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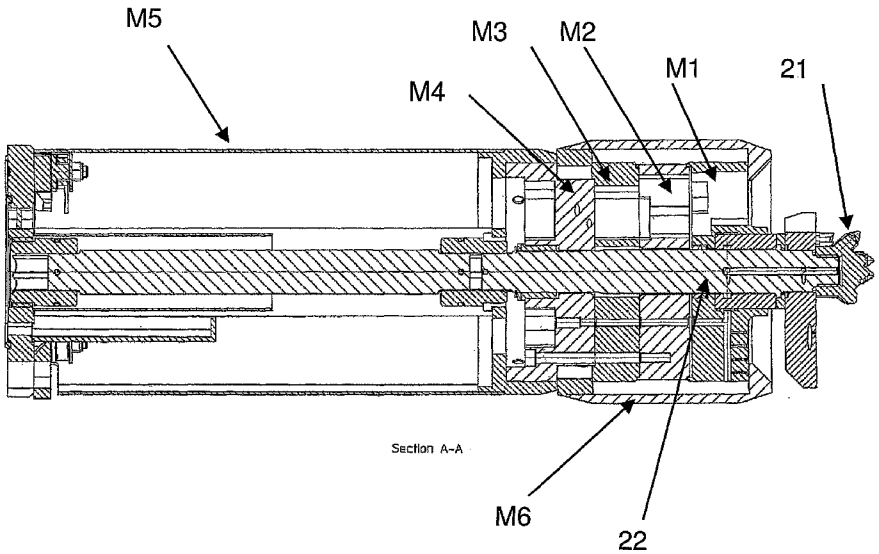
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(54) Title: MICROTUNNELLING SYSTEM AND APPARATUS



(57) Abstract: A microtunnelling apparatus and system that includes an external drive system having rotational and linear thrust drive means, a drill head section (20) having drill rotor (21) and drill rod (22) and connecting to intermediate drill rods (41) allowing extension of the boring hole created by the drill head section driven by the drive system. The drill head (20) includes a modular construction having a plurality of circular disc like elements, a bearing module M1, a steering module M2, a spacer module M3, and a mounting module M4, for axial alignment and abutment and mounting within a cylindrical steering shell M6. Directional steering of the drill head (20) includes a plurality of substantially radially extending channels in steering module M2, each with an hydraulically movable protuberance movable by control means to redirect the outer steering casing M6 and thereby redirect the drill head section mounted on the distal end of the drill rods.

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MICROTUNNELLING SYSTEM AND APPARATUS

Field of the Invention

This invention relates to underground boring and more particularly to an improved microtunnelling system and apparatus.

In this document "microtunnelling" is considered to comprise trenchless horizontal boring of a bore of the order of 600 millimetres and less.

Background of the Invention

Modern installation techniques provide for underground installation of services required for community infrastructure. Sewage, water, electricity, gas and telecommunication services are increasingly being placed underground for improved safety and to create more visually pleasing surroundings that are not cluttered with open services.

Currently, the most utilised method for underground works is to excavate an open cut trench. This is where a trench is cut from the top surface and after insertion of piping or optical cable is then back-filled. This method is reasonably practical in areas of new construction where the lack of buildings, roads and infrastructure does not provide an obstacle to this method. However, in areas supporting existing construction, an open cut trench provides obvious disadvantages, major disruptions to roadways and high possibility of destruction of existing infrastructure (i.e. previously buried utilities). Also, when an open cut trench is completed and backfilled the resultant shift in the ground structure rarely results in a satisfactory end result as the trench site often sinks. Open trenches are also unsafe to pedestrians and workers.

Another concept employed for underground works is that of boring a horizontal underground hole. Several methods employ this philosophy as it generally overcomes the issues of disruption to roads and infrastructure as described for open cut trenches however even these methods have their inherent problems.

One method is horizontal directional drilling (HDD). In this method a boring device is situated on the ground surface and drills a hole into the ground at an oblique angle with respect to the ground surface. A drilling fluid is typically flowed through the drill string, over the boring tool, and back up the borehole in order to remove cuttings and dirt. After the boring tool reaches a desired depth, the tool is then directed along a substantially horizontal path to create a horizontal borehole. After the desired length of borehole has been obtained, the tool is then directed upwards to break through to the surface. A reamer is then attached to the drill string, which is pulled back through the borehole, thus reaming out the borehole to a larger diameter. It is common to attach a utility line or other conduit to the reaming tool so that it is dragged through the borehole along with the reamer. A major problem with this method is that the steering mechanism is extremely inaccurate and unsuitable for applications on grade. The stop and start action utilised by the operator results in a bore that is not completely straight. The operator has no way of knowing exactly where the hole goes which can result in damage to existing utilities. This could pose a safety threat particularly if the services in the area are of a volatile nature.

Another method is the pilot displacement method. This method uses a drill string pushed into the ground and rotated by a jacking frame. A theodolite is focused along the drill string as a point of reference to keep the line on grade. This system is not accurately steered. The slant on the nose is pointed in the direction of intended steering. The position of the head is monitored through a total station with a grade and line set and measuring this point against a target mounted in the head of the pilot string. If the ground conditions are homogenous and the conditions absolutely perfect, it will produce a satisfactory bore. Unfortunately this is rarely the case. Ground conditions are generally variable the pilot tube will tend to steer towards whichever ground offers the least resistance irrespective of the direction in which you are the steering. As the drill strings are generally short, the time to drill is often slow with repeated connections making the process tedious. Once the bore reaches the reception shaft augers are attached and pulled back along the bore to displace the spoil into the reception shaft. This then has to be manually removed which is time consuming.

Slurry style microtunnelling utilises slurry reticulation to transport spoil removal throughout the installation process. Two lines are fed via a starting shaft along the bore. The pipes are jacked via a hydraulic jacking frame into the hole. Water is forced along the feed pipe to the cutting face where the spoil slurry of rock and mud is forced back along the return pipe. Whilst enjoying a good degree of accuracy, this system requires a structural shaft that needs a massive amount of force to push the pipes. This results in a large, expensive jacking shaft pit that is time consuming to build. The sheer weight and size of the components make them slow to connect and cumbersome to use. If the unit becomes damaged or stuck in the bore, the only method available to retrieve the unit would be to dig down onto the drill head location.

In one form of boring machine shown by US Patent Application No.US2004/0108139 to Davies and corresponding to Australian Patent 2003262292 there is disclosed a micro tunnelling machine having a tunnelling head with a boring bit which is forced in a horizontal direction by an hydraulic thruster. The direction of the head is laser guided. The beam strikes a target in the head and a camera relays an image of the target to an operator located at the tunnel entrance. The operator adjusts the direction by admitting water and draining water from a pair of rams inside the head, which move the boring bit up and down or left and right. A semi automatic version is disclosed in which a microprocessor adjusts the direction until the operator assumes control. In particular the invention is claimed to be a guidance system for the boring head of a micro-tunnelling machine of the type which bores in a selected direction and inclination using laser beam guidance having the endmost part of the drive to the boring bit adjustable in two directions at 90°, wherein, the endmost part of the drive has a target for the laser beam, means to convey an image of the target and the laser strike position thereon to an operator situated remotely from the boring head and input means for the operator to adjust the direction of the endmost part of the drive.

The major approach of the directional control of the disclosed apparatus of US Patent Application No.US2004/0108139 to Davies is to have the drive shaft connected at its end distal to the cutting edge in a manner that allows the drive shaft to move as required and to allow the cutting element to be redirected to correct position as

determined by the laser controlled directional system. However this form of apparatus places all the strain on an elongated movable drive shaft retained by cylinders and therefore readily increases the risk of breakage. There is clearly a need to provide an improved system to decrease chance of breakage of the drill head components.

It can be appreciated that present methods of underground tunnelling are cumbersome, inaccurate; and require repeated halting of boring operations due to waste removal and heating effects. Moreover, there is an inherent delay resulting from replacement of parts of conventional boring systems since it usually requires the boring tool to be recovered from the site and returned to the assembly factory. Recovery in itself can be cumbersome and expensive particularly if a new vertical access hole is required to recover the tool. This could damage the road or services under which the bored tunnel is extending. Further present systems are unable to accurately remain on fixed boring direction, which are often needed when a buried obstruction is detected or changing soil conditions are encountered.

Summary of the Invention

In accordance with the invention there is provided an apparatus and method for underground boring on grade more particularly to an improved microtunnelling system and apparatus.

In this document "microtunnelling" is considered to comprise trenchless horizontal boring of a bore of the order of 600 millimetres and less. This is particularly relevant to the insurgence of pipes of the order of around 300 millimetres.

The drawbacks of current microtunnelling technology are significant and have been overcome or are at least ameliorated by the current invention including one or more of the following improvements and other improvements as will be understood from the description.

A first fundamental improvement is the use of an external casing with flow channels therein and the drive rod mounted therein and allows for all cabling and hosing to be

mounted in an external cavity, which thereby allows for continuous cabling over a plurality of encased intermediate drill rods.

A second fundamental improvement is the incorporation of the driveline within the vacuum chamber. Incorporating the rotation within the vacuum achieves multiple goals. Firstly, the vacuum area can be dramatically increased and so maximize the machines ability to remove spoil and in such increased productivity. Secondly, the rotation component of the drill rod generates heat. The removal of this heat from the laser area is critical to laser accuracy. By combining the rotation into the vacuum area, any heat generated is immediately removed and the laser therefore is unaffected.

A third fundamental improvement is the steering mechanism of the encased drill rod using radially protrusions engaging steering shell to direct the drill head and prevent any undue force on the drill head centrally mounted within the casing.

A fourth fundamental improvement is the modular structure of the drill head by a plurality of disc like modules that can be created by direct external etching, drilling or casting or the like and be combined in cylindrical shells to form a readily assembled drill head.

A fifth fundamental improvement is the modular components of the drive means that allows for differing rotational units to be used with a thrust unit that provides linear pull as well as push capabilities. This allows matching of rotational units to material being bored and size of pipe being inserted and further allows for reverse reaming to a larger diameter after initial bore has been accurately drilled.

Brief Description of the Drawings

In order that the invention is more readily understood an embodiment will be described by way of illustration only with reference to the drawings wherein:

Figure 1 is a perspective view of a drive means of a microtunnelling system and apparatus in accordance with the invention including a thrust module and rotation module mounted on a rack system and further including a vacuum for assisting return

slurry;

Figure 2 is a perspective exploded view of a drill head able to be driven by the drive means of Figure 1 for use in the microtunnelling system and apparatus in accordance with the invention;

Figure 3 is a front view of an enclosed drill head with front cutting means able to be driven by the drive means of Figure 1 for use in the microtunnelling system and apparatus in accordance with the invention;

Figure 4 is a cross sectional view of the enclosed drill head with front cutting means of Figure 3 through section A-A;

Figure 5 is a cross sectional view of the enclosed drill head with front cutting means of Figure 3 through section B-B;

Figure 6 is a cross sectional view of the enclosed drill head with front cutting means of Figure 3 through section C-C;

Figure 7 show front and rear perspective views of the steering module of the drill head of Figure 2;

Figure 8 is a side view of the of the steering module of Figure 7 and a cross sectional view through section B-B;

Figure 9 show front and rear perspective views of the bearing module of the drill head of Figure 2;

Figure 10 is a side view and a cross sectional view of a drill shaft;

Figure 11 show front and rear perspective views of the front bearing bush of the drill head of Figure 2;

Figure 12 is a side view of the of the front bearing bush of Figure 11 and a cross sectional view through section A-A;

Figure 13 is a cross sectional view of the enclosed drill head showing the pressure fluid path through the modules to the bearing module and the front bearing bush supporting the front cutting arm;

Figure 14 is a perspective view of a drive rod for extending between the drive means of Figure 1 and the drill head of Figure 2

Figure 15 is a perspective reverse view of the drive rod of Figure 6;

Figure 16 is are end views of the drive rod of Figures 14 and 15 showing mating male and female ends; and

Figure 17 is a perspective detailed view of the drill rod of Figures 14 and 15 showing the toggle locking mechanism.

Figure 18 is a rear perspective view of a vacuum assisted precision reamer showing the connection means to the drill rod and rearward facing cutting face.

Figure 19 is a front perspective view of a vacuum assisted precision reamer of Figure 18 showing the connection means to the product pipe to be installed.

Figure 20 is a rear perspective view of a vacuum assisted precision reamer of Figure 18.

Figure 21 is a cross-sectional view through section A-A of Figure 20 of a vacuum assisted precision reamer of Figure 18 showing the internal pressure fluid passages, vacuum cavity, air channel, input drive shaft, planetary gear set, cutter hub and bearing.

Detailed Description of the Invention

Referring to the drawings there is shown a microtunnelling apparatus and system that comprises a drive system (11), a drill head section (20) and intermediate drill rods (41) allowing extension of the boring hole created by the drill head section driven by the drive system.

The drive system (11) as shown in Figure 1 includes a power source and a track system for allowing limited linear drive of the power source. The track system includes a rack and pinion gearing system (12) to allow maintained linear thrust pressure along the length of the track. The power source includes a hydraulic thrust module (13), which reciprocates a rotation module (14) housed in the thrust box in the launch shaft. The product pipe can be either pushed or pulled into place for pipeline completion.

To the front of the rotation module (14) is attached encased intermediate drill rods (41) such as shown in Figures 14 and 15.

Attached to the distal end of the last intermediate drill rod (41) is attached a drill head (20) shown in exploded view in Figure 2 and in cross sectional views in Figures 4, 5,

and 6. As such a drill rotor assembly (21) connected to the end of the drill shaft or drill rod (22) and connecting to intermediate drill rods (23) form a continuous drill string that is driven by the external drive means (11) comprising the hydraulic thrust module (13), reciprocating a rotation module (14) and linearly movable on the rack and pinion gearing system (12).

The casing (42) of the intermediate drill rods (41) and the casing of the drill head (20) formed by the steering shell (M6) and the rear shell (M5) form a continuous covering of the continuous drill string with internal defined continuous bores or channels. In particular a vacuum channel (51), as shown particularly in Figure 16, can be formed by a number of continuous cavities extending along the length of the intermediate drill rods (41) to the drill head (20). This vacuum channel (51) has vacuum seals at connecting female end (46) to maintain vacuum between longitudinally engaged and aligned intermediate drill rods. Within this vacuum channel 51 is located the connecting intermediate drill rods (41). A separate air channel (52) is formed by a separate number of continuous cavities extending along the length of the intermediate drill rods (41) to the drill head (20). This forms a linear channel within which the controlling laser can penetrate to the drill head (20). By the separation of the heat generating drill rod (22) to the linear laser channel and the cooling effect of the return slurry along the vacuum channel (51) creates a highly effective and accurate steering mechanism.

The microtunnelling system and apparatus further includes:

a) drill head with fluid bearing bush and modular construction
b) enclosed drill rods with internal cooling system
c) pullback extraction reamer
d) rack and pinion thrust module with rotation unit
e) rod loading system
f) microprocessor control system.

In use upon excavation of a launching shaft, the base of the shaft would be prepared for the installation of the drilling machine. The shaft would typically have a pipe invert start point already marked and a line surveyed. A laser would be set up in the

shaft at the extreme rear on line and grade. Thick boards are typically placed along the base of the shaft horizontally on grade. The microtunnelling drive means (11) including thrust module (13) and rotation unit (14) is lowered into the shaft and set up on line and grade.

The drill head (20) is lowered into the shaft and data, hydraulic and pressure fluid lines (44) are attached to the drill head (20). The drill head size and ground conditions are entered into the control panel which selects appropriate parameters for drill thrust speed and force, drill rotation speed and torque, vacuum flow and pressure, and pressure fluid flow. The drill head is attached to the vacuum thrust adaptor mounted on the rotation unit. Once set in launch mode, the vacuum unit is started and the pressurised drill fluid is actuated to eject at the drill face. The drill head is launched into the earth face.

The hole is cut via a combination of rotating cutting tooling and assisted by ejecting pressurised fluid. This pressurised fluid flow, which also acts as a fluid bearing, is shown in bold in Figure 13. Whilst drilling, the drill head (20) is thrust into the ground with the slurry/spoil being vacuumed up back into vacuum pipe (15) into a waste tank for removal. Once the drill head is completely in the ground the thrust, rotation, vacuum and pressure fluid is stopped. The drill head is detached from the vacuum thrust adaptor, and the thrust trolley with rotation unit return to the starting position.

