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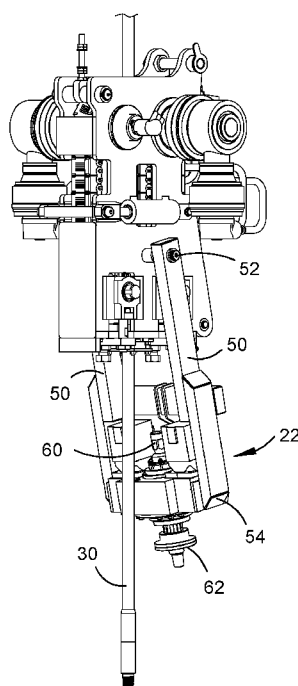


Figure 5(a)

(57) Abstract: A mobile, coiled tubing drilling apparatus with a rotary drill head, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector below a coiled tubing reel, the injector defining an operational axis for the coiled tubing, wherein the rotary drill head is pivotally mounted on the injector so as to be movable between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

ROTARY DRILL HEAD FOR COILED TUBING DRILLING APPARATUS

Related Application

[0001] This application claims convention priority from Australian provisional patent application 2017900143 filed on 18 January 2017 and International patent application PCT/AU2017/050508 filed on 30 May 2017. The contents of both of those applications are incorporated herein by reference.

Technical Field

[0002] The present invention relates to a rotary drill head for a coiled tubing drilling apparatus, primarily for use in mineral exploration, the drilling apparatus being of the type where the coiled tubing is not required to rotate about its longitudinal axis in order for the drilling apparatus to operate.

Background of Invention

[0003] Mineral exploration has historically used rotating drill strings (being a series of attached, rigid, pipe sections) with drill bits attached at one end to drill subterranean holes in an effort to locate valuable mineral deposits. As a rotating drill bit drills into the earth to form a borehole, additional pipe sections are added in order to drill deeper, while the opposite occurs as the drill bit is withdrawn from the borehole. A significant amount of time and energy (and thus cost) are consumed in adding and removing these pipe sections to assemble and disassemble drill strings during drilling.

[0004] Coiled tubing has been developed as an alternative to the use of drill strings (albeit typically for use in the oil industry not for mineral exploration), the coiled tubing typically being a ductile metal available in virtually unlimited lengths. The use of coiled tubing involves the uncoiling of a tube from a reel carrying such tubing, typically by an injector located above and close to a borehole, the injector being responsible for raising and lowering the tubing. The reel is typically located horizontally away from the injector and the borehole, and a curved guide (often referred to as a "gooseneck") is used between the reel and the injector to guide the

tubing from the reel across the apparatus to the injector. An example of this can be seen in Figure 6 of US patent publication 2013/0341001 A1.

[0005] In most coiled tubing drilling, a bottom hole assembly (BHA) located at the bottom of the tubing typically includes a mud motor that powers and rotates a drill bit (given that the coiled tubing does not rotate about its own longitudinal axis), the mud motor being powered by the motion of drilling fluid pumped from the surface through the coiled tubing. In other forms of coiled tubing drilling, above-ground apparatus has been developed to allow for the rotation of the coiled tubing about its longitudinal axis. Needless to say, substantial and complex above-ground apparatus is required to be able to rotate an entire reel of coiled tubing to achieve such rotation of the tubing, and the present invention does not relate to rotating coiled tubing drilling of this type.

[0006] However, in the normal operation cycle of even a “non-rotating” coiled tubing drilling apparatus, there is still often a need for drilling of the conventional type that uses rotating drill strings and thus the insertion and connection of multiple pipe sections down a borehole. Typically this need occurs at the commencement of drilling a borehole, such as during drilling through the regolith. Also, it will be appreciated that even with coiled tubing drilling apparatus, there is still a need for the installation of casing, which typically requires the ability to insert and rotate multiple casing sleeves into a borehole and to subsequently inject cement or the like down the borehole through the casing sleeve to subsequently pass back up the borehole between the walls of the borehole and the exterior of the casing sleeve.

[0007] With coiled tubing drilling to date, this has typically required the use of additional fluid handling equipment associated with a traditional rotary drill head, such as that used to drill with conventional drill strings, so as to be able to provide both torque and drilling fluid to a bottom hole assembly. It is an aim of the present invention to avoid the use of such additional fluid handling equipment in non-rotating coiled tubing drilling apparatus.

[0008] Before turning to a summary of the present invention, it must be appreciated that throughout this description, terms such as “horizontal” and “vertical”, “upper” and “lower”, and “before” and “after” will be used. It should be understood that these and other similar orientation-type descriptive terms are made in relation to

the orientation of an operational drill rig, which would normally be located on a reasonably flat (and thus horizontal) surface at ground level, and with respect to a normal tubing pathway on and off a reel and down and up a borehole. The terms are not, however, intended to bring operational limitations, or a requirement for parts of the apparatus to be perfectly horizontal or perfectly vertical.

[0009] Finally, it should also be noted that discussion of the background to the invention herein is included to explain the context of the invention. This is not to be taken as an admission that any of the material referred to was published, known or part of the common general knowledge as at the priority date of this application.

Summary of Invention

[0010] The present invention provides a mobile, coiled tubing drilling apparatus with a rotary drill head, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector below a coiled tubing reel, the injector defining an operational axis for the coiled tubing, wherein the rotary drill head is pivotally mounted on the injector so as to be movable between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

[0011] In another form, the present invention provides a mobile, coiled tubing drilling apparatus, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector, a coiled tubing reel having a tubing pay-off point associated therewith, and a tubing control system, the injector defining an operational axis for the coiled tubing, wherein:

the tubing control system is between the reel and the injector, and includes a tubing abutment adjacent the tubing pay-off point for applying an opposite bend to the tubing during pay-out of the tubing; and

the reel is mounted for horizontal (x,y) movement such that, during pay-out of the tubing, the tubing pay-off point can be maintained generally above the injector, and can also be moved towards or away from the tubing abutment;

the apparatus also including a rotary drill head pivotally mounted on the injector so as to be movable between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

[0012] During further description of the present invention, two modes of operation will be referred to. The first mode will be a coiled tubing drilling mode, where the coiled tubing is inserted down the borehole and fluid passed down the tubing powers the bottom hole assembly. The second mode will be a conventional rotating drill string mode where the coiled tubing connects to the top swivel of the rotary drill head and moves no further than that, while pipe sections are connected to the bottom spindle of the rotary drill head forming a rotating drill string for the bottom hole assembly. The use of the present invention allows for a relatively simple transition between the two operation modes, with relatively simple apparatus.

[0013] During the first mode of operation, the reel may be mounted for horizontal (x,y) movement such that, during pay-out of the tubing, the tubing pay-off point can be maintained generally above the injector but away from the injector's operational axis, the operational axis being defined by the pathway through the injector of the longitudinal axis of the tubing.

[0014] In contrast, and in relation to the re-coiling of the tubing that would occur during the first mode when the tubing is being withdrawn from the borehole, given that the tubing entering the injector from below has already been straightened, and thus is not subjected to the existing bend that is present with coiled tubing being uncoiled, it is envisaged that the tubing abutment need not be utilised by the apparatus during tubing take-up, and that a tubing take-on point (being essentially the same point during re-coiling as the tubing pay-off point during uncoiling) will actually be as close as operationally possible to a point along the injector's operational axis, and thus will be directly above the injector. During take-up, it will be appreciated that the only bend event that need be applied to the tubing is the bending created by the re-coiling itself.

[0015] Therefore, the reel may also mounted for horizontal (x,y) movement such that, during take-up of the tubing, the tubing take-on point can be maintained directly above the injector at a point along the injector's operational axis.

[0016] The tubing control system may include an adjustable tubing straightener after the tubing abutment and before the injector, the tubing straightener being adjustable such that it can engage tubing entering or exiting the injector and be utilised to provide more or less (or no) force to tubing entering or exiting the injector. For example, in one form, the adjustable tubing straightener will engage with tubing entering the injector (during pay-out), but not with tubing exiting the straightener (during take-up), for reasons that will be outlined below.

