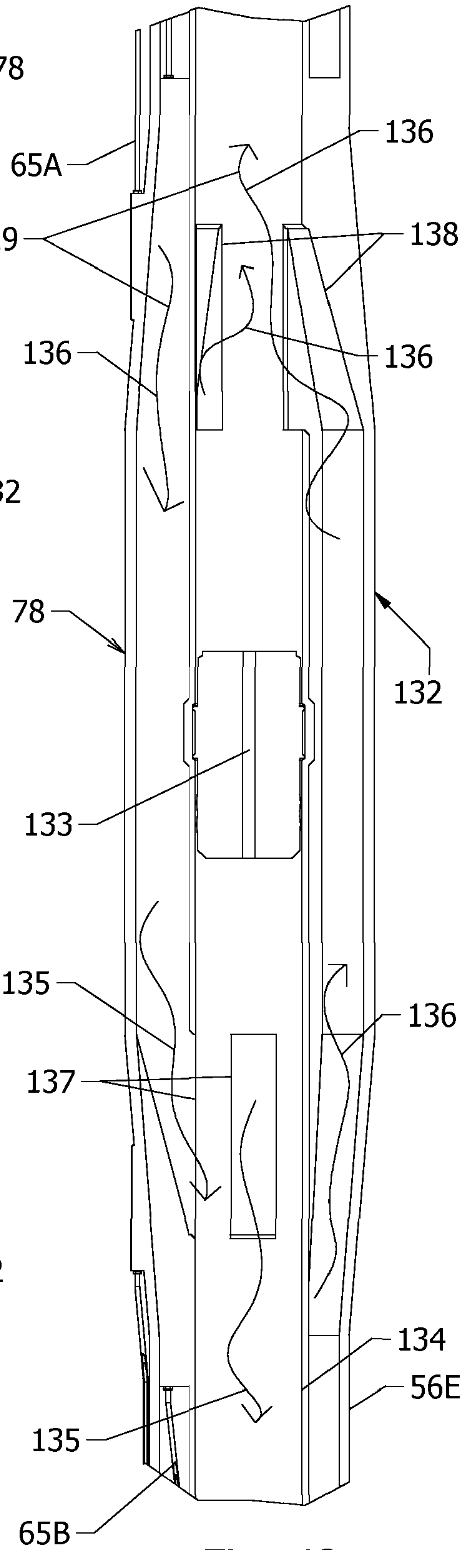


Fig. 43
Detail I

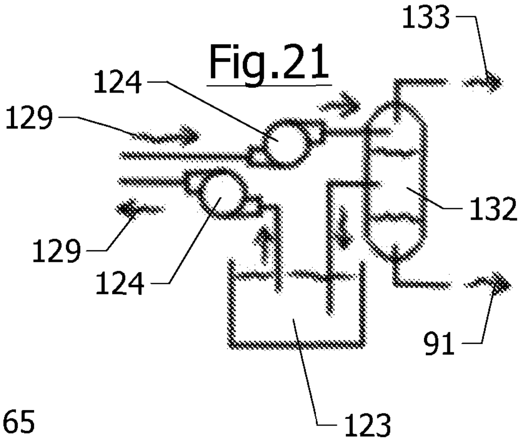
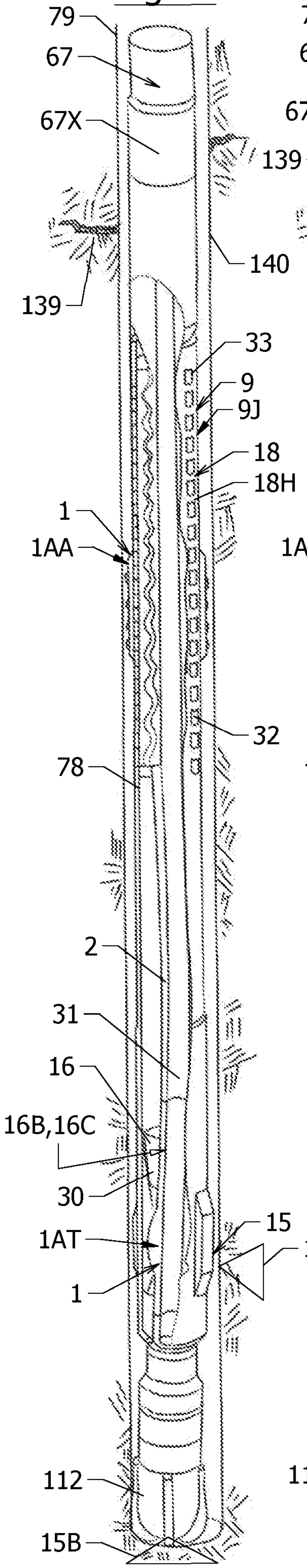


Fig.21

Fig.14



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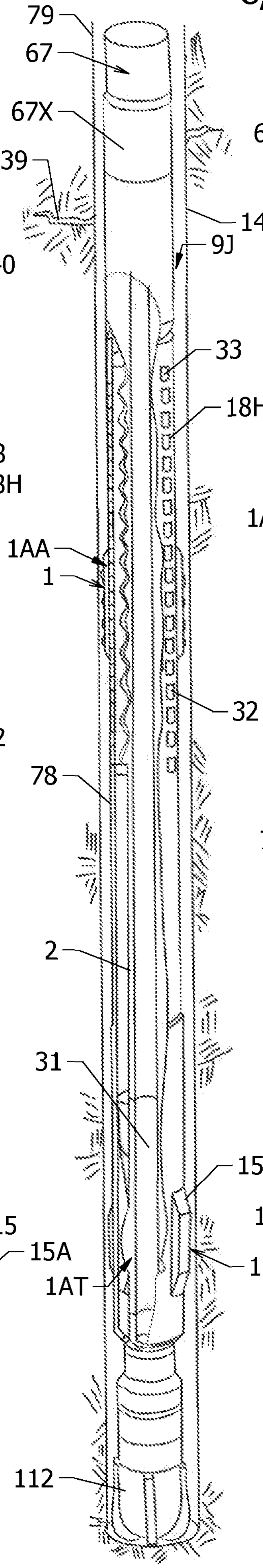

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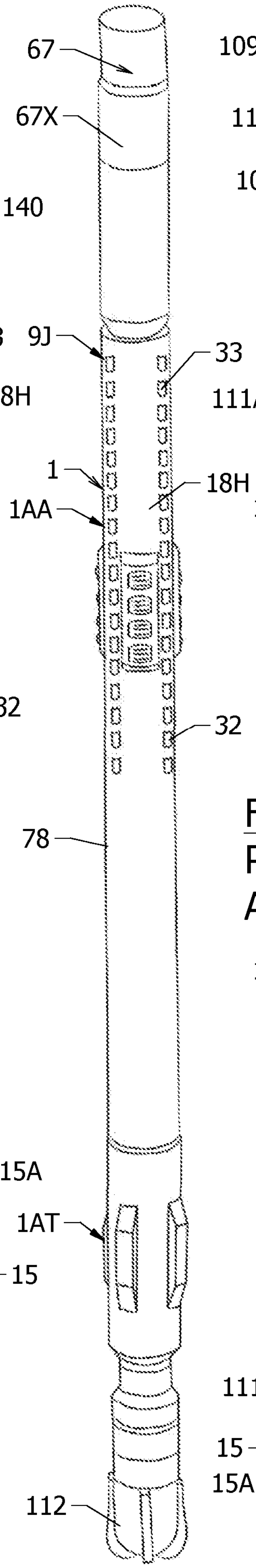


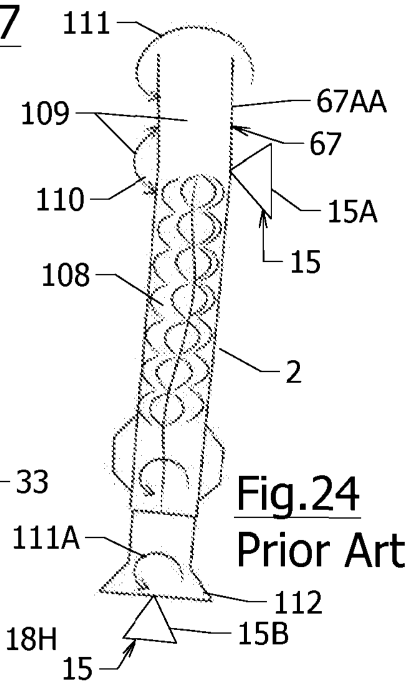


Fig.24
Prior Art

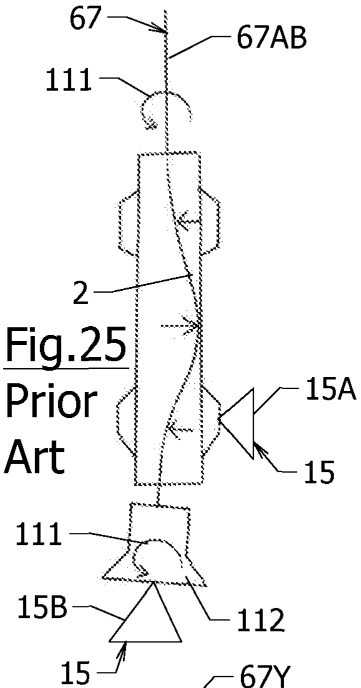


Fig.25
Prior
Art

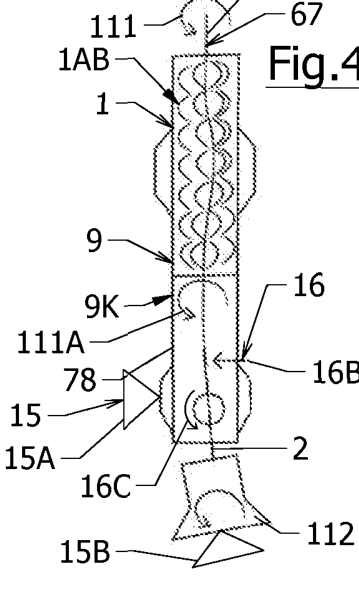


Fig.48

Fig.26 Prior Art

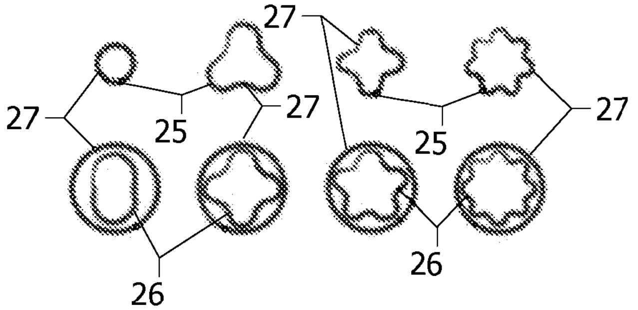


Fig.27 Prior Art

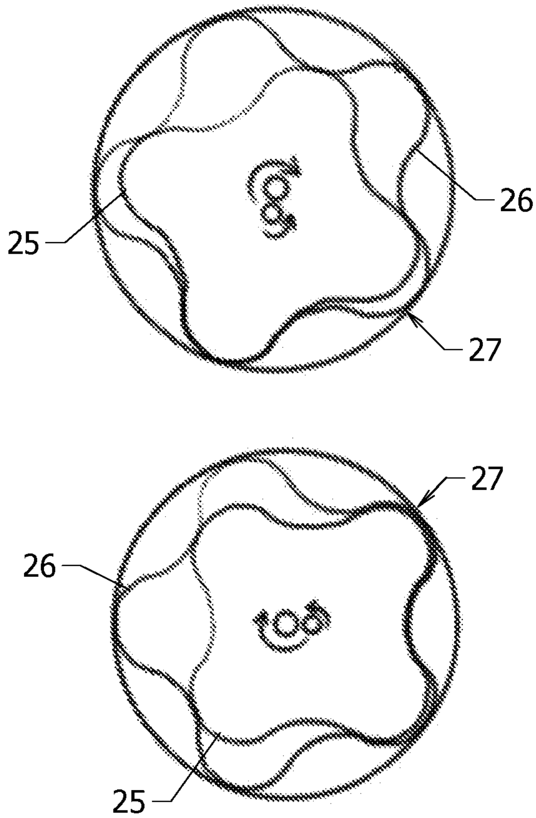


Fig.49

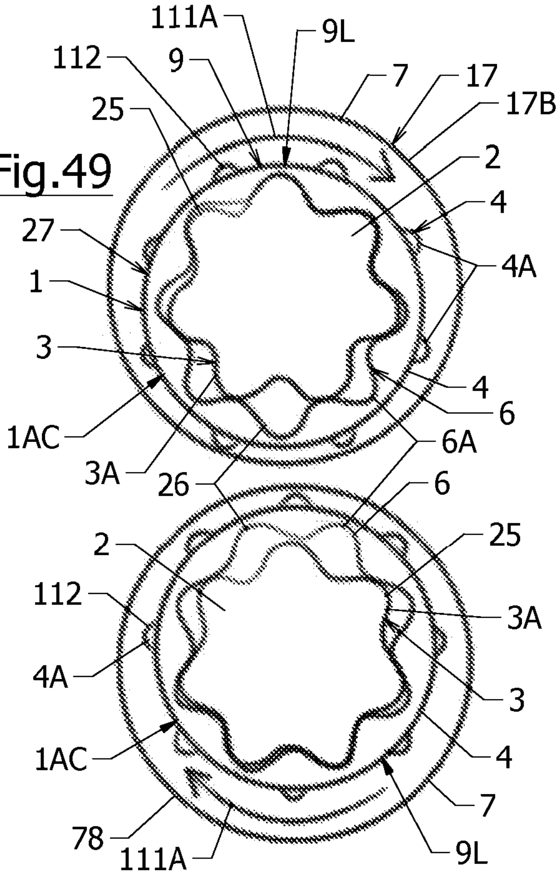
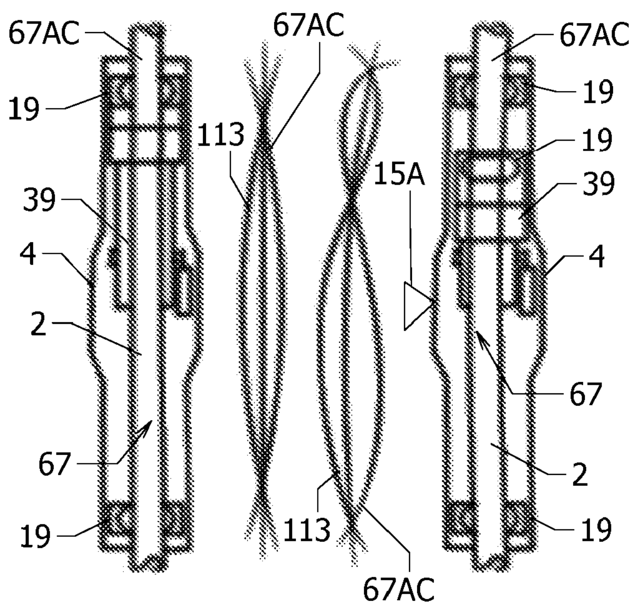


Fig.28 Prior Art



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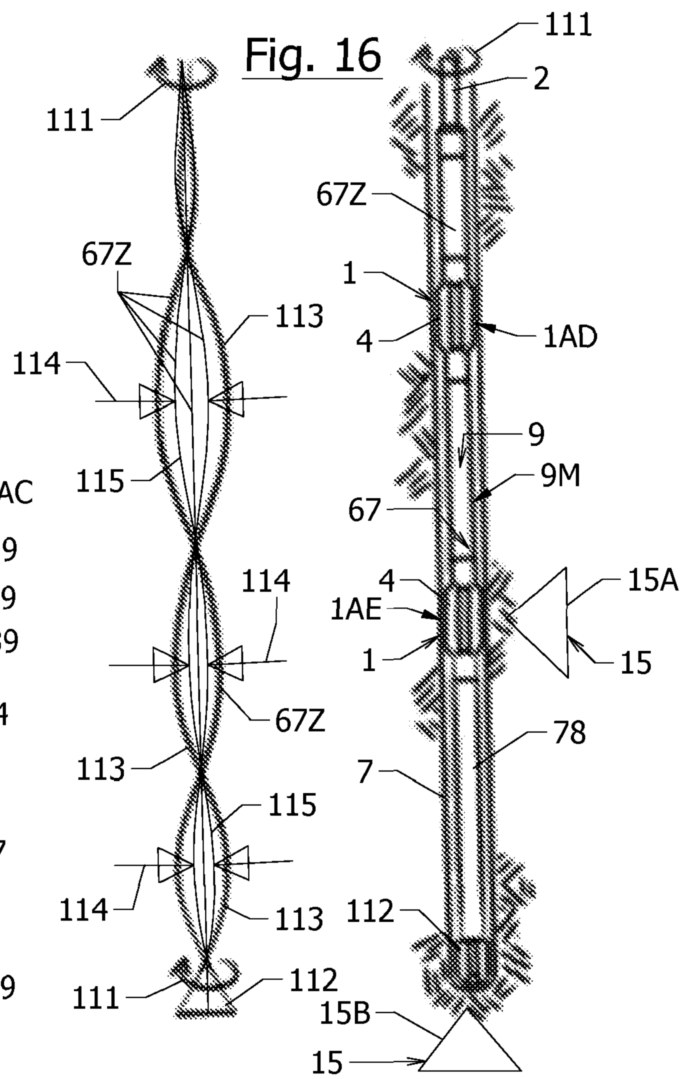


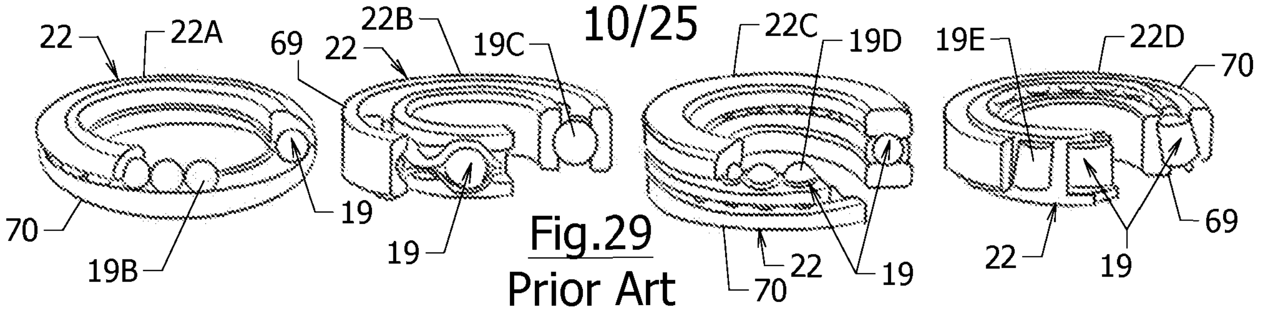
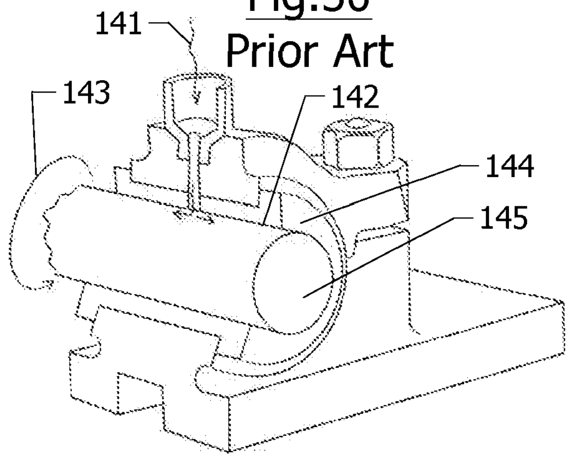


Fig.29
Prior Art

Fig.30
Prior Art



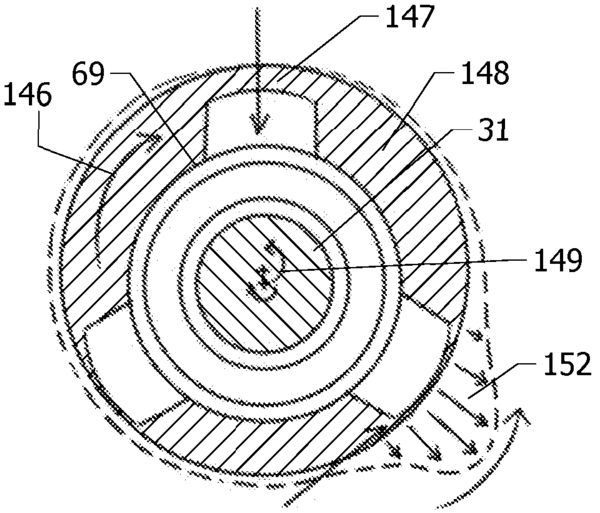
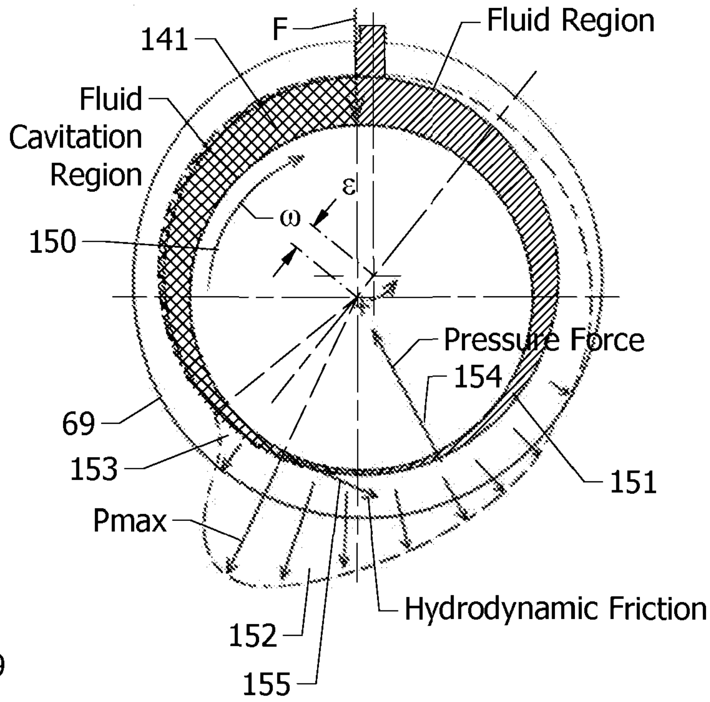


Fig.32
Prior Art

Fig.31
Prior Art



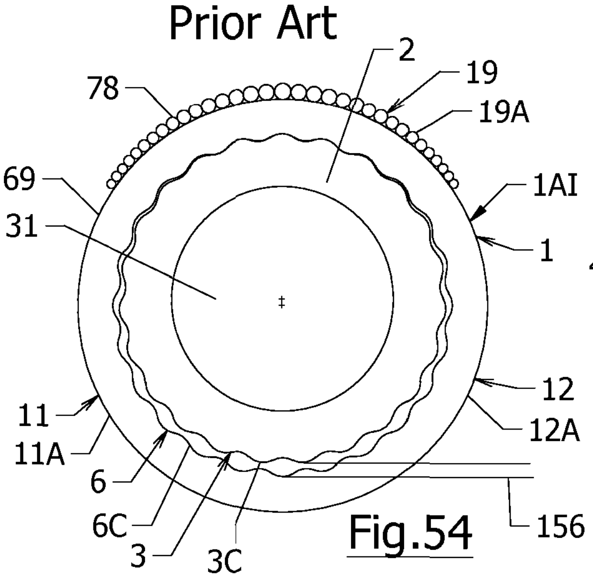
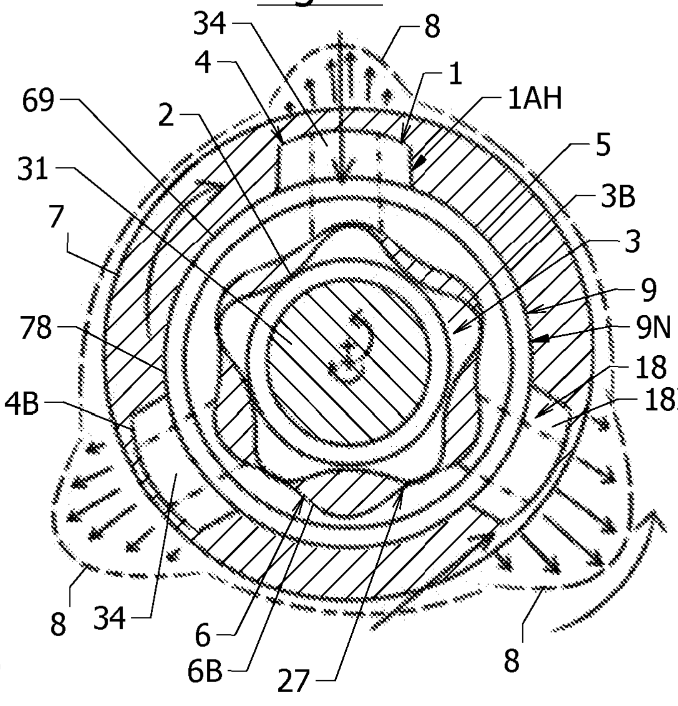
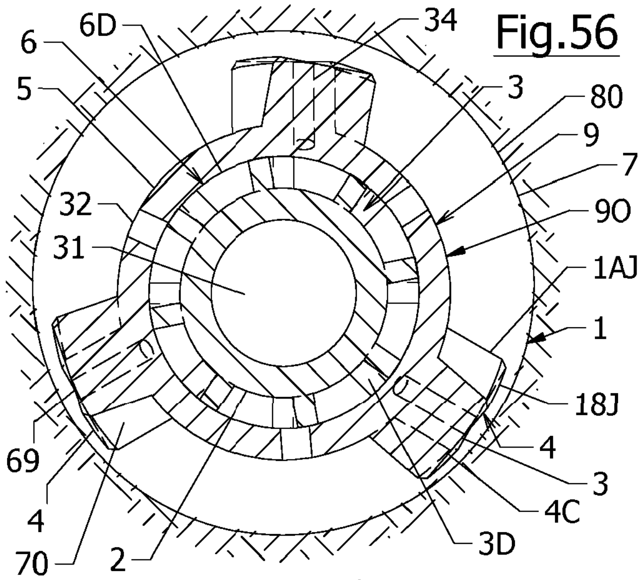


Fig.54

Fig.55





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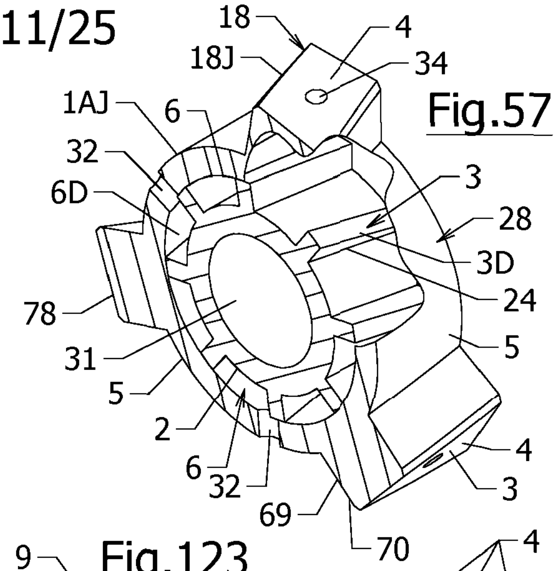

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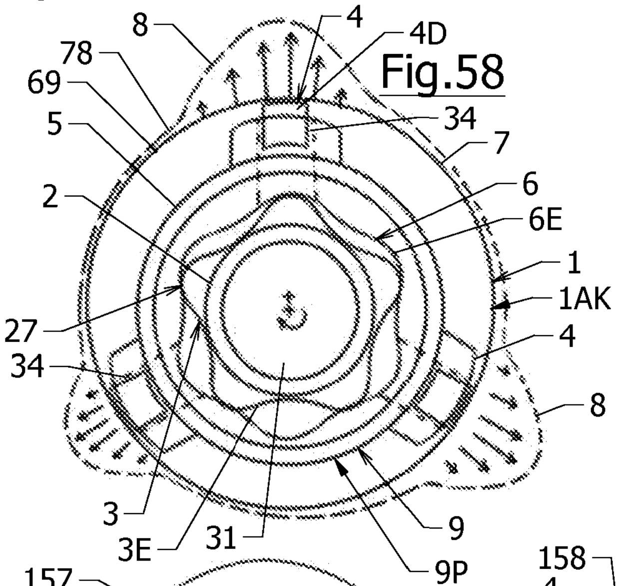
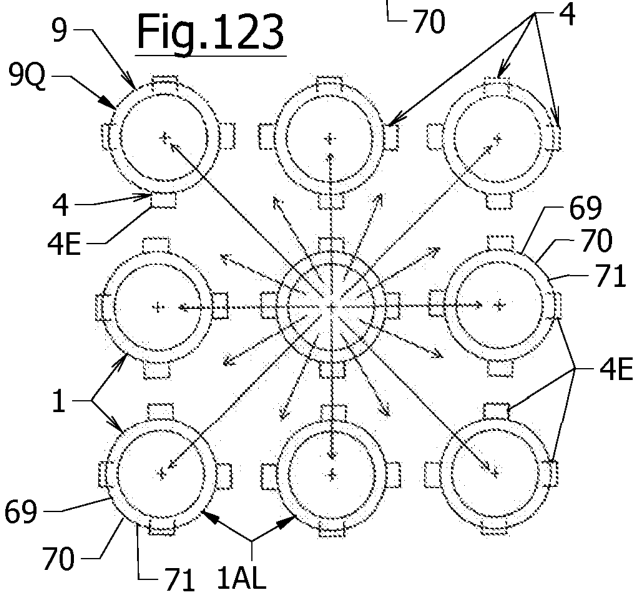


Fig.58



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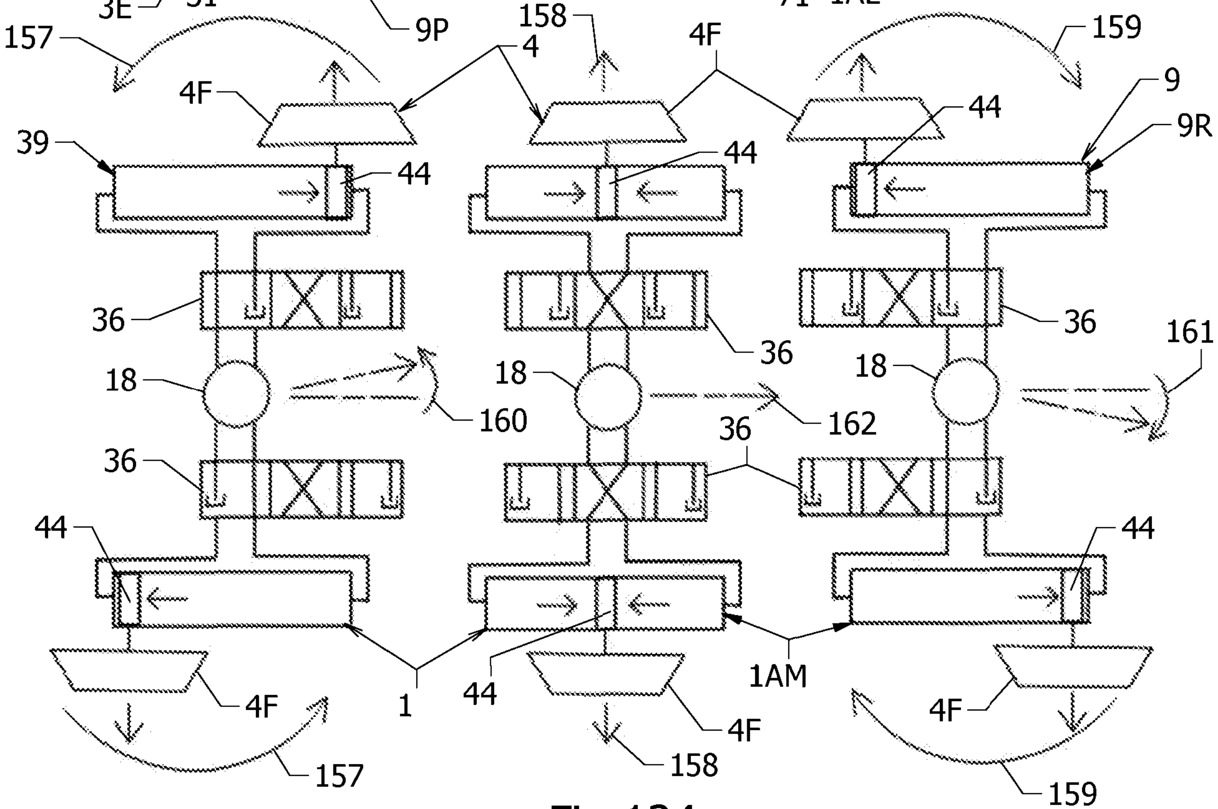