Once in the start position an intermediate drill rod (41) is loaded either manually with a crane or via the use of the automated rod loader. Once the drill rod is sitting in the bed of the thrust module the thrust trolley and rotation unit are started at low speed, low thrust and low torque respectively to engage the drill rod. The rod engagement is automatic in that the drill rod has self-aligning pins (48) that accurately aligns the rod to both the drill head and the drill machine. Upon full alignment and further forward travel, the self-locking toggles (shown in detail in Figure 17) engage behind the locking pins to affect a solid connection. Control hoses and cables (44) are inserted into the concave cavity (43) of the outer cover or casing (42) encasing the drill rod

(23). Vacuum and pressure fluid resume with the drilling process reverting to preset drilling speed, thrust and torque. This process is continued until the final bore end point is reached.

Operation of the microtunnelling machine is performed remotely via a control box, which displays all the current pressure and speed settings. The control box is computerised and integrates the control of the steering, thrust module, rotation unit, vacuum unit and the pressure fluid. The operator can adjust any of the parametric settings to perfectly suit the current ground conditions. Both the drilling process and the steering process can be automated via the use of integrated computer software and can also be manually controlled. Throughout the drilling process the drill position is monitored via the laser hitting a target positioned in the drill head (20) and viewed through the use of closed circuit television (CCTV) so that the operator or software package constantly steers the drill head to keep the laser in the centre of the target.

Once the bore is complete there are three options; progress the drill rods into the reception shaft whilst inserting jacking pipes, pull back to the launching shaft whilst trailing a pipe directly behind it, or remove the drill rods prior to pipe insertion.

Currently, the microtunnelling industry only allows for forward excavation. The current invention is the only system of microtunnelling that incorporates precision back reaming. As shown in Figures 18 to 21 there is provision for the drill head (20) to be replaced by a back reamer (60) that is similarly connected to the intermediate drill rod (41) and driven by the drill string and external drive means. However instead of forward facing drill rotor assembly (21) of similar diameter to the drill head (20), instead there is a rearward facing reaming assembly (61) of larger diameter to the intermediate casing (42). The pipe can be installed by back reaming and attaching pipe to open cylindrical end housing (65) mounted at the very end of the back reamer (60). Thereby as the back reamer (60) is drawn back by the drive means (11) while undertaking rotational drilling with rearward facing reaming assembly (61) of larger diameter, a pipe of same or smaller diameter is drawn along and laid in the enlarged bore.

Back reaming allows use of low cost reamers to open the hole for different pipe size installations. Back reaming also utilises one size drill head and drill rod for each thrust module which in turn simplifies the rod loading process and reduces overall equipment cost.

Looking at the apparatus in further detail the system includes:

Guidance system with a laser striking a target, which is monitored to constantly maintain an accurate position.

Vacuum: Use of vacuum allows for clean operation, fast extraction minimising regrind and Vacuum also reduces volume area occupied by extraction unit

Pressure Fluid: Allows for enhanced cutter life whilst creating greater option via the use of drill fluid when dealing with different drill conditions.

Drill rods: providing the ability to push or pull means that we can cut in both directions. This allows the machine to essentially drill a pilot hole accurately on the thrusting forward of the line and then cut back or open the hole as you pull back. As the line and grade of the hole is already determined the tooling required is simplistic and inexpensive which allows the machine to be more versatile through a large range of hole sizes at minimal cost. Pulling back in microtunnelling is unique. By only using one sized drill rod for each unit the jacking frame can be customised to automate the loading and unloading of the drill rods. With automated loading and unloading of drill rods the system reduced the need for man entry whilst operating. This enhances safety on the worksite.

The thrust module, which is installed in the launching shaft, can provide 300kN force for thrust and pullback of 2.5 metre stroke within a longitudinal space of 3.0 metres. The thrust module uses rack and pinion gearing for increased stroke to retracted length ratio. It provides a high load capability with positive force. Pressure, force and speed are fully adjustable for both thrust and pull back and have a programmable stroke with adjustable limit stops for the trolley assembly. Overall the thrust module allows fast drop in boxes for the rotation unit.

A variety of rotation modules can be selectively utilised with the one thrust module according to the requirements. Rotation modules ideally cater for one drill diameter, by maximising available hydraulic power, rotating at ideal speeds (rpm) by maintaining optimum cutting face surface speeds (m/min) to best utilise working range of tungsten and carbide cutting inserts, and by maintaining the most desirable cut face / vacuum area ratio. Other sizes of rotation modules can also be used but with less efficiency.

Each rotation module comprises its own hydraulic motor (low speed/high torque, high speed/low torque, two-speed automatic selective unit, or other) coupled through a drive train assembly (chain and sprockets, simple gear box, planetary gearbox, or other) to rotate a drive shaft with a hexagonal end, which is to be coupled to the drill string inside the drill rods.

Each rotation module also includes a Vacuum thrust adaptor for connection with drill rods. This vacuum thrust adaptor incorporates the features suited to each drill rod, being vacuum sealing method, drill rod alignment, drill string torque transmission connection, thrust face and pullback connection. The Vacuum thrust adaptor also houses any hydraulic clamping and disconnection mechanisms for drill rods.

The microtunnelling machine targets extremely precise small diameter trenchless pipe installations particularly <600mm and more particularly <300mm. This is achieved by tracking a laser striking a target in the drill head, which is monitored via CCTV in the drill head and then steered accordingly to maintain line and grade. A unique fluid bush assembly transmits water and thrust to the rotating cutting face, where the pressure water and subsequent cutting spoil are mixed to a slurry for removal by vacuum extraction.

The drill head utilises a unique radial steering system capable of directly variable directional changes to continually and precisely cut the bore hole. The drill head is progressed through the ground by connecting subsequent drill rods between the drill head and thrust module until final bore length is achieved. These drill rods are either

encased or open and combine rotation shaft / drill string, vacuum, air and control channels providing mechanical and control workings. Hydraulics, water and data is remotely controlled and utilised by the operator at the remote control panel and conveyed by cables and pressure hoses.

The front cutting rotor assembly consists of tungsten, carbide or other sintered hard metal inserts housed both axially and radially on a variety of face styles. The shape of the front cutting face varies remarkably with ground conditions, and can be flat, piloted or conical in shape and is built to suit.

All front cutting rotors are designed so that cuttings large enough to potentially block drill head vacuum cavity are kept ahead of cutters for further processing (mixing, cutting, grinding or shattering). Once cuttings are small enough, they are permitted past the cutter face for vacuum extraction.

A clay cutting face will have a multitude of spokes (range from 3 to 6) possibly connected together again to an outer rim. The main consideration is the clay consistency, as the openings through the cutting face are calculated to restrict cut spoil ahead of the cutter until small enough to be able to fit through the vacuum chamber of the drill head. When clay is soft it is easy to drill, but builds on itself and can cause blockages if the correct cutter is not chosen.

A shale cutting face will be similar to the clay version, but face openings are modified to allow for front regrind of large chipped material prior to vacuum extraction.

A rock cutting face generally comprises a cutter face with three, six or nine conical roller assemblies with peripheral openings (usually three) for cutting spoil extraction. Utilising multiple small diameter conical rollers, each set of three are staggered in distance and angle from the front face. The inner set of three cones being most forward, the intermediate set radially skewed from the inner at 60 degrees and setback by 25-100% of the cut diameter, and the final set again radially skewed from the intermediate at 60 degrees to bring the inner conical portion back in line with the

radial centre-lines of the inner set of cones, and setback from the intermediate face by another 25-100% of the cut diameter. Roller cutter face then has the benefit of continual steering capability, increased stability in non-homogenous ground conditions, and increased chip rate resulting in less regrind time prior to vacuum extraction of spoil.

Downhole drilling technology has been using "tri-cone" rollers to cut rock for decades. They are available in a variety of grades – soft, medium and hard formation. A tri-cone roller utilises three conical rollers, equispaced at 120 degrees, fitted with hard metal inserts each rotating about their own bearing shaft. The conical shape of each roller, tapered into the centre of the cutting face, rotating about an axis skewed 60 degrees forward in towards the centre of the cutter results in a full flat face cut diameter. The resultant large flat cutting face is very difficult to maintain stability in non-homogenous ground, and due to the size of three rollers required to obtain the full cut diameter, the axial distance travelled prior to any steering response is often half the cut diameter.

All front cutting rotors have pressure fluid ports. Holes are drilled radially to the centre of the cutter to coincide with the porting on the drill shaft. Additional holes are drilled axially from both the front and rear faces of the cutter. These holes are sized approx 2mm diameter to allow extreme pressure at face for best cutting and mixing qualities with minimal pressure fluid usage. An internal chamfer on front ports to increase surface area at opening only to allow for blockage ejection. Rear ports are directed back towards drill head to aid in clearing any residues from air channel and vacuum cavity.

All front cutting rotors have a central cavity for connection with the drill shaft in the drill head. This cavity is either threaded with a trapezoidal or acme thread taking up onto a shoulder on the shaft, or a hollow hexagon for the quick connection arrangement used in conjunction with a front threaded cone and lock bolt. Both styles accommodate for through shaft and cutter pressure fluid transmission.

The drill head drives the front cutting rotor by way of the drill shaft. The front of the shaft is a male hexagonal drive, with 75-100% of across flats dimension of the hexagon in length, with a front threaded extension generally 50-75% of the across flats dimension of the hexagon in diameter, and 75-100% of the thread diameter in length.

The drill rod is radially drilled (eg 3 x 5mm diameter holes at 120 degrees) through the faces of the hexagonal final drive through to a central larger axial port (eg 8mm – 12mm diameter). This axial port is drilled as a blind hole into the drill shaft, to the length corresponding to the position of the front fluid bush. Here, another series of smaller radial holes are drilled through to meet with the axial port (eg 3 x 5mm diameter holes at 120 degrees). These holes are peened (eg 8-10mm concave diameter) to eliminate any seal degradation from the rotating shaft.

The front fluid bearing bush encapsulates this mid-front section of the drill rod and provides a centralised bearing location capable of high radial and thrust forces combined. The peened radial holes of the drill rod are longitudinally aligned with the internal radial pressure fluid distribution groove of the fluid bearing bush.

This groove is in turn fed pressure fluid from radial drill holes (eg 6 x 5mm diameter holes equispaced at 60 degrees). Fluid cannot escape to the rear of the fluid bush due to an energising U-cup seal placed at the rear of M1 bearing module. Pressure fluid is proportionally distributed – to the drill shaft axial port through to the front cutting rotor, creating back pressure to distribute to the annulus area between the outside diameter of the drill rod and the inside diameter of the fluid bush. This is achieved by high helix angle, low depth multi-start grooves machined on the inside of the fluid bush from the front edge of the distribution groove to the front face of the fluid bush (eg triple-start, 20mm pitch 0.5mm deep grooves with 1.5mm concave radius). This pressure fluid is then channelled to a helical spiral groove on the front face of the bush (eg single 10mm pitch continuously decreasing right-hand 0.5mm deep face groove with 1.5mm concave radius) . This channelling effect essentially hydrostatically separates the shaft from the bush both radially and axially, to counteract steering and

thrust face forces. The relationship is linearly proportional in that the higher the load, the harder the faces act against one another, providing a greater hydrostatic seal, which in turn acts to repel the two components. Hence we have a bearing, which mechanically transfers load, provides a pressure fluid swivel, and continually lubricates and cools itself. This method allows a very strong shaft construction with minimal stress riser points, and excellent pressure fluid conveyance.

The drill head functions to drive the front cutting rotor by means of a drill rod. The bore hole position is monitored within the drill head by means of a laser set at the launch shaft indicating a position on a target mounted in the drill head. A camera within the drill head is directed at the target, and relays a video image to a video screen viewed by the machine operator. The operator controls any required steering direction changes. Steering is achieved by altering the position of the cutting face relative to the bore hole.

The prior art was to manufacture a cylindrical drill head, and moving the cutting face. One steering method is to pivot the front portion of the drill head vertically and horizontally. Although effective in steering, this required the laser target to be situated a considerable distance from the cutting face. The further rearward the laser target position, the further the distance is required to be drilled prior to an update of current bore face location.

Another steering method is to move the drill shaft within the drill head. This has the advantage of being able to mount the laser target further forward in the drill head, and therefore, providing a more accurate target to bore face position. However, the pivotal mounting of these steering mechanisms provides a weak steering with high failure rates and increased maintenance.

These past methods of steering are physically large and cumbersome, and due to plumbing required to each hydraulic cylinder, makes this method unsuitable to small diameter drill head design. The invention entails construction of a modular drill head for increased strength and reduced size.

The drill head is of a segmental modular design to minimise overall size while achieving maximum strength and durability. Each module is centralised and retained by the next module by male and female stepped spigots. Clamping of each module achieves angular alignment and axial clamping. Each module is designed for its particular purpose in the drill head, and all hydraulic, fluid, air and vacuum channels are interconnected by way of stepped face seals. It is this method of construction that allows the use of integrated pressure porting, reliable bearing design, maximum vacuum area, good air channel ducting, maximum forward position of laser target area and plumb indicator for visual head tilt indication.

The drill head and steering module for use in the microtunnelling system has a steering shell M2 mounted axially on the drive rod (22) in a manner to allow radial movement and having a plurality of radially mounted pistons able to engage the inner surface of the steering shell M6 such that the control of the protrusion of the plurality of radially mounted pistons controls the direction of the steering shell.

As shown particularly in Figure 8, the plurality of radially mounted pistons is included in a circular steering module fitting around the drill rod and having radial bores from which the radially mounted pistons protrude. The circular steering module includes a spoked wheel effect with the radial bores extending at least partially along the radial extending spokes. Preferably cavities are between the spokes to allow axial pathways. The circular steering module includes ports near the radial centre and able to receive water or hydraulic fluid for driving the pistons to protrude from the radial bores and engage the inner surface of the steering shell.

As shown in Figure 2, the drill head includes a modular construction having a plurality of circular disc like elements for axial alignment and abutment and mounting within a cylindrical shell, wherein each of the circular disc like elements is created by direct bore construction and the axial alignment and abutment creates continuous axial and radial channels allowing fluid flow, vacuum waste return channel, and control flows.

One of the circular disc like elements forms a bearing module M1 at the front of the drill head with flow paths for providing axially extending fluid jets to assist cutting and radially extending flow paths to assist aquaplaning bearings of the rotating cutting means.

One of the circular disc like elements forms a steering module M2 at the front of the drill head with flow paths for providing axially extending fluid jets to control protrusion of pistons to engage the outer cylinder and alter direction of the drill head.

One of the circular disc-like elements forms a spacer module M3 within the drill head with flow paths for providing axially extending flow paths to adjacent modules.

One of the circular disc like elements forms a mounting module M4 at the rear of the drill head with flow paths for providing axially extending flow paths and able to form non rigid mounting of base of outer cylinder.

The drill rod (22) and connected intermediate drill rods (23) are a steel rod drive shaft, with male and female hexagonal ends to effect connection and resist torsional forces. The drill rod and connected intermediate drill rods are retained within either end of the drill rod end plates by front and rear rod bush bearings. The drill rod and connected intermediate drill rods are housed in an axially extending tubular section (51) to separate the bearings from the spoil through the vacuum section. The axially extending tubular section drill string housing is located fully within the vacuum chamber, surrounded by the vacuum channel and vacuum cavities. It is this full surround by vacuum that functions to absorb heat created by the rotating drill string, transferring it directly to the slurry and spoil cuttings and fluid returning from the drill head, and in turn to the vacuum waste tank.

The laser beam used for drill head guidance travels through the protected top air channel (52). It is the effective removal of heat and creation of a stable laser environment that minimises otherwise unavoidable hot-cold transitions at every drill rod connection. In past drill rods, these hot-cold transitions cause consecutive and

culminating laser refraction, leading to an inaccurate borehole.

During connection the drill rods (23, 23) are pushed together. The vacuum thrust adaptor has two conical combination pins (48) in the male drill rod end plate (47) about the rod's longitudinal axis and centred vertically about the drive, and offset equidistant about the horizontal plane. These combination pins have a conical taper at the front and align with two bores (49) in the female drill rod end plate (46) about the rod's longitudinal axis. As the pins are further inserted, the drill rod is aligned to a horizontal plane; the drill rod and connected hexagonal intermediate drill rods are aligned and further inserted until the two end plate faces are mating.