[0017] The tubing abutment may be fixed with respect to the mast so that the movement of the reel to maintain the tubing pay-off point generally above the injector during pay-out of the tubing also positions the tubing pay-off point of the reel adjacent the tubing abutment so that the tubing engages with the tubing abutment. In this respect, this engagement with the tubing abutment places an opposite bend in the tubing during pay-out (such a bend being "opposite" to the bend in the tubing that already exists in the coiled tubing from it being coiled on the reel), which in the preferred form occurs before the tubing passes through the adjustable tubing straightener and the injector.

[0018] Still in relation to the first mode of operation, the application of this opposite bend to the tubing at a location closely adjacent to the tubing pay-off point has been found to minimise stress on the tubing (and thus increase the operational life of the tubing) while reasonably accurately aligning the tubing with the injector and, if present, the adjustable tubing straightener. Indeed, although an adjustable tubing straightener is required to be adjustable and is referred to as a straightener, in practice, because of the arrangement of the tubing abutment in the manner outlined above, it has been found that only minimal further stresses are added to the tubing if an adjustable tubing straightener is adopted, and which then tends to actually only require minimal adjusting and minimal straightening.

[0019] Additionally, the application of the opposite bend to the tubing at a location closely adjacent to the tubing pay-off point has been found to reduce any residual

plastic bend remaining in the tubing before entering the injector and the borehole, assisting in avoiding subsequent difficulties with the control and direction of the borehole.

[0020] In contrast to this engagement of the tubing with the tubing abutment during pay-out, during take-up of the tubing it is preferred to avoid such engagement by moving the reel away from the tubing abutment (and out of engagement with it) such that, as mentioned above, the take-on point is maintained generally above the injector at a point along the injector's operational axis. Additionally, the tubing is ideally not engaged by the adjustable straightener during take-up. In this way, no additional bend event occurs to the tubing during take-up (via either the adjustable straightener or the tubing abutment), other than the bending of the tubing that occurs as the tubing is re-coiled back on to the reel.

[0021] In one form, the tubing abutment may be an elongate abutment beam, fixed generally vertically to the mast with an upper end and a lower end, and with the upper end being the end located adjacent the tubing pay-off point of the reel during operation. In this form, the uncoiling tubing will engage with the upper end of the abutment beam and will ideally be guided along the abutment beam to the injector (or an adjustable straightener, if present) during pay-out of the tubing. Preferably, the elongate abutment beam will be a substantially straight and elongate abutment beam, having a channel therealong that is capable of receiving and guiding therealong tubing from the reel.

[0022] In relation to the second mode of operation, being a rotating drill string mode where the coiled tubing connects to the top swivel of the rotary drill head and moves no further than that, while pipe sections are connected to the bottom spindle of the rotary drill head forming therebelow a rotating drill string, the fluid communication provided between connected coiled tubing and connected pipe section during operation permits drilling fluid to be provided for drilling via the coiled tubing rather than having to provide alternative fluid handling equipment and an alternative fluid source. By pivotally mounting the rotary drill head on the injector, the rotary drill head may be moved out of the way of the coiled tubing during the first mode of operation and may be moved back into an operational position for this second mode of operation.

[0023] The pivotal mounting of the rotary drill head may be achieved by any suitable means, such as by the use of elongate arms mounted at one end to the injector for pivotal movement and at the other end to opposing sides of the rotary drill head, so as to swing the drill head into and out of position. The movement of the drill head into and out of position may also be achieved by any suitable means, such as by a hydraulic ram or the like.

[0024] The present invention thus also provides a method of operating a mobile, coiled tubing drilling apparatus with a rotary drill head, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector below a coiled tubing reel, the injector defining an operational axis for the coiled tubing, wherein the rotary drill head is pivotally mounted on the injector and is moved between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

[0025] The present invention thus also provides a method of operating a mobile, coiled tubing drilling apparatus, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector, a coiled tubing reel having a tubing pay-off point associated therewith, and a tubing control system between the reel and the injector, the injector defining an operational axis for the coiled tubing, wherein the reel is mounted for horizontal (x,y) movement and the tubing control system includes a tubing abutment adjacent the tubing pay-off point, the apparatus also including a rotary drill head pivotally mounted on the injector, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the method including:

maintaining the tubing pay-off point generally above the injector and adjacent to the tubing abutment during pay-out of the tubing by way of the horizontal (x,y) movement of the reel;

applying an opposite bend to the tubing during pay-out of the tubing by engagement of the tubing adjacent the pay-off point with the tubing abutment;

maintaining a tubing take-on point above the injector and away from the tubing abutment during take-up of the tubing by way of the horizontal (x,y) movement of the reel; and

moving the rotary drill head between a retracted position away from the operational axis and an operating position in line with the operational axis, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

[0026] In relation to the mobile platform and the requirement for the mast to be non-rotating, in a preferred form the mast is mounted on the mobile platform so as to be movable between an upright drilling position where the reel is above the injector, and a lowered transport position, and also so as to be non-rotatable.

[0027] In relation to the mast being mounted so as to be non-rotatable, some drilling rigs that utilise coiled tubing are designed to allow for the rotation of a reel about the vertical axis of the tubing down a borehole. Apparatus of that type has differing design requirements than apparatus of the type that the present invention relates to, being apparatus with non-rotating masts.

[0028] Further, the movability of the mast between an upright drilling position where the reel is above the injector, and a lowered transport position, assists with the mobility of the apparatus, allowing for transport to occur by road or by rail in traditional forms. Also, the mobility of the platform itself can of course be provided by any known and desirable means for movement on land, such as by a continuous track propulsion system or a traditional wheel-based propulsion system, while the ancillary drilling equipment that may additionally be provided on the mobile platform may include any of fluid pumps, air compressors, nitrogen purge systems, a diesel engine, hydraulic pumps and valves, and suitable control and operating systems, including remotely controlled systems as necessary.

[0029] In another preferred form, not only is the reel mounted on the mast for horizontal (x,y) movement during drilling, but the reel is preferably also mounted on the mast for vertical (z) movement. This vertical movement may be provided by the mast including, for example, a telescoping type of configuration.

[0030] Such vertical movement of the reel is advantageous in providing for relatively small vertical movement of a drill bit (for example), located at the bottom of the tubing in a borehole, into and out of contact with the bottom of the borehole, or simply for connecting the coiled tubing with the top swivel of the rotary drill head when transitioning from the first mode of operation to the second mode of operation. This is in preference to such movement having to be provided by rotating the reel, which, if avoided, can further reduce the stresses placed on the tubing, further increasing the operating life of the tubing.

[0031] Turning now to a description of the reel and its mounting, which is particularly relevant for the first mode of operation, as mentioned above the reel is mounted on the mast for horizontal (x,y) movement such that the tubing pay-off point can be maintained generally above the injector during pay-out and, preferably, directly above the injector during take-up of the tubing. In this respect, and identifying movement in the x direction as being movement of the reel towards and away from the mast, and movement in the y direction as being movement of the reel along its own longitudinal axis, the x direction movement is preferably provided by mounting the reel on the mast via pivoting arms that are controlled to pivot towards and away from the mast.

[0032] Such pivoting movement therefore moves the entire reel towards and away from the mast (as required, either before, during or after drilling) and thus towards and away from the tubing abutment mentioned above. Mounting the reel in this manner thus essentially provides for movement of the longitudinal axis of the reel towards and away from the tubing abutment, and of the coiled tubing on the reel towards and away from the tubing abutment, and thus of the pay-off point of the tubing towards and away from the tubing abutment. Indeed, during drilling, this movement permits the tubing at the pay-off point to be continually urged towards and against the tubing abutment as the tubing uncoils from the reel and as the diameter of the tubing coiled on the reel decreases.

[0033] The y direction movement is movement of the reel along its own longitudinal axis, again so as to maintain the pay-off point of the tubing adjacent to the tubing abutment as the tubing uncoils from the reel. In this respect, it will be appreciated that the pay-off point of the tubing will move along the longitudinal axis of

the reel as the reel rotates about its longitudinal axis and as the tubing uncoils. With the reel being adapted to provide for continual adjustability of the reel along its longitudinal axis, the reel can be moved in the y direction in response to the pay-off point moving in the y-direction, thus keeping the pay-off point adjacent to the tubing abutment as required, and also keeping the tubing at that point in engagement with the tubing abutment to apply the requisite opposite bend thereto.