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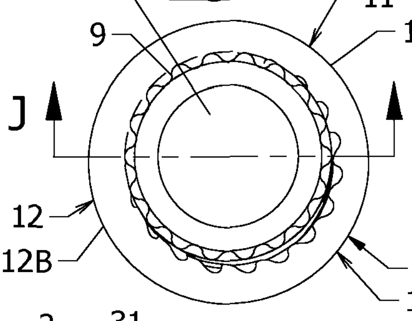

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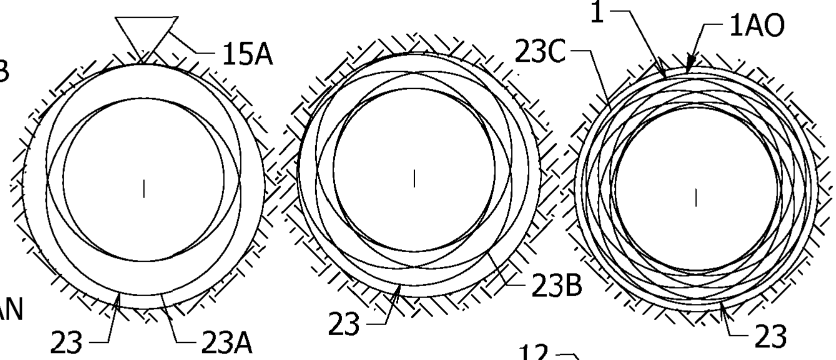

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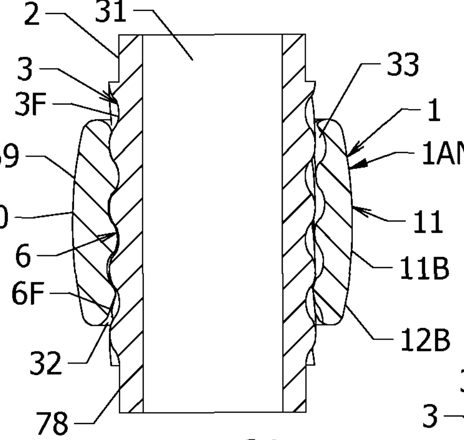
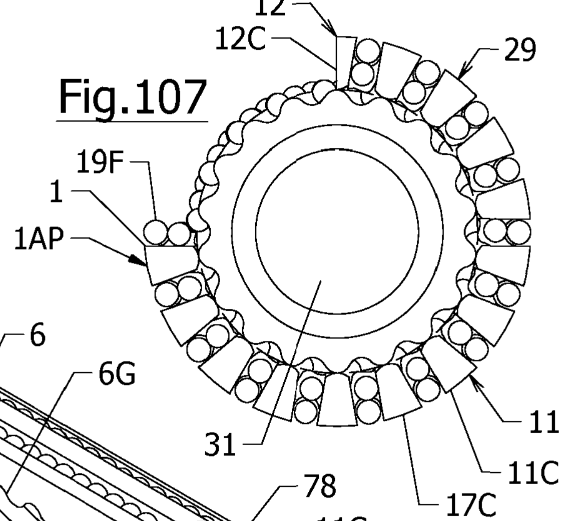


Fig. 61
Section J-J



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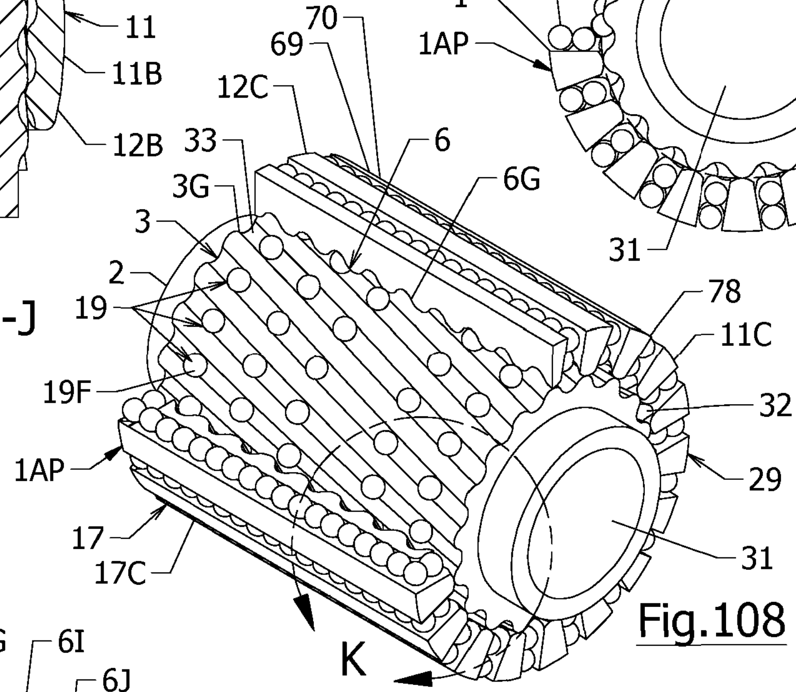


Fig.108

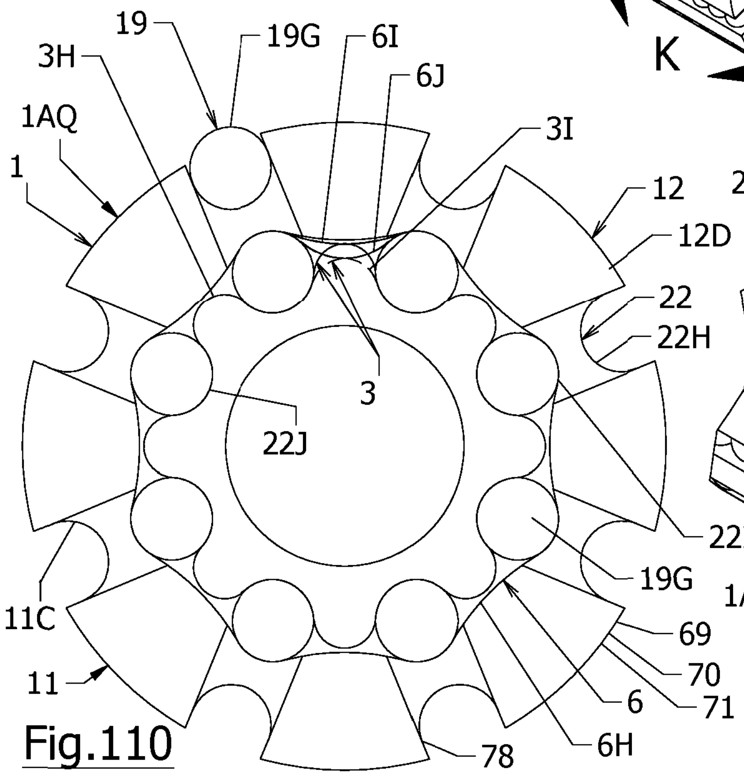


Fig.110

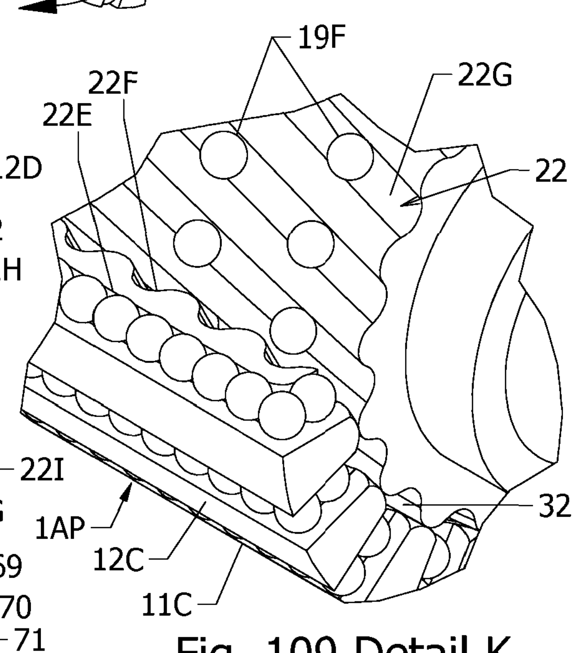


Fig. 109 Detail K

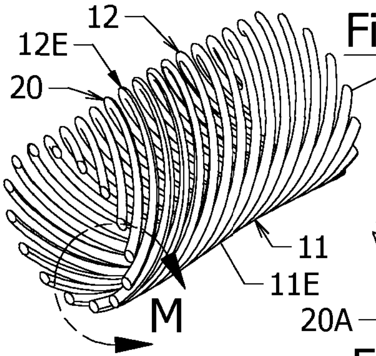


Fig.66

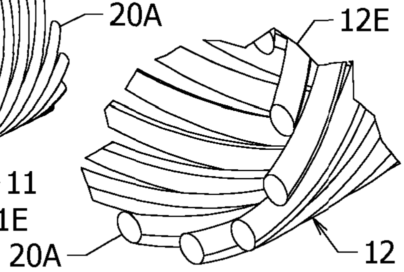


Fig.67 Detail M

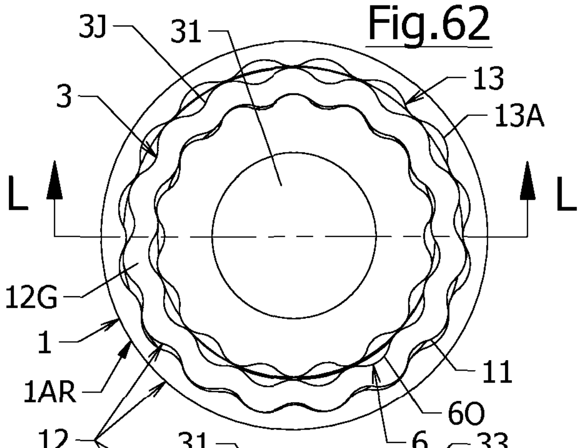
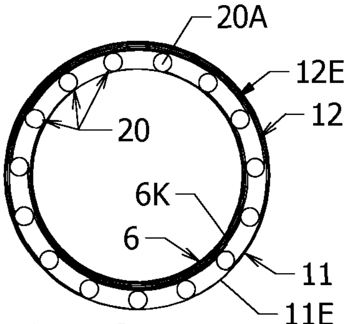


Fig.62



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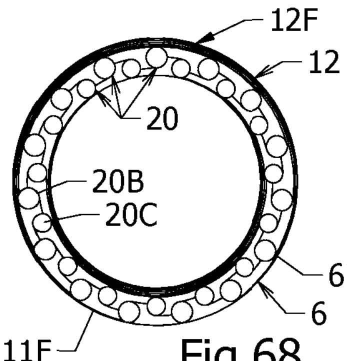


Fig.68

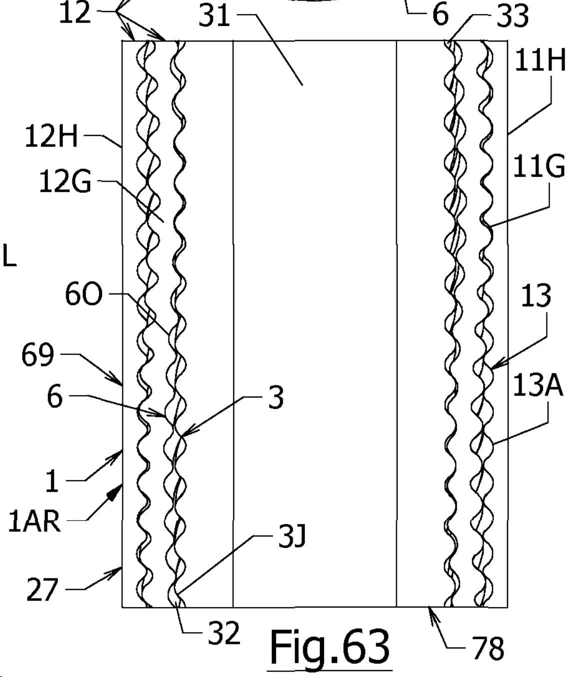


Fig.63
Section L-L

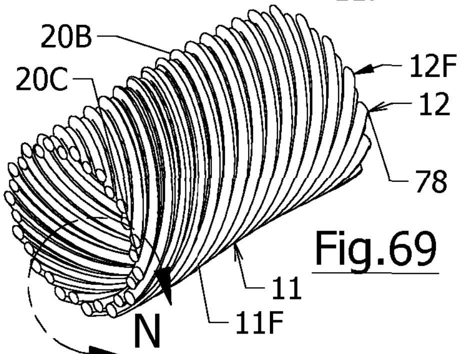


Fig.69

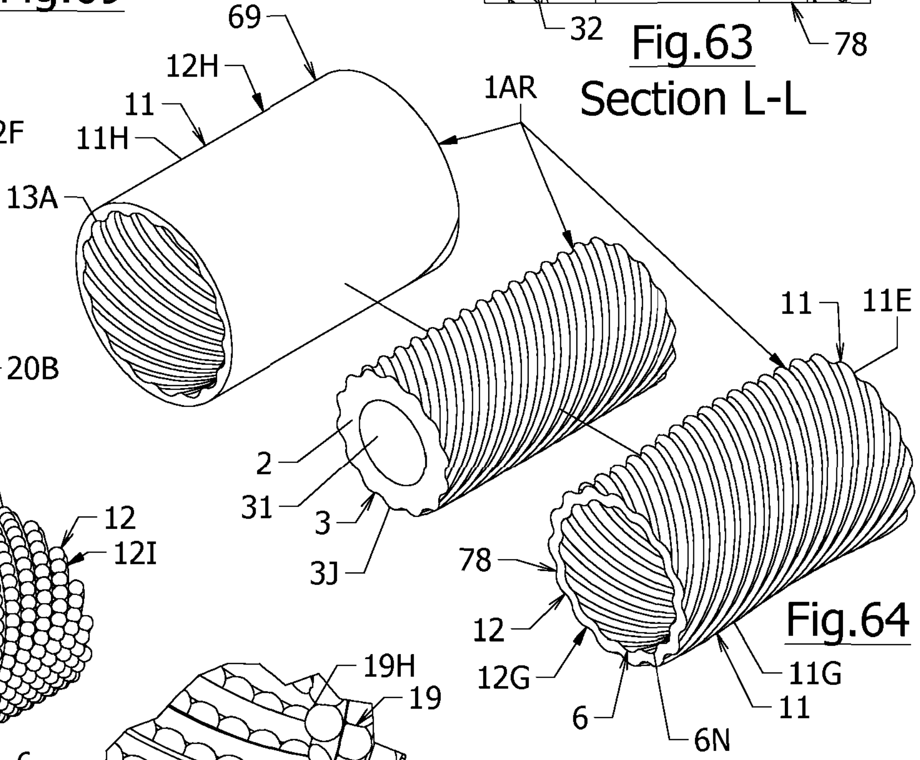


Fig.64

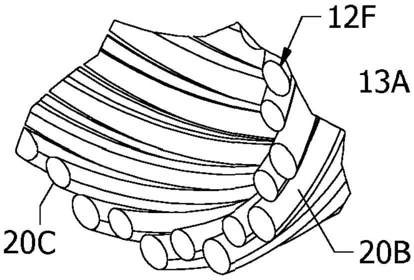


Fig.70 Detail N

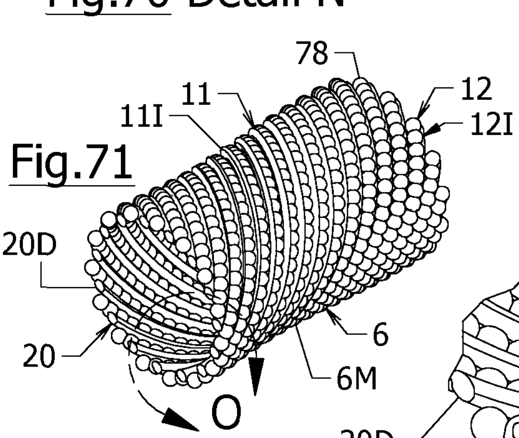


Fig.71

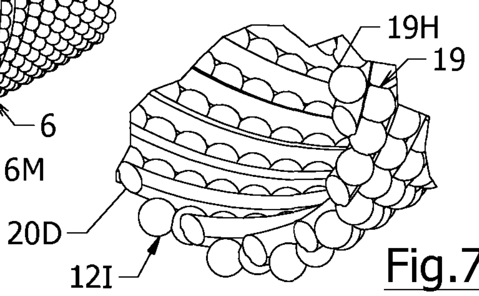


Fig.72 Detail O

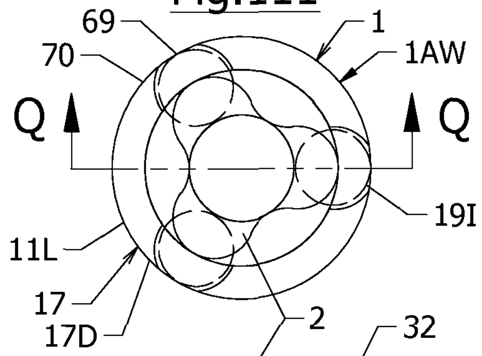


Fig.111

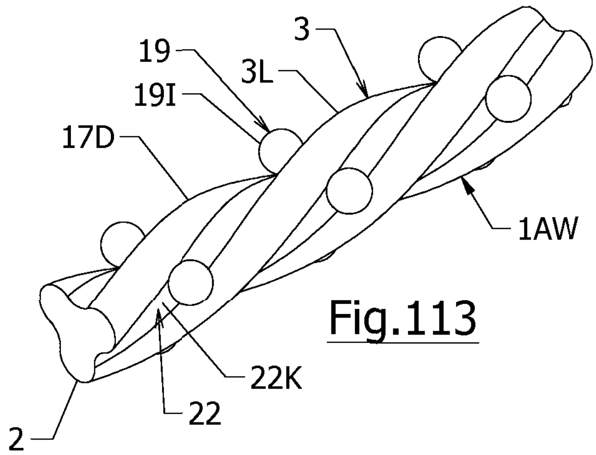


Fig.113

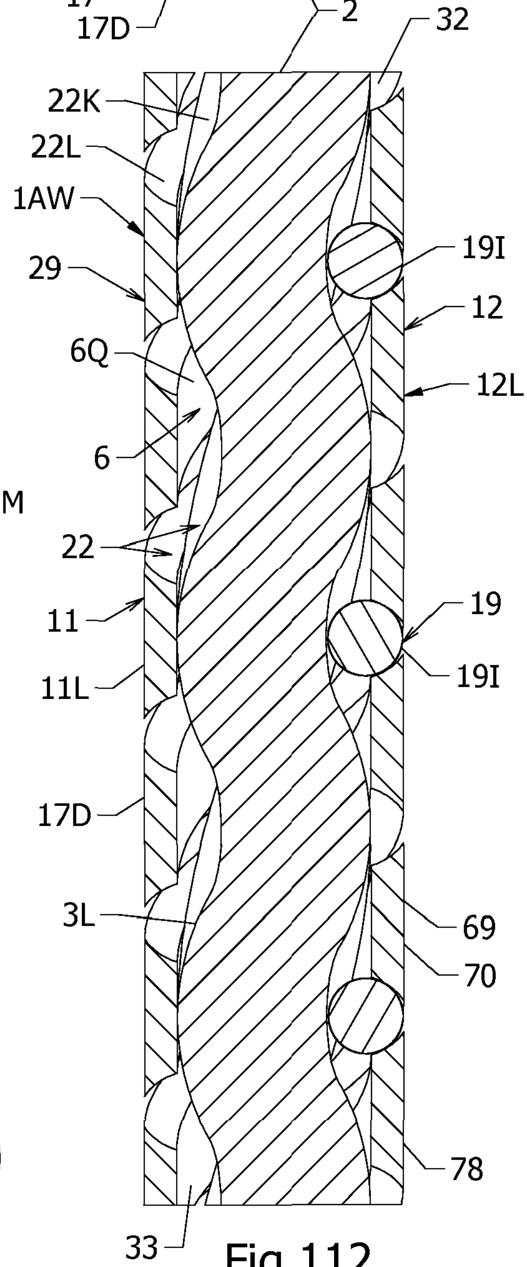


Fig.112
Section Q-Q

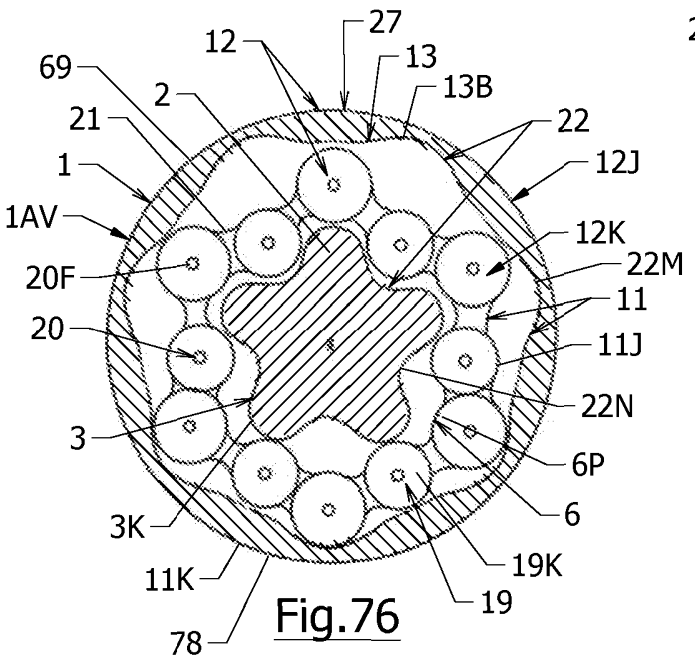


Fig.76

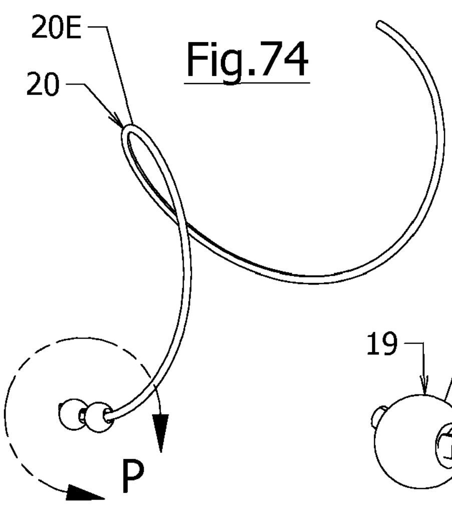


Fig.74

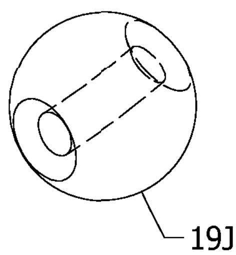


Fig.73

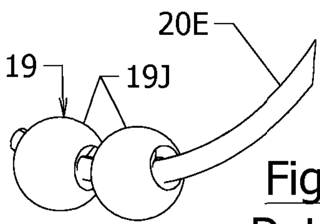
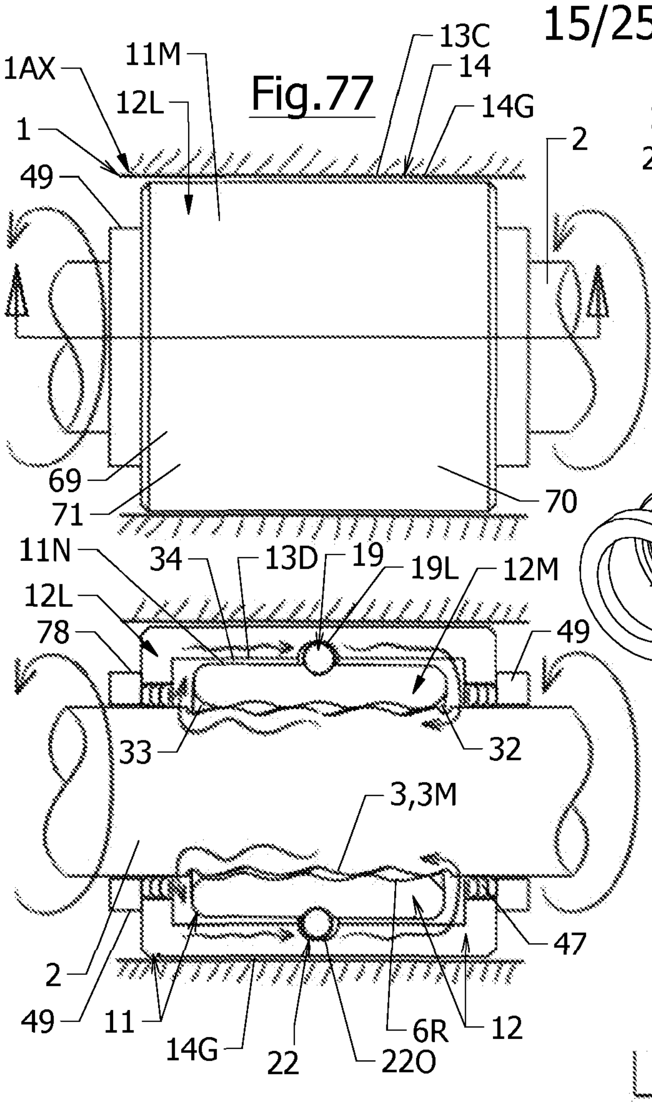