Consecutively during this alignment process, the toggles mounted to the female end plate are caused to pivot about the pivot bush axis, moving radially outwards from the end plate diameter, allowing the major diameter of the combination pins past the toggles. Once the Combination Pins pass the major diameter, the toggles are allowed to spring back to their original position, moving in between the combination pins and the female end plate, thus locking the connection, and allowing either thrust or pullback under load. Once the drill rod end plates are mated face to face, the vacuum and laser space are sealed due to the elastomeric seals inserted in the milled grooves of the female plate.

Referring to Figures 2, 4, and 5 the M1 bearing module comprises of a circular disc with a central stepped bore for the location of the front fluid bearing bush. The housing is cross-drilled to divert an axial pressure fluid port originating to the side of the drill rod, connected to a radially drilled port which in turn connects to a radial groove on the inside of the central bore. Two additional smaller radial grooves – one to the rear and one to the front of the channel groove provide housing for o-ring seals which completes this cavity and directs all pressure fluid through to the radial holes drilled through the fluid bush. The radial pressure cavity also connects to a vertical radial port fitted with a jetted plug, which directs some fluid to the Annulus between the steering ring and steering shell M6. At the rear of the M1 bearing module is a self-energising u-cup seal retained by a soft metal bush to complete the front seal cavity.

As shown in Figures 2, 6, 7 and 8 the M2 steering module comprises a circular disc with a central bore through which the drill rod passes. At the top and to the sides are air channels. At the bottom is the vacuum cavity. There are four radial drillings, bores and counter bores equispaced around the circumference of the disc. Four independent oil ports drilled axially from the rear of the housing and countersunk with face sealing enter the lower portion of the radial drilling in each of the four bores. These bores house the steering pistons with high pressure seals. With pressurised hydraulic oil entering any of these cavities, the associated piston is forced radially outward providing force to move the steering shell M6. The piston is retained from ejection from the housing by a stepped gland ring incorporating a piston rod wiper and auxiliary seal which in turn is retained by an internal circlip within the stepped bore.

The M6 steering shell comprises a hollow tubular section with a front end stepped return section reducing in inside diameter then tapered both internally and externally towards the front. This front stepped return is faced up against the front of M1 bearing module, and the main inner bore has full annular clearance around the circumference of the steering ring assembly allowing the shell to move about radially in any direction. As one piston in the M2 steering module is actuated, the M6 steering shell is forced radially and moves with the extending piston. As the opposing side of the M6 steering shell moves in towards the steering ring assembly, the piston radially opposed to that actuated is in turn retracted, allowing for the next steering manoeuvre. The same applies to the other set of pistons acting about an axis at 90 degrees to the first set of pistons. This actuation on 2-cylinder movement axes, either independently or together allows the drill head to alter its shaft and cutter position relative to the bored hole thus providing steering control.

The hydraulically steered drill head has a fast system for changing cutting tooling. Rock capabilities have been enhanced with the design of a rock roller system for the microtunnelling unit.

The drill head has been modified to accommodate the covered drill rod system and

designed to allow for the introduction of automated steering. Drill head segmental design allows for strength and durability whilst enhancing the ability to maintain drill head positioning via hydraulic rams holding a position of one circular piece within a second circular ring providing for maximum strength in minimal space.

The drill shaft must rotate freely under high loads, and pressure fluid must be transferred to the drill face. The use of high-pressure fluids out of the drill face allows for enhanced tooling life whilst also giving the ability to flush tacky ground.

The prior art was to retain the shaft within steel bearings, either tapered roller, or ball bearings with needle thrust bearing. This solved the mechanical rotation issue, but brought with it a whole plethora of associated problems to do with sealing bearings from ingress of cutting spoil and water, both ingredients deadly to bearings. Maintenance is increased as seals and bearings have to be replaced regularly. If a bearing was to seize, it would halt the complete drilling process, drill head would have to be removed for overhaul, causing unplanned down-time and site delays.

The prior art for pressure fluid transmission is with a pressure swivel assembly, which rotates about the shaft axis. The swivel construction would be tubular in design with two pressure seals axially opposed to retain a central pressure chamber within the swivel. A threaded inlet port enters this central pressure chamber radially, flows around the axis of the cavity, through a radial hole drilled in the drill shaft, then through an axial hole in the drill shaft to the front face. This design required external retention of the swivel housing to stop it rotating with the drill shaft, causing radial side-loads on one inside face, in turn, causing seal failure and therefore leakage. The seals had to have a high preload to accommodate high pressure, and would wear grooves in the drill shaft, causing leakage. The swivel would be located behind the target position, so any water spray from leaks would upset visual sight of target. Using pipe fittings from the swivel housing with elbows to bring hose in axially beside drill shaft meant size was too large to be used in small diameter drill heads, assembly and maintenance of hose and fittings would be awkward at best.

The invention entails construction of a modular designed drill head, with integrated pressure fluid conveyance cavities. Further, the invention includes the use of a fluid bearing bush to act as a front drill rod bearing and pressure swivel in one assembly. The fluid bearing bush is retained in the M1 bearing module by three grub screws (equispaced at 120 degrees). Pressure fluid directed to the distribution groove in the M1 bearing module is sealed form escaping past the inside of the stepped bush bore and the outside diameter of the fluid bearing bush by means of two O-ring seals on each side of the distribution groove. This M1 bearing module distribution groove is longitudinally aligned with radial drill holes (eg 6 x 5mm diameter holes equispaced at 60 degrees) around the perimeter of the fluid bearing bush. These drill holes enter the inside diameter of the bush and are interconnected with an internal radial distribution groove within the fluid bearing bush. Fluid cannot escape to the rear of the fluid bush due to an energising U-cup seal placed at the rear of M1 bearing module.

The fluid bearing bush encapsulates a mid-front section of the drill rod and provides a centralised bearing location capable of high radial and thrust forces combined. The peened radial holes of the drill rod are longitudinally aligned with the internal radial pressure fluid distribution groove of the fluid bearing bush.

Pressure fluid is proportionally distributed – through radial holes in the drill shaft, connecting to an axial port through to the front cutting rotor, creating back pressure to distribute to the annulus area between the outside diameter of the drill rod and the inside diameter of the fluid bush. This is achieved by high helix angle, low depth multi-start grooves machined on the inside of the fluid bush from the front edge of the distribution groove to the front face of the fluid bush (eg triple-start, 20mm pitch 0.5mm deep grooves with 1.5mm concave radius).

This pressure fluid is then channelled to a helical spiral groove on the front face of the bush (eg single 10mm pitch continuously decreasing right-hand 0.5mm deep face groove with 1.5mm concave radius). This channelling effect essentially hydrostatically separates the shaft from the bush both radially and axially, to

counteract steering and thrust face forces. The relationship is linearly proportional in that the higher the load, the harder the faces act against one another, providing a greater hydrostatic seal, which in turn acts to repel the two components.

Hence we have a bearing, which mechanically transfers loads, provides a pressure fluid swivel, and continually lubricates and cools itself. This method allows a very strong shaft construction with minimal stress riser points, excellent radial and axial bearing loads, excellent impact resistance, excellent pressure fluid conveyance, minimal assembly and maintenance costs, and is field replaceable.

The position of the target at the extreme front of the drill head ultimately enhances the drills ability to be extremely accurate and responsive to positional changes. The use of high-pressure fluids out of the drill face allows for enhanced tooling life whilst also giving the ability to flush tacky ground. The ability to run drill fluids at the cutting face creates greater efficiencies within cutting and assists our abilities through varied ground conditions. Front bearing combination of high load axial and thrust bearing with a high-pressure fluid and integrated lubrication system.

The drill rods are inserted and connected consecutively with the thrust module to allow bore hole progression while maintaining drill string, vacuum, air channel, hydraulic, pressure and data line connection. The drill rod transmits torque from the rotation unit mounted on the thrust module to the drill head at the bore face via a drill rod and connected intermediate drill rods. The drill rod also transmits thrust from the rotation unit mounted on the thrust module to the drill head at the bore face via a vacuum tube.

The prior art was to have the vacuum tube section aligned longitudinally with the drill string, situated below it, generally to rest on the invert of the borehole. This allows cutting spoil extraction by vacuum.

The vacuum tube has bearing bushes mounted at each end along the drill rod and connected intermediate drill rods axis to retain the drill rod and connected

intermediate drill rods, and male and female cleats at each end for connection by means of a manual pin inserted to two holes either vertically or horizontally aligned. The drill string is exposed, causing possible operator injury from the rotating shaft. The connection method with manual pin insertion is tedious, and pin extraction after bore completion is difficult.

The manual connection method required clearance to allow manual connection. This clearance between subsequent drill rods allows each rod to rotate slightly about its axis as a result of drill string rotational torque. This rotation, possibly only 1 degree per rod, extrapolates the error the further the borehole. Final error over a 100m bore could be a 50-degree rotation, causing an inaccurate target position relative to the start point. This target position is then potentially out by up to 100mm.

The borehole is not peripherally supported, causing ground collapse in certain ground conditions, thereby blocking laser and target view, and halting drilling operation. The bearings are directly under the laser position, causing hot sections at each end of the drill rod and a cooler section between the bearings. These hot-cold transitions cause consecutive and culminating laser refraction, leading to an inaccurate borehole.

The microtunnelling system uses a casing mounted on the drill rod that includes at least two axially extending cavities or bores wherein liquid is axially transported along one of said axially extending cavities or bores under pressure to the drill head to assist drilling and resulting slurry is vacuum returned along the other of said axially extending cavities or bores. However as drill rods are fully enclosed, and slightly smaller than the drill head diameter allowing the microtunnelling machine to be effective in collapsing ground conditions, under water table, soft or hard ground. The vacuum or slurry spoil extraction volume within the drill rod provides minimum restriction to increase productivity and length of lines achievable. With all moving components enclosed, the drill rod is safer to use.

Rotation within vacuum or slurry spoil eliminates heat from bearings, minimising laser distortion and wear and tear to the equipment. Enclosed laser space for stability

of beam. Provides airflow to equalise temperature and humidity, more accurate operation. Automatic alignment system speeds and simplifies operation. Automatic clamping system, for positive joining, withstands full load in both forward and reverse directions. Clamping system maintains strong sealing of vacuum. Fully encapsulated hose and dataline pocket, protecting sensitive data and pressure lines.

The pullback extraction reamer is used to increase the size of a microtunnelled bore hole. This is advantageous for operators as one size microtunnelling drill head and drill rods can be used in conjunction with a pullback extraction reamer in various bore sizes, while maintaining good productivity. Once the drill head reaches the reception shaft, the drill head is removed from the end of the drill rod and replaced by the pullback extraction reamer. The product pipe to be installed can be coupled to the pipe pullback adaptor mounted on the rear. Drilling is now commenced in reverse, or pullback mode. The drill string is coupled to a drive spur gear that rotates three planetary gears fixedly mounted to the vacuum thrust plate. The spur gears are meshed inside an internal ring gear that is fixed to the cutter hub, allowing the cutter hub to rotate at a lower speed but higher torque than its input drive. The cutter hub is mounted to the pipe pullback adaptor by way of thrust and radial bearings. This embodiment allows the drill rod and pullback pipe to remain rotatably fixed and the reamer cutter hub can rotate about the longitudinal axis at a greater torque. The cutter hub is typically concave within its cutting face, so that as it is pulled back through the ground, slurry and spoil are offered to the vacuum or slurry channel entrance for evacuation.

It should be understood that the above description is of a preferred embodiment and included as illustration only. It is not limiting of the invention. Clearly a person skilled in the art without any inventiveness would understand variations of the microtunnelling system and apparatus and such variations are included within the scope of this invention as defined in the following claims.

Claims

1. A microtunnelling apparatus including a drill head section connected to the end of one or more intermediate drill rods, which can be driven by an external drive means, and wherein addition of further intermediate drill rods allows extension of the boring hole created by the drill head section.

2. A microtunnelling apparatus according to claim 1 wherein the external drive means includes a thrust module, which linearly moves the one or more intermediate drill rods, and a rotation module which rotates the drill head section mounted on a distal end of the end one of the one or more intermediate drill rods, which together effect the boring of the hole.

3. A microtunnelling apparatus according to claim 2 wherein the external drive means includes a frame means for mounting a thrust module and a selected rotation module, the frame means including a linear track for directing the linear movement of the thrust module and rotation module for the length of a drill rod extension before attaching a further intermediate drill rod.

4. A microtunnelling apparatus according to claim 3 wherein the external drive means includes a frame means having a rack and pinion arrangement.

5. A microtunnelling apparatus according to claim 1 or 2 including a casing mounted around at least a substantial portion of the drill rods, the casing housing a directional steering means having elements able to selectively protrude by control means to direct the movement of the casing and thereby direct the drill head section mounted on the distal end of the drill rods.

6. A microtunnelling apparatus according to claim 3 wherein the directional steering means includes a plurality of substantially radially extending channels each with an hydraulically movable protuberance movable by control means to redirect an outer steering casing and thereby redirect the drill head section mounted on the distal end of the drill rods.

7. A microtunnelling apparatus according to claim 6 wherein the directional steering means includes four substantially radially extending channels in the casing near the drill head with approximately 90° angular spacing between radial channels.

8. A microtunnelling apparatus according to claim 6 wherein the directional steering means includes four substantially radially extending channels in a modular ring component of the casing near the drill head with approximately 90° angular spacing between radial channels.

9. A microtunnelling apparatus according to claim 8 wherein the casing near the drill head includes further modular ring sections including a bearing module for redirecting fluid to provide at least a partial fluid bearing of the drill rod and drill rotor assembly.

10. A microtunnelling apparatus according to claim 6 wherein the control means includes a substantially axial channel extending from a liquid source and leading to substantially radially extending channels able to hydraulically extend protuberances from the casing to redirect the casing and thereby redirect the drill head section mounted on the distal end of the drill rods wherein the control means allows external steering control.

11. A microtunnelling apparatus according to claim 3 wherein the casing includes at least one axially extending cavity or bore with liquid axially transported along one of said axially extending cavities or bores under pressure to the drill head to assist drilling.

12. A microtunnelling apparatus according to claim 9 wherein the casing includes a plurality of axially extending cavities or bores which in use allow liquid to be axially transported along one of said axially extending cavities or bores under pressure to the drill head to assist drilling and resulting slurry is returned along another of said axially extending cavities or bores.

13. A microtunnelling apparatus according to claim 3 wherein the control means includes a laser providing a beam within the casing to assist in precision steering of the casing and thereby directing of the drill head section mounted on the distal end of the drill rods.

14. A microtunnelling apparatus according to claim 3 wherein the casing includes at least one axially extending cavities or bores with liquid axially transported along at least one of said axially extending cavities or bores between the drill head and the external drive means and said at least one of said axially extending cavities or bores located at least partially between the laser beam path and the drive shaft providing a cooling barrier and minimising disturbances of the laser beam.

15. A microtunnelling apparatus according to claim 3 wherein the casing includes at least one axially extending cavities or bores connectable to external vacuum means and forming a slurry return path with liquid slurry axially transported along at least one of said axially extending cavities or bores between the drill head and the external drive means and said at least one of said axially extending cavities or bores located at least partially between the laser beam path and the drive shaft providing a cooling barrier and minimising disturbances of the laser beam.

16. A microtunnelling apparatus according to claim 1 or 2 wherein the intermediate drill rods are mounted in cylindrical intermediate casings that include respective male and female connectors at respective ends to allow end on end connection of the intermediate casings and enclosed intermediate drill rods to form a single continuous drill rod.

17. A microtunnelling apparatus according to claim 15 wherein the respective male and female connectors are offset from the centre such that interengagement ensures linear end on end alignment of attached drill rods to form a single continuous drill rod as well as ensuring respective radial alignment of internal cavities and bores.

18. A microtunnelling apparatus according to claim 16 wherein the drill string is housed within an axially extending cavity which in turn is housed within one or more additional axially extending cavities for pressure slurry, slurry return or vacuum to form a heat escapement channel for the heat created by the rotation of the drill string.

19. A microtunnelling apparatus according to claim 16 whereby there is an axially extending cavity formed on the upper side of the drill string to form a protected laser environment to maintain accuracy.

20. A microtunnelling apparatus according to claim 1 or 2 wherein the casing includes an axially elongated concave recess in the outer side of at least a plurality of the intermediate casings to allow receipt of a control line formed in sections longer than the at least a plurality of the intermediate casings such that in use connection of control line sections can occur after a plurality of connections of the intermediate casings to form the extension of the encased drill rod.