Brief Description of Drawings

[0034] Having briefly described the general concepts involved with the present invention, a preferred embodiment of a mobile coiled tubing drilling apparatus will now be described that is in accordance with the present invention. However, it is to be understood that the following description is not to limit the generality of the above description.

[0035] In the drawings:

[0036] Figure 1 is a perspective view from above of a mobile, coiled tubing drilling apparatus in accordance with a preferred embodiment of the present invention, deployed in its drilling position;

[0037] Figure 2 is a side view of the apparatus of Figure 1 in a transport position;

[0038] Figures 3(a) and 3(b) are schematic side views of the mast and reel of the apparatus of Figure 1 when in tubing pay-out mode (Figure 3(a)) and tubing take-up mode (Figure 3(b));

[0039] Figures 4(a) and 4(b) are schematic top views of a preferred reel mounting configuration for use with the apparatus of Figure 1 when in tubing pay-out mode (Figure 3(a));

[0040] Figures 5(a) and 5(b) are perspective and side views of an embodiment of a rotary drill head pivotally mounted on an injector, being suitable for use with the apparatus of Figures 1 to 4, showing the rotary drill head in its retracted position away from the operational axis (in the first mode of operation for the drilling apparatus);

[0041] Figure 6 is a perspective view similar to Figure 5(a) but showing the rotary drill head in its operating position in line with the operational axis (in the second mode of operation for the drilling apparatus); and

[0042] Figure 7 is a section view through the rotary drill head of Figure 5(a).

Detailed Description

[0043] Illustrated in Figure 1 is a mobile, coiled tubing drilling apparatus 10 in its upright drilling position, while Figure 2 shows the same apparatus 10 in its lowered transport position. The apparatus 10 generally includes a mast 12 mounted on a mobile platform 14 in a manner such that the mast is not rotatable about a vertical axis when in its upright drilling position. The apparatus also includes a coiled tubing reel 16, an injector 18 (with injector guide rollers 19) and a tubing control system in the form of an elongate tubing abutment 20. As will be better understood from the following description, point A in Figure 1 is a point on the reel and is the general location of both a tubing pay-off point and a tubing take-up point (referred to later as A').

[0044] The vertical axis mentioned above is designated in Figure 1 as the z axis in the identified x-y-z coordinate system, with the x axis (or x direction) being the direction of movement for the tubing pay-off point A (and thus also the reel 16) towards and away from the tubing abutment 20. The y axis (or y direction) is then the direction of movement for the tubing pay-off point A (and again also the reel 16) along the longitudinal axis of the reel 16. It will be appreciated that references to pay-off and take-up of the tubing are references to the first mode of operation of the apparatus, utilising the coiled tubing as the primary drilling means.

[0045] The mobility of the platform 14 is provided in this embodiment by a continuous track propulsion system 15, while much of the ancillary drilling equipment provided on the mobile platform (such as fluid pumps, air compressors, nitrogen purge systems, a diesel engine, hydraulic pumps and valves, and suitable control and operating systems) have been omitted from Figure 1 and Figure 2 for ease of illustration. Additionally, in this embodiment, the reel 16 is mounted on the mast 12 for vertical (z) movement by way of the mast 12 having a telescoping configuration (not shown).

[0046] As mentioned above, such vertical movement of the reel 16 is advantageous in providing for relatively small vertical movement of a drill bit (for example), located at the bottom of the tubing in a borehole, into and out of contact with the bottom of the borehole. This is in preference to such movement having to be provided by rotating the reel 16 to raise or lower the drill bit, which, if avoided, can further reduce the stresses placed on the tubing, further increasing the operating life of the tubing.

[0047] The mast 12 of the apparatus 10 also includes, below the injector 18, a pivotally mounted, retractable, rotary drill head 22 (only partly shown) that can be used for drilling with a conventional rotating drill string in a second mode of operation. In this second mode, the apparatus 10 can be used to install casing or the like to the borehole, or to connect and disconnect the different elements of a bottomhole assembly, or simply to drill with a rotating drill string, using fluid provided through the coiled tubing, which will be described in more detail below with reference to Figures 5(a), 5(b), 6 and 7.

[0048] Referring now to Figures 3a and 3b, the reel 16 can be seen mounted for horizontal (x,y) movement, with the x direction being left-right across the page and the y direction being into and out of the page, such that, during pay-out of the tubing 30, the tubing pay-off point A can be maintained generally above the injector 18 but away from the injector's operational axis, the operational axis being defined by the pathway through the injector 18 of the longitudinal axis of the tubing 30 therein.

[0049] In this embodiment, the tubing control system of the apparatus 10 also includes an adjustable tubing straightener 32 after the tubing abutment 20 and before the injector 18, the tubing straightener 32 being adjustable such that it can engage tubing 30 entering or exiting the injector 18 and be utilised to provide more or less (or no) force to tubing 30 entering or exiting the injector 18. In this embodiment, the adjustable tubing straightener 32 is shown in Figure 3(a) as being in engagement with the tubing 30 entering the injector 18 (during pay-out), but in Figure 3(b) is shown not engaging with the tubing 30 exiting the injector 18 (during take-up), for reasons that will be outlined below. The adjustable straightener 32 is a single hydraulic powered roller configured to engage with tubing against a fixed abutment.

[0050] The tubing abutment 20 is shown fixed with respect to the mast 12 so that the movement of the reel 16 to maintain the tubing 30 pay-off point A generally above the injector 18 during pay-out of the tubing 30 also positions the tubing pay-off point A adjacent the tubing abutment 20 so that the tubing 30 engages with the tubing abutment 20. As mentioned above, this engagement with the tubing abutment 20 places an opposite bend in the tubing 30 during pay-out (such a bend being "opposite" to the bend in the tubing 30 that already exists in the coiled tubing from it being coiled on the reel 16), which in this embodiment occurs before the tubing 30 passes through the adjustable tubing straightener 32 and the injector 18.

[0051] The tubing abutment 20 is an elongate abutment beam, fixed generally vertically to the mast 12 with an upper end 20a and a lower end 20b, and with the upper end 20a being the end located above the tubing pay-off point A of the reel 16 during operation. The uncoiling tubing 30 engages with the abutment beam and is guided along the abutment beam to the adjustable straightener 32 and then to the injector 18 during pay-out of the tubing 30. The elongate abutment beam is substantially straight and elongate, and has a channel 36 therealong that is capable of receiving and guiding therealong tubing 30 from the reel 16.

[0052] As mentioned above, the application of this opposite bend to the tubing 30 at a location closely adjacent to the tubing pay-off point A has been found to minimise stress on the tubing 30 (and thus increase the operational life of the tubing 30) while reasonably accurately aligning the tubing 30 with the adjustable tubing straightener 32 and the injector 18. The application of the opposite bend has also been found to reduce any residual plastic bend remaining in the tubing 30 before entering the borehole, assisting in avoiding subsequent difficulties with the control and direction of the borehole.

[0053] In contrast, and referring to Figure 3b which shows the re-coiling of the tubing 30 when the tubing 30 is being withdrawn from the borehole (not shown), the tubing 30 entering the injector 18 from below has of course already been straightened, and thus is not subjected to the same existing bend that is present with coiled tubing 30 being uncoiled (Figure 3(a)). In this phase, the tubing abutment 20 is not utilised by the apparatus 10 during tubing take-up, and a tubing take-on point A' (being essentially the same point during re-coiling as the tubing pay-off point A during

uncoiling) is made as close as operationally possible to a point along the injector's operational axis, and thus will be directly above the injector 18.

[0054] With reference to Figure 4(a) and 4(b), as mentioned above the reel 16 is mounted on the mast 12 for horizontal (x,y) movement such that the tubing pay-off point A can be maintained generally above the injector 18 during pay-out of the tubing 30 and such that the tubing take-on point A' can be maintained directly above the injector 18 during take-up of the tubing 30.

[0055] In this respect, and identifying movement in the x direction as being movement of the reel towards and away from the mast 12 (left and right on the page), and movement in the y direction as being movement of the reel 16 along its own longitudinal axis (axis Y-Y in Figures 4(a) and 4(b)), the x direction movement is provided by mounting the reel 16 on the mast 12 via pivoting arms 40 that are controlled to pivot towards and away from the mast 12.