Fig.75
Detail P

Fig.77



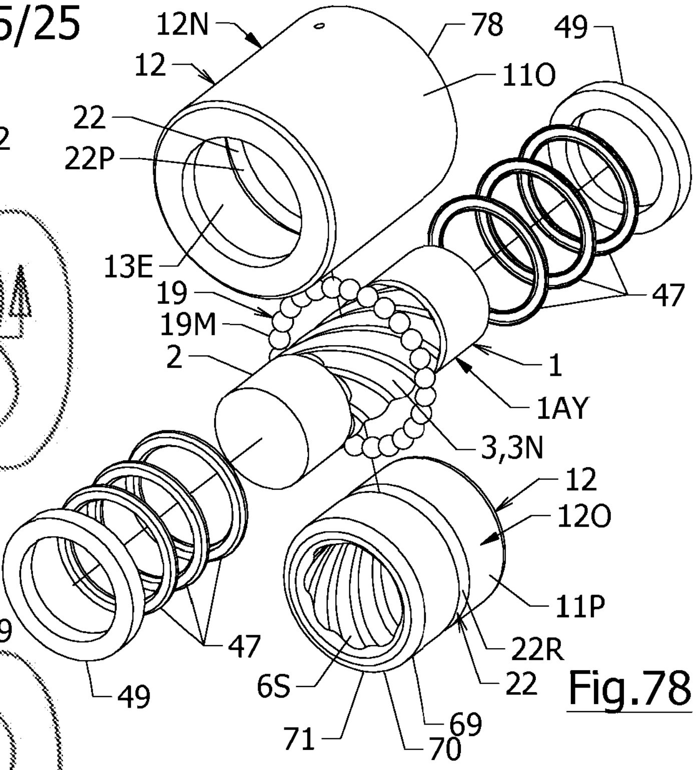


Fig.78

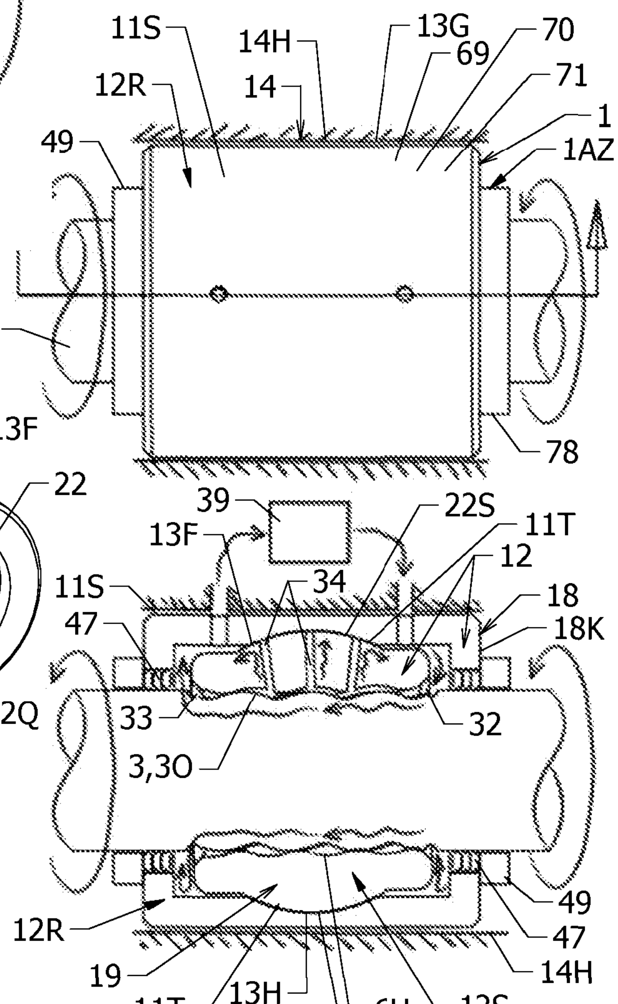


Fig.79

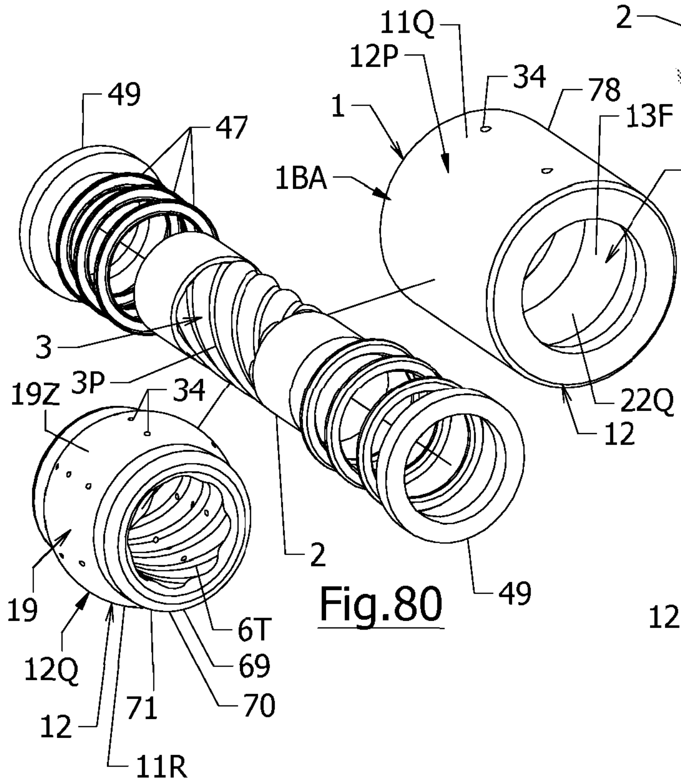


Fig.80

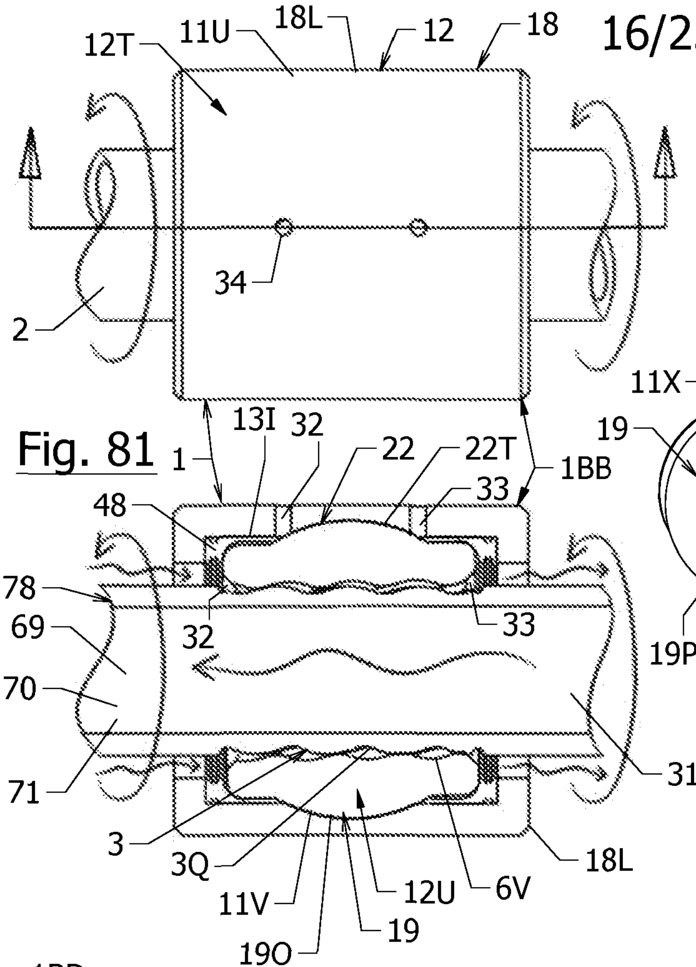


Fig. 81

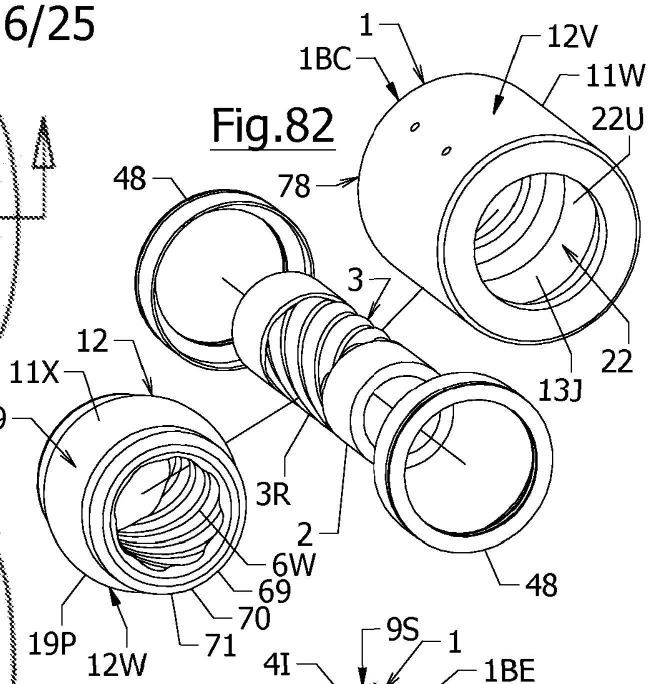


Fig.82

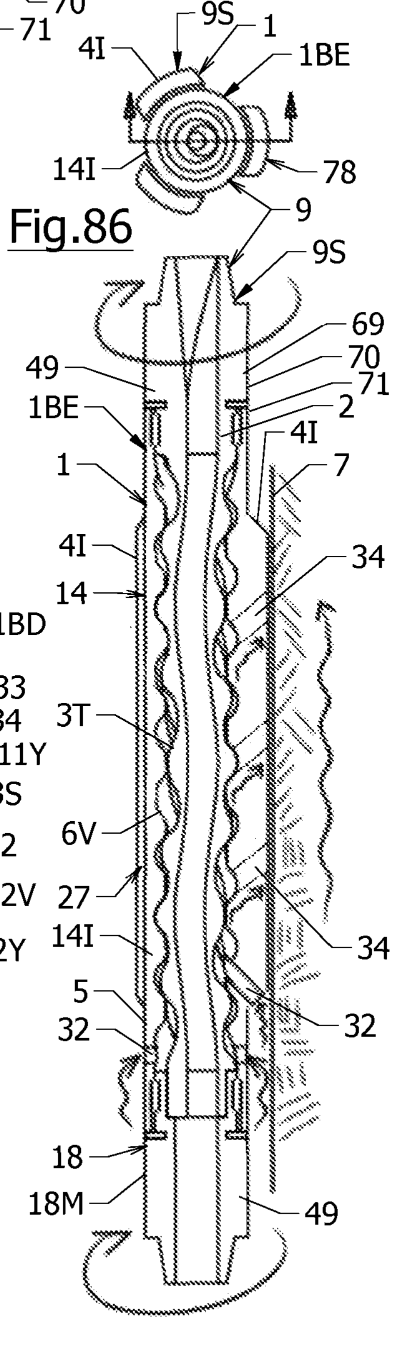


Fig.86

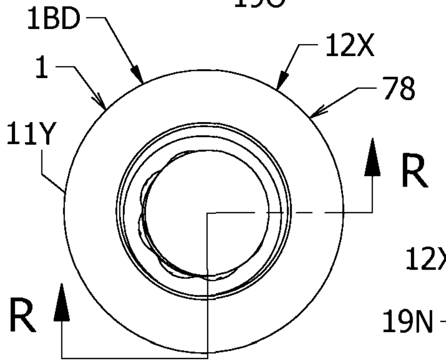


Fig.83

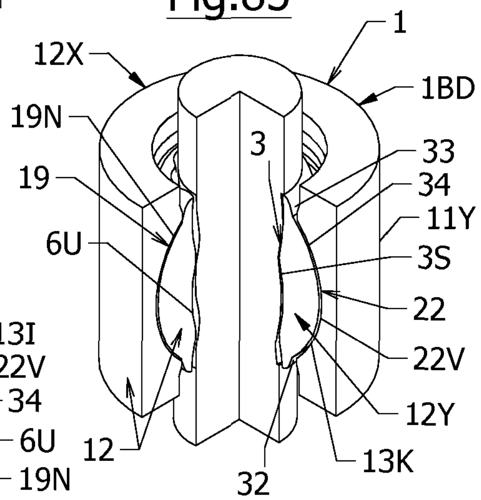


Fig.85

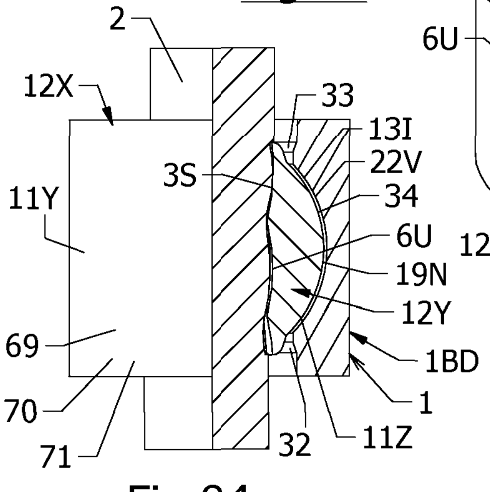


Fig.84
Section R-R

Fig.89

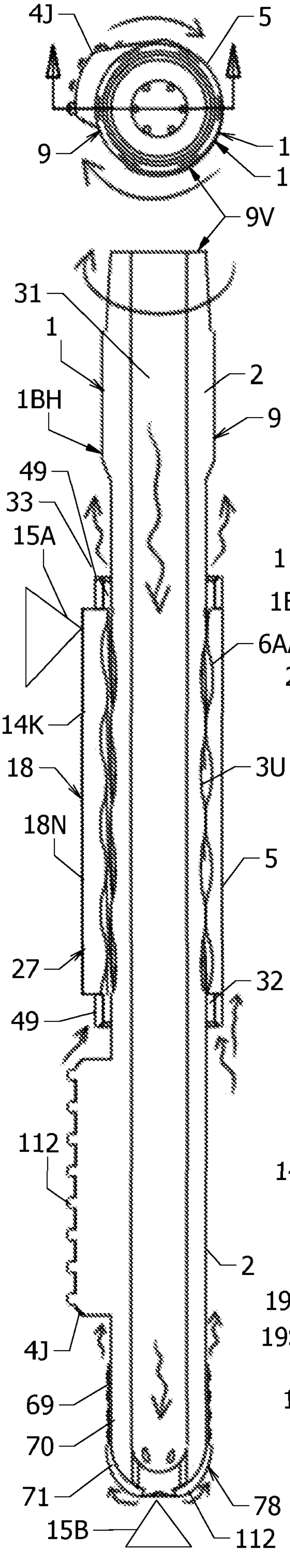


Fig.87

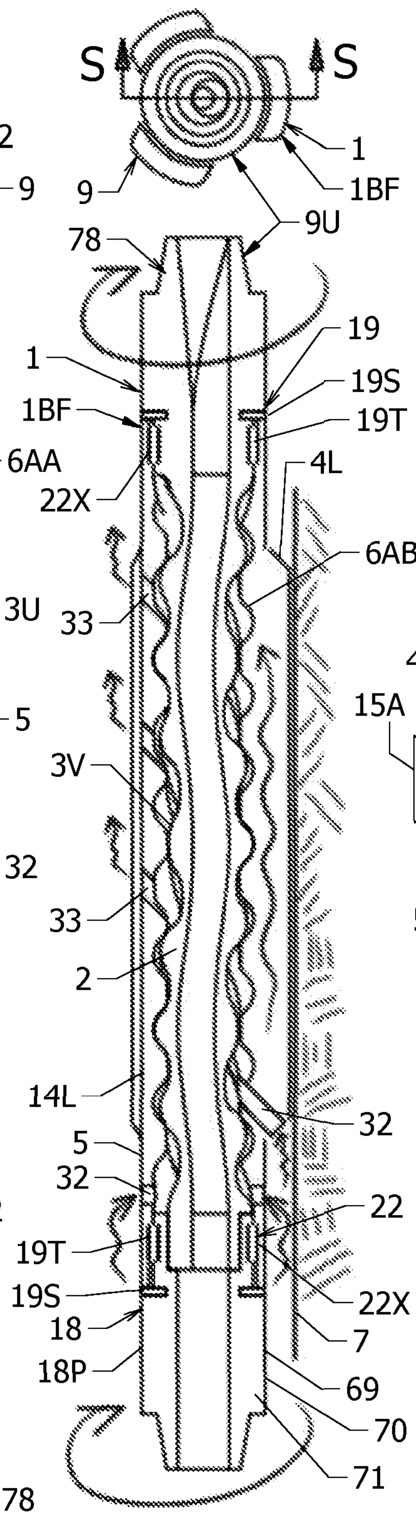
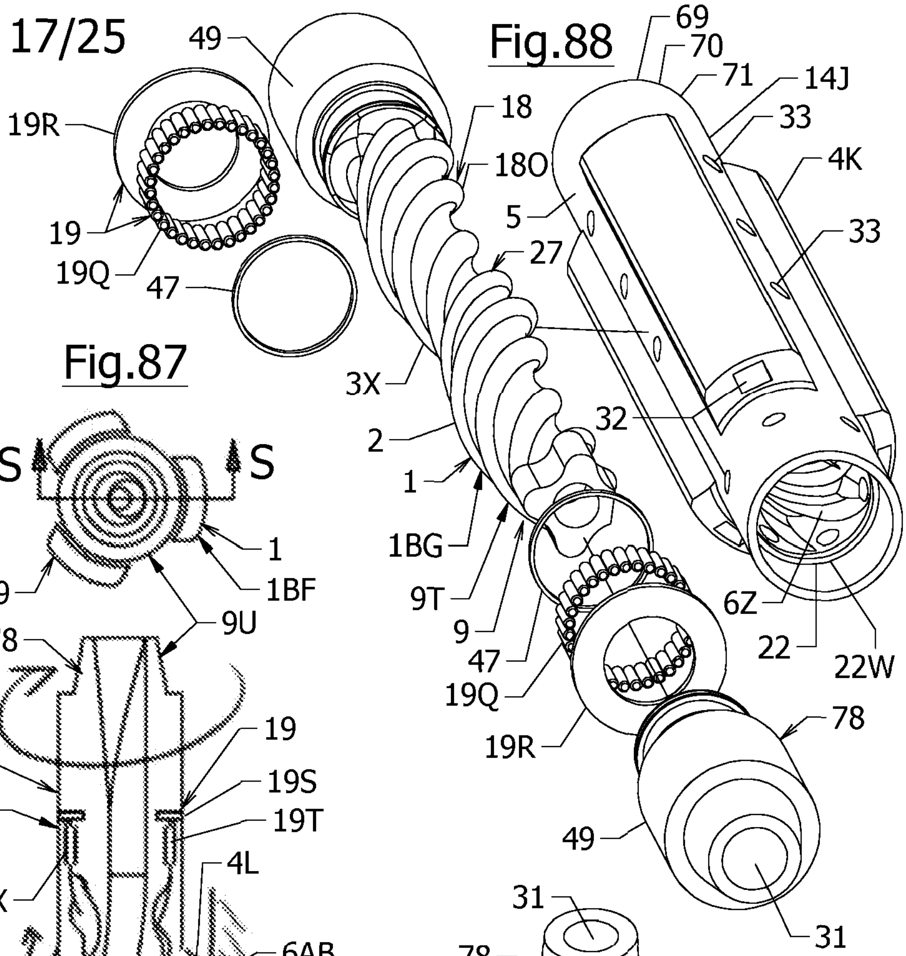


Fig.88



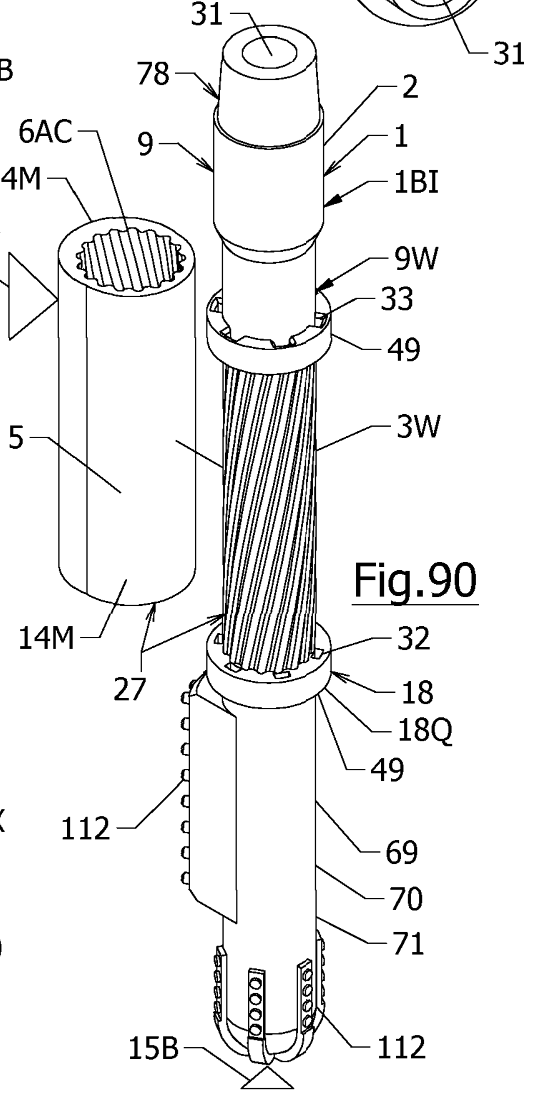


Fig.90

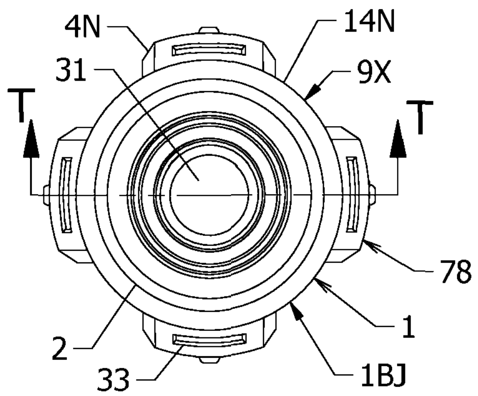


Fig.91

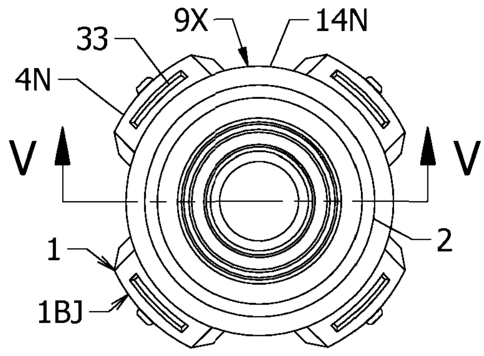


Fig.94

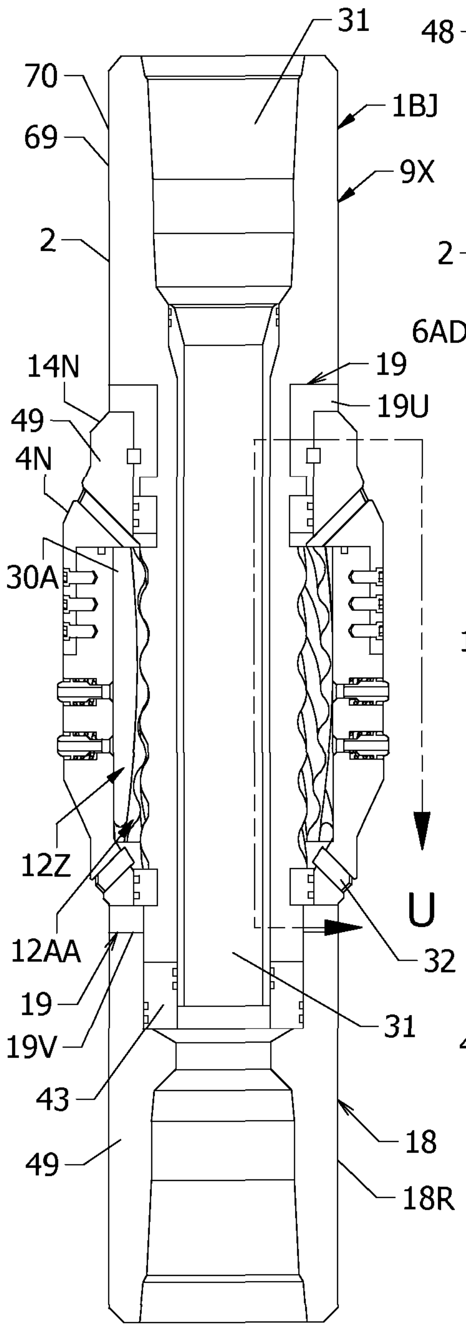


Fig.92
Section T-T

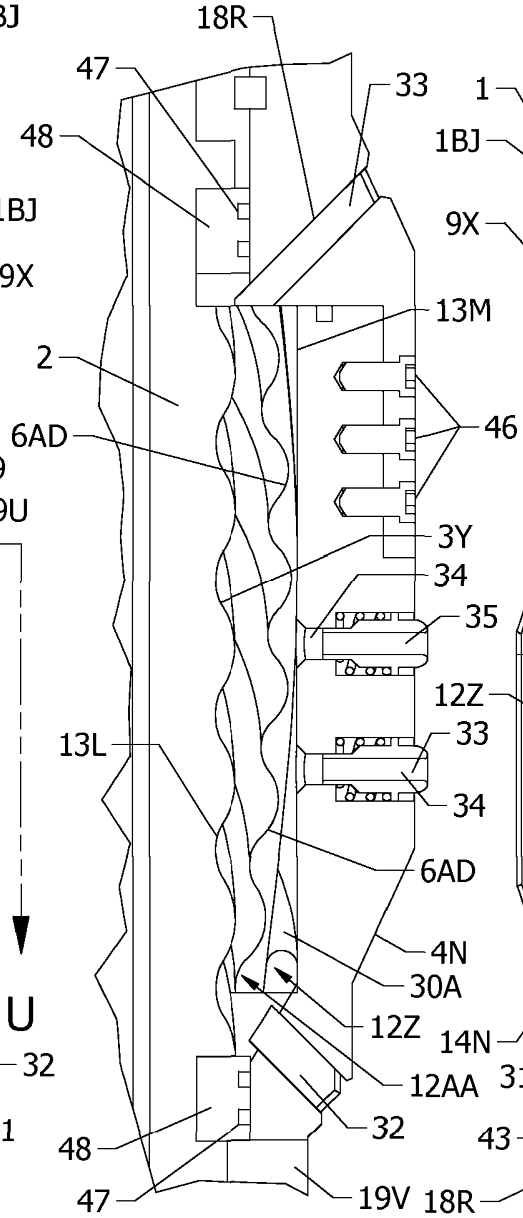


Fig.93
Detail U

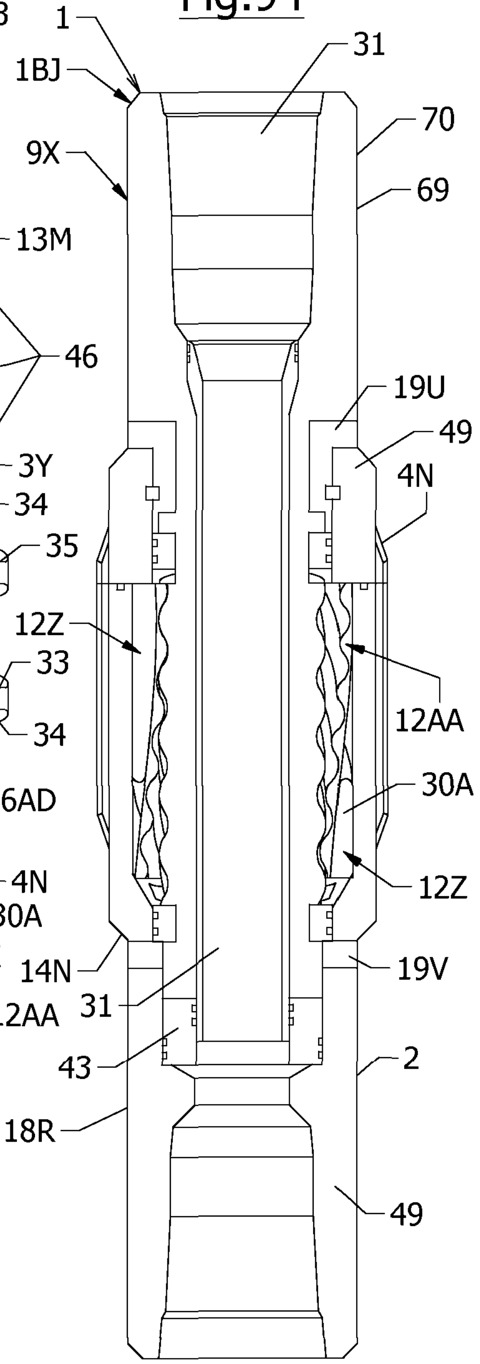


Fig. 95
Section V-V

Fig.96

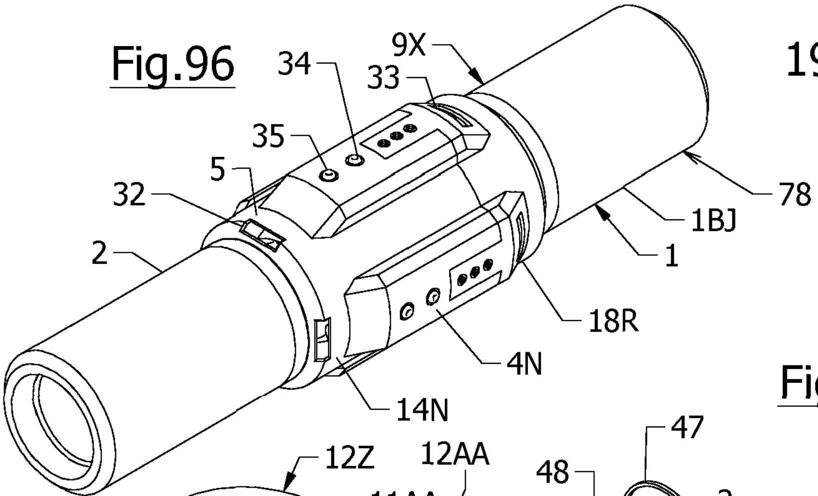


Fig.97

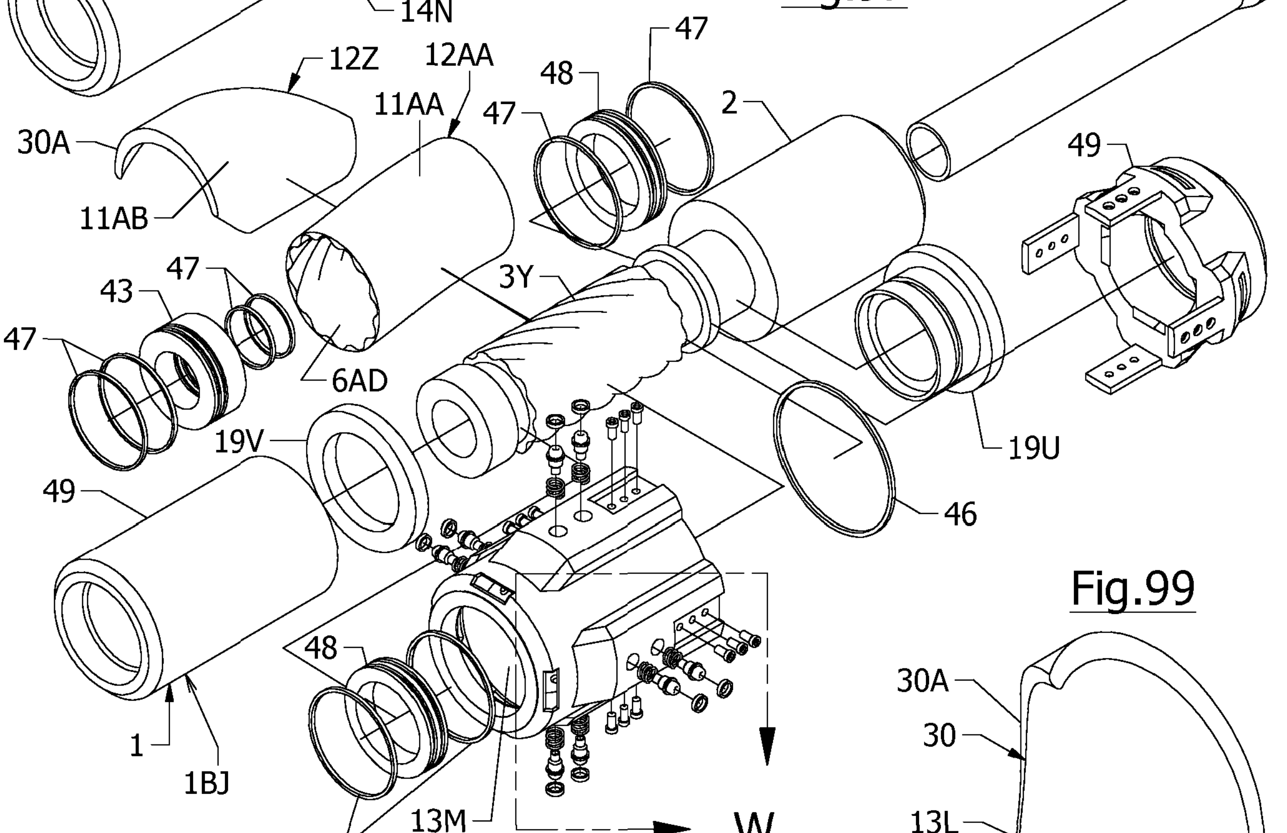
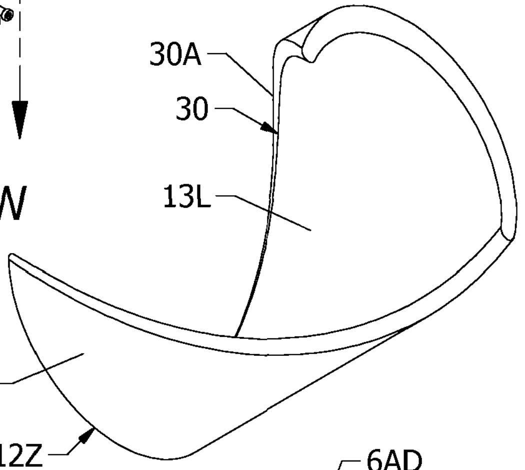