21. A drill head and steering module for use in a microtunnelling system having a drive system, a drill head section and an intermediate drill rods allowing extension of the boring hole created by the drill head section driven by the drive system; the drill head including: a steering shell mounted axially on a drive rod in a manner to allow radial movement and having a plurality of radially mounted pistons able to engage the inner surface of the steering shell such that the control of the protrusion of the plurality of radially mounted pistons controls the direction of the steering shell.

22. A drill head and steering module according to claim 21 including a plurality of radially mounted pistons included in a circular steering module fitting around the drill rod and having radial bores from which the radially mounted pistons protrude.

23. A drill head and steering module according to claim 22 wherein the circular steering module includes a spoked wheel effect with the radial bores extending at least partially along the radial extending spokes and cavities between the spokes to allow axial pathways.

24. A drill head and steering module according to claim 23 wherein the circular steering module include ports near the radial centre and able to receive water or hydraulic fluid for driving the pistons to protrude from the radial bores and engage the inner surface of the steering shell.

25. A drill head and steering module for use in a microtunnelling system having a drive system, a drill head section and intermediate drill rods allowing extension of the boring hole created by the drill head section driven by the drive system; the drill head including a modular construction having a plurality of circular disc like elements for axial alignment and abutment and mounting within a cylindrical shell, wherein each of the circular disc like elements is created by direct bore construction and the axial alignment and abutment creates continuous axial and radial channels allowing fluid flow, vacuum waste return channel, and control flows.

26. A drill head and steering module according to claim 25 wherein one of the circular disc like elements forms a bearing module at the front of the drill head with flow paths for providing axially extending fluid jets to assist cutting and radially extending flow paths to assist aquaplaning bearings of the rotating cutting means.

27. A fluid bearing bush wherein the pressure fluid is transmitted from its outer circumference, through radially formed channels to a peripheral inner channel whereby pressure fluid is distributed through the drill shaft to supply the cutting face, and past the annular area between the drill shaft and fluid bush to the front face.

28. A fluid bearing bush according to claim 27 whereby the pressure distribution and load distribution is entailed in one embodiment.

29. A drill head and steering module according to claim 25 wherein one of the circular disc like elements forms a steering module at the front of the drill head with flow paths for providing axially extending fluid jets to control protrusion of pistons to engage the outer cylinder and alter direction of the drill head.

30. A drill head and steering module according to claim 25 wherein one of the circular disc like elements forms a spacer module within the drill head with flow paths for providing axially extending flow paths to adjacent modules.

31. A drill head and steering module according to claim 25 wherein one of the circular disc like elements forms a mounting module at the rear of the drill head with flow paths for providing axially extending flow paths and able to form non rigid mounting of base of outer cylinder.

32. A microtunnelling apparatus including a precision pull back reamer which is attached to the end of the drill rod to be pulled from the reception shaft to the launch shaft whilst cutting and thereby precisely increasing the size of a previously drilled hole.

33. A microtunnelling apparatus according to claim 32 whereby the input shaft drives through a planetary gear set to increase the torque of the driven outer hub.

34. A microtunnelling apparatus according to claim 32 whereby the precision pull back reamer has an inwardly concave cutting face to channel cutting spoil up to an axially extending vacuum cavity for waste removal.

35. A microtunnelling apparatus according to claim 32 whereby pressure fluid cavity and hydraulic control lines extend through to the pipe pull back housing for pressure fluid ejection and hydraulic control of pipe clamp arrangement.

36. A drill head and steering module substantially as hereinbefore described with reference to the drawings.

37. A microtunnelling apparatus substantially as hereinbefore described with reference to the drawings.

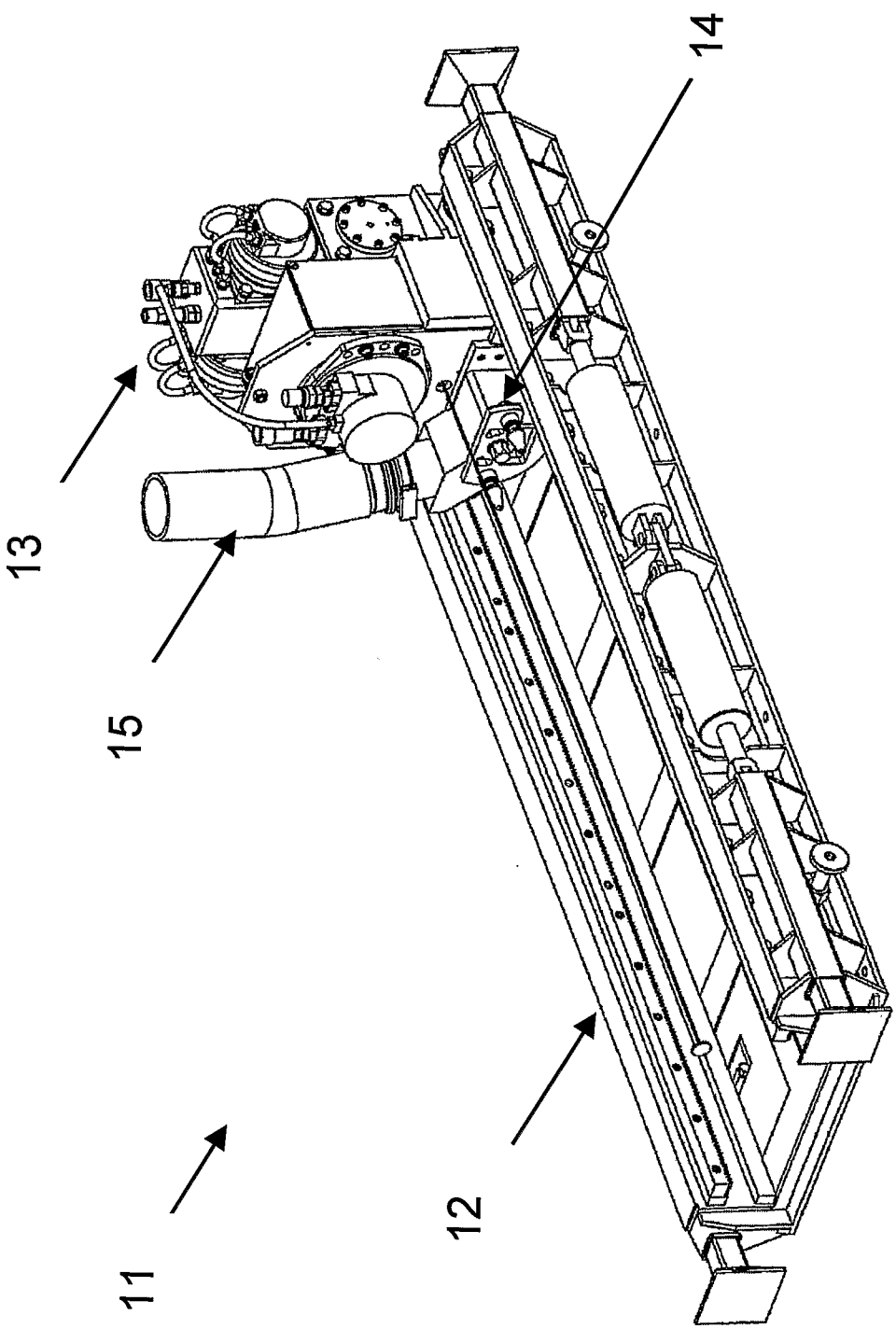


FIGURE 1

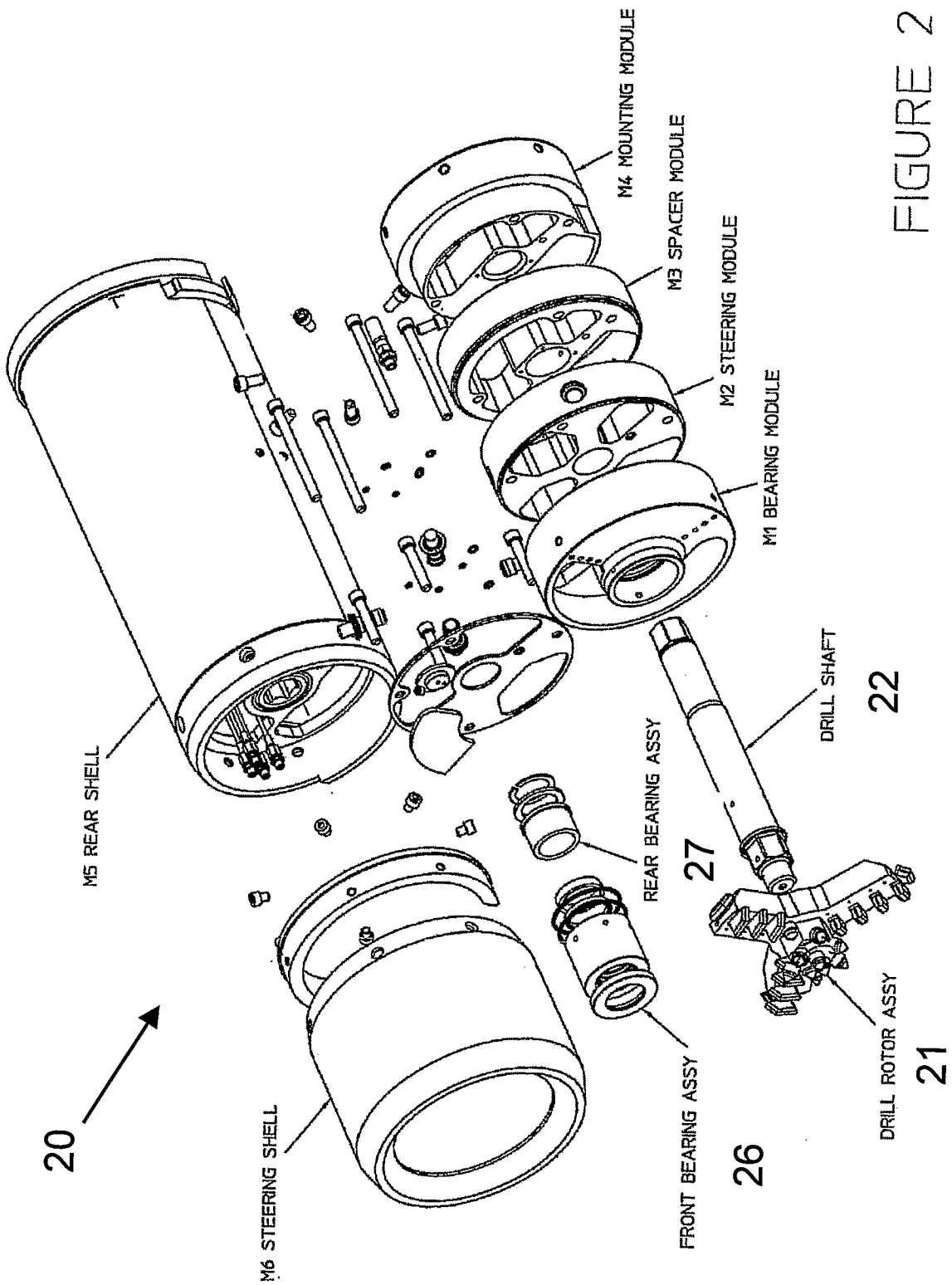
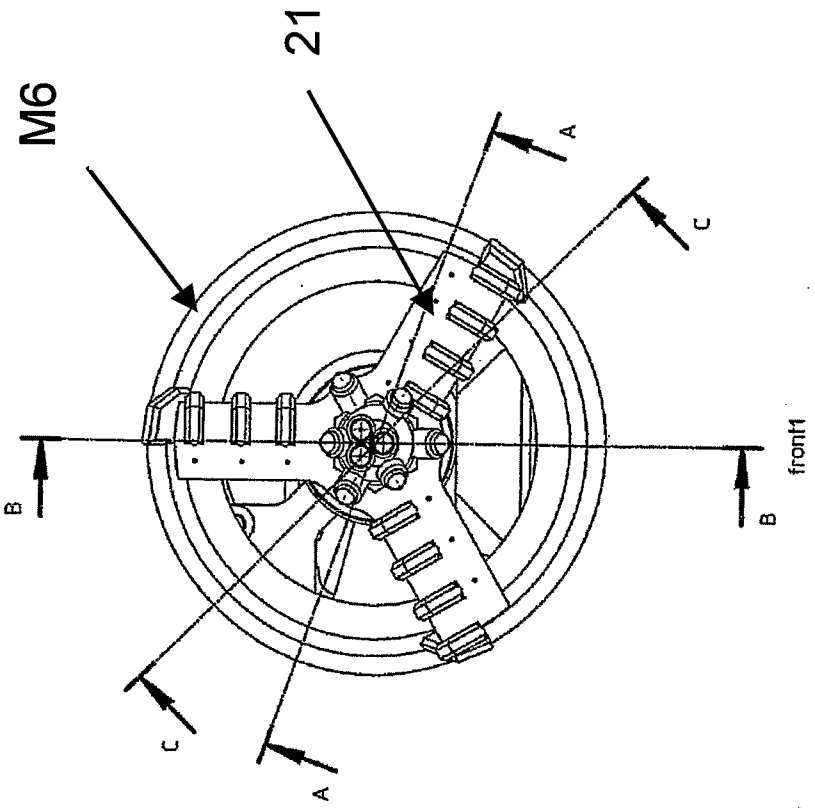

M4 MOUNTING MODULE
M3 SPACER MODULE
M2 STEERING MODULE
M1 BEARING MODULE
M5 REAR SHELL
DRILL SHAFT
22
REAR BEARING ASSY
27
20
M6 STEERING SHELL
FRONT BEARING ASSY
26
DRILL ROTOR ASSY
21