[0056] Such pivoting movement therefore moves the entire reel 16 towards and away from the mast 12 (as required, either before, during or after drilling) and thus towards and away from the tubing abutment 20. Mounting the reel 16 in this manner provides for movement of the longitudinal axis Y-Y of the reel 16 towards and away from the tubing abutment 20, and of the coiled tubing 30a,30b on the reel 16 towards and away from the tubing abutment 20, and thus of the pay-off point A of the tubing towards and away from the tubing abutment 20.

[0057] Indeed, during drilling, this movement permits the tubing 30a,30b at the pay-off point A to be continually urged towards and against the tubing abutment 20 as the tubing 30a,30b uncoils from the reel 16 and as the diameter of the tubing 30a,30b coiled on the reel 16 decreases, as is shown from Figure 4(a) where the reel 16 is full of tubing 30a through to Figure 4(b) where the tubing 30b is almost entirely unwound from the reel 16.

[0058] In this respect, it will be appreciated that the pay-off point A of the tubing 30a,30b will move along the longitudinal axis Y-Y of the reel 16 as the reel rotates about its longitudinal axis Y-Y and as the tubing 30a,30b uncoils. With the reel 16 being adapted to provide for continual adjustability of the reel 16 along its longitudinal axis Y-Y, the reel can be moved in the y direction in response to the pay-off point A

moving in the y-direction, thus keeping the pay-off point A adjacent to the tubing abutment 20 as required, and also keeping the tubing 30a,30b at that point in engagement with the tubing abutment 20 to apply the requisite opposite bend thereto.

[0059] Figures 5(a), 5(b), 6 and 7 illustrate an embodiment of a rotary drill head 22 pivotally mounted on an injector 18, being suitable for use with the apparatus of Figures 1 to 4, showing the rotary drill head in its retracted position (Figures 5(a) and 5(b)) away from the operational axis (in the first mode of operation for the drilling apparatus, as described above) and in its operating position (Figures 6 and 7) in line with the operational axis (in the second mode of operation for the drilling apparatus, as will now be described).

[0060] Figure 5(a) illustrates the use of elongate arms 50 mounted at one end 52 to the injector 18 for pivotal movement and at the other end 54 to opposing sides of the rotary drill head 22, so as to allow movement of the drill head 22 between the retracted position of Figures 5(a) and 5(b) and the operating position of Figure 6.

[0061] Figure 5(b) also shows that movement of the drill head 22 between the retracted position and the operating position is achieved by a hydraulic ram 56 mounted between the injector 18 and the drill head 22.

[0062] The second mode of operation illustrated in Figures 6 and 7 is a rotating drill string mode where the coiled tubing 30c connects to a top swivel 60 of the rotary drill head 22 and moves no further than that, while pipe sections (not shown) are connected to a bottom spindle 62 of the drill head 22 forming therebelow a rotating drill string. In this respect, the swivel 60 is fixed and does not itself rotate, with the bottom portion thereof being received within the upper portion 63 of the main shaft 64 in a manner that permits the swivel 60 to move axially within the upper portion 63 and the main shaft 64 to rotate relatively to the swivel 60, while maintaining a suitable fluid/air seal therebetween.

[0063] Of course, the main shaft 64 is powered by hydraulic motors 65 connected thereto via gears, providing rotation for the bottom spindle 62. The main shaft 64 can be floating to allow for axial movement thereof while, for example, drill rods are being threaded onto the spindle 62.

[0064] Fluid communication is provided between the connected coiled tubing 30 and the connected pipe sections (not shown) during operation to permit drilling fluid to be provided for drilling via the coiled tubing 30, through the bore of the top swivel 60, through the hollow drive shaft 64, and through the bore of the bottom spindle 62, there thus being no need to provide alternative fluid handling equipment or an alternative fluid source. By pivotally mounting the rotary drill head 22 on the injector 18, the rotary drill head 22 may be moved out of the way of the coiled tubing 30 during the first mode of operation and may be moved back into an operational position for this second mode of operation.

[0065] Finally, there may be other variations and modifications made to the configurations described herein that are also within the scope of the present invention.

The claims are:

1. A mobile, coiled tubing drilling apparatus with a rotary drill head, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector below a coiled tubing reel, the injector defining an operational axis for the coiled tubing, wherein the rotary drill head is pivotally mounted on the injector so as to be movable between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.
2. Apparatus according to claim 1, including elongate arms mounted at one end to the injector for pivotal movement and at the other end to opposing sides of the rotary drill head, so as to allow movement of the drill head between the retracted position and the operating position.
3. Apparatus according to claim 1 or claim 2, wherein movement of the drill head between the retracted position and the operating position is achieved by a hydraulic ram mounted between the injector and the drill head.
4. Apparatus according to any one of claims 1 to 3, wherein the top swivel is fixed with a bottom portion thereof received within an upper portion of a main shaft in a manner that permits the swivel to move axially within the upper portion and the main shaft to rotate relatively to the swivel.
5. Apparatus according to claim 4, wherein the main shaft is floating to allow for axial movement thereof while pipe section is connected to the bottom spindle.
6. Apparatus according to any one of claims 1 to 5, the coiled tubing reel having a tubing pay-off point associated therewith, and a tubing control system, wherein:
the tubing control system is between the reel and the injector, and includes a tubing abutment adjacent the tubing pay-off point for applying an opposite bend to the tubing during pay-out of the tubing; and

the reel is mounted for horizontal (x,y) movement such that, during pay-out of the tubing, the tubing pay-off point can be maintained generally above the injector, and can also be moved towards or away from the tubing abutment.

7. Apparatus according to any one of claims 1 to 6, wherein the reel is mounted for horizontal (x,y) movement such that, during pay-out of the tubing, the tubing pay-off point can be maintained generally above the injector but away from the injector's operational axis.
8. Apparatus according to claim 7, wherein the reel is mounted for horizontal (x,y) movement such that, during take-up of the tubing, the tubing take-on point can be maintained directly above the injector at a point along the injector's operational axis.
9. Apparatus according to any one of claims 1 to 8, wherein the tubing control system also includes an adjustable tubing straightener after the tubing abutment and before the injector.
10. A method of operating a mobile, coiled tubing drilling apparatus with a rotary drill head, the apparatus including a non-rotating mast on a mobile platform, the mast having mounted thereon an injector below a coiled tubing reel, the injector defining an operational axis for the coiled tubing, wherein the rotary drill head is pivotally mounted on the injector and is moved between a retracted position away from the operational axis and an operating position in line with the operational axis, the rotary drill head including a top swivel for non-rotating connection to the coiled tubing and a bottom spindle for rotating connection to a pipe section, the top swivel and the bottom spindle providing fluid communication between connected coiled tubing and connected pipe section during operation.