Fig.99



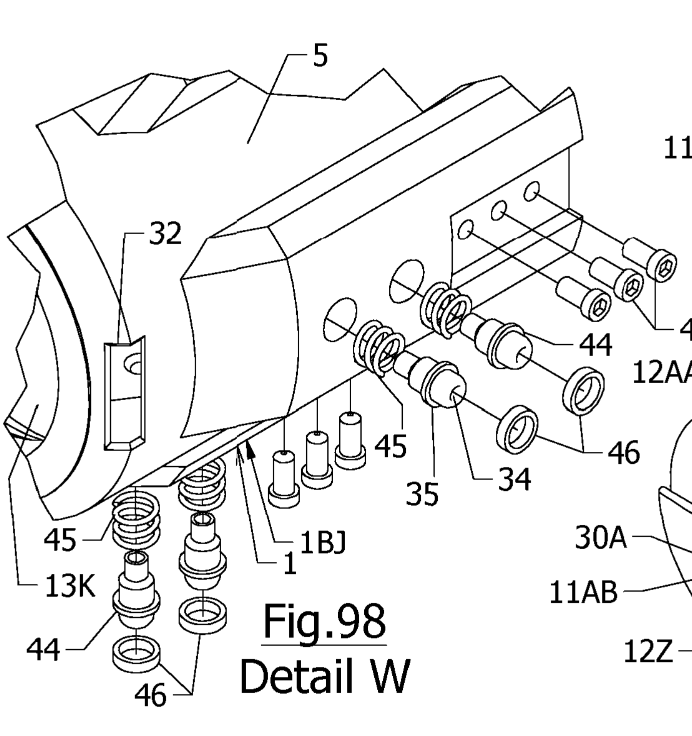


Fig.98
Detail W

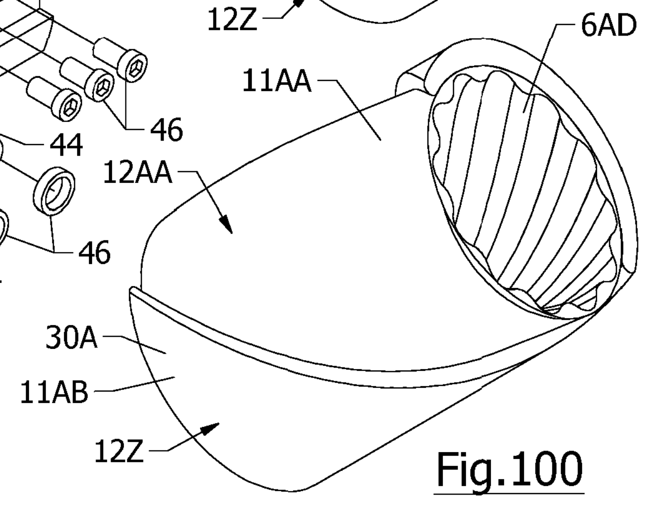


Fig.100

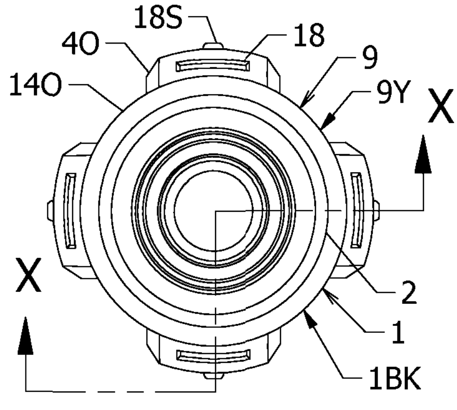


Fig.101

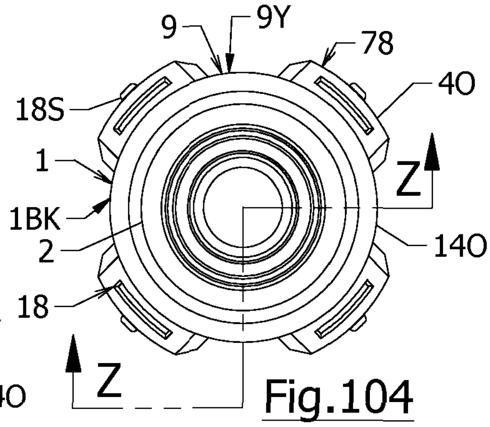


Fig.104

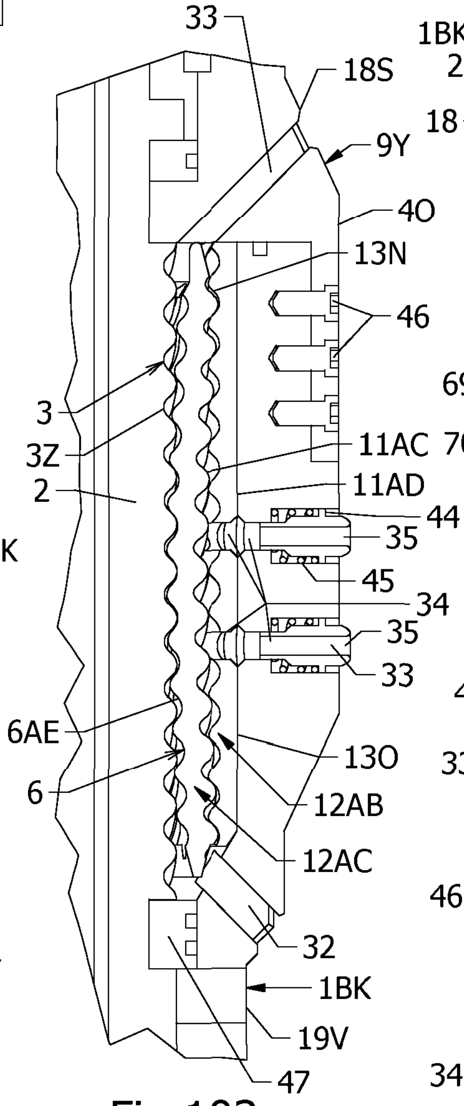


Fig.103
Detail Y

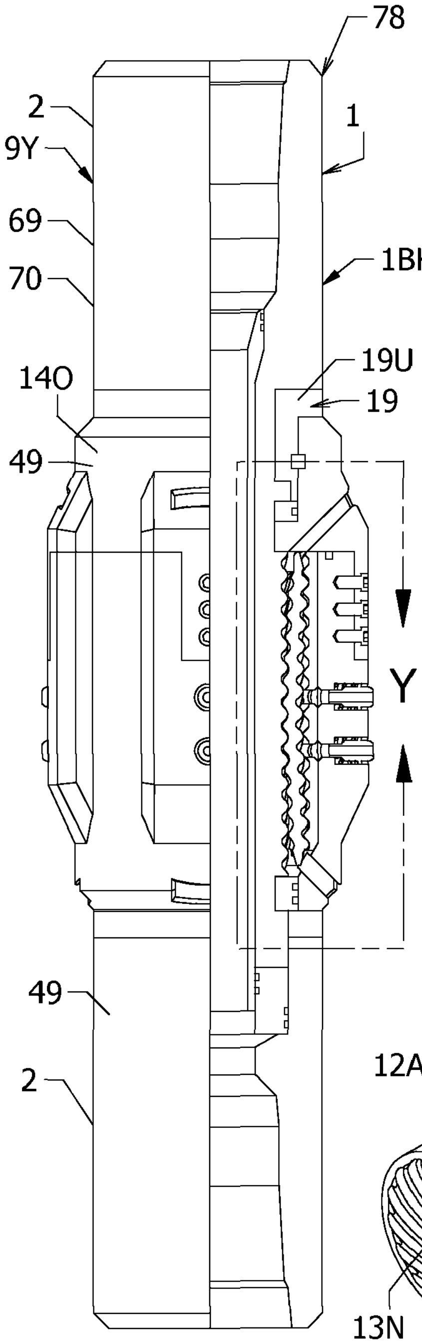


Fig.102
Section X-X

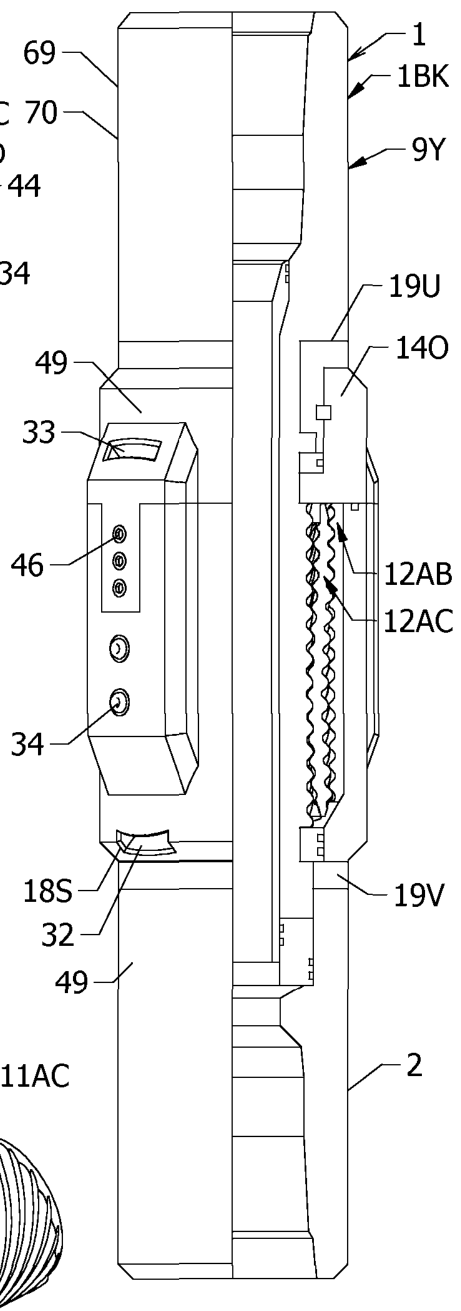


Fig.105
Section Z-Z

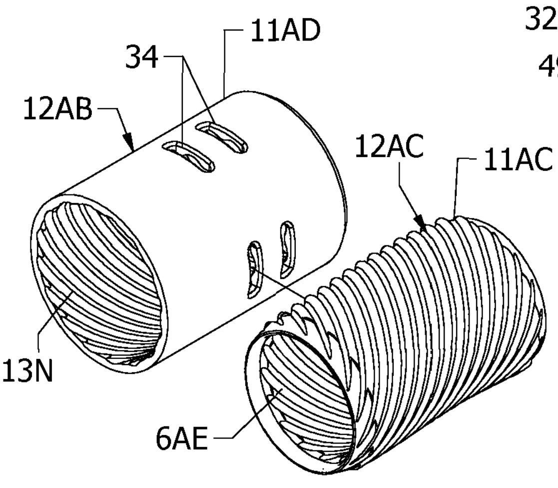
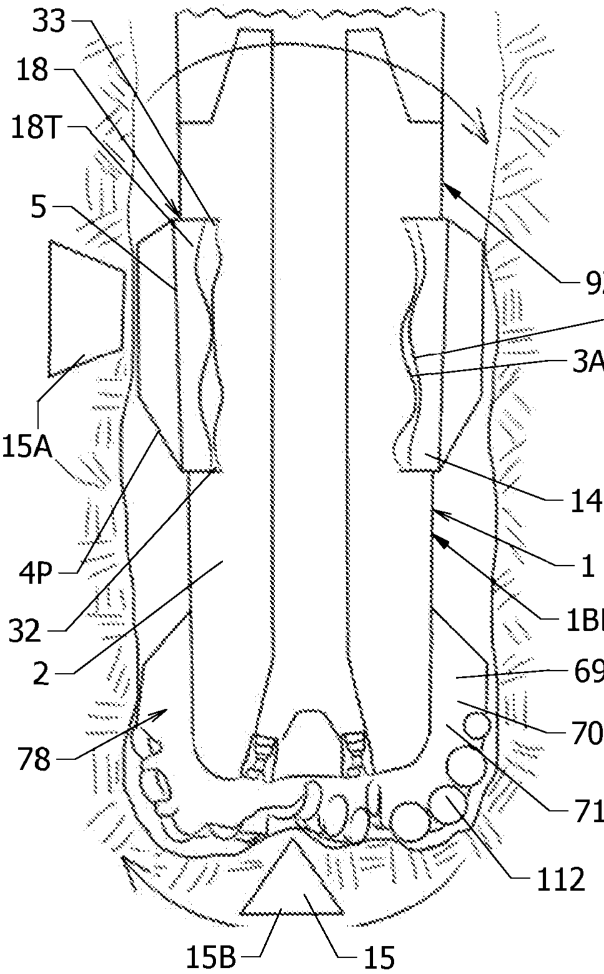


Fig.103A

Fig.106



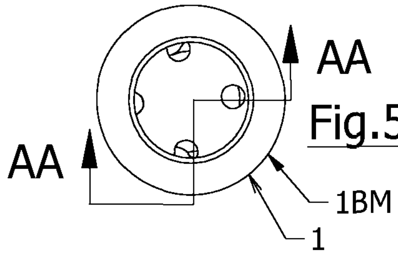


Fig.51

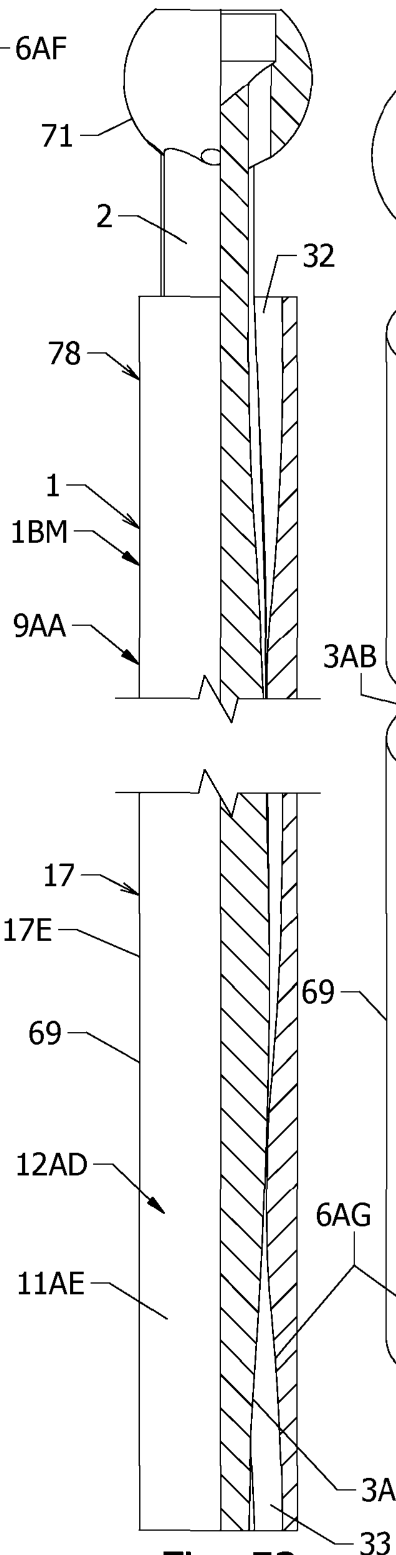


Fig. 52
Section AA-AA

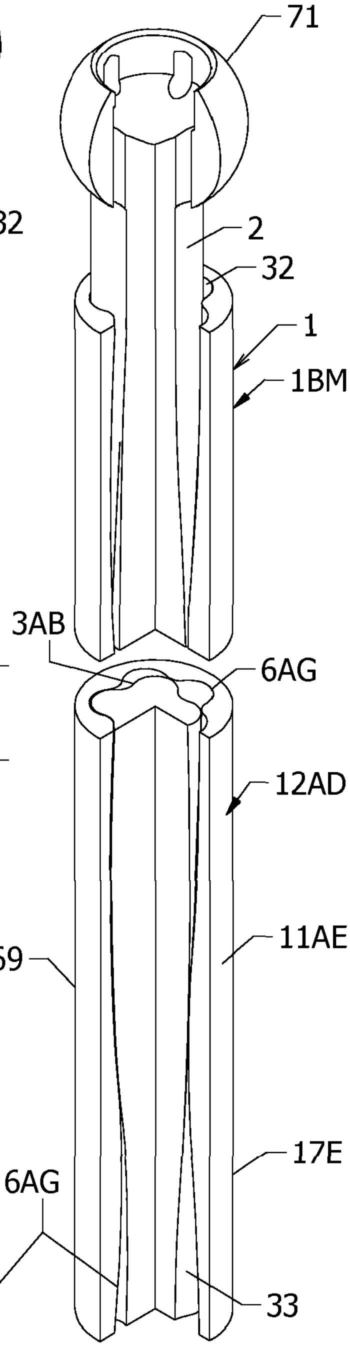


Fig.53

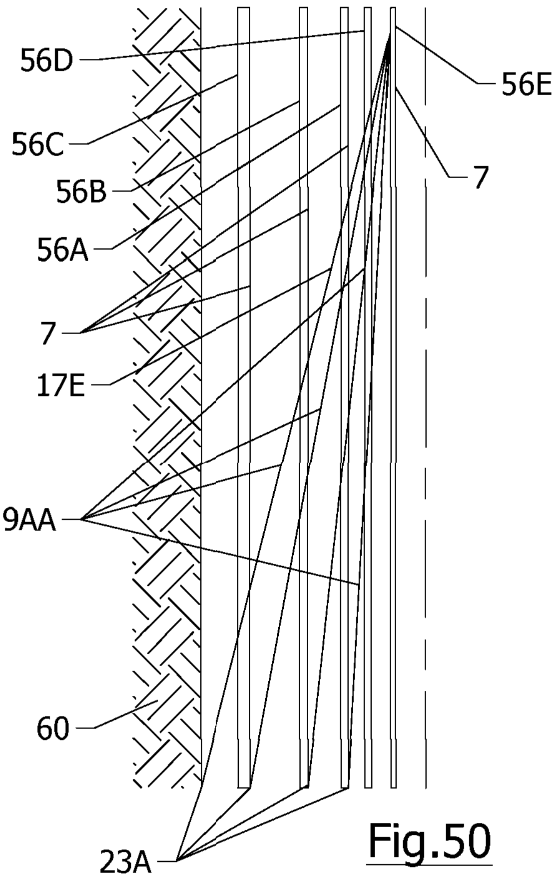


Fig.50

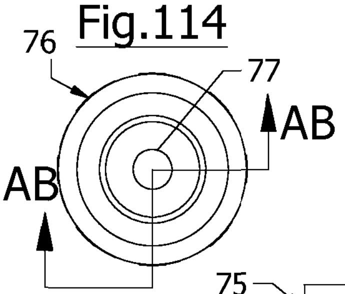


Fig.114

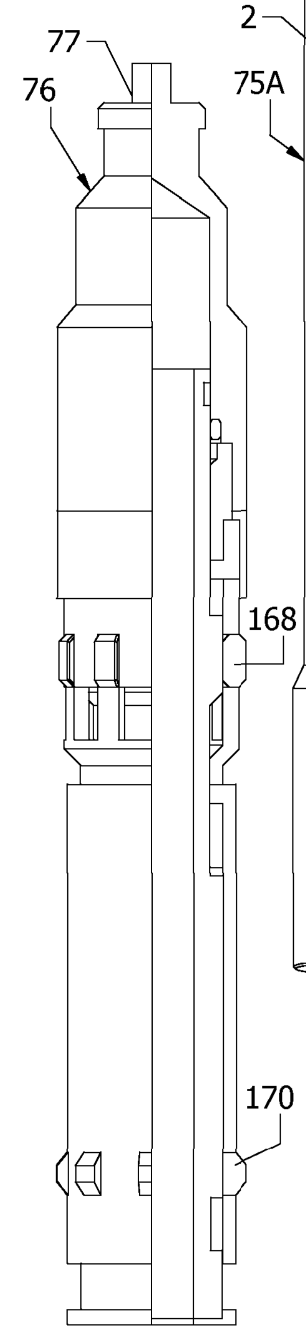


Fig.115
Section AB-AB

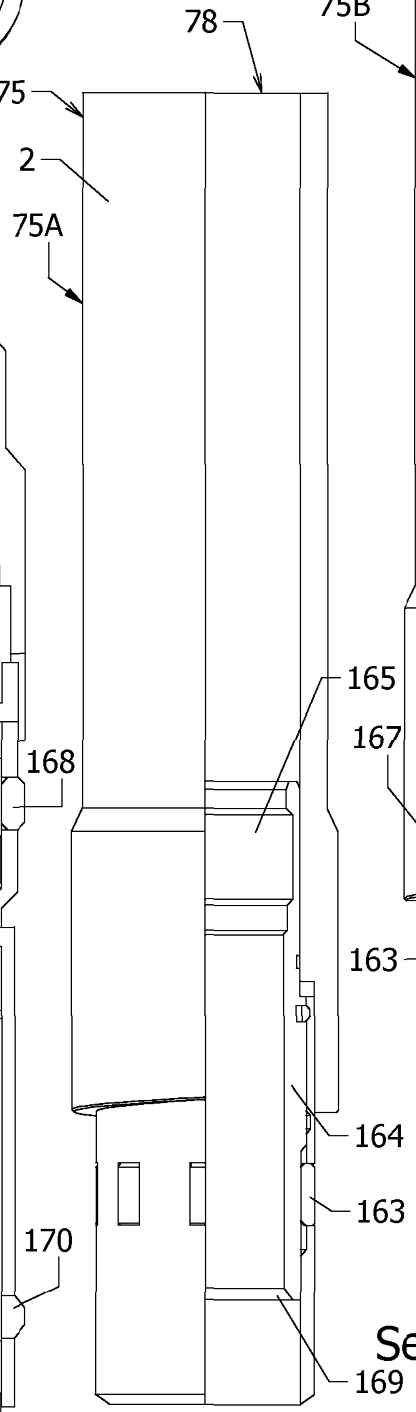


Fig. 116
Section AB-AB

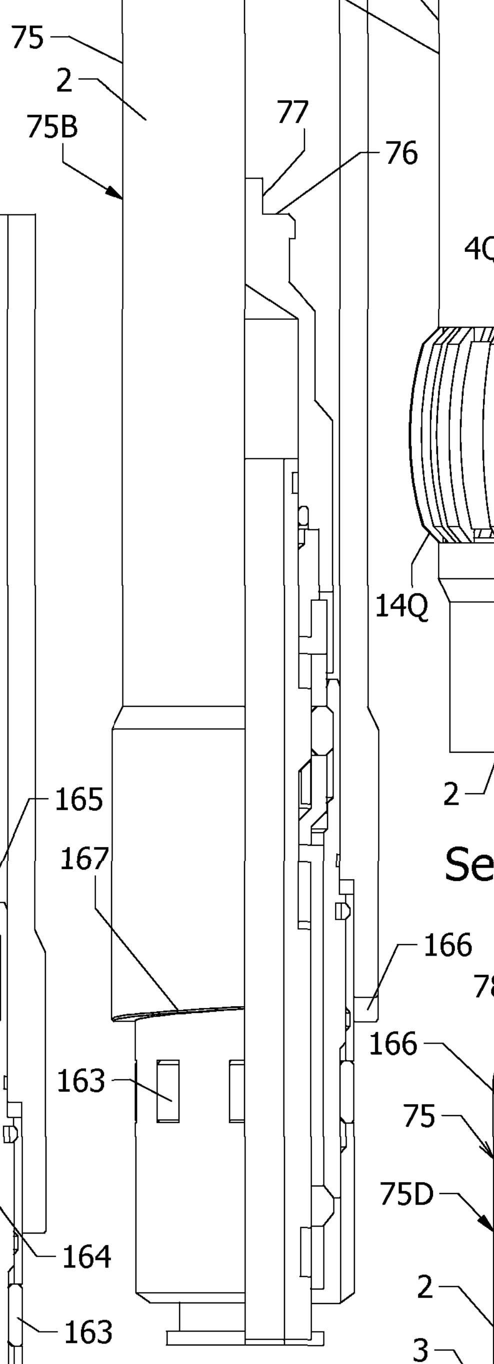


Fig.117
Section AB-AB

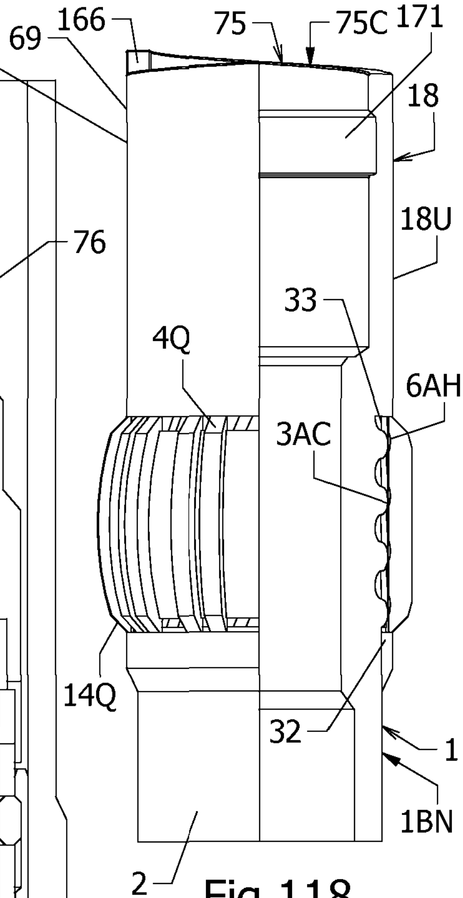


Fig.118
Section AB-AB

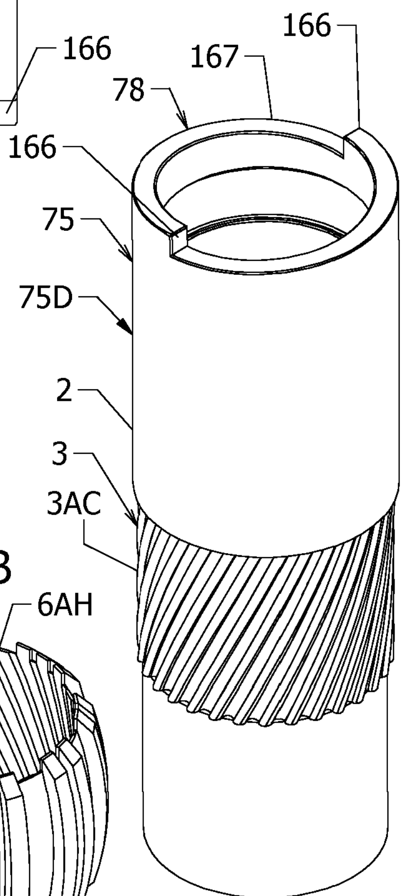


Fig.119

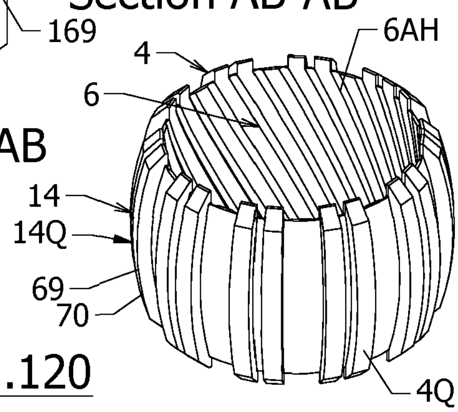


Fig.120

Fig.121
Section
AB-AB

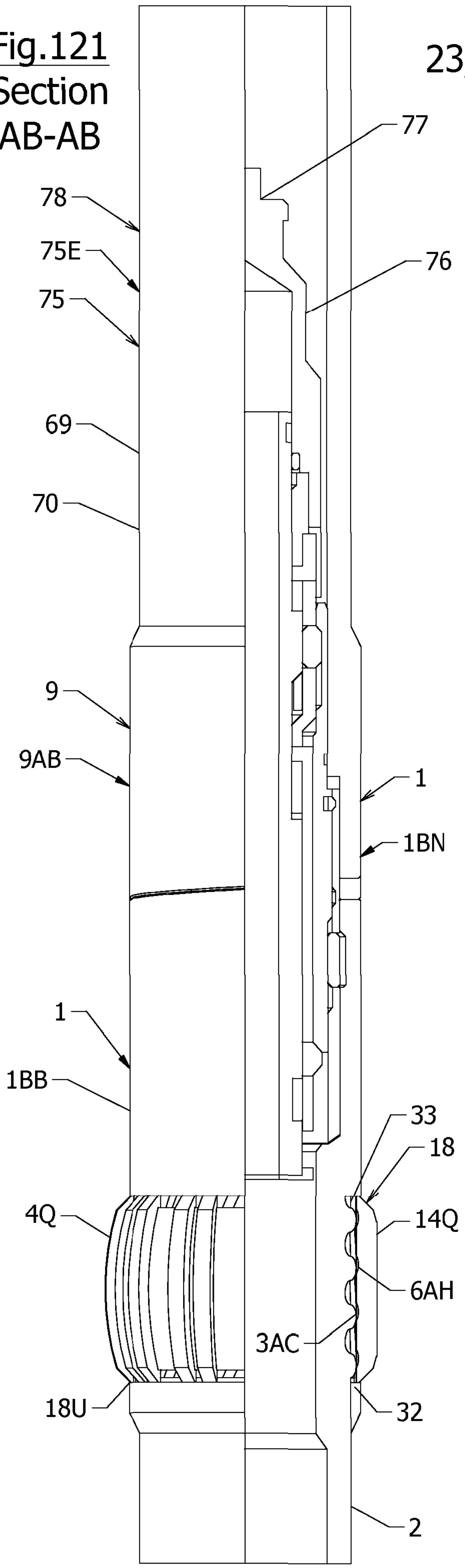
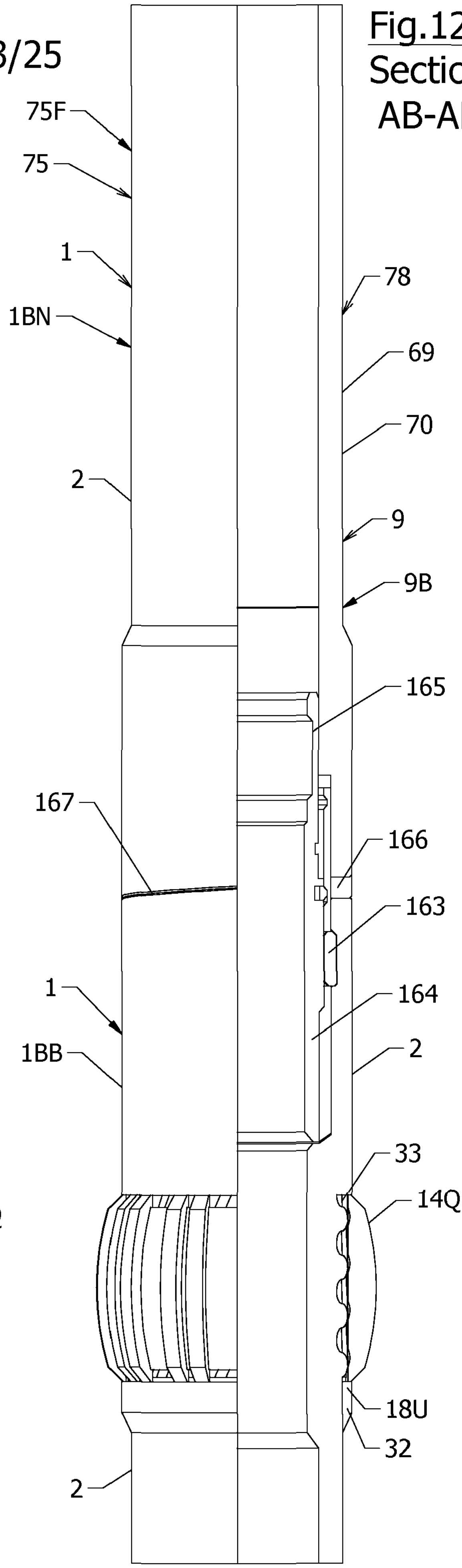


Fig.122
Section
AB-AB



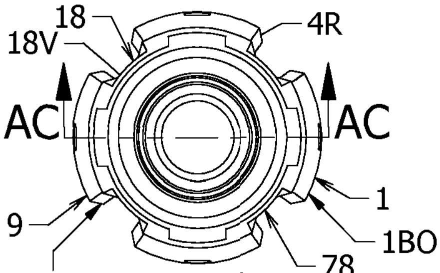


Fig.125

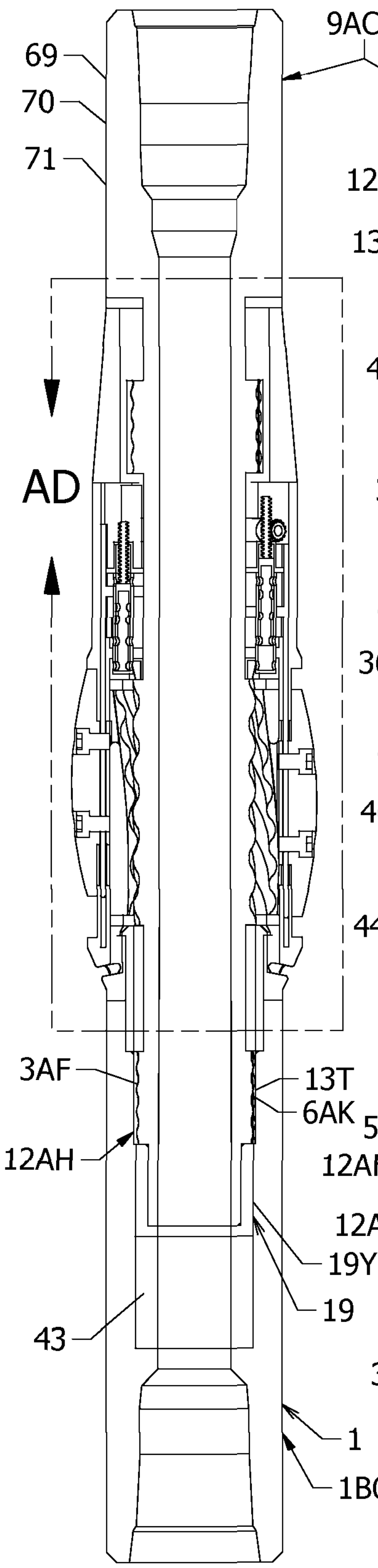
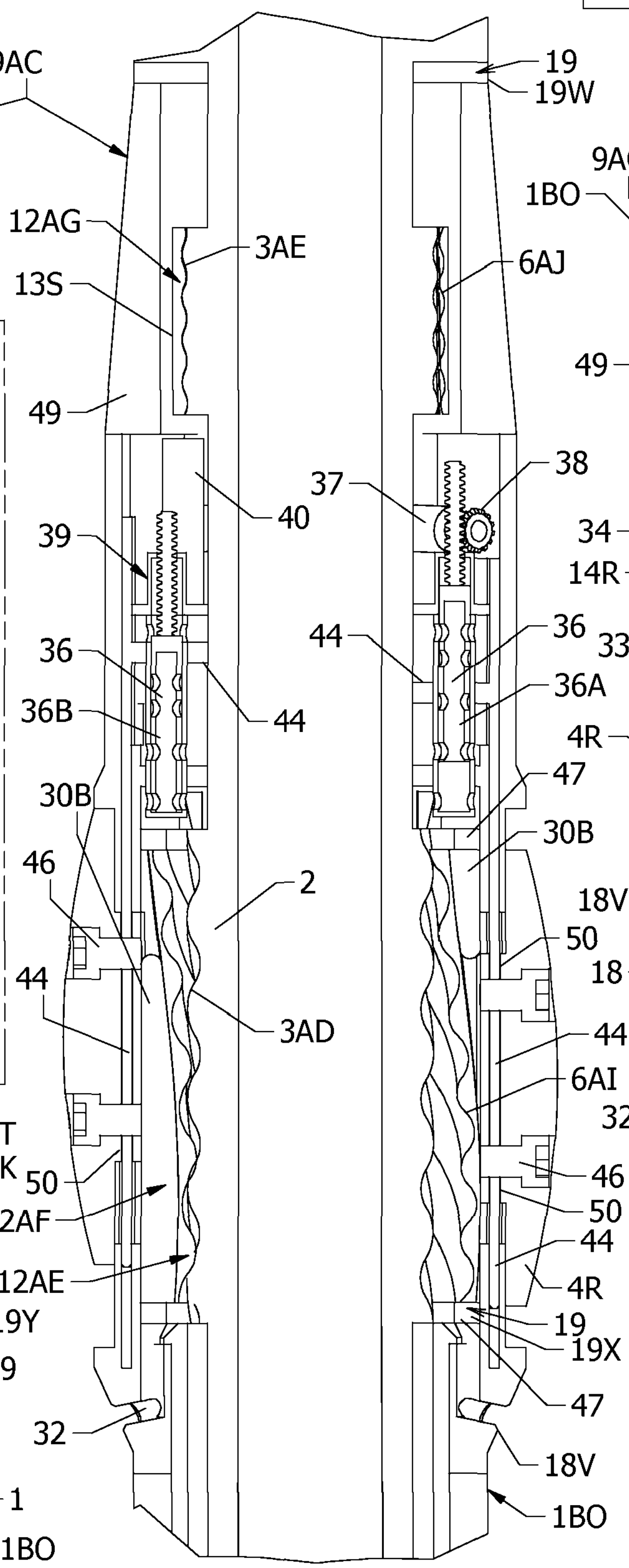


Fig.126 Section AC-AC

Fig.127
Detail AD



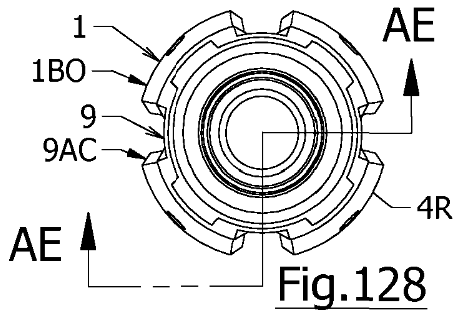


Fig.128

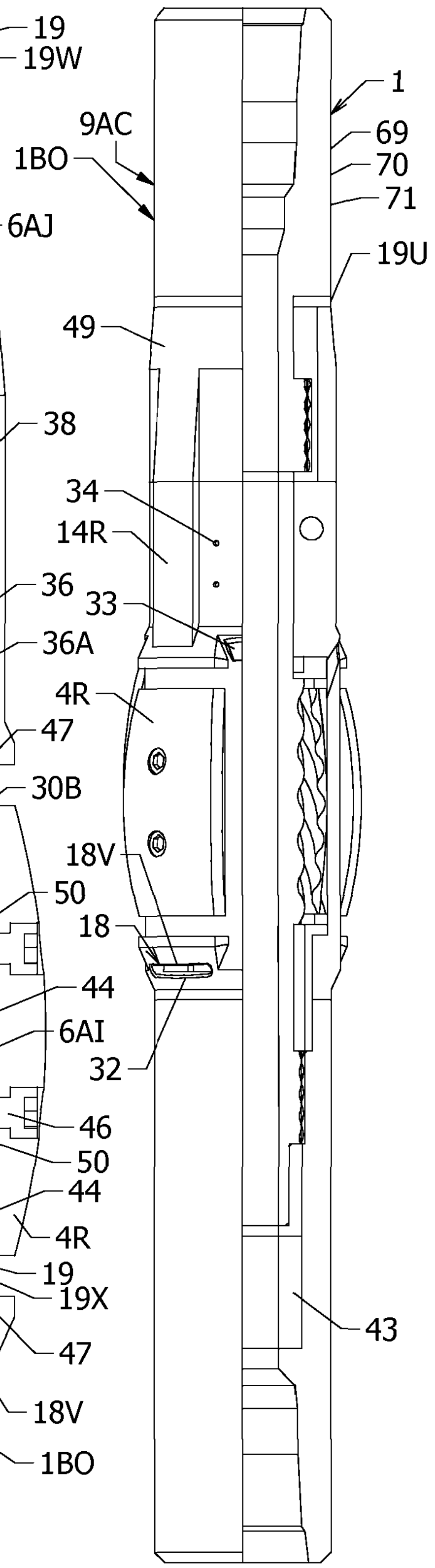


Fig.129 Section AE-AE

Fig.130

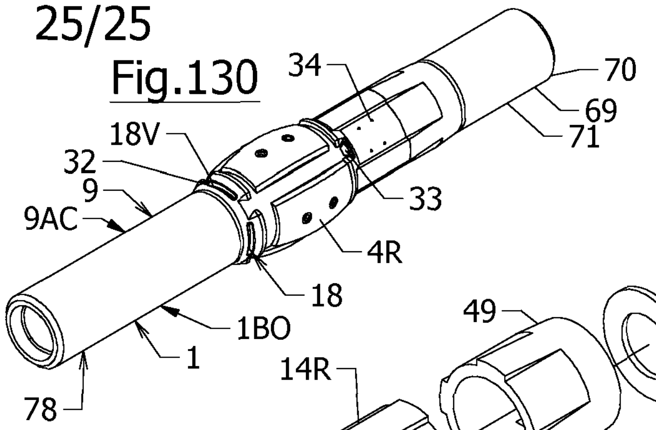
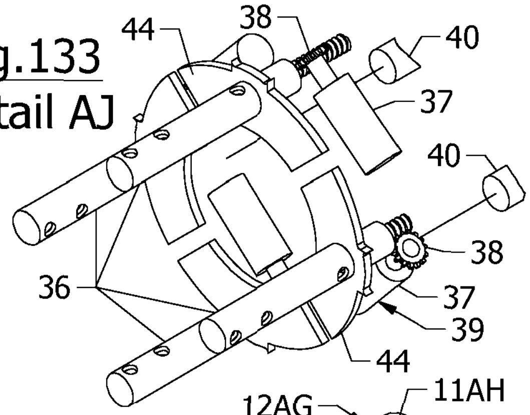


Fig.133
Detail AJ



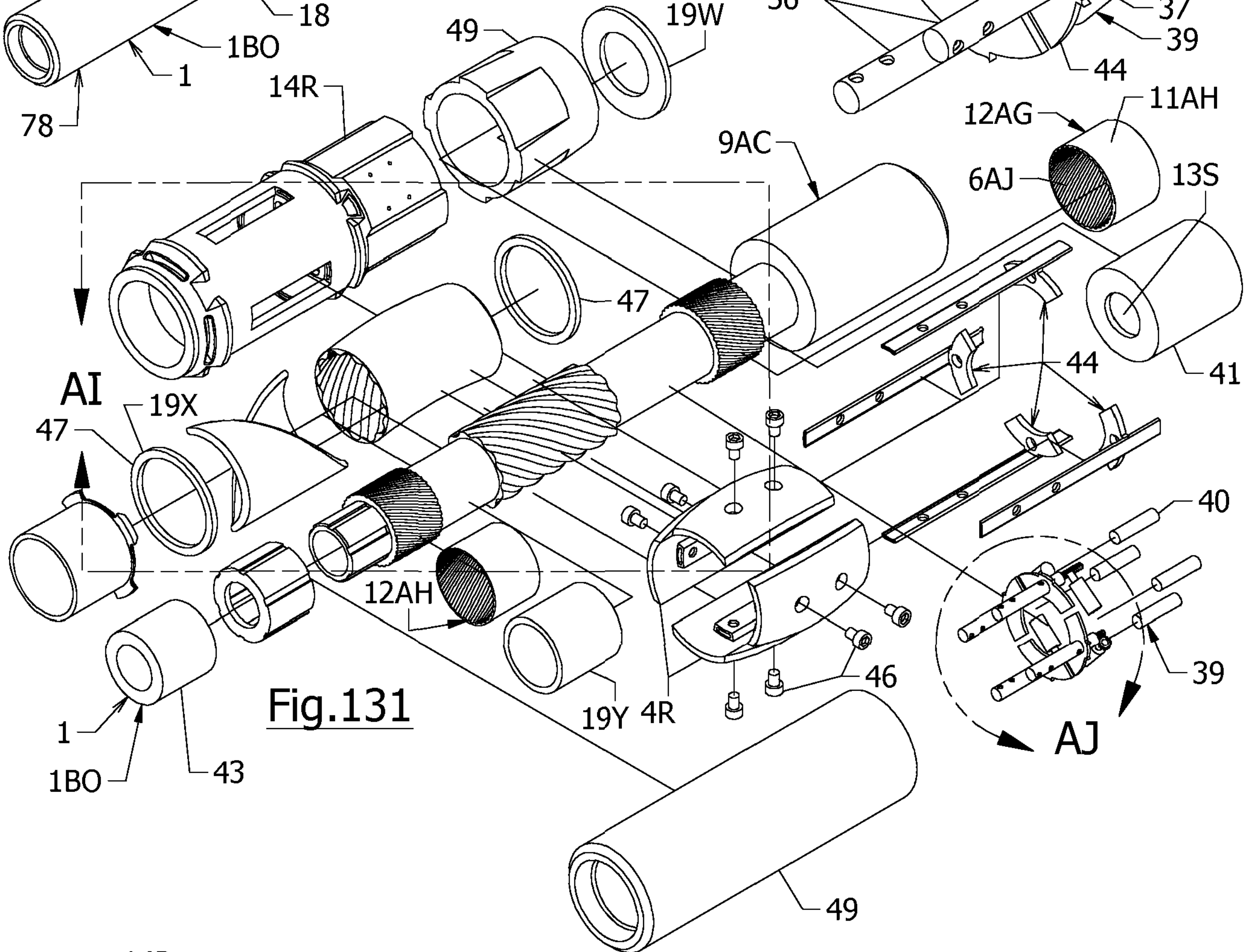
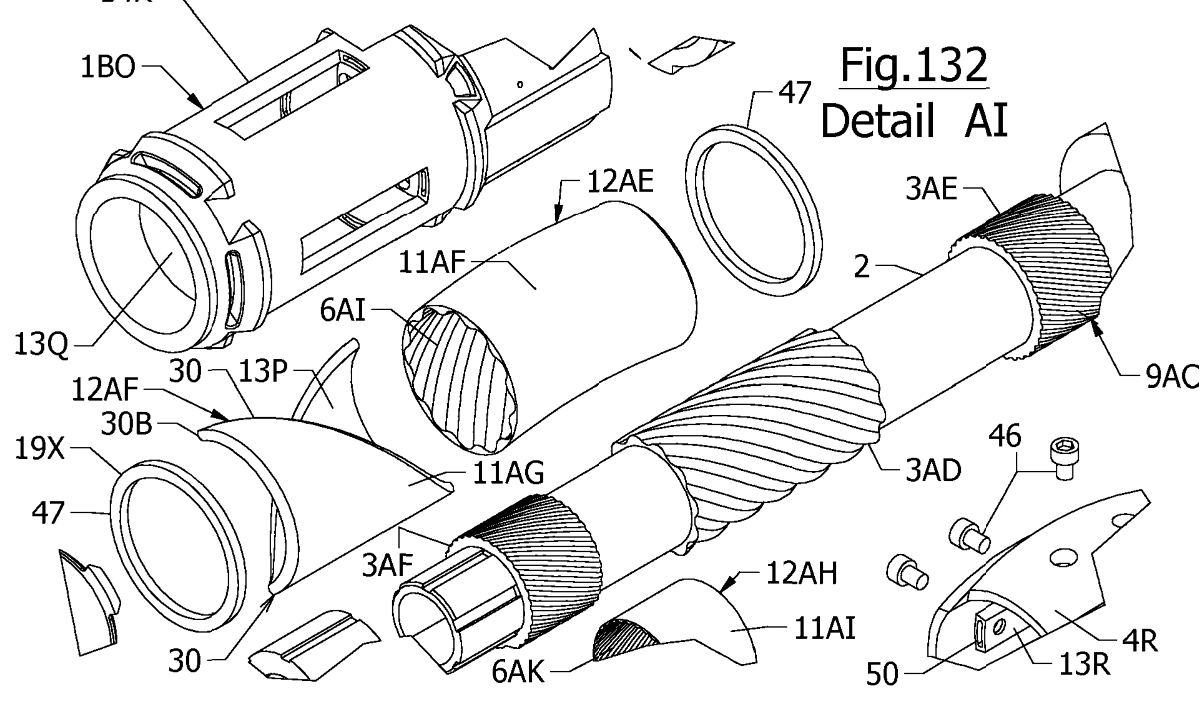


Fig.131

Fig.132
Detail AI



ROTARY STICK, SLIP AND VIBRATION REDUCTION DRILLING STABILIZERS WITH HYDRODYNAMIC FLUID BEARINGS AND HOMOGENIZERS

[0001] The present application claims priority to United Kingdom Patent Application having Number GB1021305.6, entitled “Method For Using Or Removing Unused Rock Debris From A Passageway Through Subterranean Strata Using Rock Breaking Apparatus”, filed 16 December, 2010, United Kingdom Patent Application having Number GB1111482.4, entitled “Cable Compatible Rig-Less Operatable Annuli Engagement System For Using And Abandoning A Subterranean Well”, filed 5 July, 2011, Patent Cooperation Treaty Application Number US2011/000377, entitled "Manifold String For Selectively Controlling Flowing Fluid Streams of Varying Velocities In Wells From A Single Main Bore," filed March 1, 2011 and United Kingdom Patent Application having Number GB1104278.5, of the same title, filed 15 March, 2011, PCT Application Number US2011/000372, entitled "Pressure Controlled Well Construction and Operation Systems and Methods Usable for Hydrocarbon Operations, Storage And Solution Mining," filed March 1, 2011, United Kingdom Patent Application having Number GB1104278.5, of the same title, filed 15 March, 2011, and United Kingdom Patent Application having Number GB1116098.3, entitled “Rig-less Abandonment Testing”, filed 19 September, 2011, each of which is incorporated herein in its entirety by reference.

FIELD

[0002] The present invention relates to the field of hydrodynamic fluid bearing for boring string shafts using various helical nodal, cavity, impellor and race hydrodynamic profiles for journal, thrust and pivotal fluid bearings with substantially stationary and substantially rotating rotary drill string stabilizer housings with partial circumference, bladed or arced walls supporting a low diameter-to-length rotating boring shaft susceptible to friction, stick-slip, bit whirl and harmonic resonance vibrations during boring operations within high pressure hot subterranean environments that may vary significantly between geologic periods and epochs. .

[0003] The present invention is usable within a fluid slurry environment, particularly in instances where homogenization of rock debris into said slurry is desired for hole cleaning and/or for preventing or inhibiting the propagation of strata fractures, and/or when an improved fluid bearing for dampening or minimizing rotary stick slip and/or harmonic resonance is needed.

BACKGROUND

[0004] The present invention relates, generally, to apparatus and method for reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, usable with various inventions of the present inventor, which are generally described in UK Patent 2465478, entitled “Apparatus And Methods For Operating A Plurality Of Wells Through A Single Bore”, United Kingdom Patent Application having Number GB1011290.2 and PCT Patent Application GB2010/051108, both entitled "Apparatus And Methods For A Sealing Subterranean Borehole And Performing Other Cable Downhole Rotary Operations," and both filed July 5, 2010, United Kingdom patent application having Patent Application Number GB1021787.5, entitled "Managed Pressure Conduit Assembly Systems And Methods For Using a Passageway Through Subterranean Strata," filed December 23, 2010, and United Kingdom Patent Application Number GB1015428.4, entitled “Shock Absorbing Conduit Orientation Sensor Housing System” filed 16 September, 2010, which are incorporated herein in its entirety by reference.

[0005] The present invention is usable with rotary drilling tools for debris and drilling fluid homogenization, anti-stall, anti-vibration and directional drilling control relating to controlling weight-on-bit and/or directional orientation during drilling operations, wherein the debris homogenised into the drilling fluid is also usable as lost circulation material (LCM).

[0006] Additionally, the present invention relates, generally, to a steerable rotary drilling device and a method for directional drilling with jointed, coiled tubing and/or cable conveyed rotary drilling strings of the present invention and inventor, wherein the debris and drilling fluid homogenization is usable to prevent or inhibit the initiation of strata fractures while the fluid dampening effective of the rotor stator fluid bearing is usable prevent or inhibit stalling, and/or adverse shock or vibration of rotary drilling strings during drilling and/or directional drilling operations for any combination of hole angle, curvature rate and bit load.

[0007] Cable drilling assemblies of the present invention and inventor and/or coiled tubing drilling assemblies may use a downhole positive displacement motor (PDM) to rotate a boring drill bit.

[0008] A downhole tool that homogenizes drilling rock debris into the fluid circulation system, monitors frictional factors and reduces the occurrence of adverse shocks, stick slip and/or vibration will increase overall drilling efficiency by: i) increasing the effective time of the downhole assembly's associated boring bit engagement with strata while drilling, thus increasing the average rate of penetration; ii) decreasing the damaging shock and vibrational forces to the downhole assembly, thereby decreasing occurrence of downhole failure; iii) increasing the pressure capacity of the circulating system with increased fluid carrying capacity through homogenization and disposal of boring bit cuttings through lost circulation material (LCM) compaction in the sidewall or screening as surface, thus increasing the penetration limit imposed by debris removal; and iv) decreasing the time spent tripping for all strings and fatigue cycles for cable and coiled tubing strings, thus increasing the distance drilled before tripping for repairs and/or replacement.

[0009] More efficient drilling operations reduce overall required resource costs, wherein reducing the forces exerted on downhole tools also increases their useful life.

[0010] During drilling operations, regardless of whether rotary equipment, e.g. a top drive, is located at surface or a PDM is used downhole, it is desirable to support a rotating shaft or conduit about the axis of boring so as to effectively place weigh on bit (WOB). For complex closed loop rotary steerable systems one or more gimbaling spherical bearings may be placed on drilling shafts to ensure the proper rotation or movement and/or orientation of the boring bit relative to the axis. For straight hole or directionally controlled bottom hole drilling assemblies various centralizing, fulcrums or pivot points, generally comprising drilling tools contactable with the borehole sidewall, are used to align the drill string and bit with the desired axis of boring.

[0011] Conventionally, standard bearings are used for the support of complex closed loops rotary steerable systems (RSS) which often suffer from significant adverse stick slip and vibration limitations, which generally are not significant for PDM down hole assemblies. Artisans may sometimes combine a PDM with a RSS to increase the penetration rate in hard drilling areas, but such combinations are not generally easy.

[0012] Conventional fluid bearing misalignment between associated rotating complementary surfaces may affect fluid passage and prevent the fluid bearings from accurately supporting loads, since any such misalignment will adversely affect the gap between the rotor and stator surfaces. Generally, fluid bearings depend upon the small gap between rotating complementary surfaces, wherein any misalignment is detrimental to the performance of the bearing to the point of making the bearing inoperable. Additionally non-uniform loading on the shaft or conduit can cause a lack of circular symmetry of loading on the conduit or shaft, resulting in deflection of the ends of the shaft in the bearings.

[0013] Conventional PDM technology uses fluid to positively displace helical lobes of a rotor within the associated helical profiles of a stator, wherein a planned deflection of the rotor within the stator occurs as the rotor rotates about the rotor's and stator's axis. Generally, the rotor is left free to deflect at its upper end with controlled rotation of downhole apparatuses at its lower end.

[0014] The defined deflection of a helical lobed rotor within the helical cavities of a stator, or vice versa, may be used to form a fluid bearing to, for example, reduce shocks and vibration in a rotational drilling shaft or homogenize boring bit cuttings within drilling fluid slurry to facilitate removal or use as LCM.

[0015] A spherical bearing or gimballing system forming part of a helical lobe rotor and stator fluid bearing can be used to provide a self aligning fluid bearing pump usable to drive downhole tools. Alternatively, a helical lobe rotor and stator may automatically compensate for misalignment between the axes of a spaced bearing arrangement on a drilling tool axis so as to compensate for non-uniform circular shocks and vibrations or loads placed on the drilling conduit or shaft; wherein sinusoidal, harmonic or non-uniform vibrations and deflections of the rotating drilling conduit or shaft are fluidly dampened; and wherein such fluid bearings may be applied to a various downhole apparatuses.

[0016] Hydrostatic and hydrodynamic conventional thrust and journal bearings of the fluid or frictionless type use a predetermined gap between moving parts and between which a pressurized fluid maintains said gap or spacing between moving parts. Hydrostatic bearings continually supply pressurized fluid to and from the spaces between moveable or relatively movable parts. Hydrodynamic bearings supply pressurized fluid between the moving parts by the relative movement of said parts. Hydrostatic bearings are usable where there significant, little or no movement between any movable or relatively movable parts, whereas hydrodynamic bearings generally are applicable with a high rate of relative movement between the parts so as pressurize and move fluid and maintain the gap between parts during rotation.

[0017] The fact that a stabilizer placed within the drill string forms a crude fluid bearing within the bore hole is not generally recognized by many in the art.

[0018] Components of the bottom hole assembly (BHA) above the boring bit and comprising drilling stabilizers, drill collars and other ancillary equipment, including the associated deployment string, are generally cylindrical and of a smaller diameter than the borehole, so as to permit drilling mud and boring bit cuttings debris to flow back to the surface through the annular space between the pipe string and bore hole, wherein the drilling mud reduces the drag of the crude fluid bearings formed between the stabilizers and the wall of the strata bore as the drilling assembly is rotated and axially.

[0019] As a result, two major elements, comprising tensioned and compressed string portions axially above and below a neutral point, respectively, may incur torsional resonance when a the drill string undergoes harmonic oscillations or shock forces during stick and slip of the drill string during rotation between the conventional crude fluid bearing stabilizers, which may be inadequately spaced and/or under gauge relative to the bore hole's diameter and axial inclination or deviational deflection. Improperly configured drill strings with significant inefficiencies may incur torsional loading and harmonic oscillations of sufficient magnitude to cause drill string failure, especially in the case rotary coiled tubing and cable string drilling assemblies where rotation of the deployment string may be catastrophic.

[0020] Torsional resonance or stick slip for components with high torsional stiffness and moduluses of elasticity, e.g. drill-collars, may also damage drilling string components, e.g. boring bit polycrystalline diamond compact (PDC) cutters, with torsional loads and/or reverse rotation of the drilling assembly.

[0021] Stick-slip behaviour of a drill string may represent chaotic disturbances in normal and destructive torsional resonances of the rotating portion of the drill string that depend upon various factors including axial drag, axial shock loading or bit bounce, bit whirl caused by disengagement from the boring face, back-lash or backwards spin resulting from stick-slip, the resulting torque shocks and vibation of bit whirl and stick-slipe, buckling of rotational components, and lateral harmonic vibration associated with portions unsupported by a bearing, e.g. a stabilizer .

[0022] If a drill string is not arranged to naturally balance such destructive centrifugal forces, adverse rotational forces may become self-sustaining due to the momentum of a continuously rotated mass and associated harmonic vibrations, wherein stopping rotation or axially withdrawing contact with the boring face may be the only means of countering said destructive forces once they start.

[0023] Successfully avoiding adverse stick-slip and/or managing drill string harmonics to improve the drilling process requires examination of the rotational driving mechanism, the rotating components, the torsional rigidity of the components and the interaction of the boring bit with the strata being drilled. While each of the factors has an effect, each factor may also affect another factor, thus causing significant complexity with regard to the avoidance of adverse torsional loading and harmonic vibration because the factors are constantly changing.

[0024] With regard to the nearest competing prior art, McLoughlin and Swietlik, US Patent Application No. 12/733,480, propose confining the radial motion of a stabilizer within the borehole, thus providing limitations to the internal attitudinal motion and constraining lateral and torsional movements with an improved stabilizer design that inherently falls short of forming a fluid bearing. The full extent of potentially destructive forces cannot however be fully passed to the sidewall because the design does not actively supply fluid lubrication between the side wall and the drill string stabilizer blade. Additionally, the debris removal, LCM, rotary steerable aspects, and the rotary cable tool compatibility provided by the present invention are not present in the teachings of McLoughlin and Swietlik.

[0025] As the frequency of harmonic vibrations associated with the rotating drill strings may vary widely across drill string configurations and geologic conditions the timely corrective action of an active hydraulic system response is generally required for active damping of continuously changing harmonic motion. Periods of high bit generated vibration frequency and amplitude require active and responsive damping of the BHA to prevent adverse harmonic and torsional rotation, and consequently feedback to the bit which may further degrade drill string rotation. This can be especially problematic for rotary cable tool boring operations.

[0026] Unfortunately, despite having significant merit, the new technology proposed by McLoughlin and Swietlik, by the present invention and by present inventor, is difficult to deploy due to the risk tolerance of Operators and the oligopolistic practices of the remaining large service providers who, understandably, prefer using technology with the highest immediate return, thus making new technology development difficult.

[0027] Ultimately solutions to such problems come developed from field testing and development, however well operators face a series of challenges at each stage of a well's lifecycle as they seek to balance the need to maximise economic recovery and reduce the net present value of an abandonment liability to meet their obligations for safe and environmentally sensitive operations and abandonment. When wells lose structural integrity, which may be defined as an apparent present or probable future loss of pressure or fluid bearing capacity and/or general operability, all or portions of a well may be shut-in for maintenance or suspension until final abandonment or may require immediate plugging and abandonment, potentially leaving reserves within the strata that cannot justify the cost of intervention or a new well.

[0028] Some of the more frequently reported structural integrity problems are a lack of centralization leading to conduit erosion from thermal cycled movement, corrosion within the well conduit system; e.g., from biological organisms or H2S forming leaks through or destroying conduits or equipment and/or valve failures associated with subsurface safety valves, gas lift valves, annuli valves and other such equipment. Other common issues include unexplained annulus pressure, connector failures, scale, wear of casings from drilling operations, wellhead growth or shrinkage and xmas or valve tree malfunctions or leaks at surface or subsea. Such issues comprise areas where operators are able to, or chose to, test and there are others (such as the internals of a conductor) which they cannot, or do not test, and which may represent a serious risk to economic viability and the environment. Problems within various portions of a well, in particular the annuli, cannot be conventionally accessed without significant intervention or breaking of well barriers, e.g., with a drilling rig, and thus, are a significant cost and safety risk to operators that are unsuitable for conventional rig-less operations.

[0029] A primary advantage of using drilling specification rigs for well intervention is the removal of conduits and access to annuli during well intervention and abandonment, wherein the ability to access and determine the condition of the annuli casing and primary cement behind the production conduit or tubing is used to make key decisions regarding the future production and/or abandonment. If well casings are corroded or lack an outer cement sheath, remedial action, e.g. casing milling, may be taken by a drilling rig to provide a permanent barrier. Conversely, the problem may be exacerbated by conventional rig-less well abandonment when blind decisions are made without cement logging access to annuli and attempts to place cement fail, thereby placing another barrier over potentially serious and worsening well integrity issues that can represent a significant future challenge, both technically and economically, even for a drilling rig.

[0030] Various method embodiments of the present invention are usable for benchmarking, developing, testing and improving new technology relating to the gathering of information that conventional rig-less operations cannot, by providing access and/or space for both measurement devices and sealing materials. Once such information is gathered, still other method embodiments are usable for benchmarking, developing, testing and improving rig-lessly placed barriers, mill or shred conduits and casings to expose and bridge across hard impermeable strata or cap rock formations for placement of permanent barriers without imbedded equipment to ensure structural integrity.

[0031] In general, age is believed to be the primary cause of structural well integrity problems. The combination of erosion, corrosion and general fatigue failures associated with prolonged field life, particularly within wells exceeding their design lives, together with the poor design, installation and integrity assurance standards associated with the aging well stock is generally responsible for increased frequency of problems over time. These problems can be further exacerbated by, e.g., increasing levels of water cut, production stimulation, and gas lift later in field life.

[0032] However, the prevalent conventional consensus is that although age is undoubtedly a significant issue, if it is managed correctly it should not be a cause of structural integrity problems that may cause premature cessation of production. Additionally, fully depleting producing zones through further production prior to abandonment provides an environment of subterranean pressure depletion better suited for placing permanent barriers by lowering the propensity of lighter fluids to enter, e.g., cement during placement.

[0033] The present invention provides a lower cost rig-less means of for benchmarking, developing, testing and improving the accessing of annuli and selectively placing pressure bearing conduits and well barrier elements at required subterranean depths between annuli when intervening in, maintaining and/or abandoning portions of a well to isolated portions affected by erosion and corrosion, which, in turn, extends well life to fully deplete a reservoir to further reduce the risk associated with well barrier element placement and the pollution liability from an improperly abandoned well.

[0034] The level of maintenance, intervention and workover operations necessary for well maintenance is restricted by the substantial conventional costs involved. The limited production levels of aging assets often cannot justify the conventional practice of using higher cost drilling rigs and conventional rig-less technology is generally incapable of accessing various passageways or all annuli within the well.

[0035] Therefore, well operators generally place an emphasis on removing troublesome assets from their portfolio and seek to prevent future problems using improved designs rather than attempting to remedy a poorly designed well, which in turn precipitates a greater focus on asset disposal, well design, installation and/or integrity assurance. Passing the problem on to others with the sale of a well does not however solve the issue of abandoning existing and aging wells from a liability viewpoint.

[0036] When intervention is required, risk adverse major oil and gas companies generally prefer asset disposal and replacement rather than remediation, favouring sale of aging well assets to smaller companies with lower overheads and higher risk tolerances. Smaller companies, requiring a lower profit margin to cover marginal cost, are generally eager to acquire such marginal assets, but may in future be unable to afford well abandonment, thus putting the liability back to the original owner and preventing sale or creating a false economy for the seller. Low cost reliable rig-fewer placements of well barrier elements to delay or perform abandonment is critical to major and small companies if aging assets are to be bought and sold and/or to avoid such false economies. Thus, the rig-less methods and members of the present invention, usable to place and verify well barrier elements for reliable abandonment, are important to all companies operating, selling and/or buying aging wells.

[0037] Therefore, the structural integrity of producing and abandoned wells is critical because the liability of well abandonment cannot be passed on if a well ultimately leaks pollutants to surface, water tables or ocean environments, because most governments hold all previous owners of a well liable for its abandonment and environmental impacts associated with subsequent pollution. Hence the sale of a well liability does not necessarily end the risk when the asset is sold or abandoned unless the final abandonment provides permanent structural integrity.

[0038] Methods embodiments of the present invention are usable for benchmarking, developing, testing and improving of rig-less well intervention and maintenance to extend the life of a well by placing well barrier elements to isolate or abandon a portion of a well then operating another, until no further economic production exists or well integrity prevents further extraction or storage operations, after which the well may be completely and permanently abandoned for an indefinite time using the present invention capability to rig-lessly selectively access annuli for both placement and verification of well barriers, including said benchmarking, developing, testing and improving of new technology.

[0039] A need exists for improved stability of drilling and directional drilling assemblies for jointed and rotary coiled string operations.

[0040] A need exists for benchmarking, developing, testing and improving new technology usable for delaying abandonment with low cost rig-less operations for placement of well barrier elements to increase the return on invested capital for both substantially hydrocarbon and substantially water wells through rig-less sidetracking for marginal production enhancement, suspending and/or abandoning portions of a well to re-establish or prolong well structural integrity for aging production and storage well assets, preventing pollution of subterranean horizons, such as water tables, or surface and ocean environments.

[0041] A need exists for benchmarking, developing, testing and improving new technology usable for small operating foot print rig-less well barrier element placement operations usable to control cost and/or perform operations in a limited space, e.g. electric line or slickline operations, on normally unmanned platforms, from boats over subsea wells or in environmentally sensitive area, e.g. permafrost areas, where a hostile environment and environmental impact are concerns. A related need also exists for benchmarking, developing, testing and improving new technology usable for working within a closed pressure controlled envelope to prevent exposing both operating personnel and the environment to the risk of losing control of subterranean pressures if a well intervention kill weight fluid column is lost to, e.g., subterranean fractures.

[0042] A need exists for benchmarking, developing, testing and improving new technology usable for avoiding the high cost of drilling rigs with a rig-less system capable of suspending, side-tracking and/or abandoning onshore and offshore, surface and subsea, substantially hydrocarbon and substantially water wells using published conventional best practices for placement of industry acceptable permanent abandonment well barrier elements.

[0043] A need exists for benchmarking, developing, testing and improving new technology usable for preventing risks and removing the cost of protecting personnel and the environment from well equipment contaminated with radioactive materials and scale by rig-lessly placing abandonment barriers and leaving equipment downhole. A further need exists for benchmarking, developing, testing and improving new technology usable to rig-lessly side-track or fracture portions of a well to dispose of hazardous materials resulting from circulation of the wells fluid column during suspension, sidetracking and abandonment operations.

[0044] A need exists for benchmarking, developing, testing and improving new technology usable for rig-lessly accessing annuli to measure whether acceptable sealing cementation exists behind casing and to rig-lessly mill the casing and place cement if acceptable cementation does not exist. A further need exists for benchmarking, developing, testing and improving new technology usable to verify the placement of well barrier elements during rig-less operation to ensure the successful settable material bonding and sealing of a well's passageways has occurred or whether further remedial work is required.

[0045] A need exists for benchmarking, developing, testing and improving new technology usable for rig-lessly accessing annuli presently inaccessible with minimal foot-print conventional slickline rig-less operations, including bypassing annulus blockages, created, e.g., by production packers, during placement of permanent well barrier elements within selected portions of a well across from cap rock and other impermeable formations needed to isolate subterranean pressures over geologic time.

[0046] A need exists for benchmarking, developing, testing and improving new technology usable for a plurality of permanent well barriers that are verifiable through selectively accessed annuli passageways with rig-less operations usable with conventional logging tools to maintain the structural integrity of a well prior to final abandonment that also provide access for placing permanent barriers to ensure structural integrity of the strata bore hole thereafter.

[0047] A need exists for benchmarking, developing, testing and improving new technology usable for marginal production enhancement usable to offset operating costs until final abandonment occurs, including rig-lessly providing well integrity while waiting until an abandonment campaign across a plurality of wells can be used to further reduce costs.

[0048] A need exists for benchmarking, developing, testing and improving new technology usable to reduce the abandonment liability for operators while meeting their obligations of structural well integrity for safe and environmentally sensitive well operations, suspension and abandonment in an economic manner that is consistent with providing more capital for exploration of new reserves to meet our world's growing demand for hydrocarbons by minimising the cost of operations, suspension and abandonment with lower cost rig-less suspension, side-tracking and abandonment technologies.

[0049] Finally, benchmarking, developing, testing and improving new technology usable to verify rig-less well abandonments is needed to facilitate a market where the reduction of well abandonment liability allows larger operating overhead companies to sell marginal well assets to smaller lower overhead operating companies, i.e. by lowering the risk of a residual abandonment liability, to prevent marginal recoverable reserves from being left within the strata because higher operating overhead requirements made such recoverable reserves uneconomic.

[0050] Various aspects of the present invention address at least some of these needs.

SUMMARY

[0051] Preferred embodiments, for an apparatus (1) for reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, generally comprise a hydrodynamic bearing (1, 12) disposed about said shaft and within said bore's wall (7), with at least one periphery arced wall (4) radially extending from and arranged about the circumference of an outer wall (5) of a conduit shaft housing (14) about at least one inner wall (6, 13) adjacent to at least one associated hydrodynamic profiled wall (3) rotatable by or about said shaft to displace fluid axially along said at least one inner wall anchored by the combined frictional engagements of said fluid, said at least one profiled wall (3), said at least one inner wall (6, 13), said at least one arced wall (4) and said bore's wall (7) to force said fluid between at least one adjacent set of at least two of said walls, and wherein said displacing of fluids forms a pressurized (8) cushion fluidly communicated to and from said set of at least two walls to, in use, lubricate and dampen said rotational shocks and vibrations with the shearing of said frictional engagements when bearing said shaft during rotation within said subterranean bore.

[0052] Related preferred embodiments add at least one inner wall (6) comprising the inner wall of at least one bearing sleeve (12) component with a outer sleeve wall (11) adjacent to another said at least one inner wall (13) engaged with said conduit housing (14) and rotatably disposed about said shaft (2).

[0053] Other preferred embodiments have at least one inner wall (6, 13), said outer sleeve wall (11), said arced wall (4), or combinations thereof, comprising at least one additional hydrodynamic profile rotatable by engagement with said shaft, said displaced fluid, said adjacent wall, or combinations thereof, to further form said cushion and associated shearable frictional engagements.

[0054] Preferred hydrodynamic profiles may comprise impellors (24), rotor lobes (25), stator cavities (26), bearing races (22) or combinations thereof (17, 18, 27, 28, 29), axially or helically oriented to said shaft's axis.

[0055] Preferred embodiments may also comprise rotating said hydrodynamic profiles with a motor or pumped fluid to form a pump (18) or motor (17) to displace said fluid or rotate at least one of said walls, respectively.

[0056] Other embodiment supply fluid from at least one reservoir internally or externally to at least one passageway (31, 32, 33, 34) within or about said shaft (2), said bearing sleeve (12), said housing (14), or combinations thereof, and returned to said at least one reservoir externally or internally to said passageway, respectively.

[0057] Related embodiment with at least one reservoir may comprise a contained fluid volume reservoir within said housing, a fluid flow stream reservoir about said bearing, or combinations thereof.

[0058] Preferred embodiments may also have at least one valve comprising a one-way (35) valve, plurality-of-way valve (36), or combinations thereof, component to selectively control said fluid supply to and from said reservoir.

[0059] Other preferred embodiments may have a piston (44), spring (45), or combinations thereof, component usable to urge separation or coalescing of at least two of said walls, operation of said valves, or combinations thereof.

[0060] Still other preferred embodiments may comprise a surface interface actuated electrical control system (39) usable to urge at least one said component or said walls of said bearing (1), said surface interface (42, 43) to said bearing comprising an electric cable (67R), a pulse (68) through said fluid, or combinations thereof.

[0061] Preferred embodiments may also comprise at least one journal (69), thrust (70), pivotal (71), or combination thereof, component to reduce said rotational friction, shocks and vibrations associated with bearing said rotatable shaft (2).

[0062] Still other preferred embodiments may have at least a component of said shaft (2), said at least one sleeve bearing (12), said at least one inner wall (6, 13), or combinations thereof, comprising materials of a flexible nature.

[0063] Preferred embodiments may also comprise supporting cylindrical or ball bearing (19) components usable between said walls, said shaft, or combinations thereof, to form said pump, form said motor, reduce said rotational friction, shocks and vibrations, or combinations thereof.

[0064] Related embodiments may comprise a race (22), strand (20), chain link (21), or combinations thereof, to control the effective rotating diameter (23) of said shaft, said flexible material, said cylindrical or ball bearings, or combinations thereof.

[0065] Other preferred embodiments may comprise an eccentric helical wrapping sleeve bearing (30) component usable to dynamically control said fluid supply, the effective rotating diameter (23) of said sleeve bearing (12), or combinations thereof.

[0066] Still other related embodiments may have said arced wall (4) axially extending from the outer wall (5) of an associated second shaft conduit housing proximally engaged with said first stated conduit housing (14), to provide said frictional engagement to said bore.

[0067] Other related embodiments may comprise arced wall (4) comprising a fixed (1B, 1D, 1F, 1H, 1J, 1K, 1M, 1O, 1P, 1R, 1T, 1U, 1V, 1W, 1X, 1Z, 1AA, 1AB, 1AC, 1AD, 1AF, 1AG, 1AH, 1AJ, 1AT, 1AU) or variable (1A, 1C, 1E, 1G, 1I, 1L, 1N, 1Q, 1S, 1Y, 1AE, 1AK, 1AL, 1AM) component to affect said effective rotating diameter (23) bearing (1) within said bore's wall (7) during said shearing of said frictional engagements.

[0068] Various other preferred embodiments may have variable effective rotatable outer diameter (23) formed by radially extending, axially moving, or combinations thereof, at least one arced wall component relative to at least one associated arced wall.

[0069] Still other related embodiments may have at least one variable and fixed bearing (1) arranged for pendulum rotation about a fulcrum (15A), pivot (15B), or combination thereof, bearing points (15) when axial (16A), lateral (16B), of combination thereof, forces (16) are applied to a component of said shaft (2).

[0070] Various other embodiments may comprise an assembly of reusable and replaceable component parts assembled with fasteners (46) for maintenance and seals (47) for controlling the exposure of said components to said fluids when operating said bearing and shaft with said bore.

[0071] Still other preferred embodiments may comprise drilling or milling string (9) hydrodynamic bearing subassembly usable with said fluid and string to form or enlarge a bore through subterranean strata or casing by circulating debris fluid slurry from said bore when rotating said shaft with one or more motors within (17, 72) or at the upper end (73) of said string to, in use, lubricate, bear and dampen rotational shocks and vibrations associated with operating said string's shaft to rotate one or more cutting structure components proximal to said string's lower end to perform said drilling or milling and remove said debris.

[0072] Finally, other preferred embodiments may comprise homogenizing said debris within said fluid to form a more fluid slurry of reduced particle size milling or boring debris with said rotation of said profiled walls to, in use, increase the frequency of breaking and slurrifying said debris to increase the associated propensity of its removal from said bore or casing, its associated propensity to inhibit or prevent the propagation of strata fractures by packing said reduced particle sizes into said bore's strata wall filter cake or strata fractures, or combinations thereof.

[0073] BRIEF DESCRIPTION OF THE DRAWINGS

[0074] Preferred embodiments of the invention are described below by way of example only, with reference to the accompanying drawings, in which:

[0075] Figure 1 illustrates the embodiment of a system for forming usable space for side-tracking and the development and testing of various new technologies, apparatuses of the present inventor and embodiments of the present invention.

[0076] Figures 2 to 16 depict diagrammatic subterranean well schematics for various well types usable with various embodiments of the present invention.

[0077] Figures 17 to 21 illustrate various rig and rig-less arrangements usable with various wells types A to D applicable to various embodiments of the present invention.

[0078] Figures 22 to 32 show prior art apparatuses and methods.

[0079] Figures 33 to 43 depict apparatuses and methods of the present inventor usable with various embodiment of the present invention.

[0080] Figures 44 and 45 illustrate explosive and line tension for forming space within a subterranean well which are usable with various embodiments of the present invention.

[0081] Figures 46 to 48 depict various drilling assemblies usable with various embodiments of the present invention.

[0082] Figures 49 to 53 illustrate various milling assemblies usable with various embodiments of the present invention.

[0083] Figures 54 to 106 depict various hydrodynamic stabilizing bearings usable with various embodiments of the present invention.

[0084] Figures 107 to 113 illustrate various hydrodynamic motor bearings usable with various embodiments of the present invention.

[0085] Figures 114 to 122 depict a wireline deployable drill string conduit arrangement usable with various embodiments of the present invention.

[0086] Figures 123 to 133 illustrate directional drilling hydrodynamic stabilizing bearings usable with various embodiments of the present invention.

[0087] Embodiments of the present invention are described below with reference to the listed Figures.

[0088] DETAILED DESCRIPTION OF THE EMBODIMENTS

[0089] Before explaining selected embodiments of the present invention in detail, it is to be understood that the present invention is not limited to the particular embodiments described herein and that the present invention can be practiced or carried out in various ways.

[0090] Referring now to Figure 1, depicting a flow chart of a space provision system (10) embodiment (10A), showing the identification of wells available for abandonment (82) and consummation of an agreement (83) representing, for example, a contractual rental or sale agreement (84) between a technology (85) and abandonment liability owner (86) for space usage rights (87) and optionally infrastructure usage rights (88).

[0091] A space provision system is usable to compress well apparatuses and debris (91) with a compression device (92) for form a usable space for placement of an abandonment plug (89) to satisfy an abandonment liability and provide integrity for developing new technology (78), for example further space formation devices (92) to reduce the resources required for abandonment, or side-tracking drilling and milling assemblies (9) or hydrodynamic bearings (1) to for example, more effective exploit Brownfields (79) and Greenfields (80) with less resources, to the benefit of the regional and global private and public benefit (90).

[0092] Empirical measurements (93) may be taken with logging tools or a transponder may be placed in a protective shock absorbent housing (66 of Figure 33) to provide empirical data to design, redesign, test and field prove new technology (78) in the development of Greenfield (80) and Brownfield (79) wells (57). Various inventions of the present inventor, specifically, earlier described: UK patent number 2465478 and UK patent application numbers GB1011290.2, PCT GB2010/051108, GB1021305.6, GB1111482.4, GB1104278.5, GB1104278.5 and PCT patent application numbers US2011/000377 and US2011/000372, may be tested and further developed with the present space provision system. While new technology of the present invention, specifically hydrodynamic bearings (1) and boring string (9), and the present inventor are emphasised, virtually any downhole technology that will fit through the bore of the well (57) may be tested and field proven subject to the resources available, and hence the present space formation system is further usable to create a market for testing and field proving the new technology, wherein said usable space becomes a tradable product.

[0093] The resource cost of drilling rig (58A of Figure 18) and even some rig-less operations (58C of Figure 19) is, generally, such that a usable space for testing and field proving of downhole tools deployable within the realistic environments provided during the abandonment of wells (57) with significantly less resource intensive rig-less jointed pipe (58B of Figure 17) and coiled string (58D of Figure 20) operations, represents a significant improvement in the development of new technology and hence is marketable. For example, a company owning the usage right for the usable space formed during the abandonment may offer to test and field prove technologies in exchange for a participating ownership in such technologies or for monetary gain.

[0094] Given the relatively low capital investments required for rig-less abandonment, wherein the present space provision system represents a new technology requiring minimalistic resources, and the lack of competitive forces in the present oligopolistic service provider market, well abandonment represent a significant resource cost to liability owners and opportunity for new technology companies to compete with the goliath service providers who domination the market. Alternatively, the ownership of minimalistic resources and opportunity to test new technologies with one of said goliath service providers will force competition in a relatively uncompetitive market compared to the 1970's and early 1980's. In all cases, the use of fewer resources provides significant benefit to regional and our global society (90) facing peak oil and dramatic liquid hydrocarbon price increases, because said resources may be reallocated to Brownfield (79) and Greenfield (80) developments needed to limit said dramatic liquid hydrocarbon price increases associated with peak oil.

[0095] Figures 2 to 16 show various diagrammatic elevation views of a subterranean slice through various example wells (57) and strata types applicable to the present invention. As subterranean wells (57 of Figure 2) have many components, simplified well schematics (e.g. 57 of Figures 2A and 3 to 16) are conventionally used to provide focus upon communicated aspects. Hence it is to be understood that a schematic well diagram (e.g. 57 of Figure 2A) is equivalent to a more detailed well diagram (e.g. 57 of Figure 2, below the section line A1-A1) and each of the wells described in Figures 3 to 16 are similar to Figure 2, except where noted.

[0096] Generally, a well's (57) architecture comprises various cemented (64) and uncemented casing (56A to 56D) and strata (60A to 60M) bores (7). Casings may comprise various sizes, for example, (56D) may represent a 7" liner, (56C) a 30" conductor, (56B) a 13 3/8" casing and (56A) a 9 5/8" production casing, within which an uncemented annulus and production conduit (56E) may exist. For a space formation system, devices may be used to compress the production conduit (56E) forming debris and potentially containing or covered with engaged debris, e.g. NORM or LSA scale, wherein the conduit (56E) and other associated apparatuses and debris may be compressed within the uncemented annulus of the production conduit (56A) to form a usable space within said production conduit.

[0097] With regard to new technology (78), brownfield (79) and greenfield (80) development, it is critical to understand that said new technology (78) will be subjected to diverse pressure, temperature and the forces stratigraphy that is vastly different from one well to the next and which has formed over hundreds of millions of years. Consequently, the art and practice of the well construction and production industry is to rely more upon empirical data that theoretical data give the dangers of exposure to subterranean substances, pressures and temperatures, where geothermal water may be as dangerous as explosive hydrocarbons in various instances. Hence, the field testing and proving of new technology in similar conditions to those expected is of critical importance to practitioners. Unfortunately, the common test well for Service providers are typically shallow, incomparable and generally discounted by those skilled in the art.

[0098] The presently described space provision system is usable to test and field prove new technologies, like hydrodynamic bearings (1) and directable hydrodynamic bearing pendulum boring strings (9), tested within the controlled environment of a subterranean well, wherein the lower end has been made relatively safe through said space provision system abandonment leaving room with the well to test new technology in close to actual conditions. It is to be understood that the strata below the Figure 2, Figure 2A, and Figure 3 line A1-A1 represents any of the Quaternary and Neogene period epochs, with the strata below line A2-A2 representing any of the Paleogene period Oligocene, Eocene and Paleocene epochs and strata below A3-

A3 represents any Cretaceous, Jurassic, Triassic, Permian or Carboniferous period late, middle and early epochs. The strata below lines B-B of Figure 18, C-C of Figure 19, and D-D of Figure 20 represents any of the lines A1-A1, A2-A2 or A3-A3 geologic period epochs.

[0099] Referring now to Figures 17 to 21, illustrating various elevation views of rigs (58) of what is conventionally described as drilling rig (58A) and rig-less (58B, 58C and 58D) arrangements above example slices through subterranean wells (57) and strata (60). Drilling rigs (58A) require the most resources to operation, with a large derrick (94) and associated hoisting equipment often capable of lifting over a million pounds, with associated large fluid pumping and storage capacity resources. While either coiled or jointed pipe conduit string may be used on a drilling rig (58A), high strength and torque jointed conduits are generally used. In general, drilling rigs have the most rugged and robust equipment specification that may be orders of magnitude difference resource operations costs compared to coiled string and other rig-less arrangements. Coiled tubing rigs, generally termed as drilling "rig-less," generally require significantly less resources than drilling rigs, but considerably more than, for example, jointed string rig-less arrangements (58B) and cable rig-less arrangements (58D). Consequently, when well abandonment and boring string operations use rig-less arrangements, said operations require less resources.

[0100] Drilling rig (58A) are generally efficient for quickly boring and constructing a well into the geologic periods and epochs miles and kilometres below the earth's surface, however such resource usage, generally, exceed what is required for well abandonment, testing and development of new technology. Hence, where using relatively low resource usage rig-less operations is relatively inefficient, for example, constructing a well (57) to 10,000-feet or 3,000 meters, rig-less arrangements (58B, 58C and 58D) are more resource efficient than drilling rigs (58A) of said well is already constructed and the objective is to place a permanent abandonment plug (89), test and develop new technology within regional subterranean environments similar to those where developed tools will be used. Consequently, compared to other rig-less approaches, the present space provision system will approach and potentially become the lowest resource usage system and method within the industry for abandoning wells and testing downhole tools, thus freeing resources for reallocation to new technology (78), Brownfield (79) and/or Greenfield (80) development.

[0101] Referring now to Figures 1, 22, 23, 33, 34, 44 and 45, depicting space provision system (10) members (10D, 10E, 55, 66) and prior art (51, 52). Figures 22 and 23 show isometric views of a prior art shotgun (51) and shotgun shell (52) components, respectively, illustrating a shell (52) with casing (52A) placeable in the gun's chamber (51B). Contact of a firing pin with the primer (54) within the shell orifice (52B) initiates an explosion of gun powder within the shell, comparable to a deployment conduit (56E, 56B, 56C), usable to fire a wad (53, 95A) functioning as a piston (95) to push various bullets, comparable to the severed end of a conduit (56E, 56B, 56C, respective to the deployment conduits) from the gun's barrel (51A), which is comparable to a conduit (56A, 46b, 56C, respective to the deployment conduits) with an uncemented inner bore.

[0102] Figures 44 and 45, illustrate elevation slices through a subterranean well showing example space provision system (10) explosive member compression device (92) embodiment (10D) and cable member embodiment (10E), respectively. Earlier described UK patent applications GB1011290.2, PCT GB2010/051108, GB1111482.4 and GB1116098.3 describe further usable space provision system (10) members, e.g. axial compression and/or radial compression plug and/or diaphragm piston compression devices (92) or hydraulic jar and/or explosive compression devices (92) for forming low resource cost usable subterranean spaces for the reallocation of resources that would have been used otherwise for satisfying an abandonment liability to new technology (78), Brownfield (79) and/or Greenfield (80) development.

[0103] Referring now to Figure 44, illustrating an elevation diagrammatic view of a slice through a subterranean well (57) bore (7) showing an explosive piston space provision system (10) member compression device (92) embodiment (10D). The member housing (96) is engagable to a jointed or coiled string of a rig or rig-less arrangement and contains an explosive that may be initiated by a firing head (98) to launch an piston (95) of an expandable type (95B), for example a bladder, diaphragm, or wad variety, usable to compressed the severed portion of the deployment conduit (56E, 56B, 56C) uncemented within a surrounding conduit (56A, 56B, 56C, respective to the deployment conduit), wherein an orifice or one way-valve (97) is usable to release trapped fluid below the piston (95B) compression device (92) of a jarring type (92A) as it move within the containing conduit. The deployment conduit (56E, 56B, 56C) may be anchored with a pinning arrangement (55) to allow the explosive to severe said conduit and move it axially downward relative to its anchored portion holding the member housing (96) and joint or coiled string deployment string.

[0104] Figure 45, depicts left and right side diagrammatic plan above elevation cross section slices through a subterranean well (57) bore (7) showing a space provision system (10) compression device (92) cable type (92B) embodiment (10E) before activation on the left side and after activation on the right side. The compression device (92B) is deployed via a cable (67) of a conduit buckling (99) type (67AD) anchored (102) at its lower end and passing through a plurality of eccentric orifice (100) plates (101) spaced within a compressible uncemented conduit within a containing conduit, wherein tensioning said cable buckles said uncemented conduit by aligning the orifices (100) with the axis of the tension cable (67AD) allowing axial compression relative to the anchor of said buckled (99) conduit and debris formed by engaged with said buckled conduit. A cable compression device (92B) may be combined with, for example, an explosive device (92A) of the present invention and/or axial compression and/or radial compression plug and/or diaphragm piston compression devices (92) or hydraulic jar and/or explosive compression devices (92) of the present inventor.

[0105] Referring now to Figure 33, showing an isometric view of shock absorbing apparatus (66) of the present inventor usable to place a transmitter within a well bore for measurements about or below components compressed by a space provision system of the present invention. The transmitter may be engaged within a transmitter housing (66D) which may be placed in contact with casing (e.g. 56A-56D of Figure 2 and 2A) through a cover (65C) or the housing (66A), wherein said contact may remain when the sensor is cushioned (66B) from adverse shocks and forces when, for example, compressing well components using space provision system operations.

[0106] Figure 34, illustrates a diagrammatic elevation view of conduit pinning arrangement (55) with only a portion of the well (57) bore (7) elevation radial cross section shown below an upper right hand transverse side view elevation cross section of only the pinning shaft member's (55A, 55B, 55C) diameters in differing left hand side and right hand pinning shaft configurations shown in the upper right side. A flexible shaft (55A) and boring bit (55D) may be used to bore through various casing (56) conduits (56A, 56B, 56C) with the flexible shaft (55A) usable as a spine for linked pining conduit (55C) arrangement (55) that may be combined with securing and/or stiffening partial conduit member (55B) to anchor conduits (55A, 55B and 55C) together. Such pinning arrangements are usable in, for example, the drilling, milling and space provision operations shown in Figures 3 to 7.

[0107] Figures 2 and 2A, show an elevation slice through the well and schematic views, respectively, of a well (57) with a valve tree (62) illustrating a slice through said well's subterranean portions and wellhead (61) securing casing (56A-56C) cemented (64) below strata level (60), which may be either a ground level or mud line below sea level (63).

[0108] The above ground (60) or sea level (63) valve tree (62) shown may be adapted for subsea use, wherein the conventional valve tree configuration represents a primary (61B) and secondary (61A) master valve usable with the production valve (62C) to flow production through the flow line (62F). If the tree cap (62E) is removed and a rig (e.g. 58D of Figure 20) is erected the swab valve (62D) and master valves (62A, 62B) may be opened to access the production conduit (56D) through the safety valve (65), wherein said safety valve may be operated with a control line (65A). A conventional wellhead (61) generally uses multiple annulus valves (61A, 61B) to access annulus between the various well conduits (56A, 56B, 56C) with larger shallow annuli exposed to normally pressured formations left open or without valves (61C).

[0109] The strata (60) access by any well (57) bore may be generally classified by mineral and chemical composition, by the texture of the constituent particles and by the processes that formed them, which separate rocks into igneous, sedimentary, and metamorphic. Igneous rocks may comprise, e.g., granite and basalt basalt which are particularly hard to bore through. While granite is often bored within wells, the majority of strata targeted for boring comprise sedimentary rocks formed at or near the earths surface by deposition of either clastic sediments, organic matter, or chemical precipitates (evaporites), followed by compaction of the particulate matter and cementation during diagenesis. Sedimentary rocks may comprise, for example, mud rocks such as mudstone, shale, claystone, siltstone or sandstones and carbonate rocks such as limestone or dolomite. Metamorphic rocks are formed by subjecting any rock type (including previously formed metamorphic rock) to different temperature and pressure conditions than those in which the original rock was formed, and hence may be prevalent in many well bores.

[0110] Referring now to Figure 3 illustrates using a space providing system (10) embodiment (10H) shown as a compressing device (92) comprising a slideable piston annular blockage bypass straddle (92C), described in the priority UK application number GB1111482.4, and used to compress debris (91), for example scale chemically removed and hydraulically jarred into the well and strata prior to placing an abandonment plug (89) to allow the side-tracking the well of Figure 2A using a coiled pendulum drill string (67) embodiment (67A) comprising a boring piston (73) embodiment (73A) with a reactive torque tractor (74) directable boring string (9) embodiment (9A) using a motor (17L) to rotate a wireline deployable jointed string (75) embodiment (75G) and a second in-line motor (17) to rotate an upper and lower cutting structures (112) usable to bore said side-track (59) embodiment (59A), placeable, retrievable and operable via said tensionable coiled string (67) and pump pressure through said previously formed bore (7) with fluid pressure applied through and about said conduit boring piston by one or more surface or conduit fluid pumps or motors. The space provision system (10) is also usable to bore a second side-track (59B) and optionally producing from any marginal production resources found prior to placing a final abandonment plug to permanently isolate said side-tracks (59A, 59B)/

[0111] Referring now to Figures 4, 5, 6 and 7, showing a compression device (92) embodiment (92D) and directable hole opening boring string (9) embodiment (9B) in Figure 4, with cable compressing device (92) embodiments (92E), (92F) and (92G) in Figures 5, 6 and 7, respectively.

[0112] Figure 4, illustrates a diagrammatic elevation slice view through a well's bores and casings depicting a compression device (92) embodiment (92D) and hole opening boring (9) embodiment (9B) comprising a cable (67B) deployable piston string (73) embodiment (73B) using a reactive torque tractor (74), further described in priority UK application number GB1111482.4, operated with a motor (17F) to rotate the pendulum solid shafts of a milling motor (17) embodiment (17A) similar to the milling arrangement (9L) of Figures 49 and (9AA) of Figures 50 to 53. Tension of the cable (67B) and the tractor (74) provide upward movement in excess of the downward fluid pressure applied to the piston string (73B), wherein conduits may be pinned (55) in place to prevent adverse lateral movement and stabilizing arced walls (4) comprising elbowed screw extendable arms may be radially extended to cut conduits with associated knife and/or wheeled cutting structures (112) on said arms to assist and stabilize said hole opening boring assembly (9) milling strata and/or casing. Debris (91) may be compressed into the lower end of said well by said milling of well apparatuses into smaller particles that may be compressed downward with pressure from above.

[0113] Referring now to Figure 5, a diagrammatic elevation slice view through a well's bores and casings depicting a compression device (92) embodiment (92E) usable with a tensionable cable (67C) anchored (102, 103) at both ends with a pulley (105) at the lower end. The conduit (56E) may be pinned (55) to the surrounding conduit (56A) and tension may be applied to a cable head (77) at the upper anchor (103) using a cable connector (77A) to, for example, engage the cable head, tension the associated cables, part a coupling (106) and buckle the deployment conduit (56E) below said parted coupling using the lower end cable pulley (105) to tension the cable between the upper (103) and lower (102) anchors. Compression may occur either upward or downward depending on the arrangement of the pulley (105) at the upper or lower anchor, respectively, with associated pinning (55) and parting (55) or, for example explosive, chemical or mechanical cutting of the uncemented conduit (56E) being compressed within the surrounding conduits.

[0114] Figures 6 and 7, show diagrammatic elevation slice views through a well's bores and casings depicting compression device (92) embodiments (92F, 92G, respectively) usable with a tensionable cable (67D) anchored (102, 103) at both ends with a pulley (105) at the lower end of a conduit which is also pinned (105) to a surrounding conduit (56A). The cable's tension compression devices (92) for buckling (99) an well apparatus, e.g. the deployment conduit (56E) and any associated engaged apparatus or debris (91) using the tension of the cable (67D) between the anchors (102, 103) and pulley (105) to urge the buckled conduit and debris, formed by or engaged with said buckled conduit, within an uncemented space with tension applied to the cable head (77) and cable engagement (77A)

[0115] The compression device (92) of a cable and explosive type (92F), may comprise a housing (96A) about an explosive charge that, when fired, tensions the cable between the upper (103) and lower (102) anchors to part the lower cut or weakened conduit (106A) and compress the conduit (56A) axially upward, wherein the cable engagement (77A) may be disconnected and the deployment conduit (56E) above the compressed portion between the anchors may be cut, allowing the compressed debris to fall downward, or be pushed by a piston compressing device.

[0116] The compressing device (92) of a cable and piston type (92G), may comprise using and inflatable diaphragm type (107) piston (95), with a deployable diameter similar to the explosive housing (96A) shown, to radially burst and axially buckle (99) the deployment conduit (56E) between the anchors (102, 103) by pulling on the pulley (105) with cable engagement (77A) and cable head (77) with the cable (67D), thus applying buckling tension between said anchors.

[0117] Referring now to Figures 8-10, 18, 19 and 35-37, illustrating various boring arrangements for casing boring and placement with dual fluid gradient management pressure strings and chamber junctions of the present inventor described in UK Patent Application Number GB1021787.5, UK Patent Number 2465478 and PCT Patent Application Number US2011/000377, with a drilling rig (58A) using jointed strings (67G, 67J and 67K), wherein small scale empirical testing may be carried out with, for example, coiled tubing rigs (58C) using a coiled string (67F) with the present space provision system. After forming space with a compression device (92) and placing one or more abandonment plugs (89) empirical testing of a chamber junction's (119) bore selector (121) access of an exit bore (121) can be carried out using a side-track (59C), wherein managed pressure slurry passageway tools (117, 118) with hydrodynamic bearings (1BP, 1BQ) may also be tested, prior to using said technologies with a drilling rig (58A) using jointed string (67G, 67J and 67K).

[0118] Figure 8, depicts a diagrammatic elevation view of coiled string boring piston (73) embodiment (73C) or a jointed directable boring string (9) embodiment (9D) comprises a dual string arrangement slice through a well (57) and strata (60) removed, with a wellhead (61) supporting casing (55A, 56B, 56C) and annulus valve (61A, 61B, 61C). The single drill string (67G) may be either a jointed string for a drill rig (58A) or a coiled string for a coiled tubing rig (58C) and supports an inner (67H) and outer dual string, above a second single drill string (67L), wherein mud pulses (68) may be passed through the shafts inner bore to the directable pendulum assembly (9D) with a lower motor (17G) drive cutting structures (112) with an upper pump (18B) usable to prevent clogging of the annular passageway with boring debris, which can cause pack-off and fracturing of the formation if pumping pressure is not lowered immediately upon encountering said said-pack-off. If the upper string (67G) is a non-rotatable coiled string an additional motor (17) is required above the intermediate hole opening cutting structures and pump (18B) comprising a hydrodynamic bearing (1G). Additional hydrodynamic bearings (1F) are included in the outer jointed string to aid the passage of boring debris and fluid to further reduce the chance of packing-off and fracturing the formation. Directing the pendulum string (9D) may use the hydrodynamic bearing (1H) and a pivotal hydrodynamic bearing (1J) associated with the lower cutting structure.

[0119] Referring now to Figure 9, showing a diagrammatic elevation view of coiled string boring piston (73) embodiment (73D) similar but of smaller effective diameter than (73C) of Figure 8 or a jointed directable boring string (9) embodiment (9E), which is also similar but of smaller effective diameter than (9D) of Figure 8, and wherein hydrodynamic bearings and other apparatuses are similarly of smaller diameter, for example (1F) has a larger diameter than (1K), but serves the same function in a similar manner. Accordingly, the boring of a well may progress from Figure 8 to Figure 9, if such a design is incorporated from the beginning, and wherein the empirical data obtained from the testing of such new technology (78) with the present space provision system is usable to provide practitioners with realistic testing results so as to provide the confidence to move from a more resource intensive drilling rig (58A) to, for example, a coiled tubing rig (58C).

[0120] Figure 10, illustrates providing a casing conduit string (67K) with hydrodynamic bearings (1) embodiments (1P) usable to assist circulation and reduce the propensity for pack-off using the bearing as a pump (18E) housing (14C) within which the conduit (67) may be rotated when, for example, circulating and rotating the casing in the hole during running or casing drilling operations.

[0121] Referring now to Figure 18, depicting an elevation view with a slice through strata and the well removed, showing a rig (58) show a drilling nature (58A) with a derrick (94), fluid or mud pits (123), pumps (124) and a control room, conventionally called a dog house (125). The well comprises a greenfield (80) development using a chamber junction (119) and simultaneous flow string chamber junction (122) new technology, wherein said technology is particularly useful for fracturing operations, for example shale gas fractures.

[0122] Figure 19, shows an elevation view of a slice through a well and strata, illustrating a coiled string (67F) coiled tubing rig (58C) with an injector head (126) and derrick (94) working on a brownfield (79).

[0123] Referring now to Figure 35 and 36, illustrating elevation views of managed pressure drilling upper (117) and lower (118) slurry passageway tools, with upper and lower rotary connections adaptable for piston pendulum arrangements (73) and inclusion of hydrodynamic bearings (1BP, 1BQ), wherein fluid circulation may occur through a plurality of passageways within the strings (67N) and (67O), further described in UK Patent Application Number GB1021787.5.

[0124] Referring now to Figure 37, showing an isometric section view through the well and strata, depicting a chamber junction (119), from which exit bores (120) may be bored, wherein the bore selecting feature (121 of Figure 19) and chamber junction nature further described in the priority PCT Patent Application Number US2011/000377, wherein this new technology may be tested in, for example, Figure 19 using the present space provision system.

[0125] Figures 38 and 39, show a plan view with line E-E and a cross section elevation through line E-E, respectively, depicting a simultaneous flow chamber junction (122) usable as a dual conduit, for example (56E) and (56A), wherein the this new technology if further explained in priority PCT Patent Application Numbers US2011/000377 and US2011/000372, and which may be tested in, for example, the multi-flow arrangement and bore selector and removable whipstock (128) of Figure 11 and 11A side-track (59D) using the present space provision system (10) embodiment (10F).

[0126] Figures 11, 11A, 12, 13, 20, 21, 38, 39, 46 and 106, illustrate

[0127] Referring now to Figures 11 and 11A, depicting a elevation cross section through the well and strata with line F and an associated magnified detail view within line F, respectively, showing a pendulum piston assembly (73) embodiment (73E) with a tractor (74) with hydrodynamic bearing (1) embodiments (1AF) comprising a motor (17) embodiment (17J) and (1AG) comprising a fluid pump (18) embodiment (18F) with a pivotal embodiment (1AU) above a cutting structure (112), similar to Figure 106 hydrodynamic bearing (1BL). The jointed conduit pendulum boring string (9) embodiment (9F) forming part of the piston (73E) driven by a motor (17) embodiment (17K) with a tractor (74), suspendable from a cable head (77). Axial force (16) is applied to the pendulum string (73E) by pump pressure force (73E) at the top of the cable deployable motor (17K). Reactive torque tractors (74) may also be modified with fluid bearing (1) embodiments (1AS), for example the motor (17C) of hydrodynamic bearing (1AP) of Figure 108.

[0128] Cable tool new technology (78) is further described in priority UK patent application GB1111482.4 and reference UK Patent Application GB1011290.2 and PCT

Application GB2010/051108. To facilitate the side-track (59) embodiment (59D) an abandonment plug (89) was placed after a space provision system (10) embodiment (10F) involving the compression of debris (91) to form a usable space for said plug (89) and side-track (59D) new technology (78) empirical testing.

[0129] Referring now to Figures 12 and the left side of Figure 13, illustrating elevation views of a well before and after, respectively use of the space provision system (10) embodiment (10G) comprising compressing apparatuses and debris (91) into the lower portion and placing an abandonment plug (89) to isolate the well's lower end to allow the use of new technology in a brownfield (79).

[0130] Figure 13, depicts elevation views of left and right side wells in brownfield (79) development where a space provision system (10) embodiment (10G) was used on the left hand well which was, for example, watered out or depleted well, to empirically measure and test a new technology (78) pendulum boring string (9) embodiment (9G) forming part of a cable (67T) deployable piston pendulum boring string (73) embodiment (73H) using a motorized fluid bearing (1) embodiment (1V) to drive coiled string deployable jointed conduits (67U) with a pumping hydrodynamic bearing (1) embodiment (1X) usable to assist in hole cleaning of boring debris from a lower end steerable hydrodynamic bearing (1) embodiment (1Y) with a cutting structure (112).

[0131] As cable (67) rotary drilling operations, further described in referenced UK Patent Application GB1011290.2 and PCT Application GB2010/051108, represents new technology (78) without empirical data involving small tolerances for fluid circulation (129) and tool rotation, wherein operating anti-rotation devices, fluid motors (17), pumps (18) to bore with a cutting structure (112), the space provision system (10) for abandoning wells with minimum resources represents a significant low risk opportunity to improve, for example, brownfield (79) with the development of rotary cable tool boring to, for example, facilitate wishbone side tracts using the chamber junction (122) on the Figure 13 right side well for simultaneous flow stream wells used in the fracturing of shale gas deposits. The abandonment (78) of the example watered out shale gas well and subsequent side-track (59I) benefits are two fold, in that production may be gained from the side-track and/or empirical results for designing the new well on the right side of Figure 13 to dramatically increase fracturing about a well bore, thus substantially reducing required resources by dramatically increase gas production from a single well.

[0132] Using circulation from a sliding sleeve (130) or perforation, for fluid circulation (129) allowed the jointed boring assembly (9G) and pendulum piston assembly (73H) with various hydrodynamic bearings (1V, 1W, 1X, 1Y, 1Z) usable to minimize frictional, shock and vibrational issues of boring while suspended from a cable (67T) within the tight tolerance of such small diameter applications, empirical data was obtained to during the space provision system (10G) abandonment (89) and side-tract (59I) using the minimum resources to offset research costs, provided the necessary data and confidence based on similar geologic, pressure and temperature conditions between the left and right side wells to design the right hand side chamber junction (122) and bore selector (128) well with the jointed boring assembly (9G) and pendulum piston assembly (73I) with various hydrodynamic bearings (1V, 1W, 1X, 1Y, 1Z) to drill side-tracks (59E), (59G), (59H) and (59F) from a single main bore to significantly increase the fraccing efficiency consequently increasing gas production significantly and reducing the required resources significantly to allow the reallocation of otherwise used resources to other new technology, Brownfield, Greenfield developments.

[0133] Referring now to Figure 20, showing an elevation view through of a slice through the well and strata, showing a cable rig (58D) arrangement using a coiled string (67) cable (67S) through a lubricator (130), blow out preventer (131) wellhead (61) an casing (56A, 56B, 56C, 56D) to deploy a pendulum boring piston (73) embodiment (73G) with a motor (17L) and jointed directable pendulum string (9) embodiment (9H) having a hydrodynamic bearing (1) embodiment (1U) usable to reduce the friction, shock and vibration associated with cable rotary tool boring.

[0134] Figure 21, illustrates a schematic of a mud pit (123) arrangement usable with a coiled string arrangement, for example (58D) of Figure 20 or (58C) of Figure 19, wherein fluid returned in a pressure controlled manner may be run through a separator (132) to remove hydrocarbons or gases (133) disposing of debris (91) and returning circulated fluid to a mud pit (123) or closed tank system for pumping (124) back to the boring operations. Underbalanced drilling may be accomplished in this manner using rig-less operations, to further improve both penetration rates of boring and productivity from subterranean production resources, providing another example opportunity for reducing resource costs with a space provision system of the present invention.

[0135] Referring now to Figure 46, depicting diagrammatic elevation cross section slice through a well bore and strata showing a greenfield (80) of a new technology (79) jointed pendulum boring string (9) embodiment (9I) which is part of a piston boring assembly (73) embodiment (73F) using a motor (17) embodiment (17M) to operate a cutting structure (112) boring bit hydrodynamic bearing (1) embodiment (1T) with arched wall (4) embodiments (4I) at its lower end.

[0136] The bearing (1T) is similar to (1BL) of Figure 106, wherein the bit face may be oriented relative to a pivot (15B) point (15) formed by the conical inner nature of a steerable strata boring bit. The pendulum nature of the boring string (9I) about a fulcrum (15A) point (15) is controllable with radially extendable and retractable arced wall (4) stabilizer blades, wherein the extent of retraction and extension may be controlled by a control system (39) with a electric line wet connect interface (42) from an electrical cable (67R) string (67) to exert lateral (16B) forces (16) with said electric line (67R) control system (39) actuated arced (4) stabilizer blades altering the nature of the pendulum string (9I) when axial (16A) force (16) is exerted by pump pressure above the piston string (73F) to push-the-bit, so to speak. The wet connect electric line interface (42) was pumped down through inner passageway (310 the rotor of the pump (18) embodiment (18G) of the hydrodynamic bearing (1) embodiment (1R) with a substantially stationary fixed arched blade (4) around which fluid may be pumped to assist circulation (129).

[0137] The conduit (67) embodiment (67R) and the various components of the bottom hole assembly (BHA) shown in Figure 46, represents a running tool (76 of Figures 114-115 121) and cable deployable conduit similar to conduit component arrangement embodiments (75A-75) of Figures 116-122, wherein various conduits may have integral fluid hydrodynamic fluid bearings (1), further usable with bearing (1R) to assist in the removal of boring debris through pumping. Any hydrodynamic fluid bearing (1) is applicable to the jointed boring (9I) cable piston (73F) assembly to lubricate the BHA during boring and dampen shocks and vibrations associated with stick-slip, bit whirl and the harmonic resonances of certain rotary speeds relative to different formations that may only be proven with empirical data, wherein the resource cost of obtaining relevant empirical is relatively low using space provision system (10) embodiments of the present invention.

[0138] Figure 106, shows cross sectional through the strata, well and hydrodynamic bearing (1) embodiment (1BL) usable as a combined journal (69), thrust (70) and pivot (71) bearing using the fluid intake (32) past a hydrodynamic profile (3AA0 of a housing (14P) about a shaft (2) and outer wall (5), wherein arced walls (4P) allow the bit face to be oriented over a pivot point (15B) relative to its fulcrum point (15A) forming a new technology (78) bearing pump (18) embodiment (18T) usable to assist with boring debris removal and circulation of a jointed pendulum boring string (9Z).

[0139] Referring now to Figures 13 and 40-43, illustrating a managed pressure crossover (132) well apparatus usable for simultaneous flow of fluids during boring or production, wherein a plurality of safety valves and multiple barriers and an orifice plug (133) provide the ability to shut in the well on both flow streams, wherein this new technology (78) if further described in referenced priority PCT Application Number US2011/000372.

[0140] Figures 40 and 41 depict a plan view with line G-G and a cross section view along line G-G, respectively, while lines H and I of Figure 41 are associated with magnified detail views within lines H and I of Figures 42 and 43, respectively. The manage pressure crossover (132) of the present inventor has a plurality of safety valves (65) and associated valve control lines (65B) to control simultaneous flows, for example, axially downward (135) and axially upward (136) between an inner wall (134) and outer wall (56E) of the conduit. Between the upper (138) and lower (137) crossover passageways, an orifice plug (133) may be fitted in an associated receptacle for passage of a cable during boring operations to keep the passageways separate, so as to circulate (129) the boring fluid.

[0141] Referring now to Figures 16, 24, 25, 28, 46, 47 and 48, showing various pendulum boring strings (67Z, 67AA, 67AB, 67AC, 67R, 67X, 67Y, respectively), wherein virtually all conventional strings are based upon a pendulum boring string. For example a string embodiment (9M) may be converted into a packed straight hole string by placing additional axial disposed arced walls (4, e.g. fixed or variable stabilizer blades) above the two shown in Figure 16. For directable strings that aren't packed assemblies, i.e. pendulum assemblies, boring may be controlled with axial (16A) and lateral (16B) forces (16) applied to the string (67) relative to a fulcrum (15A) and pivot (15B) reaction points (15) on the wall (7) of the bore. Push the bit directable strings (9I, 9K) and point the bit directable strings (9J, 9K) relate to using lateral forces (16B) applicable to an arched wall (4) and bending forces (16C) about the shaft (2) which may be rotated from surface (111) or using a string motor (111A) to bore through strata (60) by rotating an associated cutting structure (112).

[0142] In practice, those skilled in the art prefer the rotating stability of a bent housing and PDM arrangement (67AA), however said skilled persons generally prefer the controllability of a rotary steerable (67AB). The combination of a slideable PDM arrangement (67AA) and a rotary steerable is often practiced, but generally does not satisfy the needs for a compact design or, for example, may not be compatible with logging while drilling equipment or transmittal of mud pulses through said PDM to control the rotary steerable (67AB). Wireline controllable (67R) push-the-bit, point the bit (67X) and a combinations point-the-bit and push-the-bit (67K) embodiments of the present invention provide significant improvement over PDM arrangements (67AA) and various rotary steerable arrangements, including a point the bit arrangement (67AB), because of the versatility of using jointed or coiled string deployment and compact design with a shock and vibration (113) dampening (114) hydrodynamic bearing (1) usable with a control system (39) to apply lateral force (16A) or shaft (2) bending (16C).

[0143] Rotational shocks caused by, for example, bit whirl and/or stick-slip and harmonic vibrations (113) caused by, for example, rotational diameter (23 of Figure 59) under-gauged arced walls (4) or stabilizer blades (4) which are often unacceptable to directable boring apparatuses (9), for example (67AC) of Figure 28, may be dampened (114) to a acceptable level (115) using the shearing of frictional engagements of a hydrodynamic bearing (1).

[0144] Referring now to Figures 46 to 48, depicting subterranean hydrodynamic bearing (1_ directable boring apparatus (9) embodiments (9I, 9J, 9K) deployable with cable (9I, 9K) and jointed drill pipe and conduits (9J, 9K). Directable pendulum boring strings (67R, 67X, 67Y) of the present invention may be controlled with arced walls (4), conventionally referred to as stabilizer blades, that may, for example, be push-the-bit (9I, 9K) by selectively and radially extending at least a portion or associated component of said arced walls (4) and/or point-the-bit (9J, 9K) by bending a rotating (111, 111A) shaft (2) relative to a substantially stationary arced wall (4).

[0145] Figure 24, an elevation diagrammatic view describing a positive displacement mud motor (108, PDMs) and bent housing (109) string (67) arrangement (67AA), that provide for example 1-3 degrees of axial offset (110), use a pendulum fulcrum (15A) during sliding, wherein the only rotating portion is the portion below the PDM, and wherein the bit face changes are held by the pendulum string on the pivot point (15B) during said sliding.

[0146] Figures 25 and 28, elevation diagrammatic views describing a prior art point the bit (67AB, 67AC) string (67), respectively, are highly susceptible to the shocks of, for example, bit whirl and stick-slip and vibration (113), hence they are continually monitored to the point that it is often the case that drilling must be significantly slowed or stopped completely lest the rotary steerable (67AB, 67AC) be damaged beyond repair. Additional, rotary steerables, particularly point-the-bit types, use stationary arced wall (4) stabilizers that block the removal of debris from the bore hole, wherein inclusion of a hydrodynamic bearing of the present invention into prior art and conventional boring strings may reduce such adverse shocks, vibration and improve fluid circulation (129) with the intrinsic slurry pump or motor formable using the methods of the present invention.

[0147] Referring now to prior art Figures 26 to 27; Figures 49 to 53 showing: subterranean hydrodynamic bearing milling (9) embodiment assemblies and components; Figures 54 to 106 and Figures 107 to 113, illustrating: various example drilling and milling assembly (9) hydrodynamic bearing (1) embodiments and hydrodynamic bearing motor (1) embodiments, respectively; Figures 114 to 122, showing coiled string deployable drill string conduit (75) embodiments usable for drill pipe, drill collars or other conduit components within a cable or coiled tubing drill string and Figures 123 to 133, illustrating a directable subterranean rotary hydrodynamic bearing stabilizer embodiment for directional drilling, wherein embodiments are also usable to, for example, rotate, lubricate and dampen rotational shocks and vibrations associated with bearing and urging drilling or milling strings (9) within subterranean strata.

[0148] Fluid for is hydrodynamic bearings may be taken from an internal reservoir, for example a lubricating oil reservoir, or from a flow stream about the bearing (1). Various conventional single wall conduit shafts (2) supplying fluid through an internal passageway (31) with a fluid flow stream returned external to said conduits wall, or various dual or multiwall conduits of the present inventor, for example those of Figures 35 and 36, which may be circulated in a variety of ways described in the referenced patent applications.

[0149] Hydro dynamic bearings (1) bear (or support) a shaft's (2) rotation (111, 111A) with a bore's wall (7), wherein said bore's wall may be the inner wall of a well (57) conduit (56A, 56B, 56C, 56D, 56E) or bore through strata (60). Hydrodynamic bearings may be of a motor (17) or pump (18) type, wherein a hydrodynamic profile (3) is rotated with the associated rotation (111, 111A) of said shaft (2) adjacent to an inner wall (6) to displace fluid between walls (3, 4, 5, 6, 7, 11, 13) of the bore (7) bearing (1),

[0150] Arced walls (4) comprising the partial circumference of a larger rotatable diameter (23) form stabilizer blades (4) axially and radially disposed about a housing (14) wall (5), which is under-guage relative to the bore wall's (7) diameter to allow rotation. However, the under-gauge nature of stabilizing the arced walls (4) provides a poor bearing capability susceptible to friction, shocks and vibration when rotated (111, 111A). Consequently a hydrodynamic bearing uses at least one rotatable hydrodynamic profile (3) within the inner wall (6) of an optional bearing sleeve (12) interfacing with the inner wall (13) of the housing to pump pressurized (8) fluid between various walls (3, 4, 5, 6, 7, 11, 13) to improve the stabilized bearing (1) capability to dampen shocks and vibration (113).

[0151] An optional sleeve bearing (12) and helical wrap bearings (30) may have an internal wall (6) and outer wall (11) within another inner wall (13), is also usable to improve pumping capabilities, increase pressures between walls and pressure against (8) the bore wall (7), wherein said pressure is usable to at least partially fill the under-gauge and bear said rotating shaft within said bore wall, and wherein the effective rotating diameter (23) is more efficient with said pressure (8).

[0152] Optional sleeve bearings (12), helical wrap bearings (30) and/or other components, including portions of the shaft (2), may be comprised of any flexible materials to reduce friction, shocks and vibrations associated with rotation. Various embodiments are formable with shaft journal and thrust races, helical races and cavities, cylindrical bearings, taper cylindrical bearings, balls bearings, bead-like ball bearings, sometime referred to as spherical bearings and reinforcing flexible strands and/or chain-links usable to control and/or reinforce various rotating component aspects associated with a hydrodynamic bearing's (1) effective rotating diameter (23).

[0153] Various boring (9) embodiments may use various hydrodynamic bearing embodiments (1) depending on the stratigraphic environment of use and the boring needs, wherein efficiency and matching of bearings against subsurface conditions may be further improved using space improvement embodiments (10) prior to being subjected to the ultimately intended geologic periods and epochs to be bored or otherwise used.

[0154] Directable pendulum boring strings (9) using hydrodynamic bearings (1) to better use or adjust bearing points (15) and string forces (16), including using said bearing as a motor (17) or pump (18) to improve boring efficiency through the reduction of friction, shocks and vibration with the shearable fluid frictional engagements between various walls (3, 4, 5, 6, 7, 11, 13).

[0155] Hydrodynamic bearing embodiments (1) may have substantially stationary housings (14) and associated arced walls (4) or rotatable housings (14) and arched walls (4) depending on inclusion and configuration of a control system (39) interfaced with electric line (42) or fluid pulses (68) interfaces (43). Any form of electric line interface (42) or mud pulse system (43) may be used with any control system (39) placeable within a hydrodynamic bearing (1).

[0156] Directable boring assemblies (9) with substantially stationary housings may selectively control effective rotating diameter (23) and fulcrum (15A) and/or pivot (15B) bending points (15) using axially and laterally movable arced walls (4) with pistons (44) controlled (39) with electrical actuation systems and powered by electric line, or in-line fluid turbines for example, and/or powered by fluid pressure generated by various hydrodynamic profiles (3, 6, 11, 13) displacing fluid directed by with any downhole one-way (35) or plurality-way (36), for example 3 way, valves.

[0157] Directable boring assemblies (9) with substantially rotating housings and axially and/or transversely movable arced walls may be controlled by substantially stationary helical wrap bearings (30), by for example being rotated in an opposite direction to shaft's (2) and arced wall (4) rotation, to provide pressure to various rotated valves (35, 36) and pistons (44) and preventing fluid pressure communication to others to, in use, pressure said valve (35, 36), pistons (44) and arched walls (4) in a desired orientation.

[0158] For both substantially stationary and substantially rotating housings (14) and arced walls (4), any control system (39) may be used to vary pressure (8) exerted through various intake (32) and discharge (33) orifices, pressure discharges (34) and/or various valves (35, 36) and springs (45), in real time using wireline (42) or mud-pulse (43) interfaces to selectively direct said directable boring assemblies (9).

[0159] Various hydrodynamic profiles may be used to generate power for a control system and/or pressurize shearable fluid lubricate pumping (18) and/or motor (17) arrangements using turbines or lobes (25) and stator cavities (26) or impellors (24) or cylindrical or ball bearings (19) and bearing races (22) to form the associated rotor and stator (27) or impellor and wall (28) or ball bearing (29) motor (17) or pump (17) arrangements.

[0160] Any downhole drill string component, including electrical motor (37), electric generator (41), gear (38), piston (44), valve (35, 36), battery, control systems (39), supplemental journal (69), thrust (70) or pivotal (71, spherical) bearings and/or interfaces (42, 43) may be present within embodiment of the present invention for controlling a hydrodynamic bearing (1) and/or directable boring string (9). Additionally, any form of fastener (46), seal (47), sealing bearings (48), or service break covers (49) are usable to repair and/or replace said downhole components.

[0161] Referring now to Figures 14, 15 and 47, depicting elevation views of a cross section through strata and a breakout view in Figures 14 and 15 showing the internals, of a point the bit rotary steerable and directable pendulum (9) embodiment (9J) with a hydrodynamic bearing (1) embodiment (1AA) functioning as a pump (18), wherein the pump embodiment (18H) is used to pump and slurrify debris into lost circulation material size particles to embed in fractures (139) and filter cake (140) as shown in Figure 14, to inhibit the initiation and propagation of fractures as further described in referenced UK patent Application Number GB1021787.5. Figure 47 shows the string (9J) and directable fluid bearing (1AT) outwith the subterranean strata, while Figure 15 illustrates the assembly (9J) in drilling straight and Figure 14 shows the shaft (2) with fluid passageway (31) and a portion of the pendulum assembly (9J) deflected by, for example, a Helical Wrap Bearing (30) at the fulcrum (15A) point to orient the bit face at the pivot (15B) point. The arrangement provides significant advantage over Halliburton rotary steerable system Patent Application US2007/0235227 A1 published 11 October 2007 and included in its entirety by reference, also described prior art Figure 28, because in practice and the field experience of the inventor, said apparatus exhibits a tendency to pack-off causing the fracturing (139 of Figure 15) and mud losses in various geologic formations where drilling parameters must be adjusted to suboptimal levels to accommodate said fracturing. Additionally, the Halliburton rotary system often exhibits adverse stick slip and bit whirl and harmonic resonance vibration tendencies in various formations during boring, wherein pack-off tendencies and adverse bit stick-slip, whirl and harmonic vibration may be significantly reduced with the inclusion of a hydrodynamic bearing of the present invention.

[0162] Figures 26, 27 and 49, illustrate plan diagrammatic views of prior art rotor node (25) and stator cavity (26) combinations (27), prior art rotor rotation with a stator cavity and rotor cavity rotation about a helical nodal shaft forming a motor (17) embodiment (17B), respectiviely. Figure 26 describes the relation of N-1 one nodes within an N cavity stator, where N is the number of helical cavities. Figure 27, describes that when a rotor rotates within a stator cavity the center of the rotor and associated notes forms an effective rotating diameter, wherein the rotor axis rotates around the stator axis. The milling boring string (9) embodiment (9L) of a motor (17B) hydrodynamic bearing embodiment (1AC) of Figure 49 shows that a mills cutting structures (112) may be rotated (111A) around a shaft (2) to perform, for example, hole opening boring operations within a bore (7) by pumping fluid between the nodal profile (3) and cavity profile (6). Preferably, more than bearing (1AC) will be rotated about a central shaft using the arrangement of Figures 50 to 53.

[0163] Referring now to Figure 50, showing an elevation cross section slice view of a milling string (9AA of Figures 51 to 53) motor (17E) arrangement which pivotally deflects to engage successive larger bores (7) at ever increasing effective rotating diameters (23A) to mill conduits (56E, 56D, 56A, 57B, 56C).

[0164] Figures 51, 52 and 53, illustrate a plan view with line AA-AA, an elevation cross section along line AA-AA, and an isometric section projection along line AA-AA, respectively, showing a fluid bearing (1) embodiment (1BM) with and outer wall (11AE) bearing sleeve (12AD) journal (69) bearing with an upper end pivotal (71) bearing, wherein fluid enters (32) between profiles (3AB) and (6AG) to rotate the sleeve (12) about the shaft (2) forming a motor (17) embodiment (17E).

[0165] Figures 29, 30, 31 and 32 showing isometric views of conventional bicycle thrust (19B), ball journal (19C), caged ball bearing thrust (19C) and tapered roller journal and thrust (19D) type bearings with associated bearing races (22A, 22B, 22C 22D, respectively) with breakouts showing bearings (19) and races (22), an isometric view of a conventional hydrodynamic bearing housing (144) and shaft (145) with stable rotation (143) and a fluid oil flow (141) within tight tolerances (142), a cross section slice of a diagram showing how a conventional hydrodynamic journal bearing (69) functions, and the conventional drilling shaft stabilizer shown as a crude journal (69) fluid (148) bearing with large tolerances (147) and relatively unstable rotation (146) of the stabilizer axis around the axis of the bore, which may often leading to adverse friction, shocks and vibrations within a boring string, respectively.

[0166] Referring now to Figures 31 and 32, shown as transverse axis cross sections, wherein Figure 31 is reproduced from a presentation by Dr. Dmitri Kopeliovich, describing a hydrodynamic (1) journal bearing (69), e.g. those used within engines, which are operated with hydrodynamic lubrication, wherein the bearing surface is separated from the journal surface by a lubricant film generated by the journal bearing rotation.

[0167] Hydrodynamic journal bearing rotation causes pumping of the lubricant (141), which may for example be oil, that flows around the bearing in the rotation direction (150). Concentric rotation relative to the bearing occurs with no force applied to the journal, wherein radial force applied to the journal displaces it from concentric rotation to form a converging gap between the bearing and journal surfaces.

[0168] Conventionally the pumping action of the journal forces the oil to squeeze through the wedge shaped gap (151), of the eccentric journal within the bearing, generating a pressure (152). On the suction side of the eccentric journal pump the pressure falls to the cavitation pressure (153).

[0169] The pumping pressure creates a supporting force (154) separating the journal from the bearing surface, wherein the force of fluid pressure and the hydrodynamic friction force (155) counterbalance the external load placed on the bearing, with the final position determined by the equilibrium between the forces.

[0170] In the hydrodynamic regime, the journal may eccentrically rotate within the bearing at the boundary, wherein removal of the hydrodynamic pressure force through rotation leaves the fluid pressure force and applied force, thus causing journal eccentric rotation about the bearing axis opposite to axial journal rotation.

[0171] For conventional oil fluid bearings, various solution may be used to describe the fluid pressure distribution and fluid bearing of a hydrodynamic fluid bearing as a function of journal speed, bearing geometry, fluid clearance and fluid viscosity; however for the subterranean drill string examples comprising a borehole bearing with an significantly under gauge (147) stabilizer journal bearings within a fluid slurry comprising drilling mud and rock debris, such equations are orders-of-magnitude approximations at best.

[0172] The fundamental purpose of the journal and/or thrust portion of a bearing is to reduce friction associated with rotating and/or thrusting a rotating shaft or conduit engagement. For drill strings the stabilizer journal within the bore hole bearing forms a crude hydrodynamic fluid bearing, wherein the coefficient of friction associated with rotation and the associated fluid slurry used to remove rock debris from the borehole may be reduce by improving the fluid dynamics of a stabilizer bearing and homogenizing the fluid slurry to improve its rheological fluid flow properties so as to improve the cleaning of the bore hole and pressure strengthen the strata wall of the borehole.

[0173] Referring now to Figure 54, illustrating a transverse axis cross section of a journal (69) type hydrodynamic (1) embodiment (1AI) with a sleeve (12A) rotating eccentrically around a conduit (31) shaft (2), wherein nodes and cavities of the profiles cause a gap (156) between profiles (3C and 6C) and associated centres. This gap may be filled with gradated ball bearings (19A) to balance the eccentric rotation within a concentric housing, in a similar manner to a helical wrap bearing (30).

[0174] Figure 55, depicts a transverse axis cross section journal (69) hydrodynamic bearing (1) embodiment (1AH) with a rotor stator pump (18) embodiment (18I) that jets separating fluid pressure (8) through discharge ports between arced walls (4) and the bore wall (7), wherein the shearable fluid cushion separation is usable to reduce friction and dampen shocks and vibration associated with rotating the staff (2).

[0175] Referring now to Figure 56 and 57, showing a transverse axis cross and isometric cross section with a breakout showing an impellor profile (3D) of a journal (69) hydrodynamic bearing (1) embodiment (1AJ) which also acts as a thrust (70) due to the hydrodynamic profile (3) on arced wall (4C), wherein an impellor profile (3D) pumps fluid through high pressure discharges (34) to ports between arced walls (4) and the bore wall (7), thus stabilizing rotation by centralizing the boring string (9) embodiment (9O) and shaft (2) within the bore.

[0176] Figure 58, shows a transverse axis cross section of a journal (69) hydrodynamic bearing (1) embodiment (1AK) with radial extendable and retractable arced wall (4) components (4D) which for a substantially stationary housing (14) may be adjusted to push-the-bit cutting structure of the boring string (9), wherein the embodiment (9P) housing may also be configured to be substantially rotating with fluid pump pressure from rotating the rotor profile (3E) within the stator profile (6E) orient the pressure cushions (8) with, for example an oriented helical wrap (30), wherein rotating ports (34) expel pressurized fluid and radial arced walls (4D) as the pass the oriented cushion (8).

[0177] Referring now to Figure 123, illustrating a axially transverse section across 9 different positions of an axial extendable and retractable arced wall (4E) arrangement usable as a journal (69), thrust (70), pivotal (71) bearing depending upon the configuration of the hydrodynamic fluid bearing (1) embodiment (1AL), wherein in a manner similar to embodiment (1AK) of Figure 58, a directable fluid bearing may be oriented in any axial direction depending on the effective extension of the arced wall (4) and/or is axial displacement relative a fulcrum point (15A) and the directable pendulum boring string (9) embodiment (9Q).