FIGURE 2

FIGURE 3



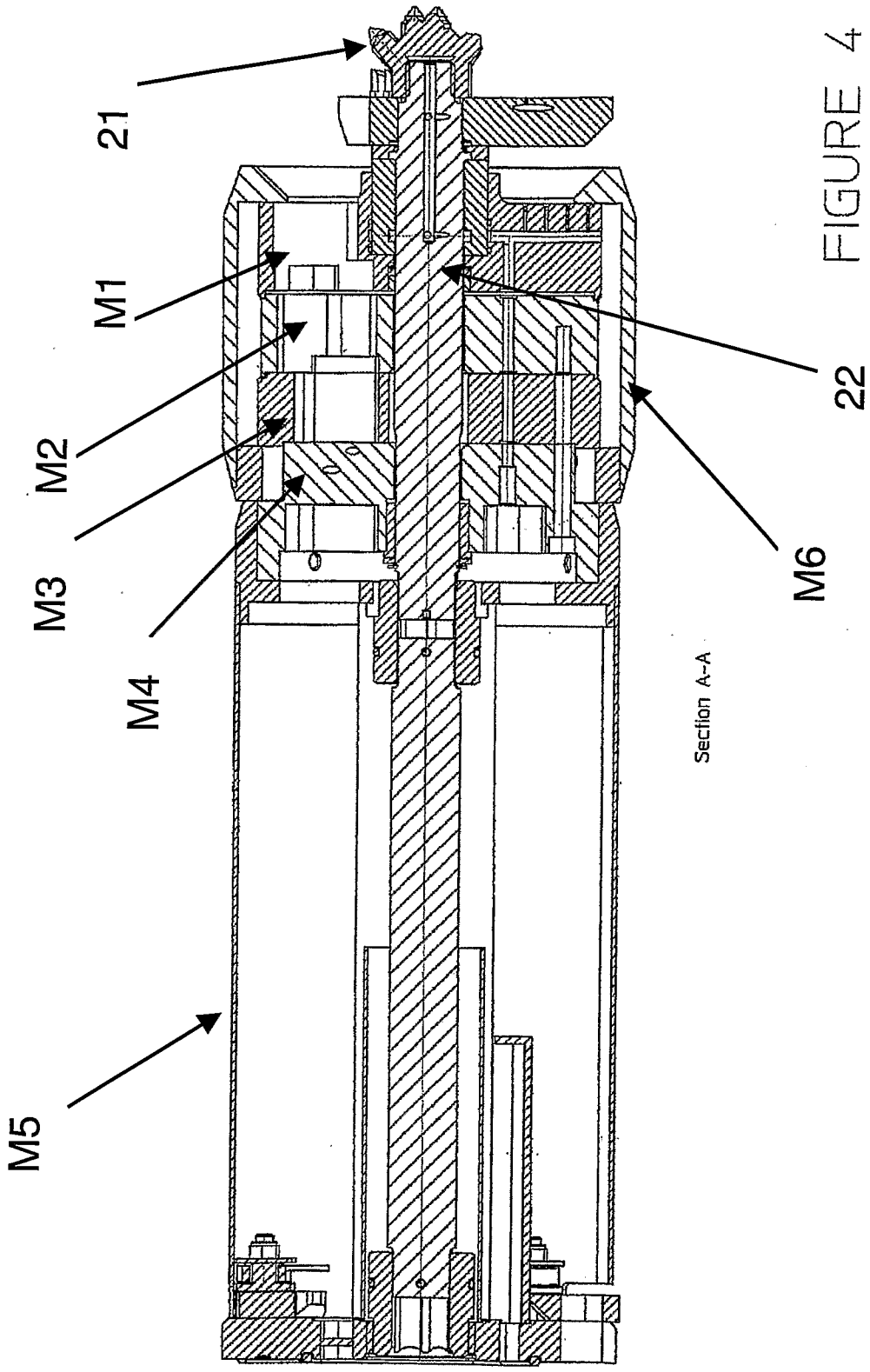


FIGURE 4

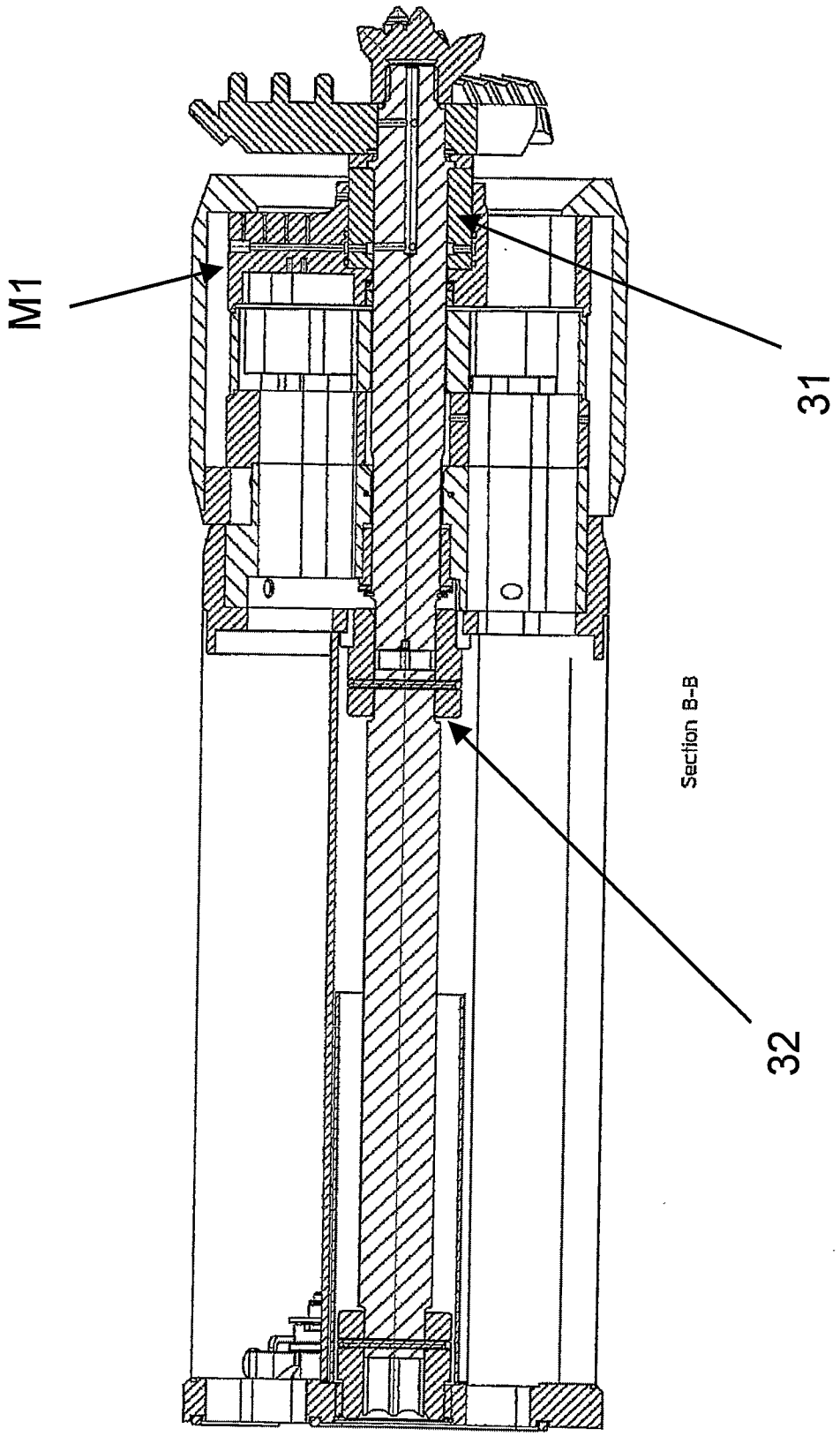


FIGURE 5

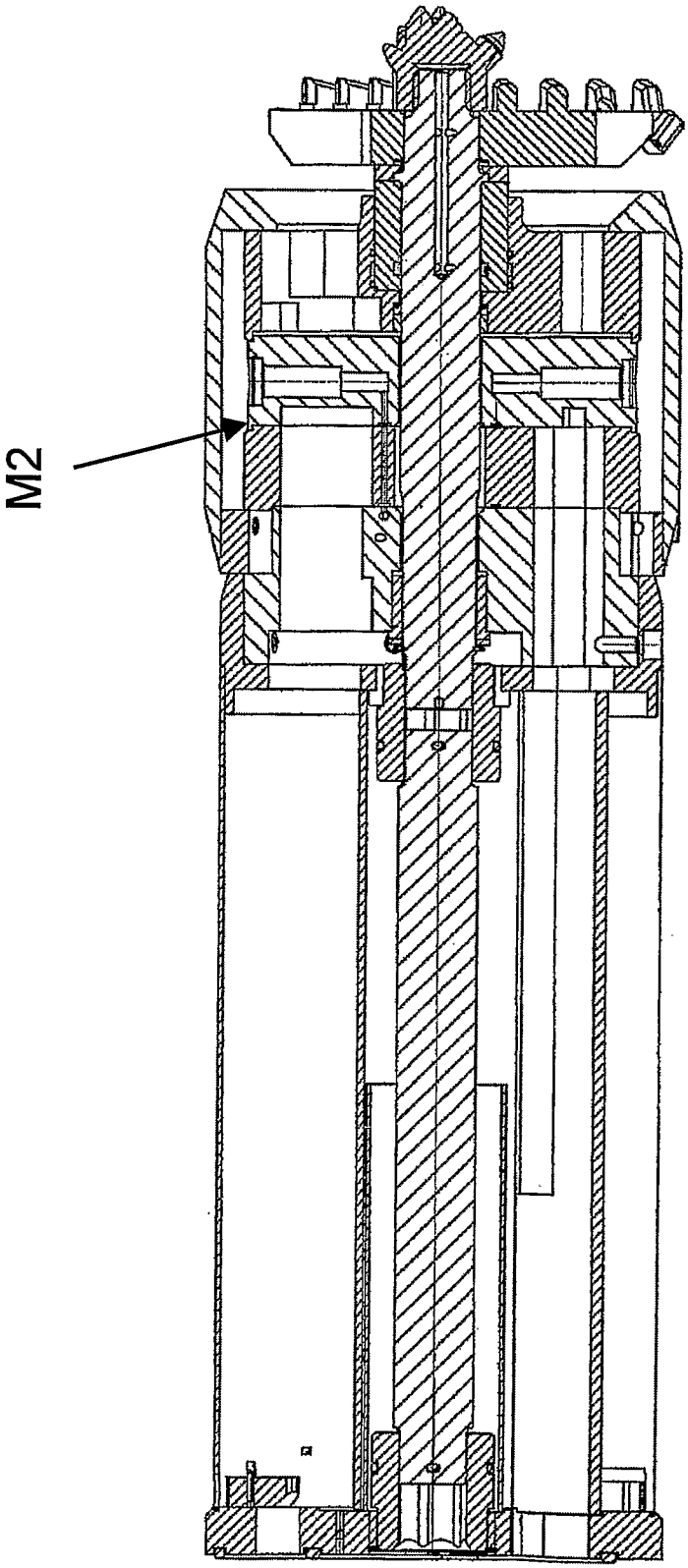


FIGURE 6

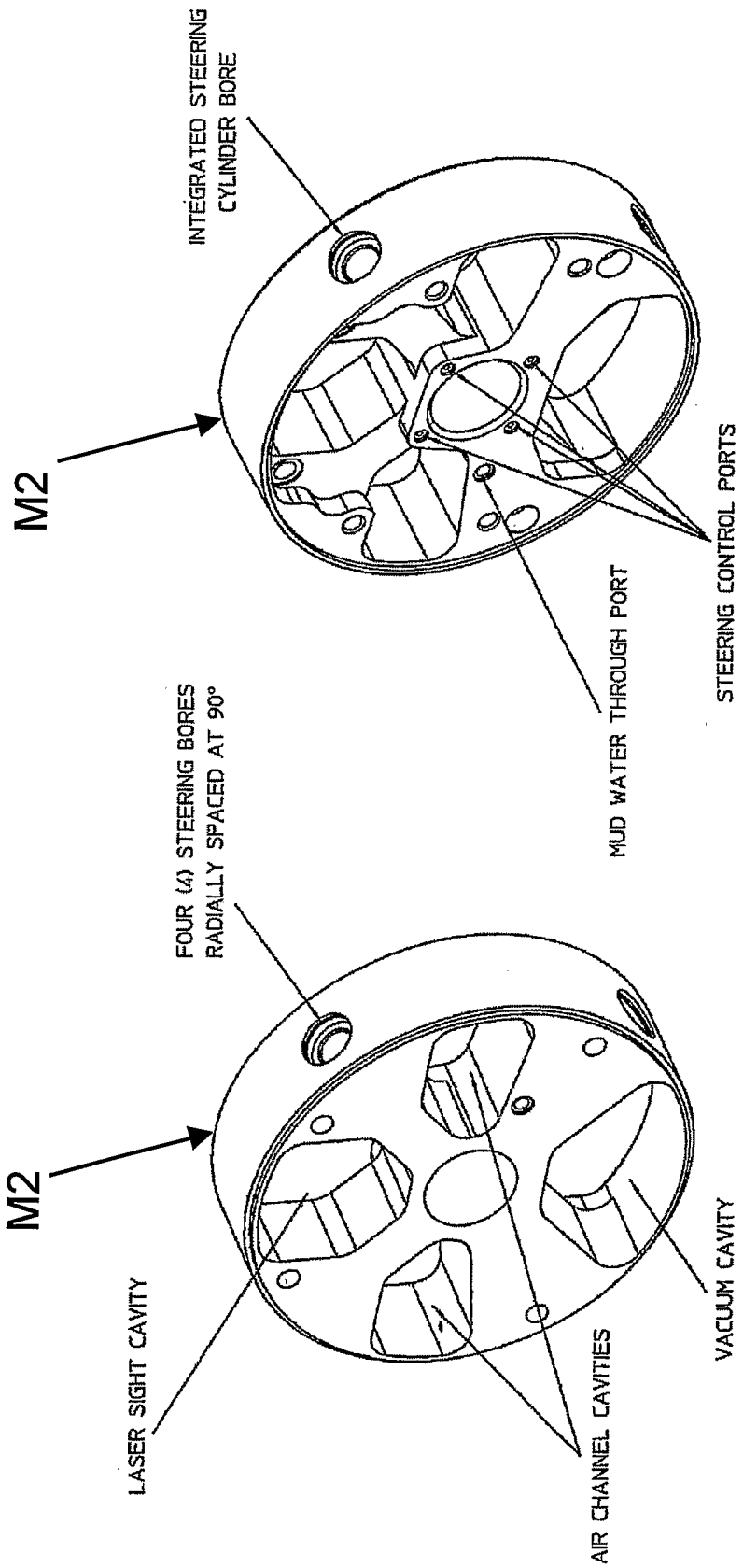

M2
INTEGRATED STEERING CYLINDER BORE
STEERING CONTROL PORTS
MUD WATER THROUGH PORT
M2
FOUR (4) STEERING BORES RADIALLY SPACED AT 90°
LASER SIGHT CAVITY
AIR CHANNEL CAVITIES
VACUUM CAVITY