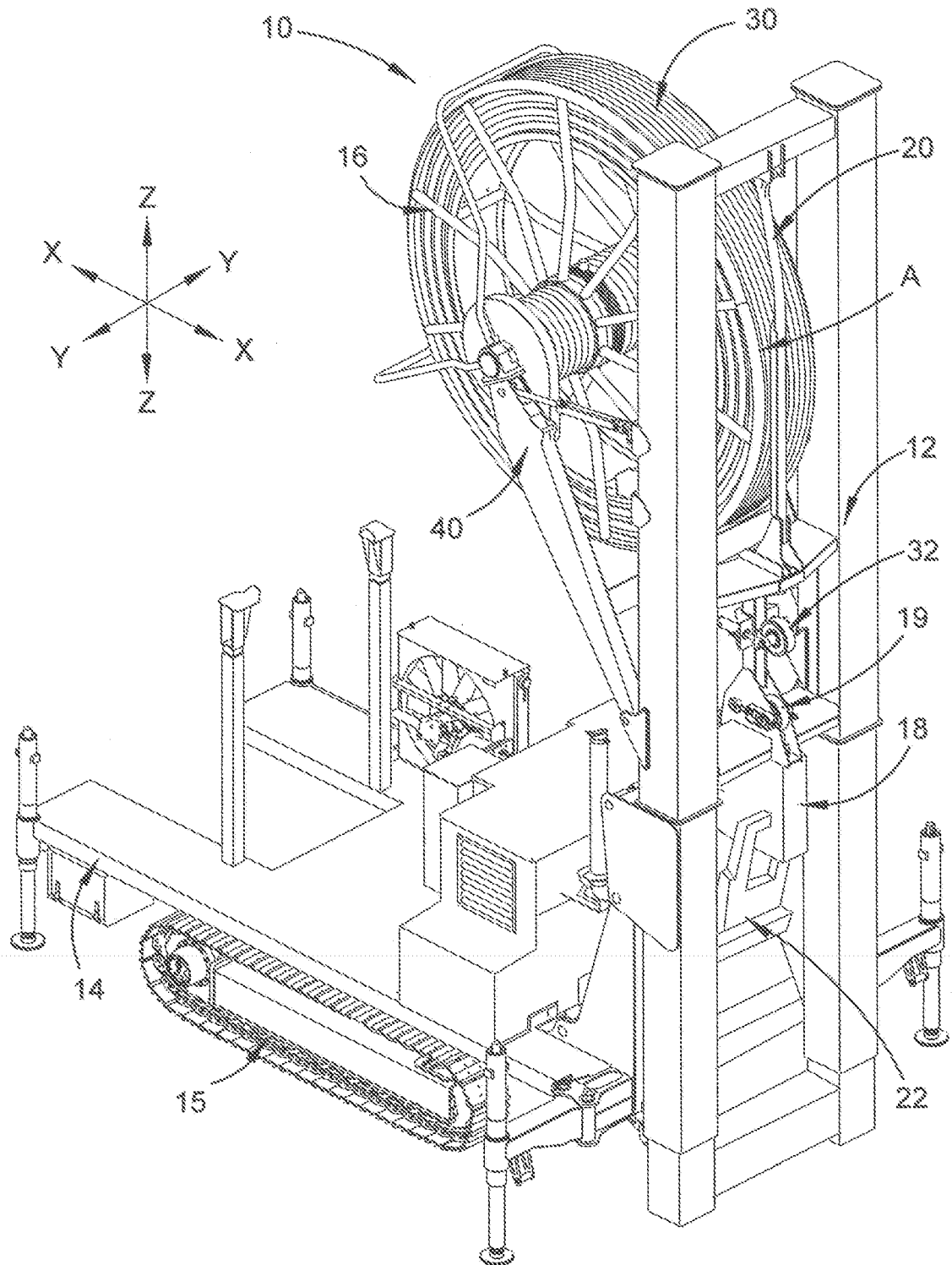
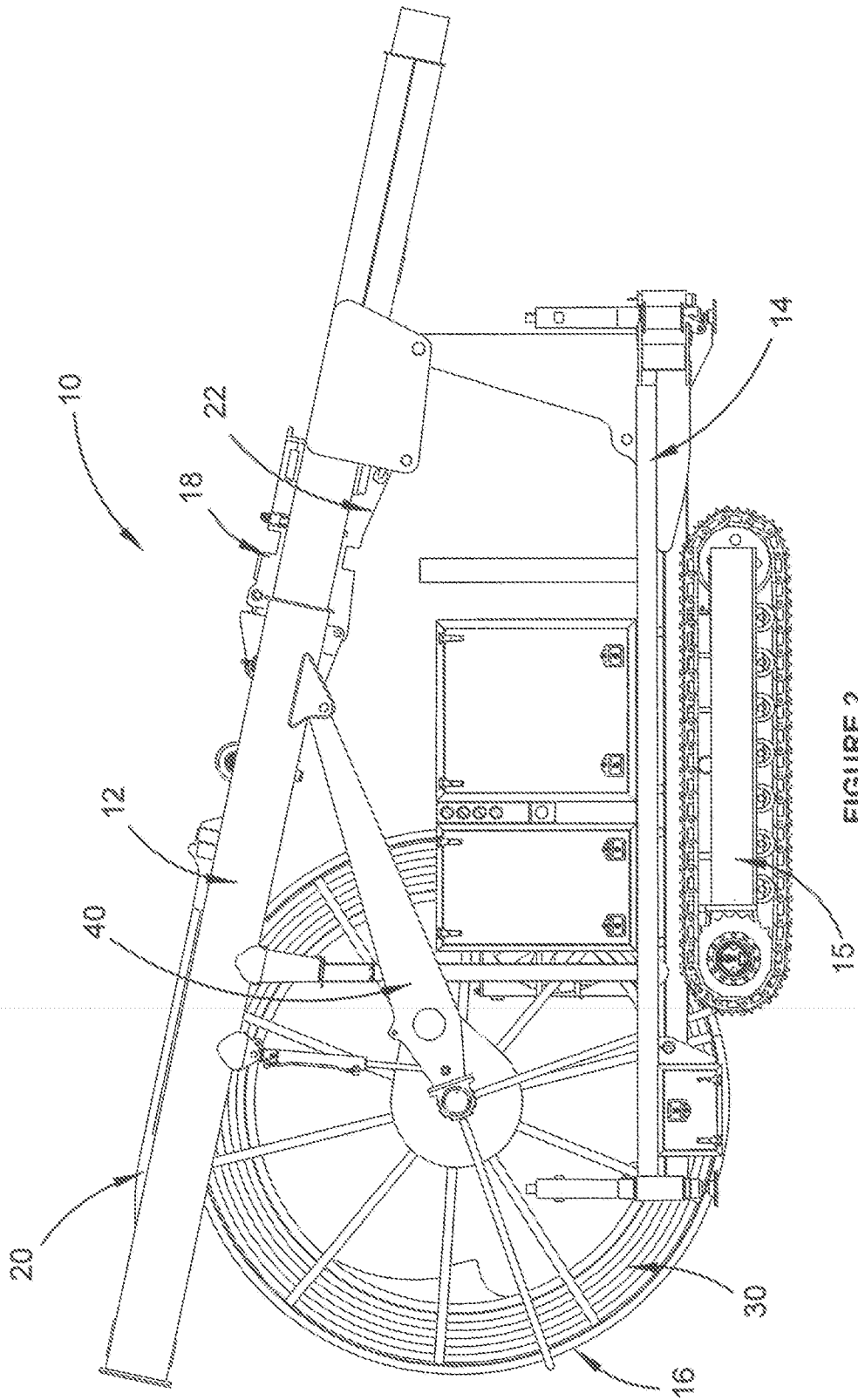