[0178] Figure 124, depicts left, middle and right schematic views of radially or axially extendable and retractable arced (4) stabilizer walls (4F) usable to point-the-bit or push-the-bit within the directable pendulum string (9) embodiment (9R) shown. The left schematic shows a pump (18) and 3-way valve (36) valve arrangement configured to move pistons (44) associated with upper and lower arced walls (4F) causing a moment (157) or bending force along the axis which is usable against a fulcrum point (15A), wherein a counter clockwise axial angular deflection (160) in the pendulum boring string (9) embodiment (9R) is enacted. Within the middle 3-way valve (36) configuration, equal pressure is placed on both side of the piston (44) by the pump (18) to place the arced walls (4F) in an offsetting or neutral moment (158) position and the string (9R) is urged to progress axially (162). With the right side schematic the 3-way valve (36) is set to provide an different moment (159) opposite to the left side moment (157) causing a clockwise axial angular deflection (161) of the boring string.

[0179] With four controllable arced walls (4F), the boring string (9R) may be directed as described in Figure 123. If radial extendable and retractable arced stabilizer blade walls are used, instead of the shown axially displaceable walls (4F), the piston may comprise the arced walls themselves with the degree of pressure applied to the pistons radial extension and retraction controlled with, for example, relief or variable pressure valves, wherein the arrangement is also controllable as described in Figure 123.

[0180] Figure 59, show left (23A), middle (23B) and right (23C) hand effective rotating diameters (23) of, for example an under gauge fluid bearing arced stabilizer blade walls (4) or a sleeve bearing (12) about a shaft profile (3), wherein the frequency of rotation increases from the left to the right to demonstrate that the crude hydrodynamic stabilizer bearing of conventional drill strings, described in Figure 32, does not prevent effective rotation as is evident on the right hand side, until adverse subterranean conditions are encountered or the drilling parameters are incorrect with stick slip, bit whirl and harmonic resonance causing averse rotation. However it is also easy to see from the effective rotating diameter shown on the right hand side, that the application of a pressurized fluid cushion could greatly increase the efficiency of rotation and dampen adverse shocks and vibrations through the immediate shearing followed by the quick re-establishment of the pressurized cushion (8). It is also easy to see why the present invention is a significant improvement over prior art, for example the pumping of fluid to supply a fluid pressure cushion (8) by the present invention will always be more effective than the limited volume instant tool spurts of fluid described in US Patent Application

US2011/0120772 A1 when the instant tool encounters the bore's wall. By providing a continuous pressurized fluid cushion (8) a stabilizer does not need to encounter the bore's wall, as is the casing in the instant on tool, hence the lack of contact will always result in more efficient rotation of the shaft and the present invention represents a significant improvement over US Patent Application US2011/0120772 A1.

[0181] Referring now to Figures 60 to 61, illustrates a plan view with line J-J above a cross section along line J-J, of a hydrodynamic fluid bearing (1) embodiment (1AN), with curved outer walls (11B) allowing thrust bearing (70) fluid engagement between the outer wall (11) and a wall (13) containing the sleeve (12B).

[0182] Figures 107, 108 and 109, illustrate an axial transverse view with a quarter section of the sleeve (12C) removed, an isometric with a quarter section of the sleeve (12C) removed with detail line K and an associated magnified plan view within line K, respectively. The hydrodynamic bearing (1) embodiment (1AP) usable as a motor (17C), similar to US Patent 3,367,201 and included herein in its entirety by reference, returns ball bearings displaced by fluid down a helical race to rotate a sleeve (12C) within a recessed race so that the sleeve may be engaged with, for example an intermediate hole opener cutting structure like that shown in Figures 8 and 9, wherein the sleeve rotates on the same axis as the shaft to produce an effective external rotating cutting structure, which could also be combined, for example, with bearing (1BL) of Figure 106, or the eccentric housing (14M) of Figure 90. A fluid ball bearing fluid pump or motor may be used in any way that a normal fluid pump or motor is used, albeit the either the housing or shaft will rotate depending on which is anchored, and wherein within certain tight tolerance rotary cable tool applications, such a fluid pump or motor would be advantageous over the conventional rotor stator pump/motor.

[0183] Referring now to Figure 110, illustrating an axial transverse section with ball bearings extending from the outer wall (11C) of the sleeve (12D) which can be used to either engage an associated race for coincidently rotating the wall of the race, or the ball may contact a flat or spherical wall to provide a true hydrodynamic bearing as opposed to a pump or motor. Additionally, if the sleeve's outer diameter bearing races (22H) and corresponding surfaces are spherical such that the ball bearing's (19G) is spherical, it may be used as a thrust bearing (70).

[0184] Referring now to Figures 62 to 76, illustrating various embodiments of sleeve bearings (12) and strands and ball bearings usable with bicycle type chain links to form sleeves or to reinforce, for example, elastomeric sleeves with steel belting similar to automobile elastomeric tyres or tires.

[0185] Referring now to Figures 62, 63 and 64, showing a plan view with cross section line L-L, an elevation cross section along line L-L and an isometric exploded view, respectively, of a hydrodynamic bearing (1) embodiment (1AR) comprising a journal (69) type bearing.

[0186] Figures 65, 66 and 67, illustrate a plan view, isometric view with detail line M and a magnified detail view within line M, respectively, of a single strand spiral cage hydrodynamic sleeve bearing (12) embodiment (12E).

[0187] Referring now to Figures 68, 69 and 70, depicting a plan view, isometric view with detail line N and a magnified detail view within line N, of a double strand spiral cage hydrodynamic sleeve bearing (12) embodiment (12F).

[0188] Figures 71 and 72, show an isometric view with detail line O and a magnified detal view within line O, of a ball bearing and strand spiral cage hydrodynamic sleeve bearing (12) embodiment (12I).

[0189] Referring now to Figure 73, 74 and 75, illustrating an isometric view of a ball bearing (19J), an isometric view of a strand (20) embodiment (20E) with detail line P and a magnified view within line P, respectively showing components form making a ball bearing strand component, similar to the strands in Figures 71-72 and Figure 76.

[0190] Referring now to Figure 76, showing a plan view of a hydrodynamic bearing (1) embodiment (1AV) using ball bearing strands (20F) engaged with chain links further engagable with races in the shaft (2) to form rotor nodes within a stator cavity profile, wherein the discontinuity between strands ball bearings and bicycle type chain links, is usable for slurrifying boring debris passing through the bearing arrangement.

[0191] Figures 111, 112 and 113, illustrate a plan view with cross section line Q-Q, an elevation cross section view along line Q-Q and an isometric of the shaft (2) and ball bearings of Figures 111 and 112, respectively, showing a motor (17) embodiment (17D) of a hydrodynamic bearing (1) embodiment (1AW), wherein the sleeve (12) embodiment (12L), with helical channels within its wall for ball bearings (19I) pumpable along the axis and returnable axially external to the sleeve via races in a containing sleeve.

[0192] Referring now to Figures 77 to 85, depicting various embodiments of a hydrodynamic bearing for circulating a lubricating fluid around the bearing itself to reduce friction, shocks and vibrations. Additionally, the arrangement of bearings and spherical surfaces and high pressure lubricating ports are all variables depending on the proportions of the shaft bearing and its intended purposes.

[0193] Figure 77, shows a diagrammatic plan view with a section line above an elevation cross section along the section line in the plan view depicting a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1AX).

[0194] Referring now to Figure 78, illustrating an exploded isometric view of a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1AY)

[0195] Figure 79, depicts a diagrammatic plan view with a section line above an elevation cross section along the section line in the plan view showing a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1AZ)

[0196] Referring now to Figure 80, showing an exploded isometric view of a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BA).

[0197] Figure 81, illustrates a diagrammatic plan view with a section line above an elevation cross section along the section line in the plan view depicting a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BB).

[0198] Referring now to Figure 82, depicting an exploded isometric view of a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BC).

[0199] Figures 83, 84 and 85, show a plan view with section line R-R, an elevation cross section along line R-R and an isometric projection with the portion of line R-R removed, respectively, showing a hydrodynamic spherical bearing (1) embodiment (1BD).

[0200] Referring now to Figures 86 to 90, illustrating hydrodynamic bearings (1) usable with, for example, slim hole rotary cable tool boring piston (73) operations. Any suitable downhole bearings (19) and seals (47) may be used to supplement a hydrodynamic bearing (1) and profiles may be arranged to allow rotation of sleeves (12) in an opposite direction to piston string (73) rotation below the top most driving motor to provide additional anti-rotation forces to anti-rotation devices and reactive torque screw tractors. Additionally, bi-centre bit rotation with the tight tolerances of cable tool boring operations may be improved significantly with said anti-rotation and/or pressurized cushion dampening of the natural stick-slip and whirl tendencies of using bicentre bit cutting structures (112). The ability to use bi-centre bits effectively would represent a significant improvement for rotary cable tool operations, because circulating and directional drilling tolerances about a rotating shaft (2) could be improved. Additionally the variation of intake and discharge ports for pumping may vary depending on the needs of boring.

[0201] Figure 86, depicts a diagrammatic plan view with a section line above an elevation view through the plan view's section line, showing a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BE) with a flexible shaft, wherein a rigid shaft is also usable with a helical wrap bearing (30 of Figures 99 and 132) within the housing (14I) usable as a component of a boring string (9) embodiment (9S).

[0202] Referring now to Figure 87, showing a diagrammatic plan view with a section line above an elevation view through the plan view's section line, depicting a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BH) usable as boring string (9) embodiment (9U).

[0203] Figure 88, illustrates an isometric exploded view of a hydrodynamic bearing (1) embodiment (1BG) of journal (69), thrust (70) and pivotal (71) bearing type also usable as a boring string (9T) component, wherein a flexible helical nodal shaft (2) is used. Alternatively a rigid shaft is usable with a helical wrap bearing (30 of Figures 99 and 132).

[0204] Referring now to Figure 89, depicting a diagrammatic plan view with a section line above an elevation view through the plan view's section line, showing a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BI) also using as a boring string component (9V).

[0205] Figure 90, shows an isometric exploded view of a journal (69), thrust (70) and pivotal (71) type hydrodynamic bearing (1) embodiment (1BQ) also usable as a boring string (9) embodiment (9W).

[0206] Referring now to Figures 91 to 100, illustrating a hydrodynamic bearing (1) embodiment (1BU) usable as a fixed arced wall (4) boring string (9) embodiment (9K).

[0207] Figures 91, 92 and 93, depict a plan view with section line T-T, an elevation cross section view along line T-T with detail line U and a magnified view within line U, respectively, of a journal (69) and thrust (70) type hydrodynamic bearing (1BJ).

[0208] Figures 94 and 95, illustrate a plan view of Figure 91 rotated 45 degrees with section line V-V above an elevation cross section along line V-V, showing hydrodynamic bearing (1BJ) of Figure 91.

[0209] Referring now to Figures 96, 97 and 98, depicting an isometric view, an isometric exploded view with detail line W and a magnified detail view within line W of comprising one-way valve and fastening components of the hydrodynamic baring shown in Figure 91. Fasteners (46) are usable to connect various components for maintenance purposes. With regard to fluidly bearing the apparatus with a bore's walls, pistons (44) with high pressure ports through their axis, may be held outward by springs (45) to engage the bores wall so as to maintain a higher pressure by requiring the compression of the spring with pump off pressure. Additionally as the bearings rotation becomes eccentric springs cause pistons to extend in the larger tolerance an contract in the smaller tolerance, before the majority of the arced wall contacts the bore, to further increase pressure and attempt to correct the rotational eccentricity.

[0210] Referring now to Figure 99 and 100, illustrating isometric views of a bearing sleeve (12Z) and helical wrap bearing (30A) embodiments and only the helical wrap bearing (30A), respectively. Depending on the type of directable fluid bearing, a helical wrap (30) may be used to directionally control pressure (8) orientation, wherein a control system, such as the electric line system of Figure 46, may be used to continually orient a helical wrap sleeve relative to rotating arced stabilizer blade walls to actuate pistons similar to the shown one-way valves (35) by covering high pressure ports (34) in some non-rotating orientations while leaving other non-rotating orientations open to said high pressure ports (34). . Additionally the profile between the shaft and sleeves may be arrange to cause rotation opposite to said staff's rotations, so as to reduce the need to continuously change the orientation of the helical wrap sleeve (30) when maintaining an orientation.

[0211] Figures 101, 102 and 103, illustrate a plan view with section line X-X, an elevation cross section view along line X-X with detail line Y and a magnified detail view within line Y, respectively, showing a journal (69) and thrust (70) hydrodynamic bearing (12) embodiment (1BK) also usable as a boring string (9) component embodiment (9Y). The bearing (1BK) is similar to bearing (1BJ) of Figure 91, except for the sleeve (12AB and 12AC) arrangement, wherein the sleeve 12AC has tapered ends to provide for eccentric rotation about the axis of the bearing sleeve (12AB) with high pressure ports (34) usable to interface with the one way valves (35) in the arced walls (4O). Preferable embodiments will have the ability to change between various types of sleeves as demonstrated in Figures 91 to 100 and 101 to 105 to accommodate varying downhole conditions, fluid homogenization and fluid bearing needs. For example the various sleeves of Figures 62 to 76 may be used with various embodiments.

[0212] Figure 103A, shows and exploded view of bearing sleeves (12AB, 12AC) of the hydrodynamic bearing (1BK) of Figure 101.

[0213] Referring now to Figures 104 and 105, illustrating a plan view rotate 45 degrees from Figure 101 with section line Z-Z and an elevation view along line Z-Z of the hydrodynamic bearing (1BK) of Figure 101.

[0214] Referring now to Figures 114 to 122, depicting a cable deployable drill string conduit using a coiled string engagable running tool. The system is usable with a conventional type running tool (76) deployed from a cable head (77) and engagable to the lower end of a rotary connectors receptacle (165) via engagement dogs (168) and lower dogs (170) supporting a profile (169) of a movable sleeve (165) for operating associated dogs (163) engagable with an associated receptacle (171) of the upper end of the rotary connection. The running tool is usable to deploy a conduit (75) joint through a lubricator and bop to engage a previously placed conduit with an upward looking helical profile (167), wherein engaging the two profiles and jarring down on the running tool rotates the connections until the keys (166) meet, after which the dogs (163) are deployed into the receptacle (171) and locked in place by the locking sleeve (164) which moves down and only releases the running tool after shearing associated pins and guaranteeing the rotary connection has made up properly. The locking design is similar to a Baker Surlok system and running tool, described in Patent Number 4,823,872, which is included herein in its entirety by reference.

[0215] Figures 114 and 115, show a plan view with section line AB-AB and an elevation cross section through line AB-AB of a running tool (76) with a cable head (77) engagement similar to conventional "GS" type running tools for various completion components such as plugs.

[0216] Referring now to Figure 116 and 117, illustrating elevation views with a quarter section removed of the lower end of a cable deployable drill string conduit (75) embodiment (75A) and an embodiment (75B) of the conduit of Figure 116 with the running tool engaged.

[0217] Referring now to Figures 118, 119 and 120, showing an elevation view with a quarter section removed of the upper end of a cable tool deployable conduit (75) embodiment (75C), an isometric view of only the conduit portion of the conduit in Figure 118, and an isometric view of the profile housing (14) embodiment (14Q) of the conduit (75C) in Figure 118, respectively.

[0218] Figure 121 and 122, illustrates upper and lower cable conveyable and engagable conduit (75) embodiments (75E) with a running tool (76) and the embodiment (75F) once the running tool is removed, respectively. The hydrodynamic bearing (1) embodiment (1BU) comprises a rotatable housing (14Q) which may remain substantially stationary when engaged to the bore's wall during conduit (75) rotation to pump (18U) fluid past the tight tolerances of the conduits rotary connection.

[0219] Figures 125 to 133, show a directable hydrodynamic bearing (1) embodiment (1BO) usable as a rotary steerable or directable pendulum string (9) embodiment (9AC), controllable with a mud pulse control system.

[0220] Referring now to Figures 125, 126 and 127, illustrating a plan view with section line AC-AC, an elevation cross section along line AC-AC with a detail line AD and a magnified detail view within line AD, respectively, of a journal (69), thrust (70) and pivotal (71) hydrodynamic bearing (1) embodiment (1BO). The left side arced wall (4R) of Figure 127 has been shifted upward by the control system (39) using fluid from the profiles (3AD) and (6AI), while the arced wall mechanisms may be lubricated by the pumping action of the helical wraps (30B) rotation.

[0221] Referring now to Figures 128 and 129, showing a plan view of Figure 125 rotated 45 degrees with section line AE-AE and an elevation cross section view along line AE-AE, showing the directable hydrodynamic bearing (1BO) of Figure 125.

[0222] Figures 130, 131, 132 and 133 illustrate an isometric view, exploded isometric view with detail lines AI an AJ, a magnified view within detail line AI and a magnified detail view with line AJ, respectively, of the hydrodynamic bearing of Figure 125. Arced walls (4) are engaged through the housing (14R) to the pistons (44) with fasteners (44). A mud pulse receiver (43) is usable to interface with surface through the fluid column. A thrust hydrodynamic bearing sleeve (12AH) is also present to provide better rotational stability.

[0223] The shaft (2) has a profile (3AE) for operable with an associated profile (13S) of an electrical generator assembly (41) usable to top up batteries (40). Various seals (47) and bearings (19X) comprise components of the assembly which may be repaired and/or replaced between uses. A flexible sleeve bearing (12AE) interfaces with a helical wrap bearing (30B), wherein the inner wall (13P) rotates about the flexible sleeve outer wall (11AF) to displace fluid and lubricate the detachable arced wall (4R) stabilizer blades. The shaft profile (3AD) is usable with the associated sleeve (12AE) profile (6AI) to pump fluid from the intake (32) the fluid discharge (33) for homogenization or slurrification of the fluids and operation of the pistons (44) engaged with the arced walls (4). Various hydrodynamic bearings may be used in place of (12AG) and (12AH), for example the bearings of Figures 107 to 110 and Figures 77 to 85.

[0224] A control system (39) with pistons (44) operated by worm gears (38), electric motors (37) and batteries (40) to move plurality of way, for example, 3-way valves (36). The pistons move associated piston rods engaged through (50) arched walls (4R) inner wall (13R) with fasteners (46) using pressure generated by the hydrodynamic bearing. The frictional engagements between profiles (3AD, 6AI, 11AF, 13P, 3AF, 6AK, 3AE, 6AJ) and the rounded arched walls (4R) engagement with the fulcrum of point a the bore's wall are all shearable and immediately re-insatiable frictional engagements lubricate and cushion shocks and vibrations associated with operating the bearing (1BO) using similar logic to the schematics of Figures 123 and 124.

[0225] While various embodiments of the present invention have been described with emphasis, it should be understood that within the scope of the appended claims, the present invention might be practiced other than as specifically described herein.

[0226] Reference numerals have been incorporated in the claims purely to assist understanding during prosecution.

CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined follows:

1. An apparatus (1) for reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, comprising:

   a hydrodynamic bearing (1, 12) disposed about said shaft and within said bore's wall (7), with at least one periphery arced wall (4) radially extending from and arranged about the circumference of an outer wall (5) of a conduit shaft housing (14) about at least one inner wall (6, 13) adjacent to at least one associated hydrodynamic profiled wall (3) rotatable by or about said shaft to displace fluid axially along said at least one inner wall anchored by the combined frictional engagements of said fluid, said at least one profiled wall (3), said at least one inner wall (6, 13), said at least one arced wall (4) and said bore's wall (7) to force said fluid between at least one adjacent set of at least two of said walls, and

   wherein said displacing of fluids forms a pressurized (8) cushion fluidly communicated to and from said set of at least two walls to, in use, lubricate and dampen said rotational shocks and vibrations with the shearing of said frictional engagements when bearing said shaft during rotation within said subterranean bore.

2. The apparatus according to claim 1, with said at least one inner wall (6) comprising the inner wall of at least one bearing sleeve (12) component with a outer sleeve wall (11) adjacent to another said at least one inner wall (13) engaged with said conduit housing (14) and rotatably disposed about said shaft (2).

3. The apparatus according to claim 1 or claim 2, with said at least one inner wall (6, 13), said outer sleeve wall (11), said arced wall (4), or combinations thereof, comprising at least one additional hydrodynamic profile rotatable by engagement with said shaft, said displaced fluid, said adjacent wall, or combinations thereof, to further form said cushion and associated shearable frictional engagements.

4. The hydrodynamic profiles according to any preceding claim, comprising impellors

(24), rotor lobes (25), stator cavities (26), bearing races (22) or combinations thereof (17, 18, 27, 28, 29), axially or helically oriented to said shaft's axis.

5. The apparatus according to claim 4, comprising rotating said hydrodynamic profiles with a motor or pumped fluid to form a pump (18) or motor (17) to displace said fluid or rotate at least one of said walls, respectively.

6. The apparatus according to any preceding claim, with said fluid supplied from at least one reservoir internally or externally to at least one passageway (31, 32, 33, 34) within or about said shaft (2), said bearing sleeve (12), said housing (14), or combinations thereof, and returned to said at least one reservoir externally or internally to said passageway, respectively.

7. The at least one reservoir according to claim 6, comprising a contained fluid volume reservoir within said housing, a fluid flow stream reservoir about said bearing, or combinations thereof.

8. The apparatus according to claim 6, further comprising at least one valve comprising a one-way (35) valve, plurality-of-way valve (36), or combinations thereof, component to selectively control said fluid supply to and from said reservoir.

9. The apparatus according to any preceding claim, comprising a piston (44), spring (45), or combinations thereof, component usable to urge separation or coalescing of at least two of said walls, operation of said valves, or combinations thereof.

10. The apparatus according to any preceding claim, comprising a surface interface actuated electrical control system (39) usable to urge at least one said component or said walls of said bearing (1), said surface interface (42, 43) to said bearing comprising an electric cable (67R), a pulse (68) through said fluid, or combinations thereof.

11. The apparatus according to any preceding claim, further comprising at least one journal (69), thrust (70), pivotal (71), or combination thereof, component to reduce said rotational friction, shocks and vibrations associated with bearing said rotatable shaft (2).

12. The apparatus according to any preceding claim, with at least a component of said shaft (2), said at least one sleeve bearing (12), said at least one inner wall (6, 13), or combinations thereof, comprising materials of a flexible nature.

13. The apparatus according to any preceding claim, with supporting cylindrical or ball bearing (19) components usable between said walls, said shaft, or combinations thereof, to form said pump, form said motor, reduce said rotational friction, shocks and vibrations, or combinations thereof.

14. The apparatus according to claim 12 or claim 13, with a race (22), strand (20), chain link (21), or combinations thereof, to control the effective rotating diameter (23) of said shaft, said flexible material, said cylindrical or ball bearings, or combinations thereof.

15. The apparatus according to any preceding claim, comprising an eccentric helical wrapping sleeve bearing (30) component usable to dynamically control said fluid supply, the effective rotating diameter (23) of said sleeve bearing (12), or combinations thereof.

16. The apparatus according to any preceding claim, with said arced wall (4) axially extending from the outer wall (5) of an associated second shaft conduit housing proximally engaged with said first stated conduit housing (14), to provide said frictional engagement to said bore.

17. The apparatus according to any preceding claim, with said arced wall (4) comprising a fixed or variable component to affect said effective rotating diameter (23) bearing (1) within said bore's wall (7) during said shearing of said frictional engagements.

18. The apparatus according to claim 17, with said variable effective rotatable outer diameter (23) formed by radially extending, axially moving, or combinations thereof, at least one arced wall component relative to at least one associated arced wall.

19. The shaft according to claim 18, with at least one variable and fixed bearing (1) arranged for pendulum rotation about a fulcrum (15A), pivot (15B), or combination thereof, bearing points (15) when axial (16A), lateral (16B), of combination thereof, forces (16) are applied to a component of said shaft (2).

20. The apparatus according to any preceding claim, comprising an assembly of reusable and replaceable component parts assembled with fasteners (46) for maintenance and seals (47) for controlling the exposure of said components to said fluids when operating said bearing and shaft with said bore.

21. The apparatus according to any preceding claim, comprising a drilling or milling string (9) hydrodynamic bearing subassembly usable with said fluid and string to form or enlarge a bore through subterranean strata or casing by circulating debris fluid slurry from said bore when rotating said shaft with one or more motors within (17, 72) or at the upper end (73) of said string to, in use, lubricate, bear and dampen rotational shocks and vibrations associated with operating said string's shaft to rotate one or more cutting structure components proximal to said string's lower end to perform said drilling or milling and remove said debris.

22. The apparatus according to claim 21, comprising homogenizing said debris within said fluid to form a more fluid slurry of reduced particle size milling or boring debris with said rotation of said profiled walls to, in use, increase the frequency of breaking and slurrifying said debris to increase the associated propensity of its removal from said bore or casing, its associated propensity to inhibit or prevent the propagation of strata fractures by packing said reduced particle sizes into said bore's strata wall filter cake or strata fractures, or combinations thereof.

23. A method for reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, comprising the steps of:

providing a hydrodynamic bearing (1, 12) disposed about said shaft and within said bore's wall (7), with at least one periphery arced wall (4) radially extending from and arranged about the circumference of an outer wall (5) of a conduit shaft housing (14) about at least one inner wall (6, 13) adjacent to at least one associated hydrodynamic profiled wall (3) rotatable by or about said shaft to displace fluid axially along said at least one inner wall anchored by the combined frictional engagements of said fluid, said at least one profiled wall (3), said at least one inner wall (6, 13), said at least one arced wall (4) and said bore's wall (7) to force said fluid between at least one adjacent set of at least two of said walls; and rotating said shaft to displace said fluids to form a pressurized (8) cushion fluidly communicated to and from said set of at least two walls to, in use, lubricate and dampen said rotational shocks and vibrations with the shearing of said frictional engagements when bearing said rotating shaft within said subterranean bore.

24. The method according to claim 23, with the step of providing at least one bearing sleeve (12) component with said at least one inner wall (6) comprising the inner wall of said bearing sleeve having an outer sleeve wall (11) adjacent to another said at least one inner wall (13) engaged with said conduit housing (14) and rotatably disposed about said shaft (2).

25. The method according to claim 1 or claim 2, with the step of providing said at least one inner wall (6, 13), said outer sleeve wall (11), said arced wall (4), or combinations thereof, with at least one additional hydrodynamic profile rotatable by engagement with said shaft, said displaced fluid, said adjacent wall, or combinations thereof, to further form said cushion and associated shearable frictional engagements.

26. The method according to any claims 23 to 25, with the step of providing impellor (24), rotor lobe (25), stator cavity (26), bearing race (22) or combinations thereof (17, 18, 27, 28, 29), hydrodynamic profiles axially or helically oriented to said shaft's axis.

27. The method according to claim 26, with the step of rotating said hydrodynamic profiles with a motor or pumped fluid to form a pump (18) or motor (17) to displace said fluid or rotate at least one of said walls, respectively.

28. The method according to any claims 23 to 27, with the step of providing said fluid supply from at least one reservoir internally or externally to at least one passageway (31, 32, 33, 34) within or about said shaft (2), said bearing sleeve (12), said housing (14), or combinations thereof, and returned to said at least one reservoir externally or internally to said passageway, respectively.

29. The method according to claim 28, with the steps of providing a contained volume within said housing as said at least one reservoir, providing for the use of a fluid flow stream about said bearing as said at least one reservoir, or combinations thereof.

30. The method according to claim 28, with the step of providing at least one valve comprising a one-way (35) valve, plurality-of-way valve (36), or combinations thereof, component to selectively control said fluid supply to and from said reservoir.

31. The method according to any claims 23 to 30, with the step of providing a piston (44), spring (45), or combinations thereof, component usable to separate said at least one adjacent set of at least two of said walls, operate of said valves, or combinations thereof.

32. The method according to any claims 23 to 31, with the step of urge at least one said component or said walls of said bearing (1) with a surface interface (42, 43) actuated electrical control system (39) comprising an electric cable (67R) interface, a pulse (68) through said fluid interface, or combinations thereof.

33. The method according to any claims 23 to 32, with the step of forming said bearing with at least one journal (69), thrust (70), pivotal (71), or combination thereof, component to reduce said rotational friction, shocks and vibrations associated with bearing said rotating shaft (2).

34. The method according to any claims 23 to 33, with the step of providing at least a component of said shaft (2), said at least one sleeve bearing (12), said at least one inner wall (6, 13), or combinations thereof, with a flexible material.

35. The method according to any claims 23 to 34, with the step of providing supporting cylindrical or ball bearing (19) components usable between said walls, said shaft, or combinations thereof, to form said pump, form said motor, reduce said rotational friction, shocks and vibrations, or combinations thereof.

36. The method according to claim 34 or claim 35, with the step of providing a race (22), strand (20), chain link (21), or combinations thereof, to control the effective rotating diameter (23) of said shaft, said flexible material, said cylindrical or ball bearings, or combinations thereof.

37. The method according to any claims 33 to 36, with the step of providing eccentric helical wrapping sleeve bearing (30) component usable to dynamically control said

fluid supply, the effective rotating diameter (23) of said sleeve bearing (12), or combinations thereof.

38. The method according to any claims 23 to 37, with the step of providing said arced wall (4) axially extending from the outer wall (5) of an associated second shaft conduit housing proximally engaged with said first stated conduit housing (14), to provide said frictional engagement to said bore.

39. The method according to any claims 23 to 38, with the step of providing said arced wall (4) as a fixed or variable component to affect said effective rotating diameter (23) bearing (1) arced wall (4) usable within said bore's wall (7) during said shearing of said frictional engagements.

40. The method according to claim 39, with the step of forming said variable effective rotatable outer diameter (23) by radially extending, axially moving, or combinations thereof, at least one arced wall component relative to at least one associated arced wall.

41. The method according to claim 40, with the step of providing at least one variable and fixed bearing (1) arranged for pendulum rotation about a fulcrum (15A), pivot (15B), or combination thereof, bearing points (15) when axial (16A), lateral (16B), of combination thereof, forces (16) are applied to a component of said shaft (2).

42. The method according to any claims 23 to 41, with the step of providing an assembly of reusable and replaceable component parts assembled with fasteners (46) for maintenance and seals (47) for controlling the exposure of said components to said fluids when operating said bearing and shaft with said bore.

43. The method according to any claims 23 to 42, with the step of providing a drilling or milling string (9) hydrodynamic bearing subassembly usable with said fluid and string to form or enlarge a bore through subterranean strata or casing by circulating debris fluid slurry from said bore when rotating said shaft with one or more motors within or at the upper end of said string to, in use, lubricate, bear and dampen rotational shocks and vibrations associated with operating said string's shaft to rotate one or more cutting structures components proximal to said string's lower end to perform said drilling or milling and remove said debris.

44. The method according to claim 43, with the step of homogenizing said debris within said fluid to form a more fluid slurry of reduced particle size milling or boring debris to, in use, increase the frequency of breaking and slurrifying said debris to increase the associated propensity of its removal from said bore or casing, its associated propensity to inhibit or prevent the propagation of strata fractures by packing said reduced particle sizes into said bore's strata wall filter cake or strata fractures, or combinations thereof.

45. An apparatus for reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, said apparatus being substantially as described hereinabove with reference to Figures 14 to 15, Figures 47 to 133 of the accompanying drawings Figures.

46. A method of reducing rotational friction, shocks and vibrations associated with bearing a rotatable shaft (2) within a subterranean bore, the method being substantially as described hereinabove with reference to Figures 14 to 15, Figures 47 to 133 of the accompanying drawings Figures.

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Application No:	GB1121741.1	**Examiner:**	Mr Colin Walker
Claims searched:	1 to 46	**Date of search:**	9 March 2012

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1 to 44	US6837621 B1 SAKAMOTO - See figures 3 and 7 and paragraphs 28 to 36 in particular
X	1 to 44	US2009/242276 A1 HUMMES et al - See figures 2 and 3 and paragraph 28 in particular
X	1 to 44	WO2010/022755 A1 TVERLID - See figure 2 to 5 and page 2 line 26 to page 5 line 14
X	1 to 44	WO00/40833 A1 MOORE et al - See figures 3A and B and page 5 line 36 to page 7 line 7

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

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E21B

The following online and other databases have been used in the preparation of this search report

Online : WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
E21B	0017/10	01/01/2006