FIGURE 7

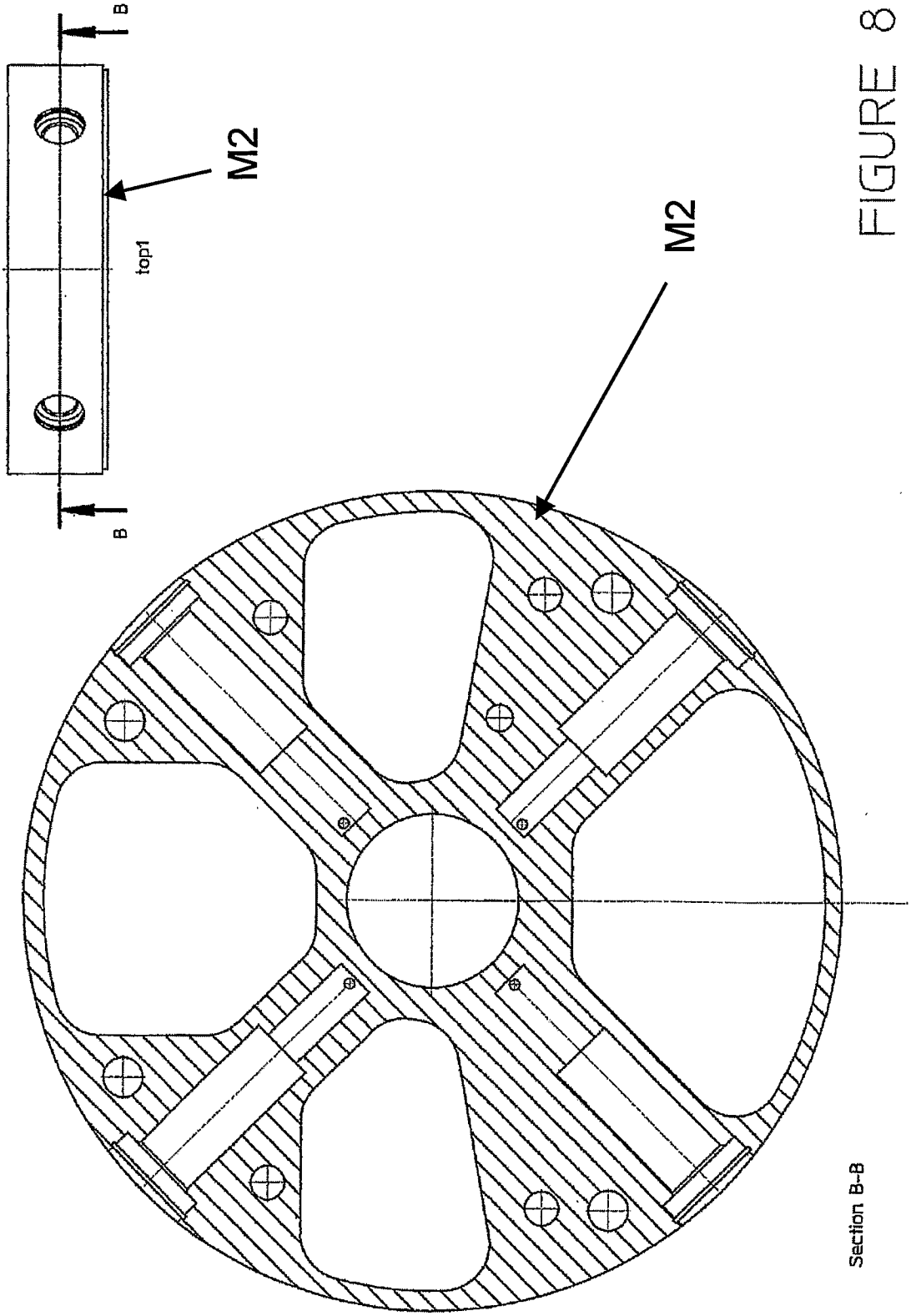


FIGURE 8

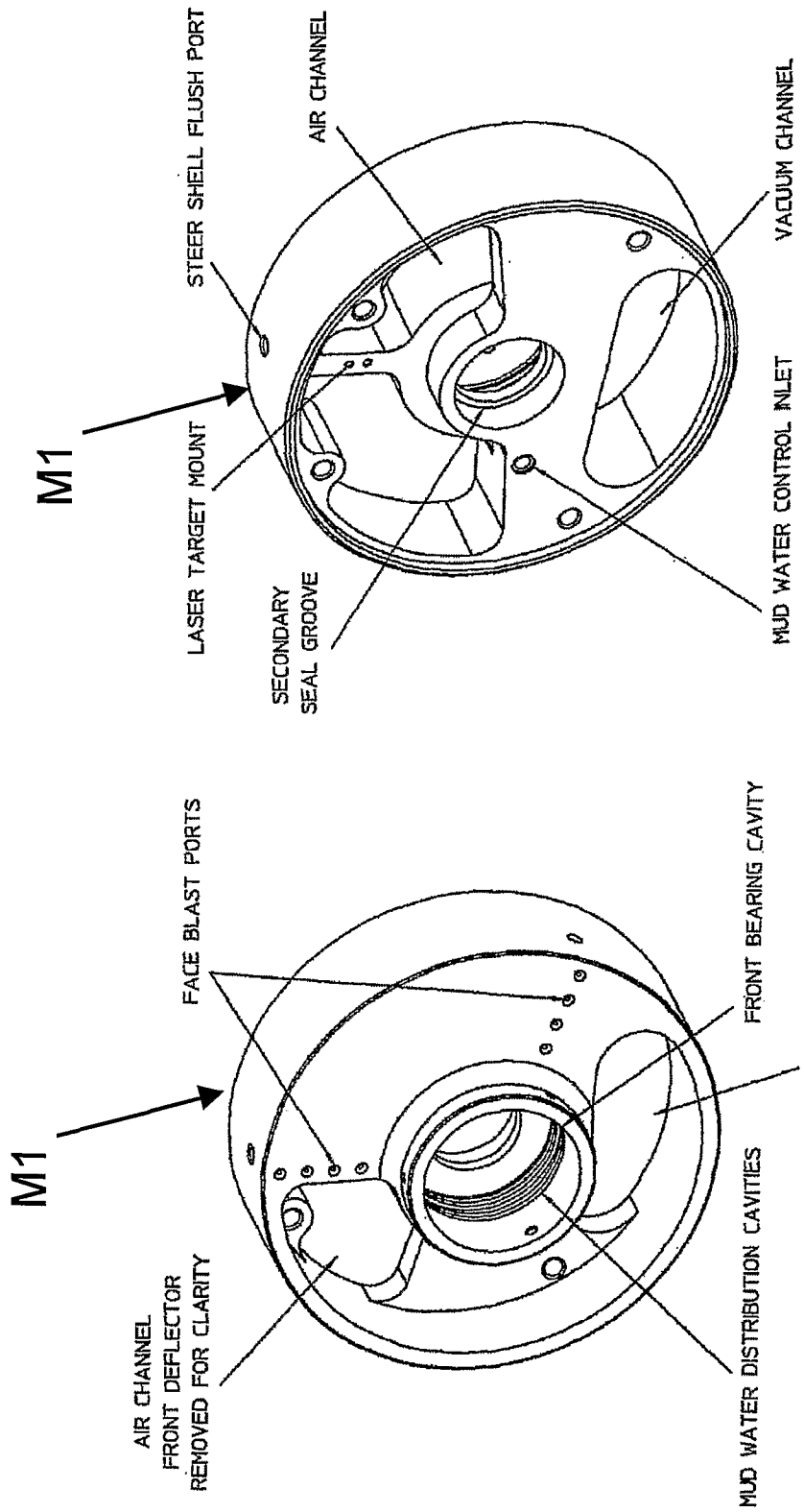

M1
STEER SHELL FLUSH PORT
AIR CHANNEL
LASER TARGET MOUNT
SECONDARY SEAL GROOVE
MUD WATER CONTROL INLET
VACUUM CHANNEL
M1
FACE BLAST PORTS
FRONT BEARING CAVITY
VACUUM CHANNEL
AIR CHANNEL FRONT DEFLECTOR REMOVED FOR CLARITY
MUD WATER DISTRIBUTION CAVITIES

FIGURE 9

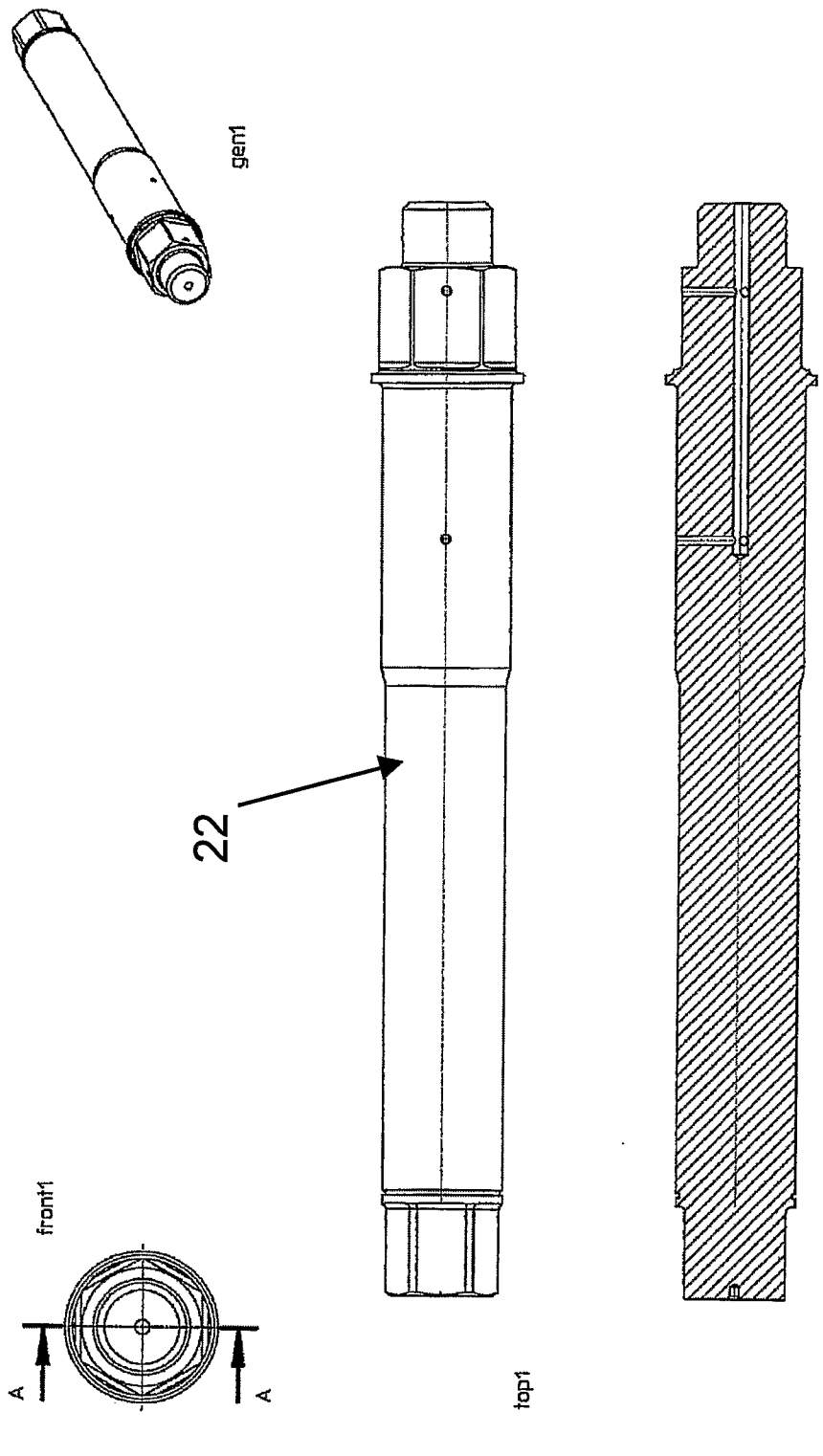


FIGURE 10

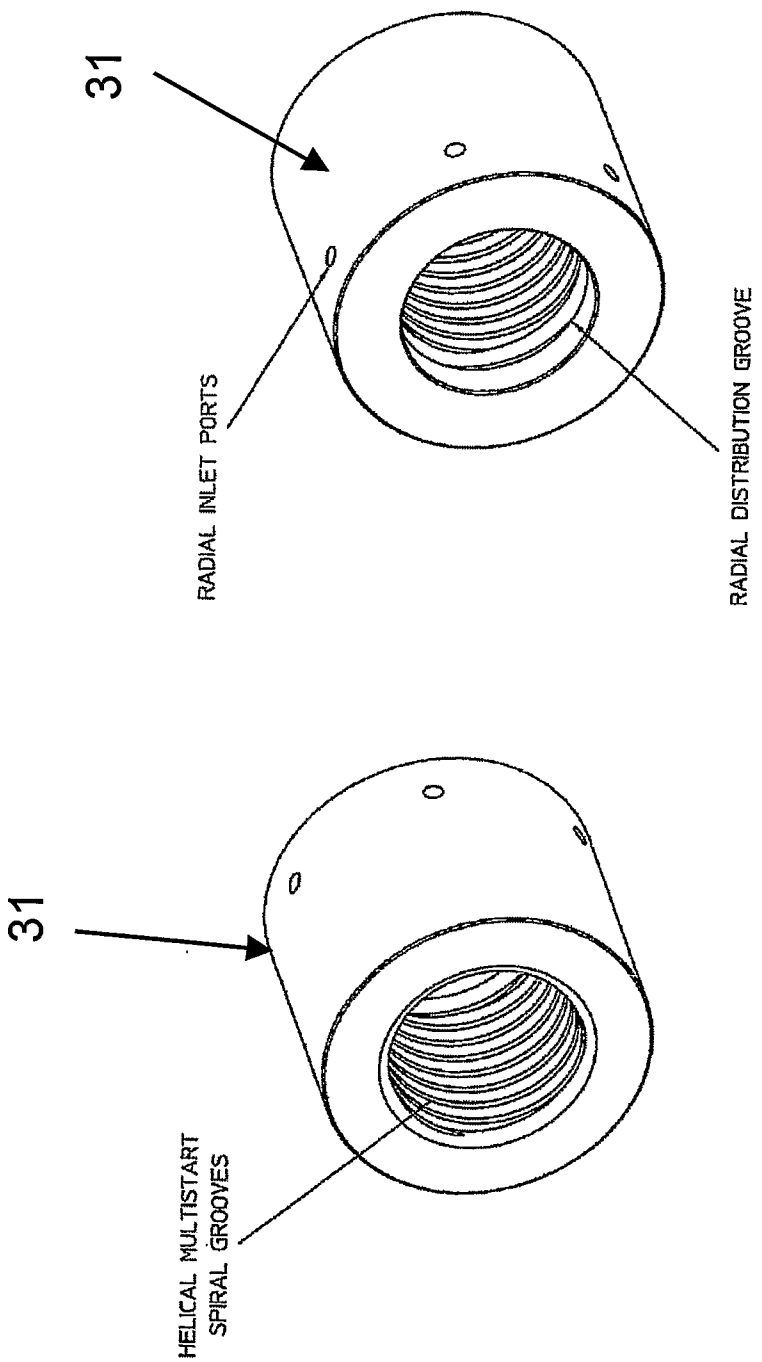
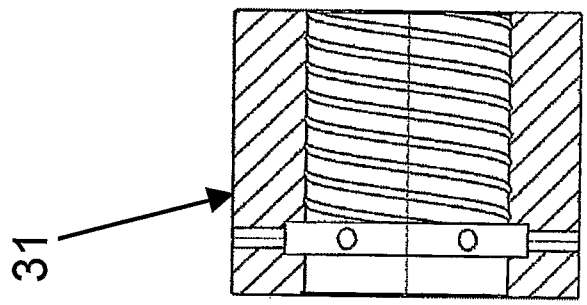
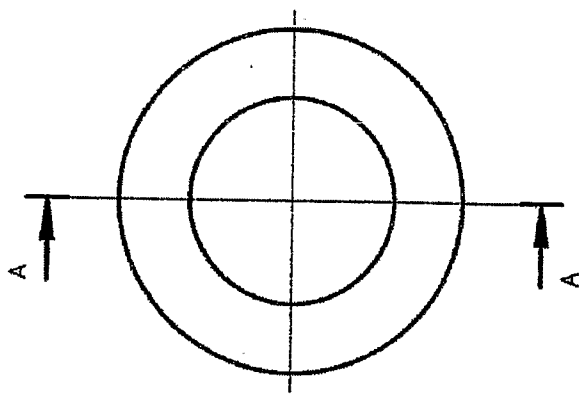