FIGURE 1



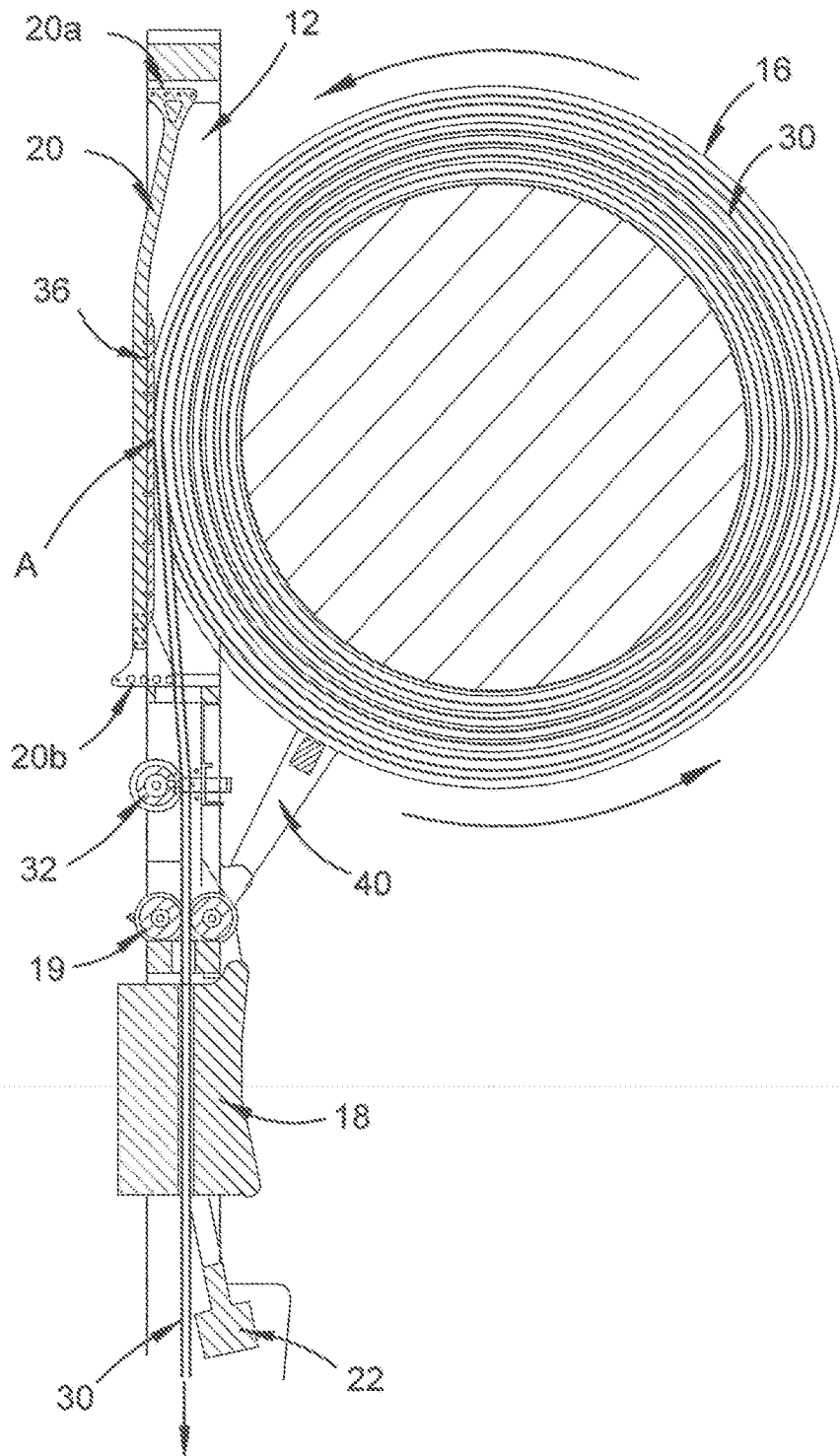


FIGURE 3(a)

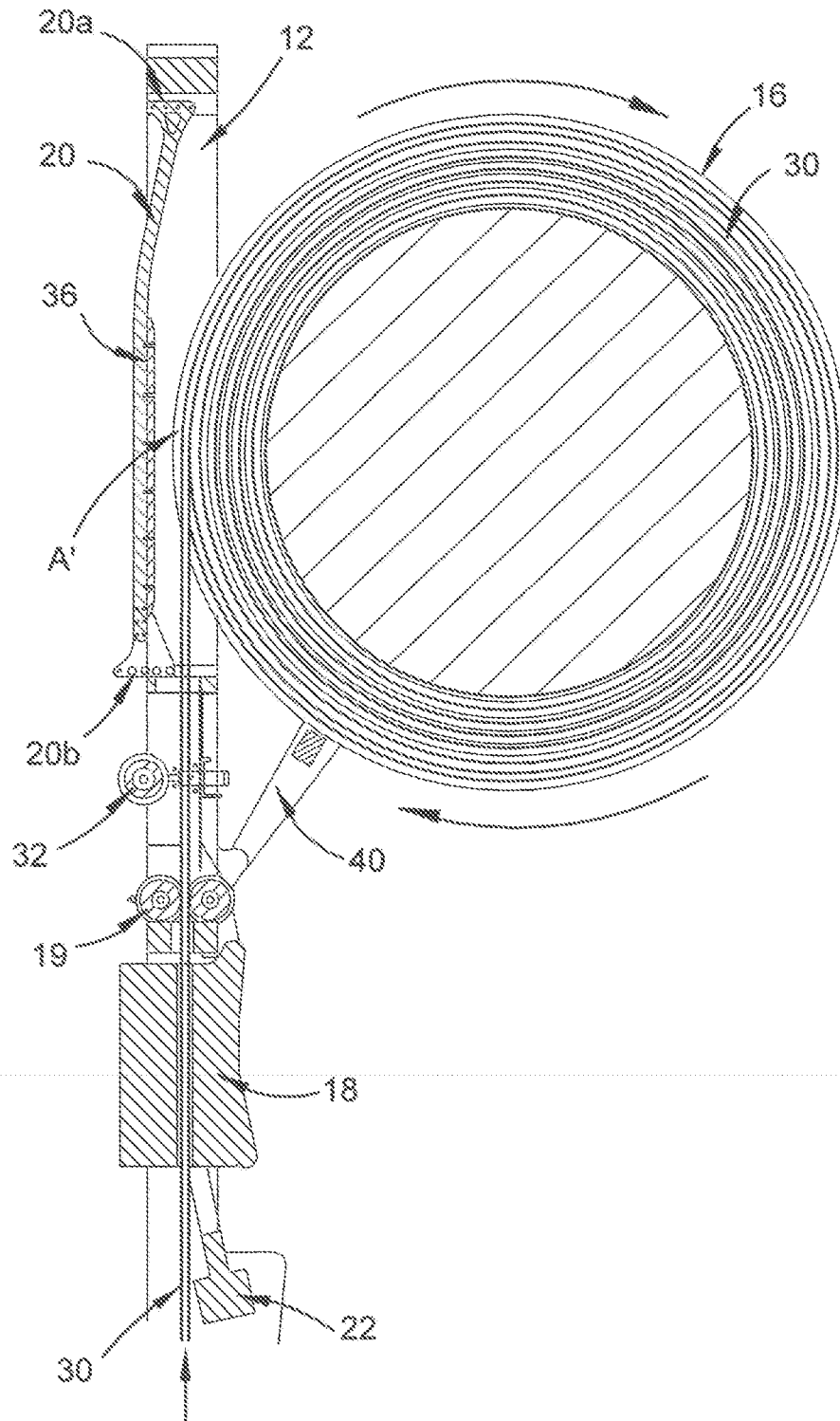
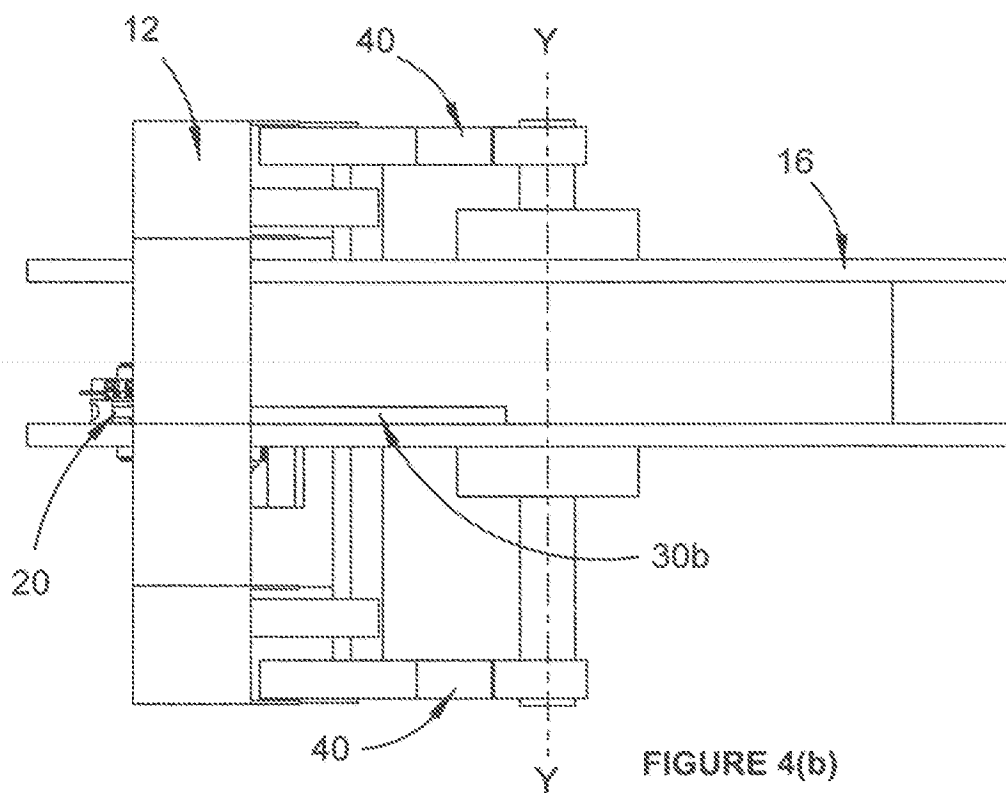
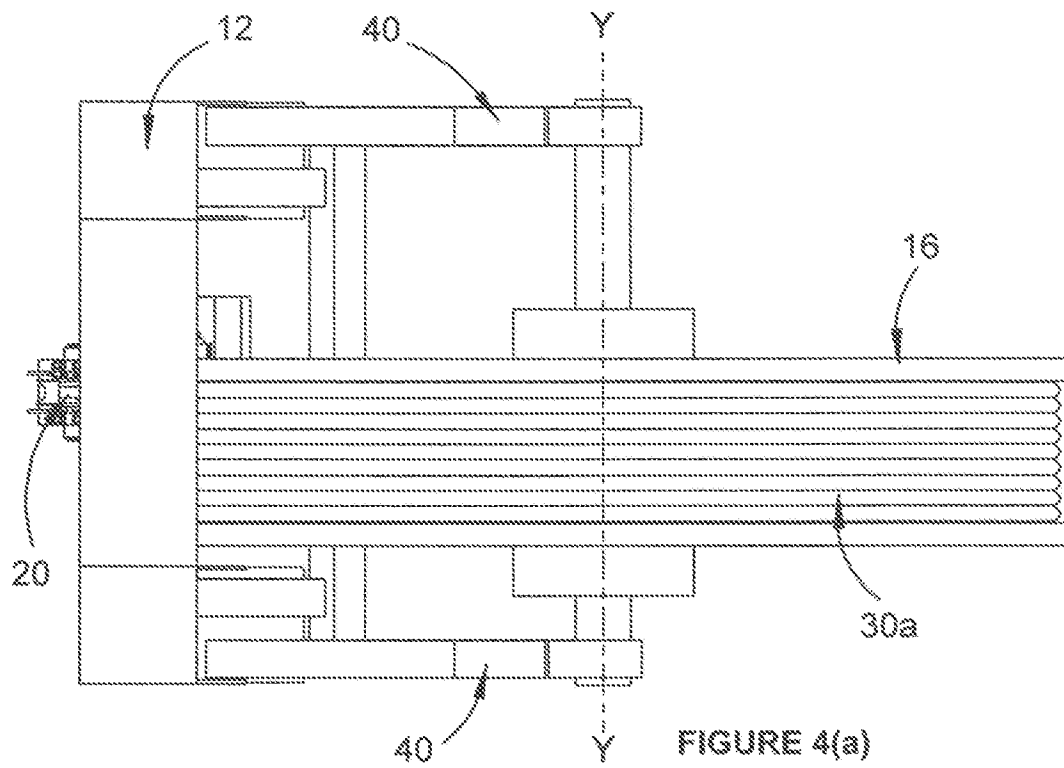


FIGURE 3(b)



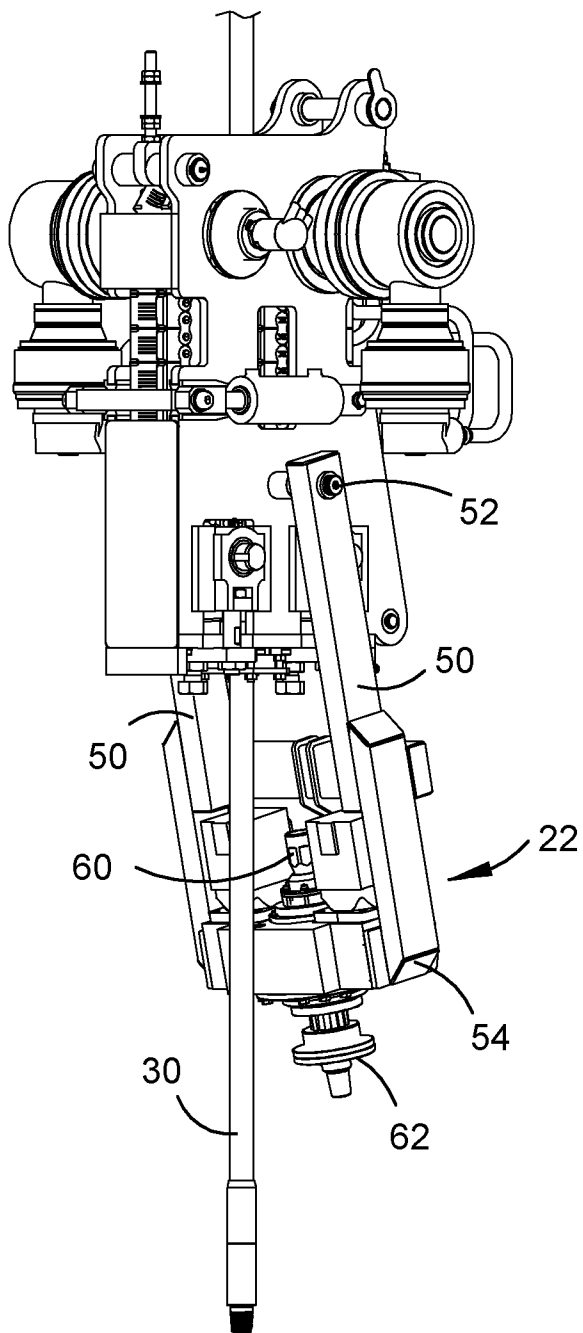


Figure 5(a)

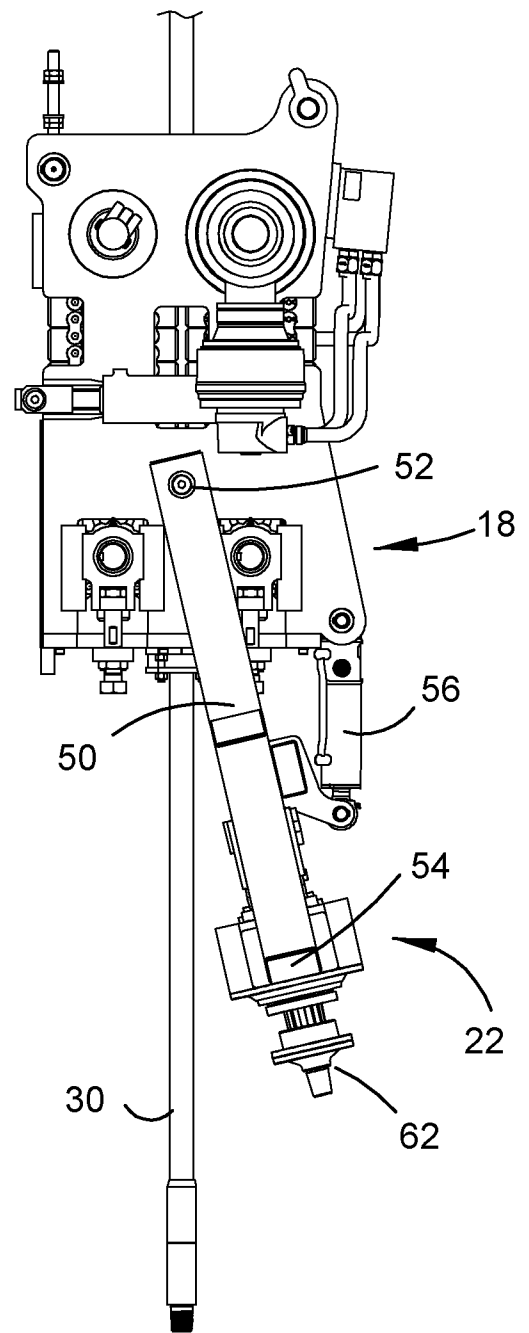


Figure 5(b)