31
RADIAL INLET PORTS
RADIAL DISTRIBUTION GROOVE
31
HELICAL MULTISTART
SPIRAL GROOVES

FIGURE 11

FIGURE 12





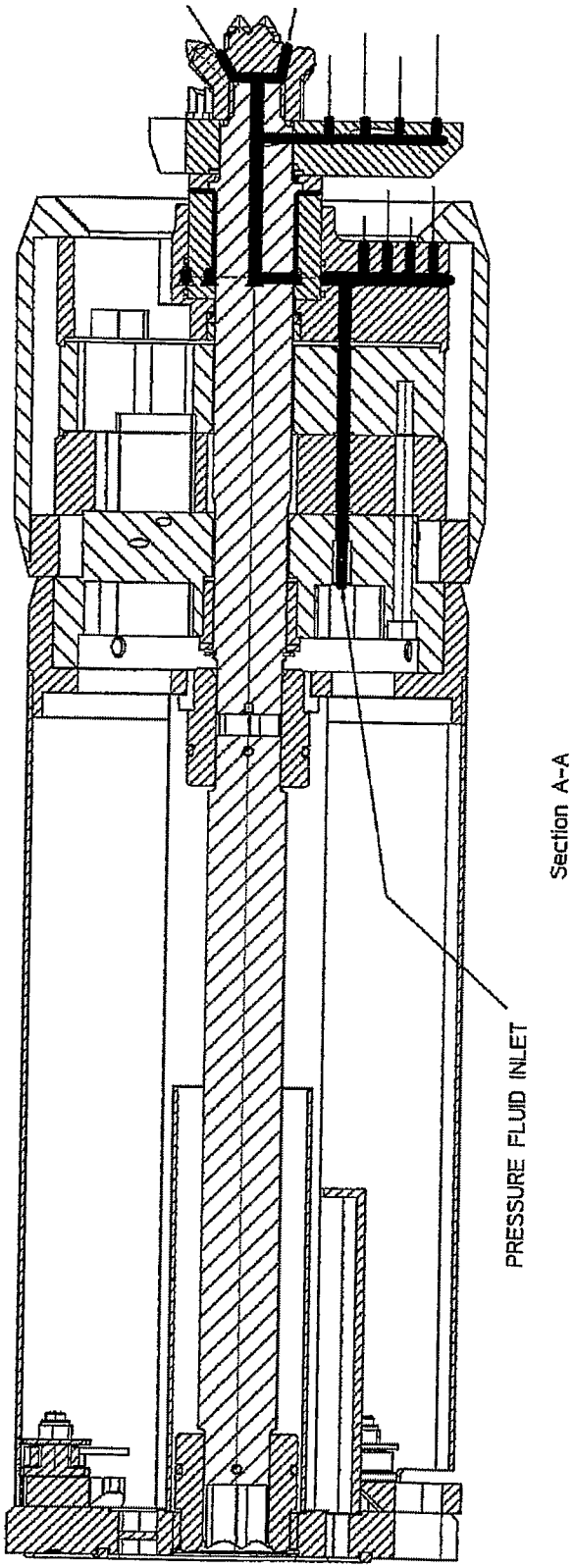


FIGURE 13

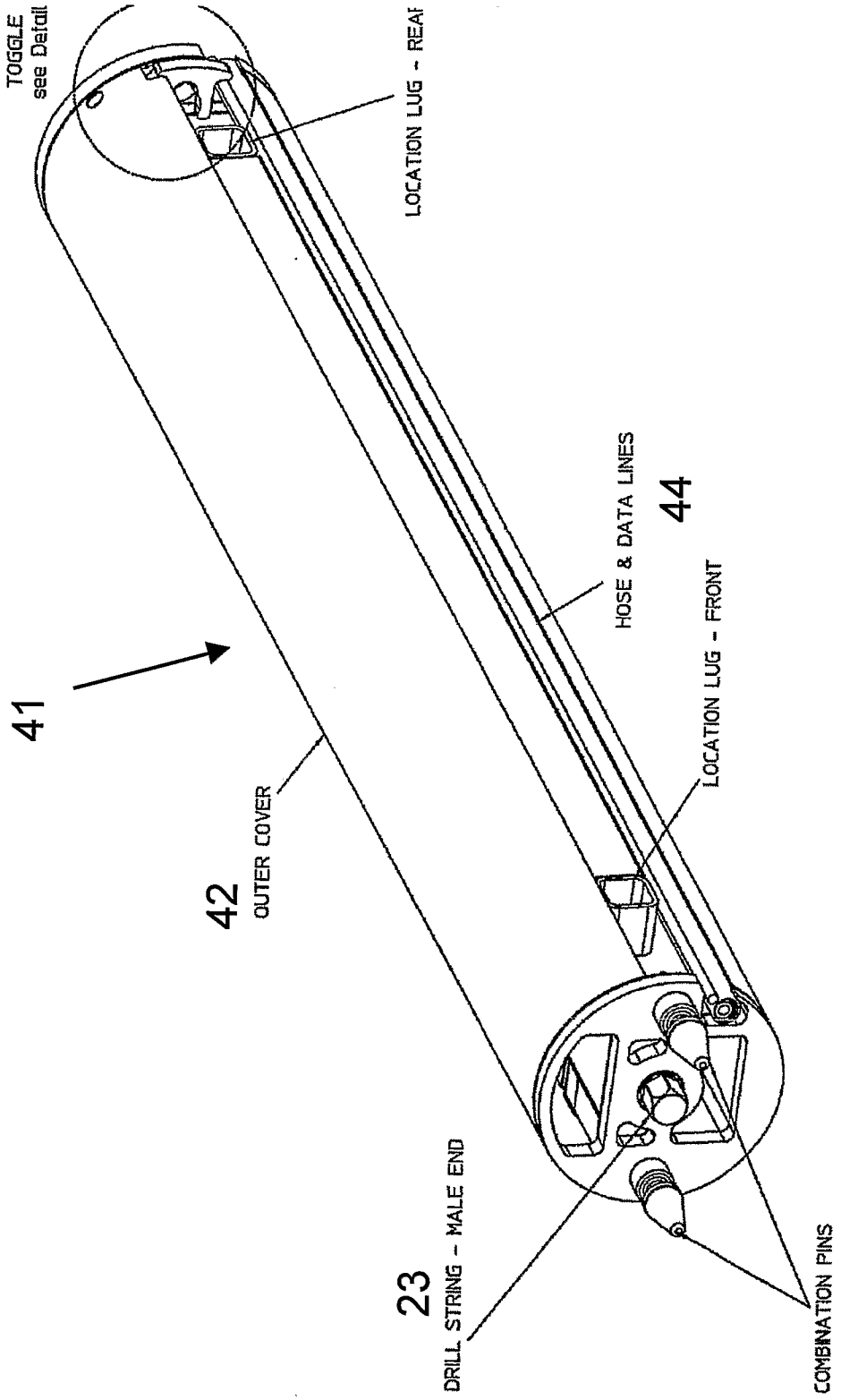

TOGGLE
see Detail
LOCATION LUG - REAR
41
42
OUTER COVER
HOSE & DATA LINES
44
LOCATION LUG - FRONT
23
DRILL STRING - MALE END
COMBINATION PINS
48

FIGURE 14

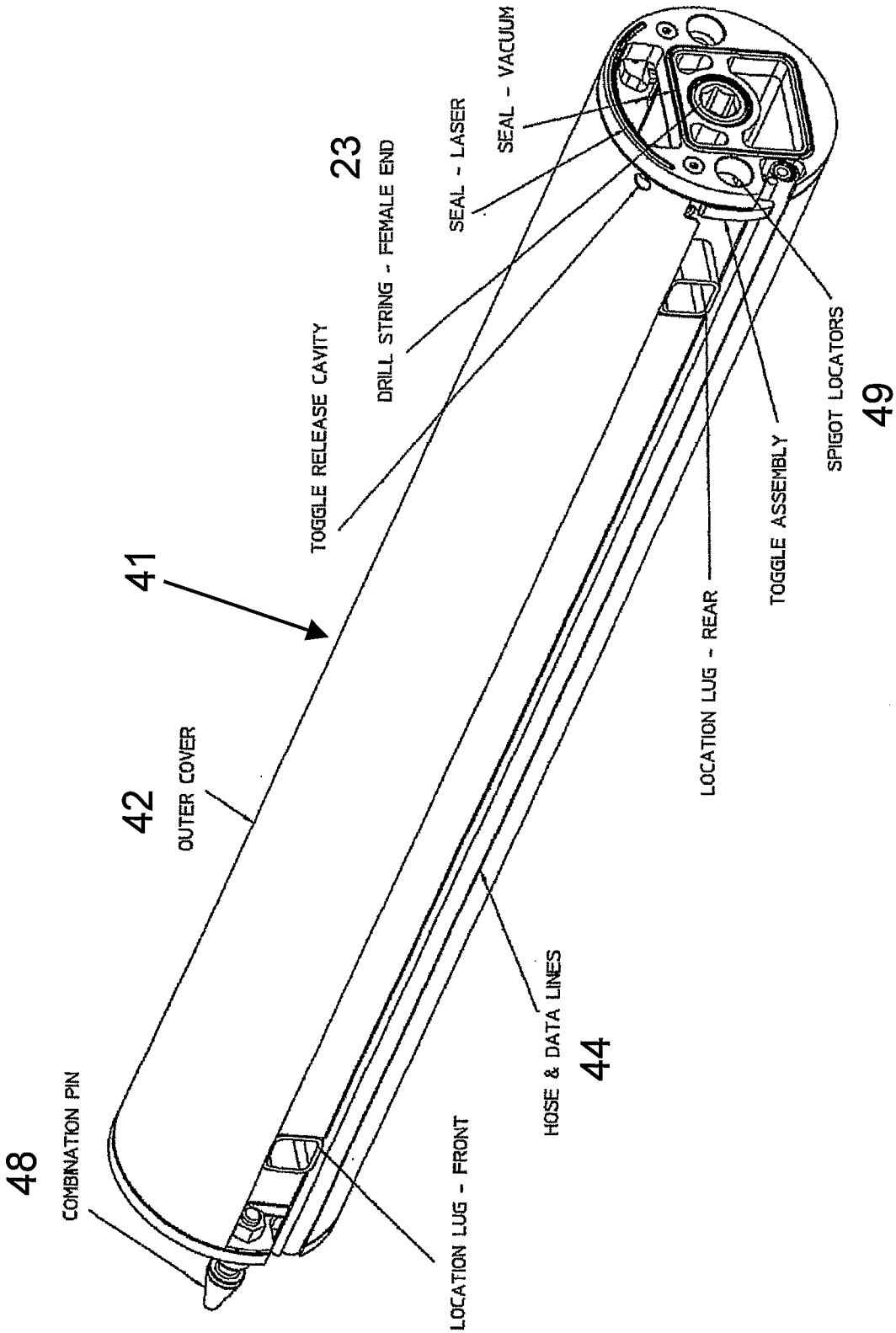

48
COMBINATION PIN
42
OUTER COVER
41
TOGGLE RELEASE CAVITY
23
DRILL STRING - FEMALE END
SEAL - LASER
SEAL - VACUUM
LOCATION LUG - FRONT
HOSE & DATA LINES
44
LOCATION LUG - REAR
TOGGLE ASSEMBLY
SPIGOT LOCATORS
49

FIGURE 15

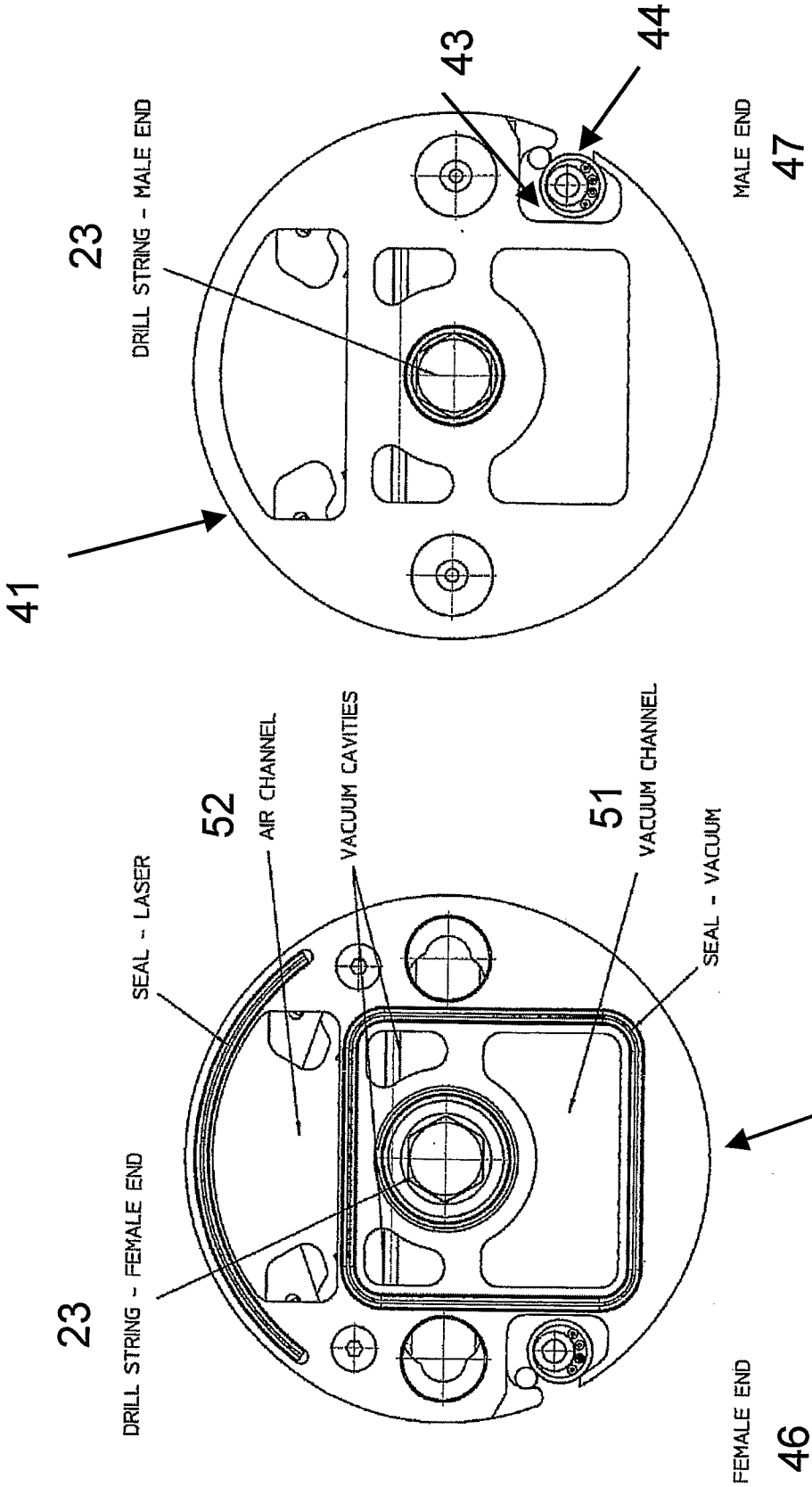

41
23
DRILL STRING - MALE END
43
44
MALE END
47
41
23
DRILL STRING - FEMALE END
SEAL - LASER
52
AIR CHANNEL
VACUUM CAVITIES
51
VACUUM CHANNEL
SEAL - VACUUM
FEMALE END
46