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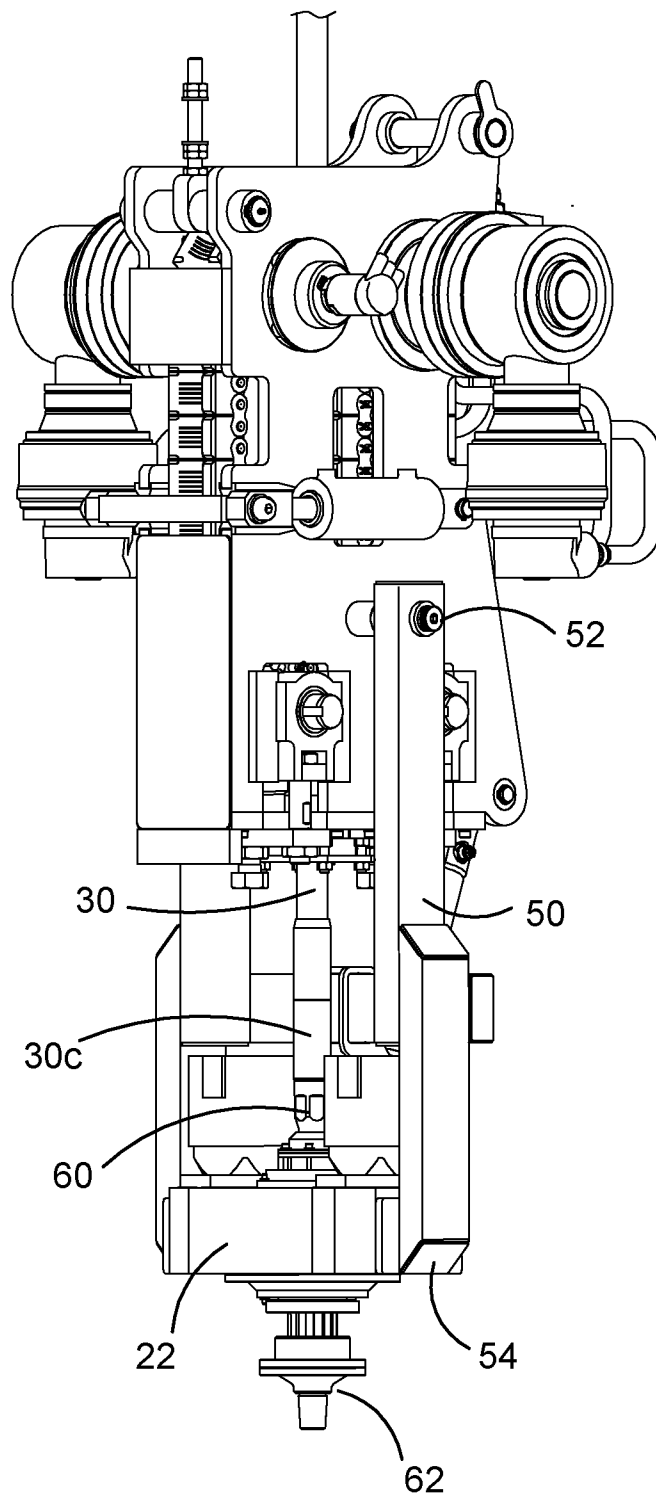


Figure 6

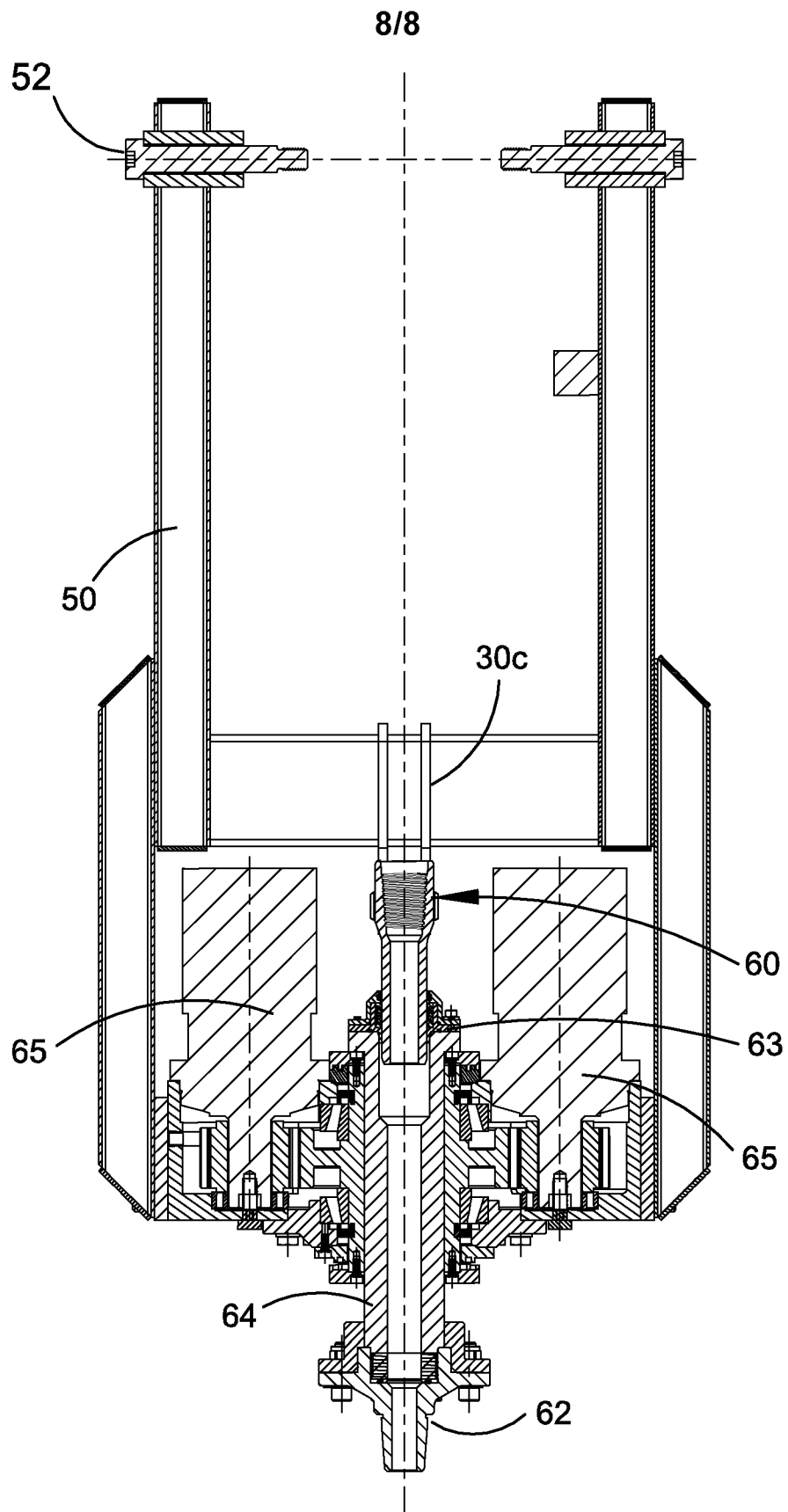


Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2017/051098

A. CLASSIFICATION OF SUBJECT MATTER

E21B 19/22 (2006.01) E21B 1/02 (2006.01) E21B 3/02 (2006.01) E21B 15/00 (2006.01) E21B 7/02 (2006.01)
E21B 17/20 (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)

DATABASES: PATENW; IPC/C/CNO/LOW: E21b19/22, e21b1/02, e21b3/02, e21b15/[003,04], e21b7/02, e21b17/20, E21B;
Keywords: Drill, Rotat, Head, Bit, Pivot, Swing, Move, Moveable, Un-retract, Withdraw, Condition, Position, Coiled, Tubing, Inject, Feed, Lower, Rais and similar keywords.

ESPACENET AND AUSPAT: Applicant/Inventor name searched; Viewed cited/citing of relevant documents.

Google patents: Pivot drill head; Rotary drill head, pivot, injector; Pivotal rotary drill head

Applicant(s)/Inventor(s) name searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 6 December 2017		Date of mailing of the international search report 06 December 2017	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Victor Maluki AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262256112	

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2017/051098
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2011/097380 A1 (1461160 ALBERTA LTD.) 11 August 2011 Entire document	1 - 10
A	US 5360075 A (GRAY) 01 November 1994 Entire document	1 -10
A	US 2007/0125551 A1 (HAVINGA) 07 June 2007 Entire document	1 -10
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A	US 2848196 A (W.W.SIMMONDS) 19 August 1958 Entire document	1 - 10

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INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2017/051098	
This Annex lists known 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/s Cited in Search Report		Patent Family Member/s	
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		US 7513312 B2	07 Apr 2009
US 2848196 A	19 August 1958	US 2848196 A	19 Aug 1958
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			