FIGURE 16

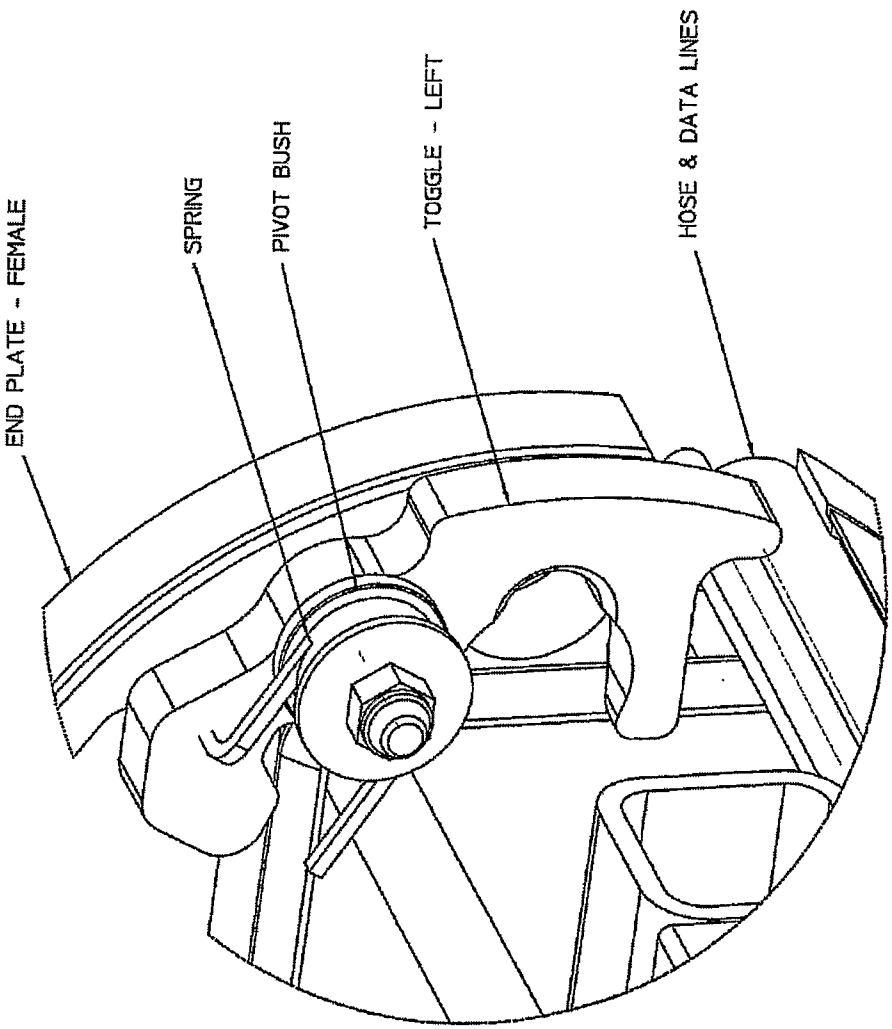

END PLATE - FEMALE
SPRING
PIVOT BUSH
TOGGLE - LEFT
HOSE & DATA LINES
COVER REMOVED
FOR CLARITY

FIGURE 17

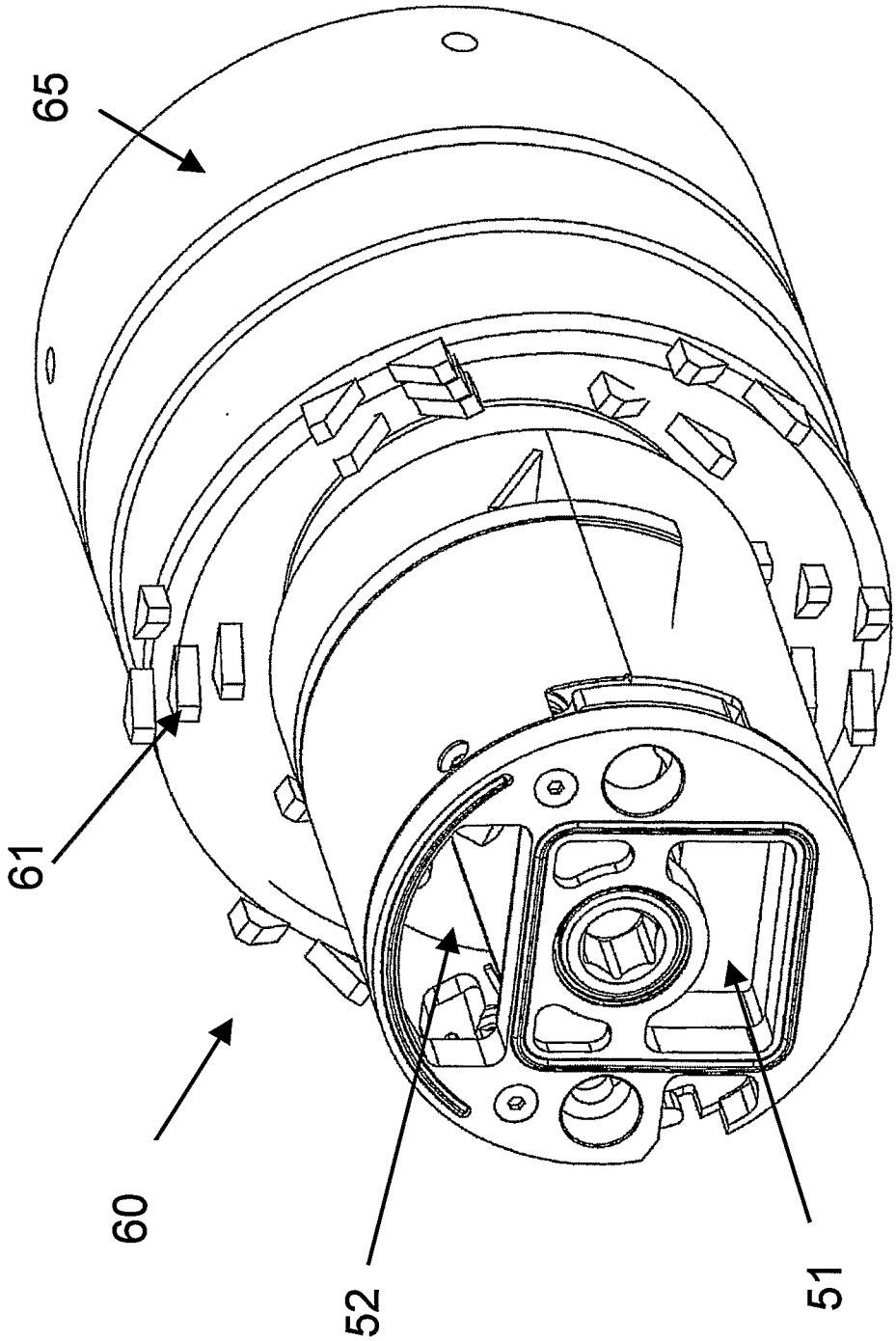


FIGURE 18

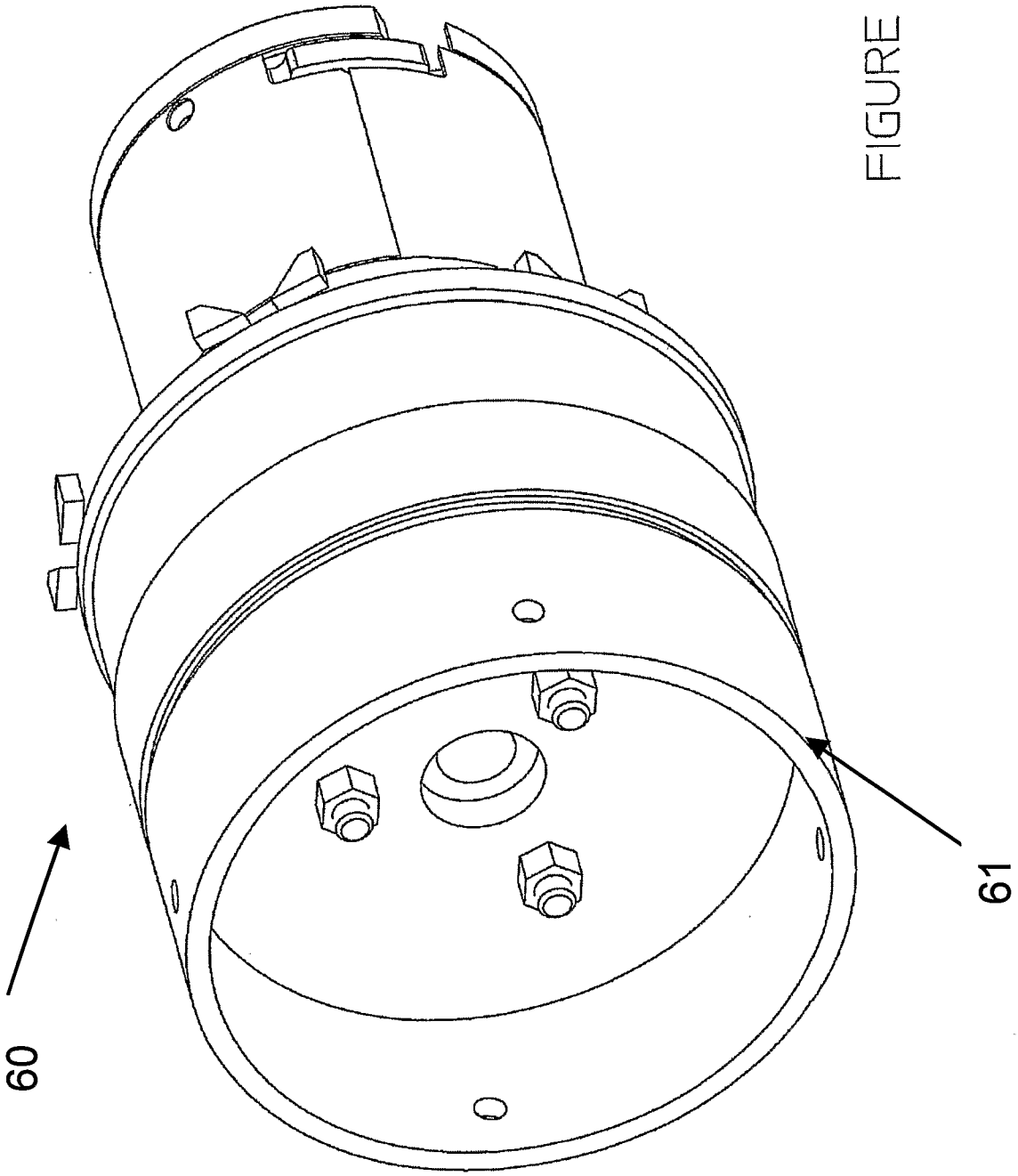
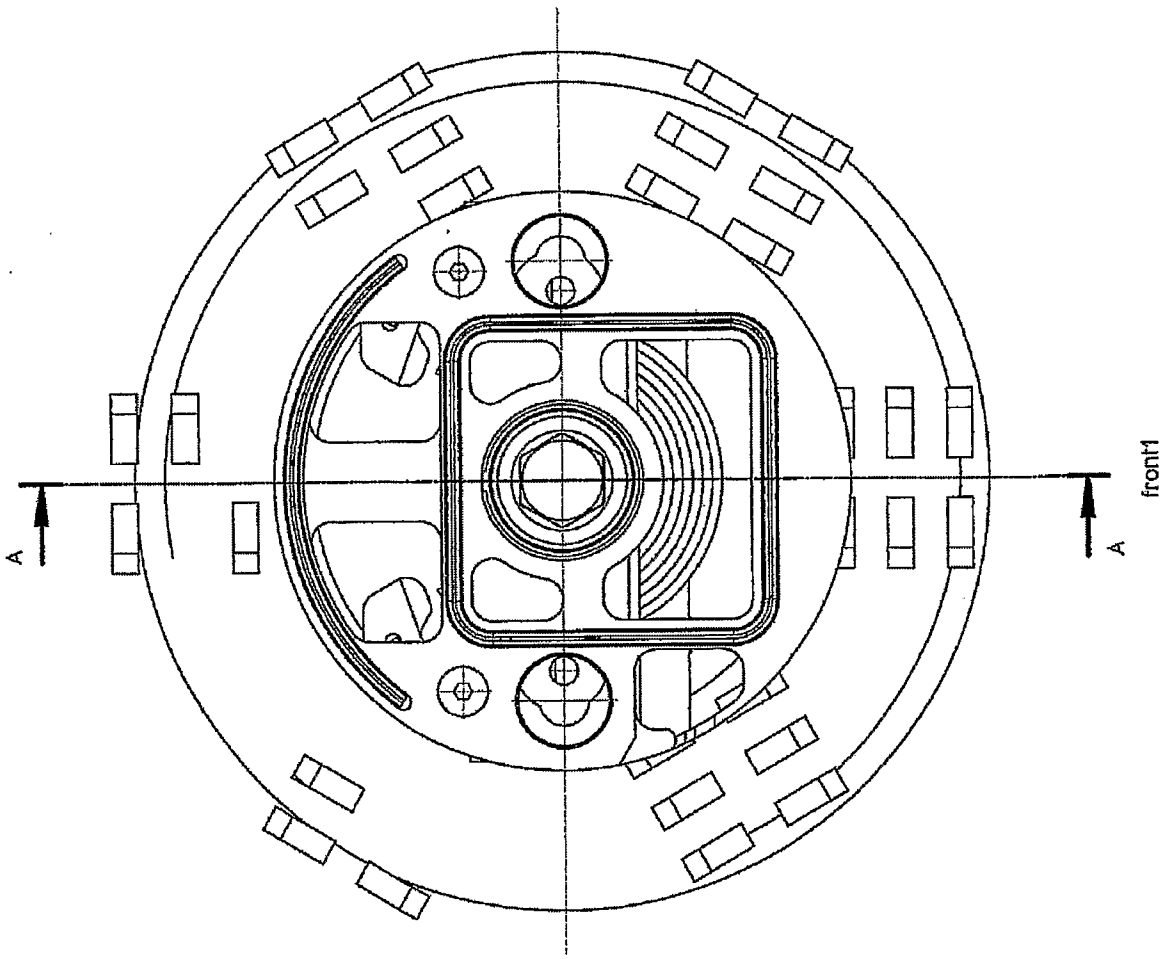


FIGURE 19

FIGURE 20



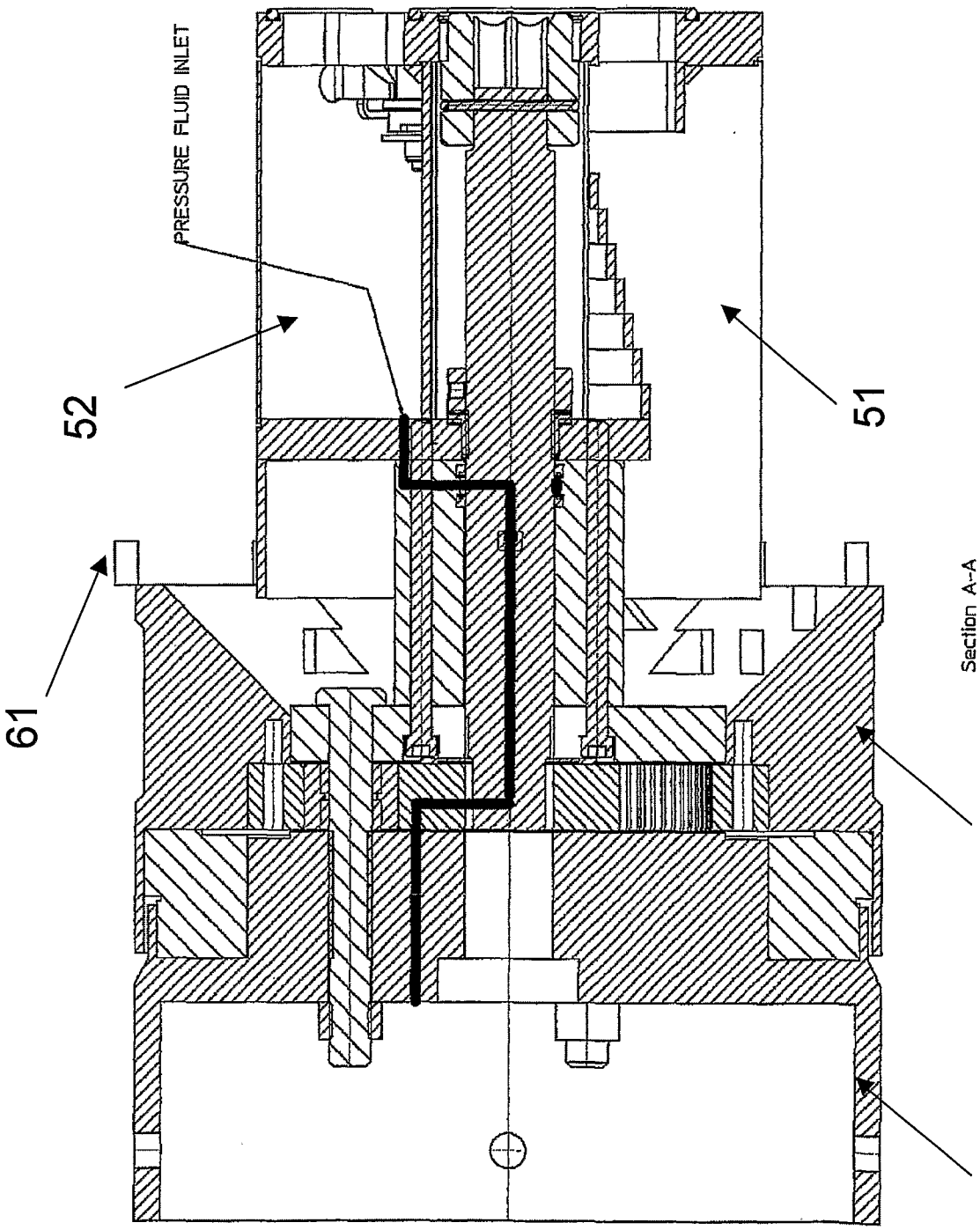


FIGURE 21

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001122

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. ***E21B 7/08*** (2006.01) ***E21B 7/30*** (2006.01) ***E21B 21/12*** (2006.01)
E21B 7/04 (2006.01) ***E21B 10/00*** (2006.01) ***E21D 9/08*** (2006.01)
E21B 7/20 (2006.01) ***E21B 12/00*** (2006.01) ***E21B 7/28*** (2006.01) ***E21B 17/18*** (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI IPC: (1) E21B 7/08, 7/20, 7/04, E21D 9/08 and keywords (horizontal, micro, trenchless, external drive) and like terms (2) E21B 21/12, 17/18, 12/- and keywords (bush, collar, sleeve, radial) and like terms (3) E21B 10/-, 7/28, 7/30 and keywords (reamer, increase, enlarge, pull, withdrawal) and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2002/044508 A (TRACTO-TECHNIK GMBH) 6 June 2002 Whole document	1 – 5, 11
X	WO 2002/044511 A (TRACTO-TECHNIK GMBH) 6 June 2002 Whole document	1 – 5, 11
X	Patent Abstracts of Japan, JP, 2005-213848 A (HITACHI METALS LTD.) 11 August 2005 abstract	1 – 5, 11

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 October 2006	3 NOV 2006
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **E.J. MARTYN** Telephone No : (02) 6283 2332

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001122

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001122

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 91-175976/24, Class Q49, SU 1579976 A (PETROLEUM IND. EQUIP. INST.) 23 July 1990 Abstract	27 - 31
X	WO 2002/064939 A (RIVES) 22 August 2002 Whole document	32 - 35
X	US 4784230 A (CHERRINGTON et al) 15 November 1998 Whole document	32 - 35

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to potentially distinguish the claimed combination of features from the prior art. Where different claims have different distinguishing features they define different inventions.

This International Searching Authority has found that there are different inventions as follows:

- Claims 1 – 26, 29 – 31 are directed to a microtunnelling system. It is considered that the means including a drill head section connected to the end of one or more intermediate drill rods, which can be driven by an external drive means, and wherein addition of further intermediate drill rods allows extension of the boring hole created by the drill head section comprises a first distinguishing feature.

- Claims 27 and 28 are directed to a fluid bearing bush. It is considered that the pressure fluid is transmitted from its outer circumference, thoroughly radially formed channels to a peripheral inner channel whereby pressure fluid is distributed through the drill shaft to supply the cutting face, and past the annular area between the drill shaft and fluid bush to the front face comprises a second distinguishing feature.

- Claims 32 – 35 are directed to a microtunnelling apparatus. It is considered that the means including a precision pull back reamer which is attached to the end of the drill rod to be pulled from the reception shaft to the launch shaft whilst cutting and thereby precisely increasing the size of a previously drilled hole comprises a second distinguishing feature.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

Each of the abovementioned groups of claims has a different distinguishing feature and they do not share any feature which could satisfy the requirement for being a special technical feature. Because there is no common special technical feature it follows that there is no technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention a priori

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2006/001122

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	0244508	AU	27964/02	AU	35745/02	DE	10146025
		GB	2389133	GB	2389134	US	7093671
		US	7111695	US	2004060740	US	2004069533
		WO	0244511				
JP	2005213848						
WO	02064939	CA	2438454	GB	2393745	US	7090034
		US	2004074672				
US	4784230	AU	18834/88	AU	57384/86	AU	75384/91
		AU	75385/91	CA	1258262	EP	0209217
		EP	0299624	US	4679637		

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX