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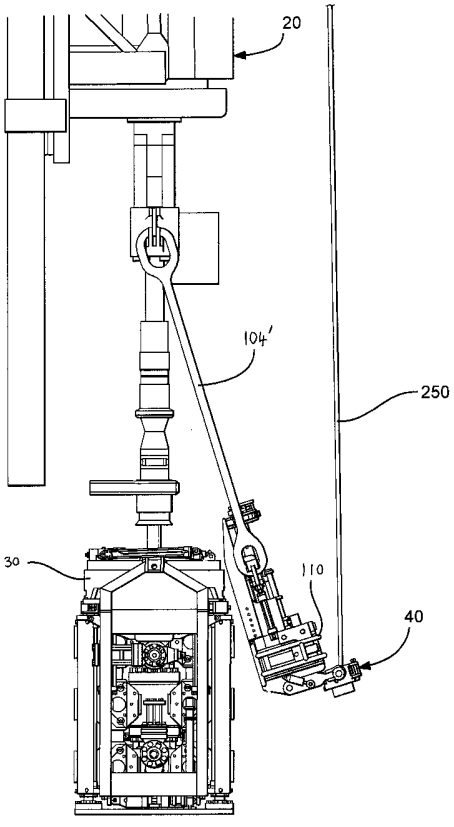
(54) Title: TOP DRIVE UNIT, PIPE GRIPPING DEVICE AND METHOD OF DRILLING A WELLBORE



(57) Abstract: A top drive unit comprising a top drive (20) and a pipe gripping device (50; 110) connectable beneath said top drive (20) , the arrangement being such that, in use, whilst a pipe is connected to said top drive (20) said pipe gripping device (50; 110) is moveable between a first position in which said pipe is accommodated within said pipe gripping device (50; 110) and a second position in which said pipe is not accommodated within said pipe gripping device (50; 110).

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TOP DRIVE UNIT, PIPE GRIPPING DEVICE AND METHOD OF DRILLING A WELLBORE

The present invention relates to a top drive unit, to a pipe gripping device for use with a top drive and to a method of drilling a wellbore.

In the construction of an oil or gas well, a borehole (or wellbore as it is sometimes known in the art) is drilled into the earth. A drill bit is arranged on the end of a drill string and is rotated to bore the borehole. A drilling fluid known as "drilling mud" is pumped through the drill string to the drill bit to *inter alia* lubricate and cool the drill bit. The drilling mud is also used to carry the cuttings produced by the drill bit and other solids to the surface through an annulus formed between the drill string and the borehole and/or casing lining the borehole.

In one prior art method a kelly bar, connected to a top joint of the drill string, is used to rotate the drill string. A rotary table at the derrick floor level rotates the kelly bar while simultaneously the kelly bar can move vertically through a drive bushing within the rotary table at the rig floor as the borehole deepens. In another prior art method, a top drive drilling unit suspended in a derrick grips and rotates the drill string and a kelly bar is not used.

As the borehole deepens further sections of drill pipe (usually "stands" each comprising two or three lengths of drill pipe) must be added to the top of a drill string in order to bore deeper; to add each stand (or a single length of drill pipe) drilling is halted to prevent *inter alia* spillage of drilling fluid. The process of adding drill pipe to a drill string, and particularly the step of applying the final torque to a

new joint, has often been called "making up". Similarly to remove drill pipe from the string, to "trip out" of a hole, (e.g. to replace a drill bit or to cement a section of casing), the process is reversed, and each stand of drill pipe must be unscrewed from the drill string and from the top drive; this can also require stopping circulation of drilling fluid while each stand (or singly length of drill pipe) is removed. The process of removing drill pipe from a drill string, and particularly the step of applying torque to undo a joint, has often been called "breaking-out". Re-instituting the flow of drilling fluid and reconstituting the required column of it in the wellbore can take a significant amount of time, and the effects of removing and then reintroducing the drilling fluid into the wellbore can have harmful effects on equipment, on the wellbore and on the formation being drilled. In such circumstances, expensive and time-consuming of additional fluid weighting may be required.

It is often preferable to maintain drilled cuttings in suspension in the drilling fluid to facilitate moving them away from a drill bit and to prevent them from falling back down in a wellbore. Cessation of fluid circulation can cause the drilled cuttings to sink. To counter this in many prior art systems additional fluid weighting is attempted, often increasing the viscosity of the fluid. This results in the need for more pumping power at the surface to move the thicker fluid; but such an increase in pump force can result in over pressuring of a downhole which can cause formation damage or loss of fluids downhole.

It is a clear that the process of drilling (both tripping into and out of the borehole) is interrupted frequently. This is highly undesirable since *inter alia*

average penetration rates are reduced.

To address this problem a continuous circulation system (CCS) has been developed and is disclosed in WO 98/16716. The CCS allows circulation of drilling mud to be carried out throughout the making-up and breaking-out of pipe to and from a pipe string. WO 98/16716 discloses, *inter alia* the use of an upper set of pipe rams to apply and seal about part of a single length or stand of pipe to be connected to the string, a lower set of pipe rams to apply and seal about part of the pipe at the top of the string in the well to create a chamber therebetween and a blind ram to divide the chamber between the end pin of the pipe to be connected and the box of the pipe at the top of the string, to form upper and lower chambers. A drilling mud inlet is arranged in the lower chamber between the blind ram and the lower set of pipe rams and a drilling mud supply is also provided at the top end of the pipe to be connected.

To make a connection, the lower set of pipe rams is activated to seal about the top end of the string of pipe in the wellbore and the blind rams are activated to form the lower chamber about the top of the drill string. Drilling mud is allowed to flow into the lower chamber and circulate into the top of the drill string. The drilling mud passes through the drill string to the drill bit and returns through an annulus formed by the drill string and the borehole in the normal way. Meanwhile, a single or stand of pipe is lowered into the top of the continuous circulation system. The upper set of pipe rams is activated to seal about the pipe. The upper end of the single length or stand of pipe is attached to the supply of drilling mud and drilling mud flows into the upper chamber following actuation of a valve. The pressures in

the upper and lower chambers are now substantially equal. The blind ram is opened and the pin end of the single or stand of pipe is stabbed into the box in the top end of the string of pipe and spun and torqued to make the connection. The drilling mud in the chamber may be drained and the upper and lower pipe rams opened to allow the pipe string with the added single or stand of pipe to be lowered into the well. Thus circulation is continuous through the pipe string and annulus whilst the connection is made and broken. This is a substantial improvement over the traditional drilling method.

Various improvements to the continuous circulation system have been made, including conducting continuous drilling whilst the single or stand of pipe is connected or disconnected from the string. The CCS is useful for drilling with drill pipe or when drilling with casing, for example.

The CCS can be used in reverse i.e. to remove stands of pipe when whilst continuously circulating drilling fluid. Removal of stands or individual lengths of pipe may take place for example when tripping out of the hole or during a backreaming operation for example. Backreaming may be desirable to smooth out the hole by removing keyseats.

To maintain continuous circulation of drilling fluid while tripping out it is necessary for the saver sub to be connected to the top of the drill string in the CCS unit. After connection drilling fluid is supplied through the top drive as described above. It is then necessary to raise the drill string above the CCS unit by approximately one, two or three joints of pipe (i.e. about 9.1m, 18.3m, and 27.5m respectively), depending on the number of lengths of pipe to be removed from the

string. The CCS unit is then able to disconnect the stand from the drill string at the appropriate point whilst maintaining flow of drilling fluid. The top drive is then relieved of the duty of supplying drilling fluid. However, the stand of drill pipe remains attached to the saver sub and must be removed before the top drive can be lowered back to the CCS unit to remove the next stand.

US-A-4 449 596 discloses a torque wrench suspended below a top drive for breaking a joint between a saver sub and a drill string. The torque wrench comprises an upper section having a circular series of parallel splines for engagement with corresponding splines on the saver sub, and a lower section comprising two jaws, one of which is moveable radially by a piston to engage the drill string. In use, the torque wrench is moveable axially along the drill string to bring the splines of the upper section partly into engagement with the splines of the saver sub. The piston in the lower section is actuated to move the jaw into engagement with the drill string. A pair of pistons, each connected to the upper and lower sections is then actuated to apply relative rotational movement between the upper and lower sections to break the joint. After this the saver sub can be spun out from the drill string with the top drive.

The drill string in US-A-4 449 596 can only be brought into the torque wrench and attached to the saver sub by axial movement along the drill string. Accordingly when a new stand of pipe is attached and drilling continues, the downward movement of the top drive is limited by the torque wrench below. Since the aforementioned CCS unit is situated between the rig floor and the top drive, this also limits the amount of downward movement of the top drive whilst drilling. With

more apparatus being used during drilling between the top drive and the rig floor there is a need for a device that permits a stand of drill pipe to be removed quickly from a top drive whilst the top drive is positioned some distance above the rig floor, but which device does not limit downward movement of the top drive whilst drilling and/or whilst attaching the top drive to the top of the drill string when tripping out of the well.

According to the present invention there is provided a top drive unit comprising a top drive and a pipe gripping device connectable beneath said top drive, the arrangement being such that, in use, whilst a pipe is connected to said top drive said pipe gripping device is moveable between a first position in which said pipe is accommodated within said pipe gripping device and a second position in which said pipe is not accommodated within said pipe gripping device. Preferably, the pipe is connected to a short length of pipe, also known in the art as a "saver sub", that is disposed between the top drive and the drill string. The saver sub, although expendable and therefore replaceable, is often considered as part of the top drive.

Preferably, said pipe gripping device permits movement having a component of direction substantially radially toward/away from a longitudinal axis of said pipe.

Advantageously, said top drive unit further comprises a pivot mechanism for pivoting said pipe gripping mechanism between said first and second positions.

Preferably, in use said pivot mechanism provides a pivoting action in a plane substantially parallel with a longitudinal axis of said pipe.

Advantageously, in use said pivot mechanism provides a pivoting action in a plane substantially perpendicular with a longitudinal axis of said pipe.

Preferably said pipe gripping device further comprises an open throat for permitting said movement.

Advantageously, said pipe gripping device comprises a body having first and second parts each part comprising an opening defining said open throat, wherein in use said first part provides a locking function in which rotation of said body relative to said top drive is inhibited, and said second part provides a rotating function relative to said body or making/breaking connections between pipes.

Preferably, said pipe gripping device comprises a body, a first jaw movably connected to the body, a second jaw movably connected to the body.

Advantageously, said first jaw and said second jaw are arranged for pivoting movement around two common axes, pivoting around a first common axis for clamping and releasing said pipe, and pivoting around a second common axis for rotating said pipe to make/break a connection with another pipe.

Preferably, said pipe gripping device further comprises an actuation device for both moving said first and second jaws to clamp and release said pipe, and for making/breaking a connection with another pipe.

Advantageously, said first jaw and said second jaw are pivotably connected to one another.

Preferably, said first jaw is connected to the second jaw so that the first jaw and the second jaw move together.

Advantageously, said pipe gripping device further comprises:

a first piston/cylinder device movably

interconnected with said first jaw,

a second piston/cylinder device movably interconnected with said second jaw,

the first piston/cylinder device for moving the first jaw to clamp a pipe and the second piston/cylinder device for moving the second jaw to clamp the pipe, and both the first piston/cylinder device and the second piston/cylinder device for rotating the pipe.

Preferably, said first piston/cylinder device is disposed for and is operable for moving said first jaw in a first direction with respect to the pipe to locate said first jaw with respect to the pipe, and said first piston/cylinder device is disposed for and operable for then moving said first jaw in a second direction opposite to the first direction for clamping the pipe with the first jaw.

Advantageously, said second piston/cylinder device is disposed for and is operable for moving said first jaw in the second direction with respect to the pipe to locate said second jaw with respect to the pipe, and the second piston/cylinder device is disposed for and operable for then moving said second jaw generally in the first direction for clamping the pipe with the second jaw.

Preferably, said first piston/cylinder device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the first jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and another tubular member, and

said second piston/cylinder device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the second

jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and said another tubular member.

According to another aspect of the present invention there is provided for use with a top drive, a pipe gripping device having any of the pipe gripping device features set our above.

According to another aspect of the present invention there is provided a method of drilling a wellbore with a top drive, which method comprises the step of whilst a pipe is connected to said top drive, moving a pipe gripping device having any of the features set out above from a first position in which said pipe is accommodated within said pipe gripping device to a second position in which said pipe is not accommodated within said pipe gripping device, or *vice versa*.

Advantageously, the method further comprises the step of breaking with said pipe gripping device a connection between said pipe and a pipe connected to said top drive.

Preferably, the method further comprises the step of making up with said pipe gripping device a connection between said pipe and a pipe connected to said top drive.

Advantageously, said breaking step and/or making up step is performed during a continuous drilling fluid circulation method.

Preferably, the method further comprises the step of, whilst said pipe is connected to said top drive during tripping into the well, moving said pipe gripping device away from a centre line of the well, whereby said top drive may move closer to a floor of the drilling rig.

Advantageously, the method further comprises the step of, whilst said pipe is connected to said top drive

during tripping out of the well, moving said pipe gripping device toward a centre line of the well, whereby a connection between said top drive and said pipe may be broken by said pipe gripping device.

The present invention, in at least certain embodiments, teaches a new top drive drilling system with a top drive drilling unit and a joint breaking system suspended below the top drive drilling unit.

In certain aspects a top drive drilling system according to the present invention includes a joint handling system which, in one aspect, is a joint breaker system that is a pipe gripper system according to the present invention which has a body with an open throat for receiving a tubular member and two selectively engageable jaws for contacting and gripping a tubular that has been positioned within the throat (in one aspect, a piece of drill pipe which, in one aspect, may be part of a stand of drill pipe). In one aspect each jaw has an interconnected hydraulic cylinder apparatus which is selectively controlled and activated to move the jaw into gripping engagement with a tubular or to move it out of gripping engagement with a tubular so that the tubular can be moved out of the throat and away from the pipe gripper system. In another aspect, e.g. by inverting the system as it is used for joint breaking, the system can be used, according to the present invention, to make connections (with appropriate re-configuration of hydraulic fluid lines).

In certain aspects such a gripper system is used not to spin a tubular (as may be a tong), but to grip a tubular and rotate sufficiently to break its threaded connection to another corresponding tubular. In one aspect hydraulic cylinder apparatuses which are used to

effect gripping of a tubular are also used to effect slight rotation of the tubular sufficient to break its threaded connection with another tubular.

In one aspect a support for a pipe gripper system according to the present invention (useful with grippers according to the present invention and with prior art grippers) has eye members connected to corresponding main links which are connected to a top drive drilling unit. Each eye member has a body with a channel therethrough and a support shaft extends through each channel. A pipe gripper body with the open throat is connected to lower ends of these support shafts. Optionally, a holding mechanism is connected to the upper ends of these shafts. This holding mechanism has two upper latches, each with an open throat, which encompass a part of the main links that connect at the pipe gripper system to the top drive drilling unit. These latches are selectively operable so that in a first mode while drilling (and while tripping or backreaming), the pipe gripper system [and, if present, an elevator connected therebelow] hang below the top drive drilling unit; and, in a second mode, the upper latches pivot so that the previously-encompassed portions of the main links exit from the upper latches freeing the support shafts thereby permitting the pipe gripper system (and equipment connected therebelow, if any; e.g., but not limited to an elevator) to be moved away from a center line coinciding with a center line of the wellbore. Thus, in one particular aspect, an elevator suspended below the pipe gripper system can be presented to rig personnel, e.g., but not limited to a derrickman for emplacement around a piece of drill pipe, e.g., but not limited to, a piece of drill pipe in a stand of drill pipe.

Such a system can be used advantageously with a continuous circulation system. The pipe gripper, with the upper latches engaging or disengaging the main links, is moved away from the wellbore center line and out of the way of the continuous circulation system so that the top drive drilling unit can continue to rotate a drill string, permitting the top drive drilling unit to move down further than it would be able to if the pipe gripper system (and, if connected thereto, an elevator, etc.) was still in the way beneath the continuous circulation system.

In certain aspects, using an elevator having dual opposed members which have dual interactive connection apparatuses so that either side of the elevator can be opened. Thus, the elevator can be opened on one side to permit the elevator unit to be moved away from the wellbore center line so that the top drive drilling unit can drill the drill string down as far as possible before adding a new piece or stand of drill pipe; and then the elevator can be opened from the other side for receiving a new piece or stand of drill pipe. In certain aspects, such an elevator has dual opposed selectively releasable latch mechanisms and dual opposed handling projections.

It is, therefore, an object of at least certain preferred embodiments of the present invention to provide a pipe gripper system in which the same piston/cylinder devices are used in torquing a tubular as are used in clamping a tubular;

Such systems and methods which employ an open throat pipe gripper system suspended below a top drive drilling unit; and

Such systems and methods with apparatus for selectively locating the pipe gripper system operably

beneath the top drive drilling unit and for selectively moving the pipe gripper system away from such a position for further tubular rotation by the top drive drilling unit without the need for disconnecting the pipe gripper system from its connection to the top drive drilling unit.

The present invention, therefore, provides in some, but not in necessarily all, embodiments a top drive system with a top drive unit, and a pipe gripping system connected to and beneath the top drive unit, the pipe gripping system having an open throat for receiving a tubular to be gripped by the pipe gripping system.

The present invention, therefore, provides in some, but not in necessarily all, embodiments a top drive system with a top drive unit, and a pipe gripping system connected to and beneath the top drive unit, the pipe gripping system having a body, a first jaw movably connected to the body, a second jaw movably connected to the body, a first piston/cylinder device movably interconnected with the first jaw, a second piston/cylinder device movably interconnected with the second jaw, the first piston/cylinder device for moving the first jaw to clamp a pipe and the second piston/cylinder device for moving the second jaw to clamp the pipe, and both the first piston/cylinder device and the second piston/cylinder device for rotating the pipe.

Such a pipe gripping system may have one or some, in any possible combination, of the following: connectible to and beneath a top drive unit, the pipe gripping system having an open throat for receiving a tubular to be gripped by the pipe gripping system; and/or wherein the pipe gripping system has a body, a first jaw movably connected to the body, a second jaw movably connected to

the body, the first jaw connected to the second jaw so that the first jaw and the second jaw move together.

The present invention, therefore, provides in some, but not in necessarily all, embodiments a pipe gripping system which is connectible to and beneath a top drive unit, the pipe gripping system having a body, a first jaw movably connected to the body, a second jaw movably connected to the body, a first piston/cylinder device movably interconnected with the first jaw, a second piston/cylinder device movably interconnected with the second jaw, the first piston/cylinder device for moving the first jaw to clamp a pipe and the second piston/cylinder device for moving the second jaw to clamp the pipe, and both the first piston/cylinder device and the second piston/cylinder device for rotating the pipe. Such a pipe gripping system may have one or some, in any possible combination, of the following: wherein the first jaw is connected to the second jaw so that the first jaw and the second jaw move together; wherein the first piston/cylinder device is disposed for and is operable for pulling the first jaw in a first direction with respect to the pipe to locate the first jaw with respect to the pipe and the first piston/cylinder device is disposed for and operable for then moving the first jaw in a second direction opposite to the first direction for clamping the pipe with the first jaw; wherein the second piston/cylinder device is disposed for and is operable for pulling the first jaw in the second direction with respect to the pipe to locate the second jaw with respect to the pipe and the second piston/cylinder device is disposed for and operable for then moving the second jaw generally in the first direction clamping the pipe with the second jaw; and/or wherein the first piston/cylinder

device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the first jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and another tubular member, and the second piston/cylinder device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the second jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and the another tubular member.

The present invention, therefore, provides in some, but not in necessarily all, embodiments a method for gripping a tubular member beneath a top drive unit, the method including moving a portion of a tubular member into a gripping system, the gripping system located beneath the top drive unit and having an open throat for receiving a tubular to be gripped by the pipe gripping system, the gripping system having a gripping mechanism for gripping the tubular member, the portion of the tubular member moved into the open throat of the gripping system, and gripping the portion of the tubular member with the gripping mechanism of the gripping system.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1A is a front elevation view of a prior art well drilling apparatus;

Figure 1B is a side elevational view taken on line 1B-1B of Figure 1A but showing the drilling unit swung to its mouse-hole position;

Figure 1C is a fragmentary front elevational view showing part of the drilling unit of Figure 1A swung to its retracted position permitting a trip of the well pipe into or out of the well;

Figure 2 is a perspective view of a top drive unit according to the present invention mounted on a derrick in use with a Continuous Circulation System (CCS);

Figure 2A is a perspective view of the pipe gripping unit that is connected to the top drive unit in Figure 2;

Figures 2B and 2C are perspective cut-away views of part of the pipe gripping device in Figure 2;

Figure 3A is a plan view, partly in cut-away and in cross-section, of the pipe gripping device of Figures 2A and 2B in use with a tubular;

Figure 3B is an enlarged plan cross section of the cut-away in Figure 3A;

Figures 4 to 8 are plan views showing steps in the operation of the pipe gripping device of Figure 3A;

Figures 9A - 9C are plan views of an alternative embodiment of jaws for the pipe gripping device of Fig. 2, each Figure showing a different position of an adjustment mechanism enabling the pipe gripping device to accommodate tubulars of different diameter;

Figure 10 is a side view of a top drive unit of Figure 2 in a first stage of operation;

Figure 11 is a side view of the top drive unit of Figure 10 in a second stage of operation;

Figure 12 is a perspective view of the pipe gripping unit of Figures 10 and 11 having been swung away from the drill string; and

Figure 13 is a side view of the top drive unit in Figure 2 with the pipe gripping device swung away from the drill pipe to permit the top drive to drill to move adjacent the CCS unit.

Figures 1A - 1C show a prior art rig and top drive system 1010 as disclosed in U.S. 4,458,768 (incorporated fully herein for all purposes).

The prior art drilling rig 1010 comprises a derrick 1011 projecting upwardly above a location at which a well bore 1012 is being drilled by a rotary drill string 1013 formed in conventional manner in a series of drill pipe stands connected together in end to end fashion at threaded connections 1014. The string 1013 is turned about the vertical axis 1015 of the well by a drilling unit 1016 (e.g. top drive) connected to the upper end of the string. The drill string and drilling unit 1016 are supported and adapted to be moved upwardly and downwardly by a hoisting mechanism 1017 including a crown block 1018, travelling block 1019, tackle 1020, supporting travelling block 1019 from crown block 1018, and power driven draw works for reeling the line 1020 in or out to raise or lower the travelling block 1019. The travelling block 1019 supports a hook 1021 from which the drilling unit 1016 is suspended, and which has a gate 1121 adapted to be opened for connecting and disconnecting the drilling unit 1016. The drilling unit 1016 and hook 1019 are guided during their upward and downward movement by two sectionally formed parallel elongated guide rails

1022 and 1023, engaging and guiding a carriage 1024 forming a portion of the drilling unit 1016 and a carriage 1025 to which the travelling block 1019 is connected.

The two sectionally formed guide rails 1022 and 1023 are preferably of H shaped horizontal sectional configuration that continues from the upper extremity of each rail to its lower extremity. The rails 1022 and 1023 have upper sections which extend from the upper end of derrick 1011 to a mid-derrick location and are attached rigidly to the derrick for retention stationary in positions of extension directly vertically and parallel to one another and to well axis 1015. Beneath the mid-derrick location the two guide rails have second portions or sections extending parallel to one another, continuing downwardly and to locations 1027, and mounted by two pivotal connections for swinging movement relative to upper sections and about a horizontal axis. An inclined mousehole 1030 is used (Figure 1B).

The rails have third lowermost sections which are carried by the second sections for swinging movement therewith between the vertical and inclined positions and which also are mounted by connections 1031 and 1032 for horizontal swinging movement about two axes 1033 and 1034 which are parallel to one another and to the longitudinal axes of the second sections.

The two pivotal connections 1031 and 1032 include two parallel mounting pipes or tubes 1037 and 1038 connected rigidly to the second sections. The two second rail sections are adapted to be power actuated between the vertical and inclined positions by a piston and cylinder mechanism 1045 whose cylinder is connected to a horizontally extending stationary portion of the derrick

1011, and whose piston rod acts against the tube 1037 of pivotal connection 1031.

Carriage 1025 to which travelling block 1019 is connected includes two frames 1056 and 1057 extending partially about the rails 1022 and 1023 respectively and rotatably carrying rollers 1058 which are received between and engage the front and rear flanges 1059 of the various rail sections in a manner effectively locating carriage 1025 against movement transversely of the longitudinal axis of the rail structure, and guiding the carriage for movement only longitudinally of the rails.

The drilling unit 1016 includes the previously mentioned rail contacting carriage structure 1024, a power unit 1061 for turning the string, and a conventional swivel 1062 for delivering drilling fluid to the drill string 1013.

The power unit 1061 of the drilling assembly includes a pipe section having a lower tapered external thread forming a pin and threadedly connectable to the upper end of drill string 1013 to drive it. In most instances, a conventional crossover sub 1072 and a short "pup joint" 1073 are connected into the string directly beneath the power unit. At its upper end, pipe section 1070 has a tapered internal thread connectable to the rotary stem 1075 of swivel 1062. The rotary stem 1075 turns with the drill string 1013 relative to the body 1076 of the swivel 1062. The body 1076 is supported in non rotating relation by a bail 1077 engaging hook 1021 of the travelling block 1019. Drilling fluid is supplied to the swivel 1062 through a flexible inlet hose 1078, whose second end is connected to the derrick at an elevated location 1079 well above the level of the rig floor. For driving the tubular shaft 1070, power unit

1061 includes an electric motor.

Figure 2 shows a top drive drilling system 10 according to the present invention which includes a top drive drilling unit 20 ("TD 20") suspended in a derrick 12 (like the rig and derrick in Figure 1A with the various parts etc. as shown in Figure 1A). A continuous circulation system 30 ("CCS 30") rests on a rig floor 14 and part of a saver sub 22 projects up from the CCS 30. The saver sub 22 is connected to and rotated by the TD 20.

The CCS 30 is any known continuous circulation system and is, in one aspect, a CCS system commercially available from Varco International, Inc. The CCS 30 operates as described in the introduction above.

An elevator 40 is suspended below the TD 20 and a pipe gripping device 50 ("PG 50") is suspended from the TD 20 above the elevator 40. Any suitable known elevator may be used with the pipe gripping device 50. The PG 50 is suspended from the TD 20 with links 18 and the elevator 40 is suspended from the PG 50 with links 24.

Referring to Figure 2A the pipe gripping device generally identified by reference numeral 110 is suspended at one end of a pair of main links 104′ below the top drive 102′; the other ends of the main links are connected to the top drive 102′ (see Figure 2). The pipe gripping device 110 comprises a holding mechanism 150′ and a movement mechanism 120′. The holding mechanism 150′ enables the pipe gripping mechanism 110 to be substantially locked in position relative to the main links 104′, in which position swinging of the pipe gripping device 110 about the main links 104′ is inhibited. The movement mechanism 120′ enables the pipe gripping device to be moved between a retracted position

in which the saver sub 160′ of the top drive 102′ is free to rotate, and an extended position in which the saver sub 160′ is prevented from rotating as described in greater detail below.

The holding mechanism 150′ has a housing 151′ comprising upper and lower plates (only one shown in Fig. 2A), to which are pivotally connected two plate members 152′. The housing 151′ is connected via intermediate springs 126′ to a pair of shafts 125′ that extend upwardly from a pipe gripping device 110. Each plate member 152′ has an open throat 155′ within which is releasably positioned part of main link 104′. The open throat 155′ is defined by two fingers 157a′ and 157b′ and the remaining plate member which are all integrally formed from one sheet plate of metal, although any other suitable material may be used. Each plate member 152′ pivots on top of shafts 125′ against intermediate springs 126′. To selectively prevent such pivoting, a pin 156b′ is inserted through each plate member 152′. A yoke plate 156 is arranged centrally on the end of a rod of a piston/cylinder apparatus 156a′ (see Fig. 12), which cylinder is fixed to the housing 151′ and the rod of which passes through the upper and lower plates 151a′ and 151b′. The yoke plate 156′ has two ends, each connected to top of the pins 156b′. Upon retraction of the rod into the piston/cylinder 156a′, the pins 156b′ pass through holes in each plate member 152′ to lock the plate member 152′ in position. Each plate member 152′ has at least one hole to lock the links and the pipe gripping device 110 in relation to one another when depending vertically and in line with the well centre (as shown in Fig. 2A). In this position the main links 104′ are held within the throats 155′ which are sufficiently deep so that the main

links 104′ as shown in Figure 2A cannot move out of the throats 155′ when in that position. With the bolts 156c′ removed when the cylinder 156a′ raises the plate 156′, the members 152′ are free to pivot and, thus, the main links 104′ are freed to move away from the throats 155′, as shown in Figure 12, and the pipe gripping device hangs under gravity below main links 104′. Swinging of the pipe gripping device 110 is inhibited by the interaction between the plate members 152′, the intermediate springs 126′ and the shafts 125′.

The movement system 120′ has piston/cylinders 128 for moving the pipe gripping device 110 up and down relative to the main links 104′ and therefore relative the top drive 102′ and saver sub 106′. Upper ends of piston rods 128d′ are secured to the bodies 123′ each having an eye 121′, and lower ends of the cylinders 132′ are secured to a main body 129′ of the pipe gripping device 110. Optional protective railings 131′ connected to the main body 129′ encompass part of the perimeter of the pipe gripping system 110 to inter alia protect its various parts. Mounting posts 128c′, move in corresponding tubes 128a′. Actuation of the piston/cylinders 128 causes the pipe gripping device 110 to move or down via relative movement between the mounting posts 128c′ and tubes 128a′.

Referring to Figures 2A and 2B the pipe gripping device 110 comprises a body 129 and two movable jaws 111, 112. The jaw 111 is pivotably connected with a pin 113 to a movable member 114 and the jaw 112 is pivotably connected with a pin 115 to a movable member 116 via a connecting bar 117. The movable member 114 is connected to four shafts 118 and the movable member 116 is connected to four shafts 119. An end 133 of the

connection bar 117 is secured with a pin 134 to the jaw 112. A gripping insert apparatus 135 with a removable insert 136 is releasably held on the jaw 112 by removable bolts 137. Studs 149 insure proper placement of the removable insert 136 in a groove 153 of a holder 135. A shoulder screw 138 (see also Figure 9A and accompanying description) extends through the jaw 112. The connection bar 117 has a hole 139 which receives a pin 143 which passes through the jaw 112. The connection bar 117 shown in Figure 2A is a top connection bar and a similar lower connection bar 117b (see Figure 9A; shown in outline in Figure 2B) is connected to the jaw 112 by the same pins 115, 134, 143. The connection bars 117 and 117b permit pivoting of the jaw 112 about pin 115.

The jaw 111 has a gripping insert apparatus 144 releasably secured to the jaw 111. Bolts 146a releasably secure the gripping insert apparatus 144 to the insert holder body 157. An insert 147 is held within a groove 148 by studs 149a. Bolts 146 secure the insert holder body 157 to the jaw 111. An end 154 of the insert holder body 157 is held in a recess 155 defined by part of the jaw 111 and by lips 156.

A hole 158 in the jaw 111 receives a pin 159 that projects through the jaw 111 and permits pivotal movement of the jaw 111 with respect to the jaw 112. The jaw 111 includes top and bottom parts 111a, 111b respectively (see Fig. 2A).

The body 129 has an open throat 161 for receiving a portion of a tubular, e.g., but not limited to, a tubular, a drill pipe, a saver sub, or a splined portion of a saver sub used with a top drive drilling system. The open throat 161 ensures that only radial movement (with respect to a tubular) is needed to bring pipe gripping

device 110 into and out of engagement with the tubular; although it will be appreciated that other directions of movement can be incorporated with the radial movement if desired.

The movable member 114 is connected to a base member 162 by the shafts 118. The movable member 116 is connected to a base 168 by the shafts 119.

Trunnion blocks 165 and 165a (only 165 shown in Figs. 2A and 2B) are connected to a parts of piston/rod assemblies as described below. Bolts 165d connect the trunnion blocks 165 to a splined torque plate 165f (see Figure 10). The splined torque plate 165f comprises an open throat similar to the open throat 161, and is substantially in alignment therewith to define an opening on one side of the pipe gripping device 110. The splines of the splined torque plate 165f do not form a closed circle in plan view. The movable member 116 is secured to a connector 166 (part of a piston/rod assembly) which has a hole 166a through which extends a pin 166b which is integral with the trunnion block 165 above it. Similarly, the movable member 114 is secured to a connector 164 (part of a piston/rod assembly) which has a hole 164a through which extends a pin 164b which is integral with the trunnion block 165a (see Figure 10). A framework 131 (solid or tubular) encompasses the body 129.

Figure 3B shows in detail a selectively activatable piston 170 with one end 170a sealingly disposed within a recess 171 in the insert holder body 157 and another end 170b projecting out from the recess 171 to contact the jaw 112. Hydraulic fluid under pressure in a hose 170c is applied to the end 170a of the piston 170 to initially maintain the jaws 111, 112 in the position shown in Figures 3A and 4 i.e. inhibiting rotation of the jaws

relative to one another about pin 159 to keep them in an open position for receiving and releasing a tubular. The hydraulic fluid under pressure can be supplied from a separate source; from existing hydraulic lines, e.g. lines to a top drive; and/or from a manifold interposed between an hydraulic power source and the gripper system 110. However, it is preferred that hydraulic fluid is supplied from the shaft 164c piston/rod assembly associated with connector 164.

Referring to Fig. 3A the piston/rod assembly with the connector 166 has a shaft 166c to which is connected a piston 166d which is movable within a housing 166e in response to hydraulic fluid under pressure (from any of the sources for the hydraulic power that moves the piston 170) introduced into the housing 166e. As shown in the "stored" position of Figure 3A, pressure is applied to a surface 166f of the end 166d to maintain the jaw 112 in the position shown i.e. in a retracted position relative to the drill pipe DP.

The piston/rod assembly with the connector 164 has a shaft 164c to which is connected a piston 164d which is movable within a housing 164e in response to hydraulic fluid under pressure introduced into the housing 164e. The housing 164e has hydraulic power fluid channels 164p and 164r for introducing/venting hydraulic power fluid from either side of the piston 166d. The housing 164e has hydraulic power fluid channels 164p and 164r (see Fig. 2B) for introducing/venting hydraulic power fluid from either side of the piston 164d. As shown in Figure 3A in the "stored" position, pressure is applied to a surface 164f of the piston 164d to maintain the jaw 111 in the position shown; as mentioned above hydraulic fluid is supplied at the same time to actuate the piston 170.

Figures 4 - 7 illustrate a method according to the present invention for gripping and torquing a tubular, e.g., in one aspect, a piece of drill pipe, to engage the tubular and then to break a connection between the tubular and another member (e.g., in one aspect, between the tubular and a saver sub of a top drive system). It is within the scope of the present invention to invert the system 110 and use it to make up connections between tubulars.

The steps performed by the pipe gripping device 110 are carried out during use of the CCS unit 30 for continuous circulation of drilling fluid during tripping out of the well, as described above in the introduction. In particular, the pipe gripping device breaks the connection between the saver sub and a stand of drill pipe after the lower joint of the stand has been broken by the CCS unit 30 and after the upper chamber in the CCS unit has been drained of drilling fluid. Following breaking of the upper joint the stand of drill pipe is supported by the elevator 40 for racking in a pipe rack for example.

When a driller initiates a method according to the present invention to break a saver-sub/drill-pipe connection, e.g. by pressing a button on the driller's console, hydraulic fluid is supplied to the piston/cylinder 128′ (see Fig. 2A) and piston/cylinder 156a′ (see Fig. 12). As described above this actuates the movement mechanism 120′ to lower the pipe gripping device 110 such that the splines of the splined torque plate 165f interengage with the splines at the end of the saver sub, and bring the jaws 111, 112 into alignment with the box of the drill string. Furthermore movement of the piston/cylinder 156a′ causes locking of the plate members

152′ relative to the housing 151′, thereby inhibiting swinging of the pipe gripping device 110 about ends of the main links 104′.

Referring to Figure 4, hydraulic fluid under pressure is then applied to a surface 166g of the piston 166d which moves the housing 166e and the components connected to it including the connection bars 117, the jaw 112, and the jaw 111 as shown in Figure 4 so that the jaws are disposed about a drill pipe DP. The piston/rod assembly 166 pivots inwardly toward the drill pipe DP about the pin 166b to permit the moveable member 116 to move outwardly along the shaft 166c without pulling the jaws across the longitudinal axis of the drill pipe DP (leftwards in the sense of Fig. 4). At the same time the piston/rod assembly 164 pivots inwardly toward the drill pipe DP about the pin 164b, so that the jaws are not pulled in the opposite sense across the longitudinal axis of the drill pipe DP (rightwards in the sense of Fig. 4). The effect of this is that the spacing between the grips 136 and 146 remains the same, but the jaws 111 and 112 have been moved from a retracted or stored position (see Fig. 3A), to a position in which the grips now lie on the diameter of the drill pipe DP.

As shown in Figure 5A, the application of hydraulic fluid under pressure to a surface 164g (and at the same time releasing of hydraulic pressure on surface 164f) of the piston 164d moves the housing 164e outwardly and moves the jaw 111 as shown so that the jaws 111, 112 now grip the drill pipe DP as shown in Figure 5A. In particular, the jaws 111, 112 are rotated about the longitudinal axis of the drill pipe DP via movement of the housing 164e along the shaft 164c. To permit this rotation, the housing 166e moves back along the shaft

166c; otherwise the movement of the housing 164e and jaw 111 would push of the drill pipe DP out of the gripping device. As explained above, hydraulic fluid pressure is only maintained on piston 170 whilst pressure is maintained on surface 164f. Accordingly, at the same time as pressure is released from surface 164f, the piston 170 is able to retract. The tendency of both housing 164e and 166e to move outwardly is resisted by contact between the jaw 112 and the drill pipe DP. Thus the weight of the stand drill pipe (recalling that it is hanging from the saver sub) resists further movement of the housing 166e outwardly. The tendency is therefore for the pivot pin 159 on jaw 112 to be moved inwardly about a pivot point on the drill pipe DP; this is counteracted by the tendency for the jaw 111 to pull the pivot pin 159 outwardly. The hydraulic pressure applied to the surfaces 164g and 166g therefore causes the jaws 111, 112 to pivot about the pin 159 (since no resistance is provided by the piston 170) to bring the grips 136 and 147 into engagement with the outer surface of the drill pipe DP. As shown in Figure 5B venting of the fluid from the end 170a of the piston 170 allowing the piston 170 to retract within the recess 171 permits the jaw 112 to move with respect to the jaw 111 to the positions shown in Figures 5A - 6.

The grips 136 and 147 are now firmly in engagement with the drill pipe DP applying a compression force but no rotational force. Furthermore by actuating the piston 166 first the jaws 111, 112 are permitted to move through a larger angle to break the joint as described below.

Figure 6 illustrates the breaking of a connection, e.g. a connection between the drill pipe DP and a saver sub to which it is connected. The pipe gripping device

110 enables a rotational force to be applied by the jaws 111, 112 to the drill DP, whilst maintaining sufficient compression force to engage the drill pipe DP with the grips 136, 147.

In particular, hydraulic fluid pressure is now applied to the surface 166f. This pushes the housing 166e inwardly, causing the jaw 112 and therefore the pin 159 to try to move in the same direction. However, this force is opposed by the outward force caused by hydraulic pressure on surface 164g, causing the jaw 111 and pin 159 to move outwardly. The result is that the jaws 111, 112 are caused to maintain their compression force on the drill pipe DP; however, now the two forces applied by the jaws are in opposite directions on opposite sides of the drill pipe DP resulting in a rotational force. The pivot pins 164b and 166b permit the shafts 164c and 166c to rotate, and therefore the jaws 111, 112 to rotate about the drill pipe without widening the separation between grips 136, 147. If sufficient hydraulic pressure is applied this results in turning of the drill pipe DP in the direction of the arrow A as ends 117a of the connection bars 117 move in the direction of the arrow W moving the jaw 112 in the direction of the arrow R1 while the jaw 111 moves in the direction of the arrow R2. The saver sub (not shown in Figure 6) is held substantially still by a splined portion 165e of the splined torque plate 165f (see Figure 10) so that the saver-sub-drill-pipe connection can be broken. Figures 10 and 11 show a top drive TD (partially) with links LS that support a support system SS that supports the pipe gripping device 110 from which are suspended links LK which support the elevator 230 and, in Figure 11, drill pipe DR.

Figure 7 shows the limit of travel of the jaws 111

and 112 provided by the pistons 164d and 166d in their respective housing 164e and 166e. The drill pipe has been turned sufficiently to break the connection. In order to ensure reliable release of the grips 136 and 147 from the drill pipe, the piston 170 is actuated causing the jaws 111, 112 to pivot apart.

As shown in Figure 8 the jaws 111, 112 are then moved to their original position or "stored" position (as in Figure 3A). In this position the piston 170 has returned to its initial position (see Figure 3B).

The pipe gripper device 110 can then be retracted by actuating the piston/cylinders 128/ to disengage the splined torque plate 165f from the splines of the saver sub. The top drive can then spin out the saver sub from the drill pipe. For this purpose the other end of the drill pipe may or may not be held by an iron roughneck in the CCS unit 30.

Referring to Fig. 13, when the top drive 20 is tripping into or out of the hole, the pipe gripping device 110 can be swung on the main links 104′ away from the centre line of the well. This allows the saver sub to get close enough to the CCS unit 30 to enable continuous circulation to take place as described above. The pipe gripping device is swung out away from the wellbore centre line by winching a tugger line 250′, whereupon the elevator 140 seats itself on a seat 254′ attached to the end of the tugger line 250′ and pulls pipe gripping device 110 radially and upwardly out of line with the wellbore centreline, allowing the saver sub to be lowered into the CCS 240 to locate the top of the drill string (if tripping out). If tripping in, the open throat 161 and the open throat of the splined torque plate 165f enable the pipe gripping device 110 to be moved radially

away from the well centre line without having to disconnect the saver sub from the top of the drill string. During raising of the top drive 20, the tugger line 250′ can be gradually released to allow the pipe gripping device 110 to swing back to the well centre line under its own weight.

As shown in Figures 9A - 9C a device according to the present invention (like the pipe gripping device 110 can effectively accommodate tubulars of different diameters. As shown in Figure 9A by using spacers 181, 182 and a nut 183 and cotter pin 184 with the shoulder screw 138, part 138a of the shoulder screw 138 projects inwardly of the jaw 112 to serve as a stop for a tubular (e.g., but not limited to, drill pipe between 3.5 inches and 4 inches in diameter).

Figure 9B shows the use of spacers 185 and 186 with the shoulder screw 138 so that part 138a of he shoulder screw projects inwardly of the jaw 112 to serve as a stop for a tubular (e.g., but not limited to, drill pipe between 4.5 and 5 inches in diameter).

Figure 9C shows the use of spacers 187 and 188 with the shoulder screw 138 so that part 138a of he shoulder screw projects inwardly of the jaw 112 to serve as a stop for a tubular (e.g., but not limited to, drill pipe between 5.5 and 5 inches in diameter).

By using the shoulder screw 138 and associated spacers as shown in Figures 9A - 9C, a tubular is positioned between the jaws 111, 112 so that the inserts 136, 147 are diametrically opposed across the tubular, enhancing efficient gripping of the tubular by the jaws 111, 112. Alternatively and/or in addition to this method of accommodating different size tubulars, jaws with different dimensions may be used.

When a system according to the present invention uses hydraulic power lines for an existing top drive and/or for an existing upper pipe handler, the in-place driller's console, buttons, and controls can be used to control the pipe gripper system according to the present invention. Alternatively a completely separate hydraulic power system and/or controls may be used.

The present invention teaches a pipe gripper in which the same hydraulic piston/cylinder devices are used to clamp a tubular and then used to rotate the same tubular. These devices may be incorporated into known pipe handlers and iron roughnecks. An extended saver sub may be used with any pipe gripper system according to the present invention, e.g. to bring a connection within a continuous circulation system.

CLAIMS:

1. A top drive unit comprising a top drive and a pipe gripping device connectable beneath said top drive, the arrangement being such that, in use, whilst a pipe is connected to said top drive said pipe gripping device is moveable between a first position in which said pipe is accommodated within said pipe gripping device and a second position in which said pipe is not accommodated within said pipe gripping device.

2. A top drive unit as claimed in claim 1, wherein said pipe gripping device permits movement having a component of direction substantially radially toward/away from a longitudinal axis of said pipe.

3. A top drive unit as claimed in claim 1 or 2, further comprising a pivot mechanism for pivoting said pipe gripping mechanism between said first and second positions.

4. A top drive unit as claimed in claim 3, wherein in use said pivot mechanism provides a pivoting action in a plane substantially parallel with a longitudinal axis of said pipe.

5. A top drive unit as claimed in claim 3, wherein in use said pivot mechanism provides a pivoting action in a plane substantially perpendicular with a longitudinal axis of said pipe.

6. A top drive unit as claimed in any of claims 1 to 5, further comprising an open throat for permitting said movement.

7. A top drive unit as claimed in claim 6, wherein said pipe gripping device comprises a body having first and second parts each part comprising an opening defining said open throat, wherein in use said first part provides a locking function in which rotation of said body

relative to said top drive is inhibited, and said second part provides a rotating function relative to said body or making/breaking connections between pipes.

8. A top drive unit as claimed in any of claims 1 to 6, wherein said pipe gripping device comprises a body, a first jaw movably connected to the body, a second jaw movably connected to the body.

9. A top drive unit as claimed in claim 8, wherein said first jaw and said second jaw are arranged for pivoting movement around two common axes, pivoting around a first common axis for clamping and releasing said pipe, and pivoting around a second common axis for rotating said pipe to make/break a connection with another pipe.

10. A top drive unit as claimed in claim 8 or 9, further comprising an actuation device for both moving said first and second jaws to clamp and release said pipe, and for making/breaking a connection with another pipe.

11. A top drive unit as claimed in claim 8, 9 or 10, wherein said first jaw and said second jaw are pivotably connected to one another.

12. A top drive unit as claimed in claim 8, 9, 10 or 11, wherein said first jaw is connected to the second jaw so that the first jaw and the second jaw move together.

13. A top drive unit as claimed in claim 8, 9, 10 or 11, said pipe gripping device further comprising:

a first piston/cylinder device movably interconnected with said first jaw,

a second piston/cylinder device movably interconnected with said second jaw,

the first piston/cylinder device for moving the first jaw to clamp a pipe and the second piston/cylinder device for moving the second jaw to clamp the pipe, and both the first piston/cylinder device and the second

piston/cylinder device for rotating the pipe.

14. A top drive unit as claimed in claim 13 wherein said first piston/cylinder device is disposed for and is operable for moving said first jaw in a first direction with respect to the pipe to locate said first jaw with respect to the pipe, and said first piston/cylinder device is disposed for and operable for then moving said first jaw in a second direction opposite to the first direction for clamping the pipe with the first jaw.

15. A top drive unit as claimed in claim 14, wherein said second piston/cylinder device is disposed for and is operable for moving said first jaw in the second direction with respect to the pipe to locate said second jaw with respect to the pipe, and the second piston/cylinder device is disposed for and operable for then moving said second jaw generally in the first direction for clamping the pipe with the second jaw.

16. A top drive unit as claimed in 13, 14 or 15, wherein

said first piston/cylinder device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the first jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and another tubular member, and

said second piston/cylinder device is disposed for and is, following clamping of the pipe between the first jaw and the second jaw, operable for moving the second jaw generally in the first direction for rotating the pipe for breaking a connection between the pipe and said another tubular member.

17. For use with a top drive, a pipe gripping device having the pipe gripping device features of any preceding claim.

18. A method of drilling a wellbore with a top drive, which method comprises the step of whilst a pipe is connected to said top drive, moving a pipe gripping device as claimed in claim 17 from a first position in which said pipe is accommodated within said pipe gripping device to a second position in which said pipe is not accommodated within said pipe gripping device, or *vice versa*.

19. A method according to claim 18, further comprising the step of breaking with said pipe gripping device a connection between said pipe and a pipe connected to said top drive.

20. A method according to claim 18, further comprising the step of making up with said pipe gripping device a connection between said pipe and a pipe connected to said top drive.

21. A method according to claim 19 or 20, wherein said breaking step and/or making up step is performed during a continuous drilling fluid circulation method.

22. A method according to claim 21, further comprising the step of, whilst said pipe is connected to said top drive during tripping into the well, moving said pipe gripping device away from a centre line of the well, whereby said top drive may move closer to a floor of the drilling rig.

23. A method according to claim 21, further comprising the step of, whilst said pipe is connected to said top drive during tripping out of the well, moving said pipe gripping device toward a centre line of the well, whereby a connection between said top drive and said pipe may be broken by said pipe gripping device.

Fig.1A
Prior Art

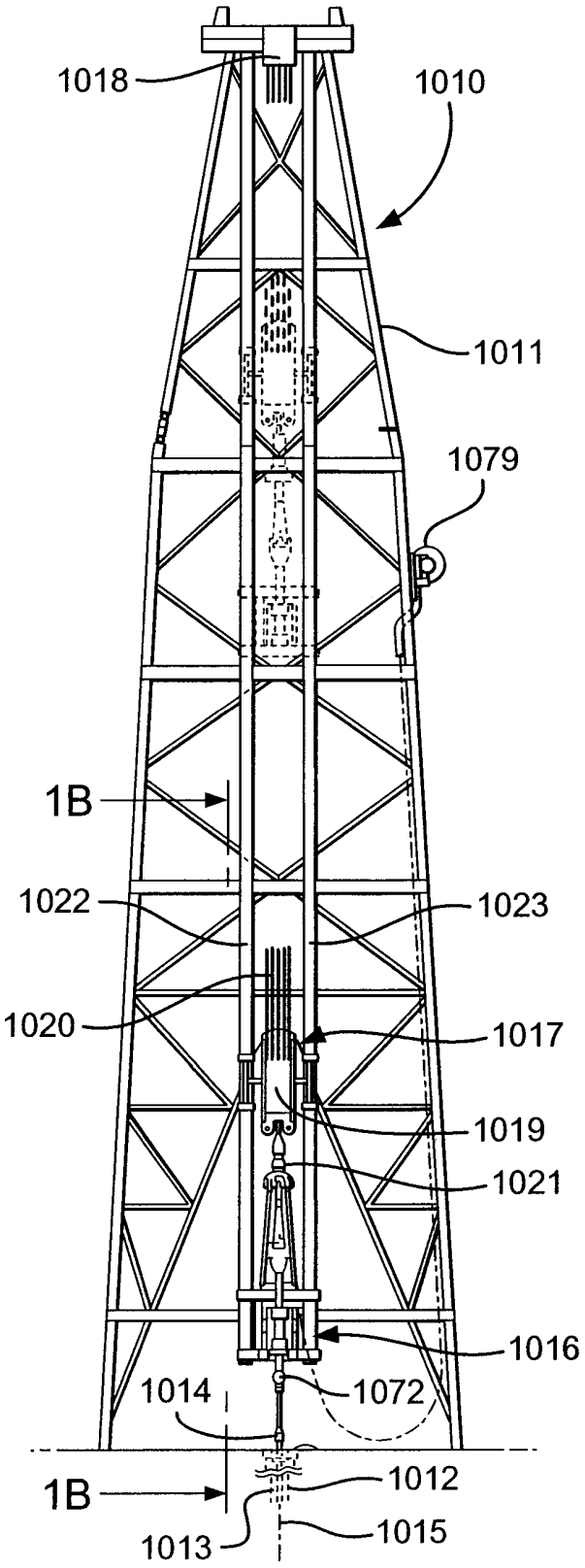

Fig.1B
Prior Art

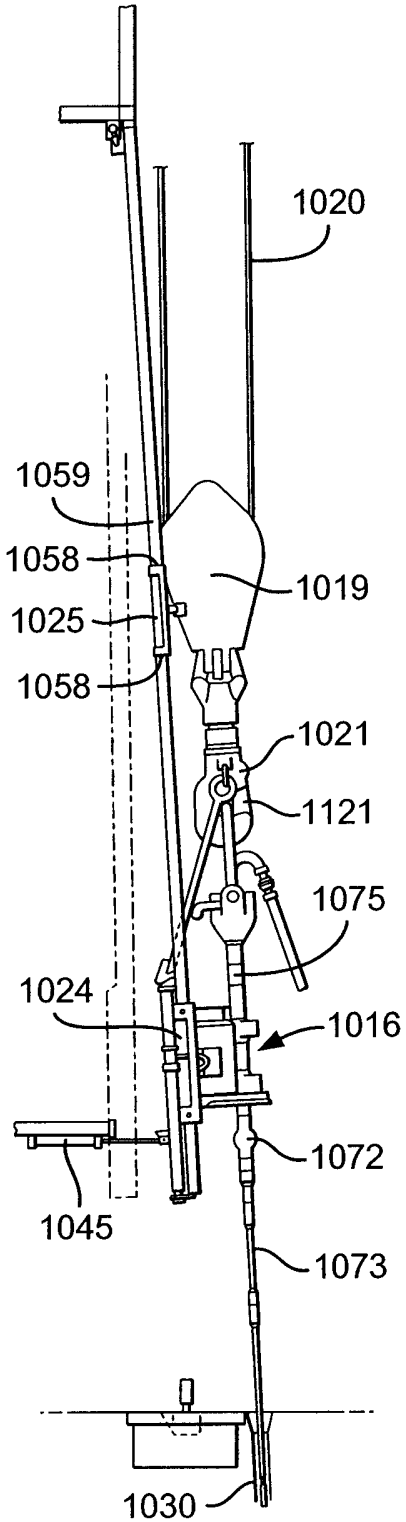

Fig.1C

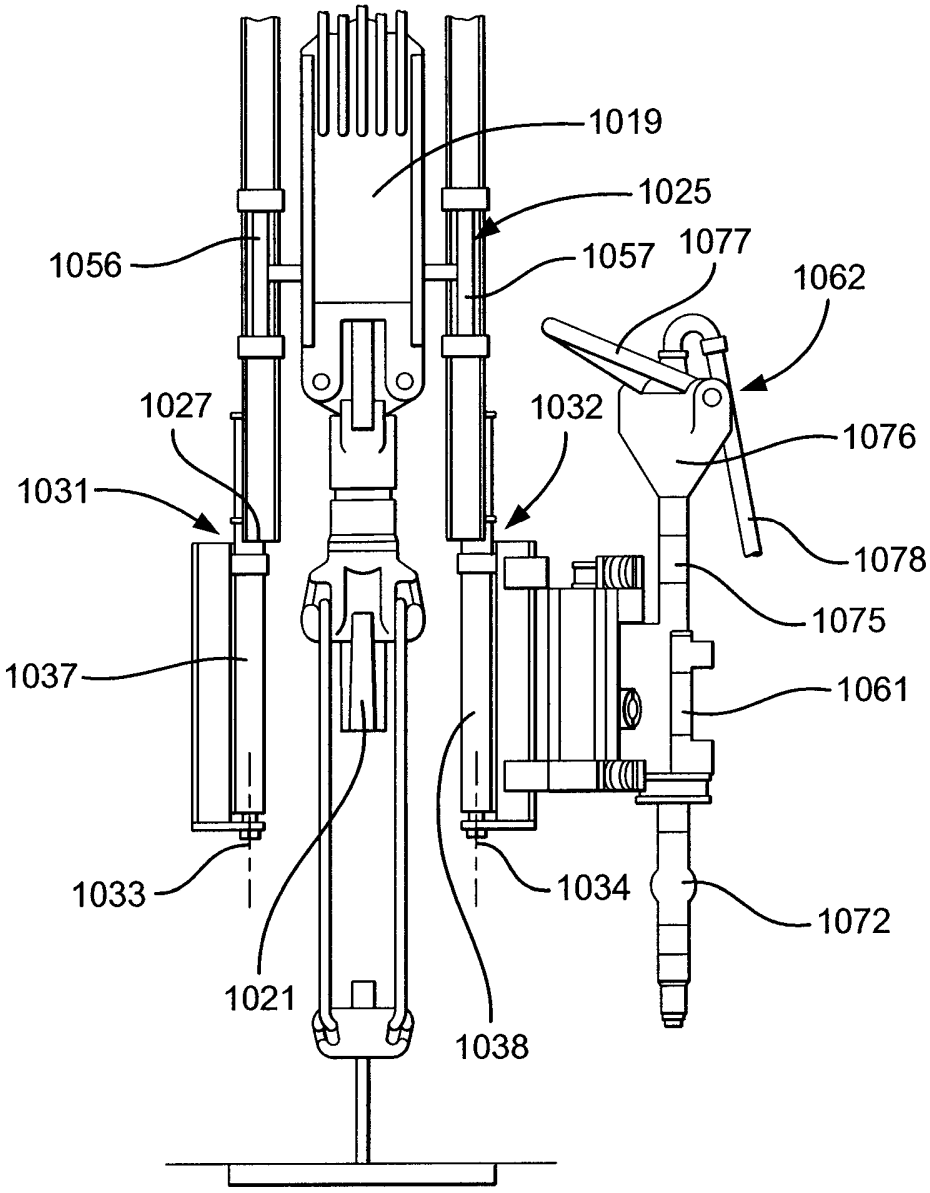
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Fig.2

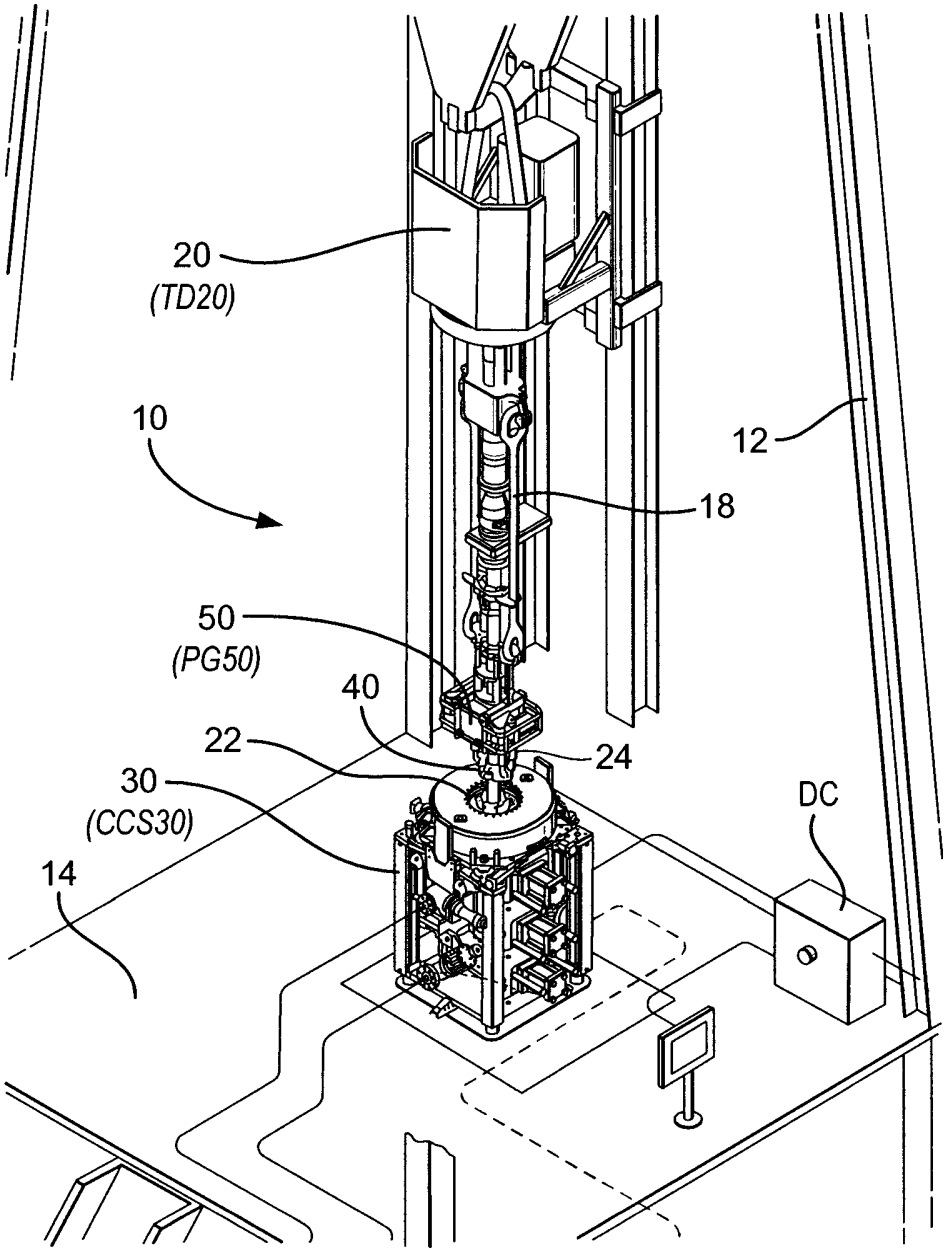
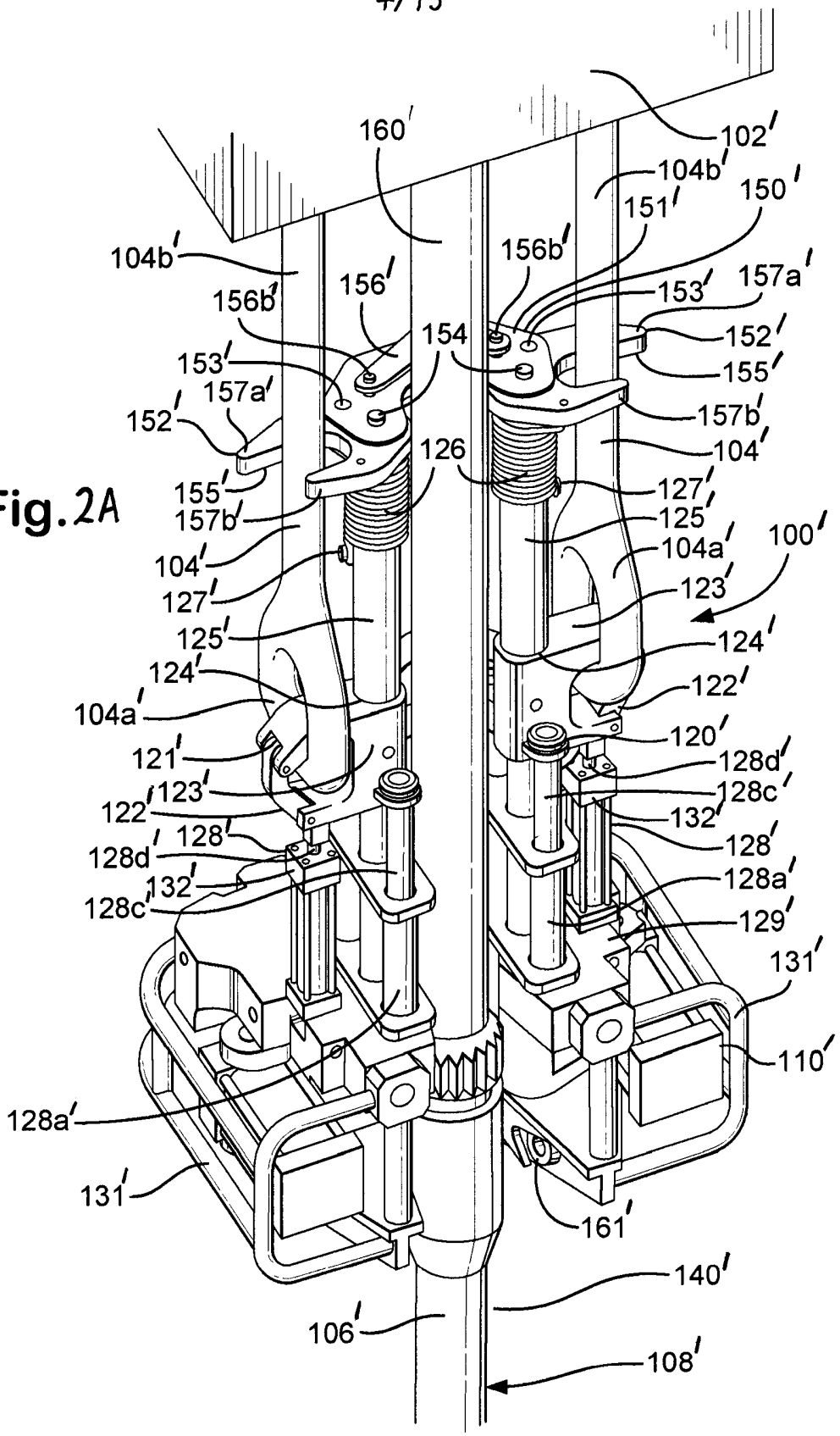


Fig.2A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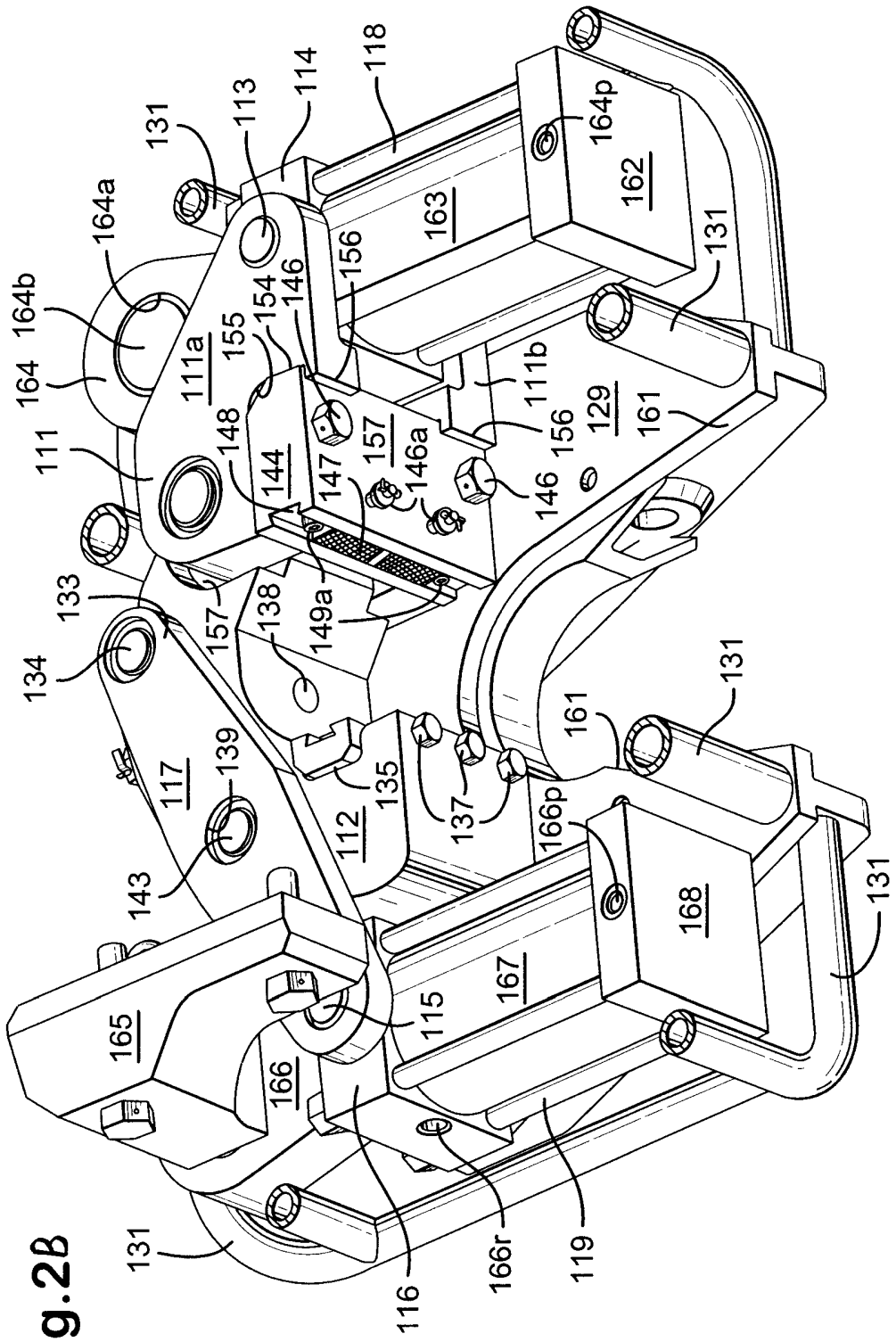
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138
149a
134
131
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166r
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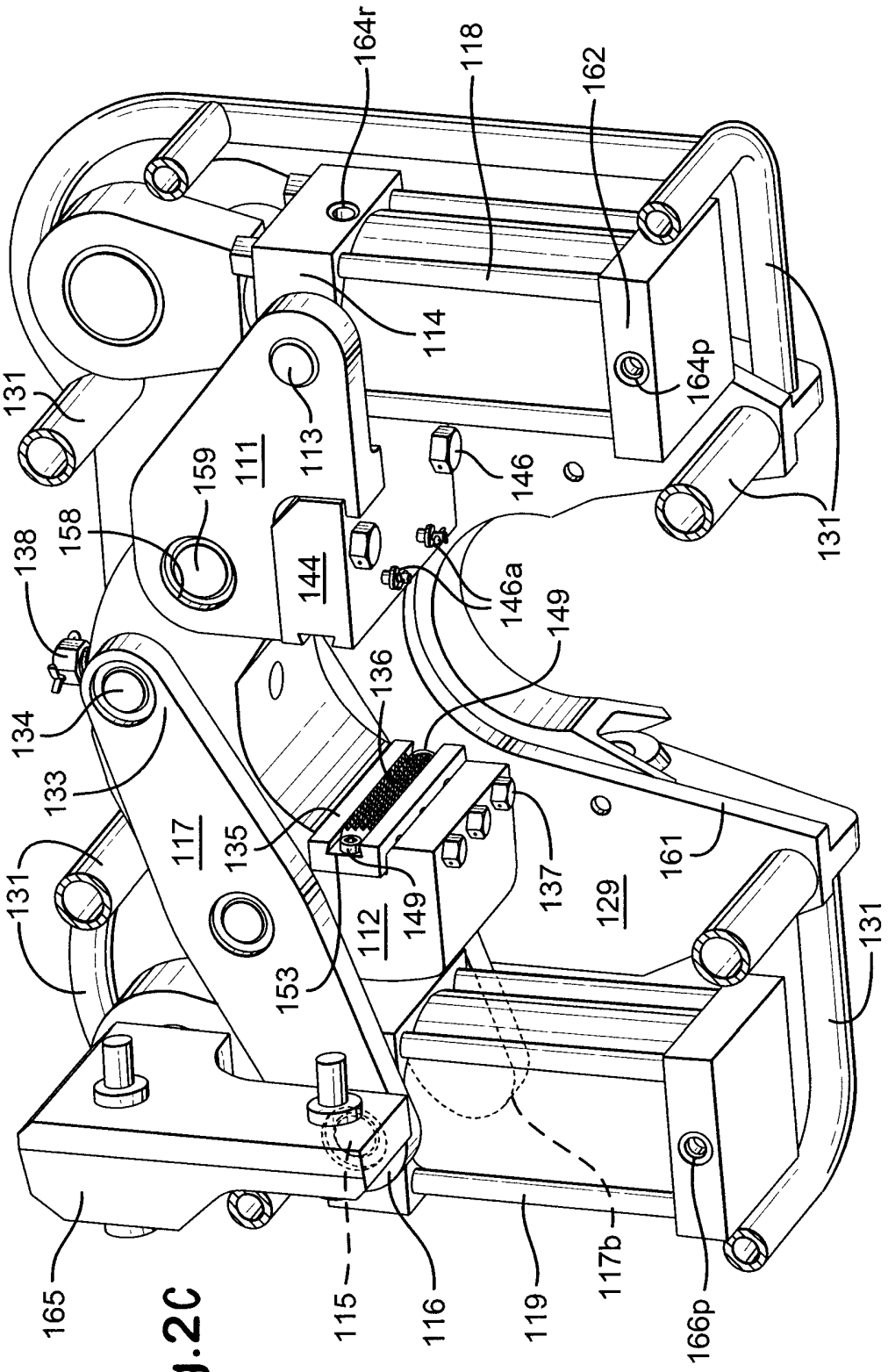
Fig.2B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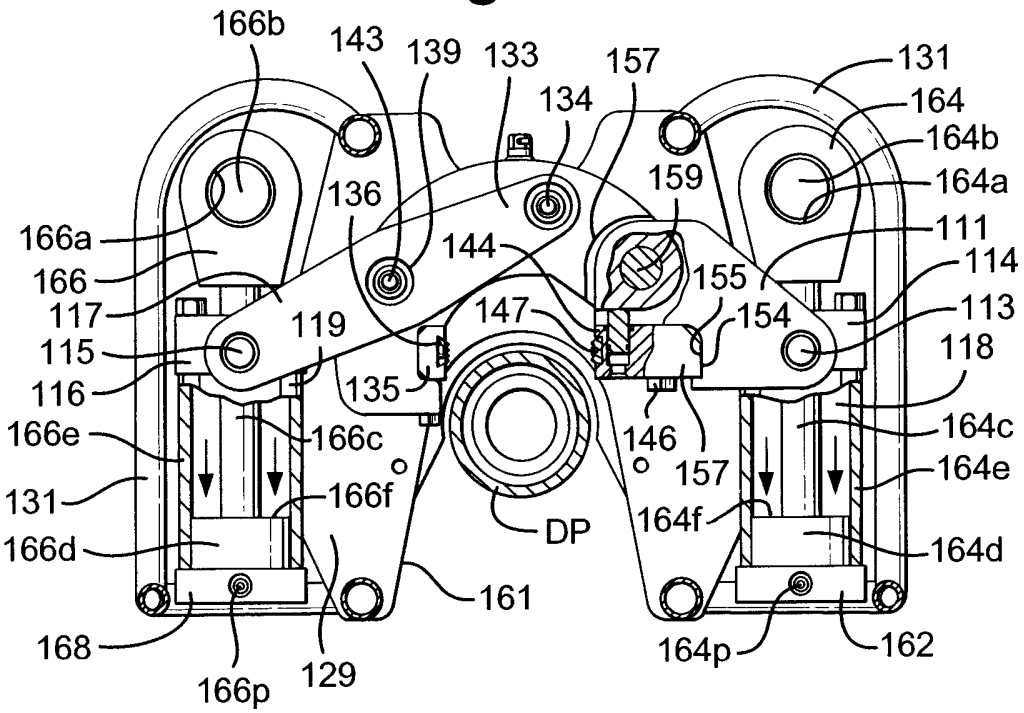
117b
166p

Fig.2C

Fig.3A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154
113
119
115
118
135
116
166e
166c
146
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DP
166d
164d
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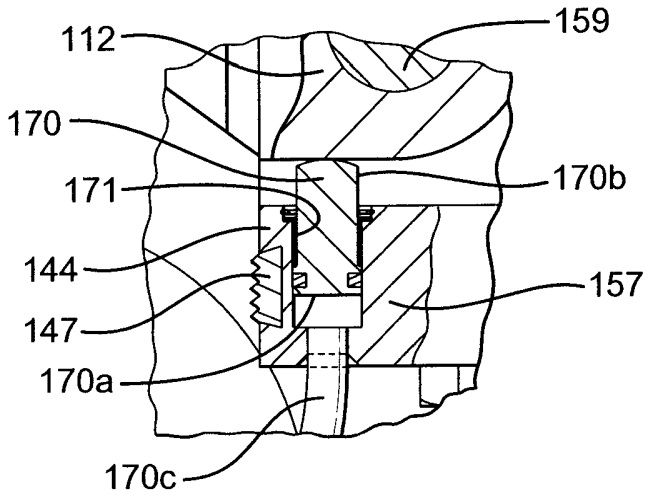
168
164p
162
166p
129

Fig.3B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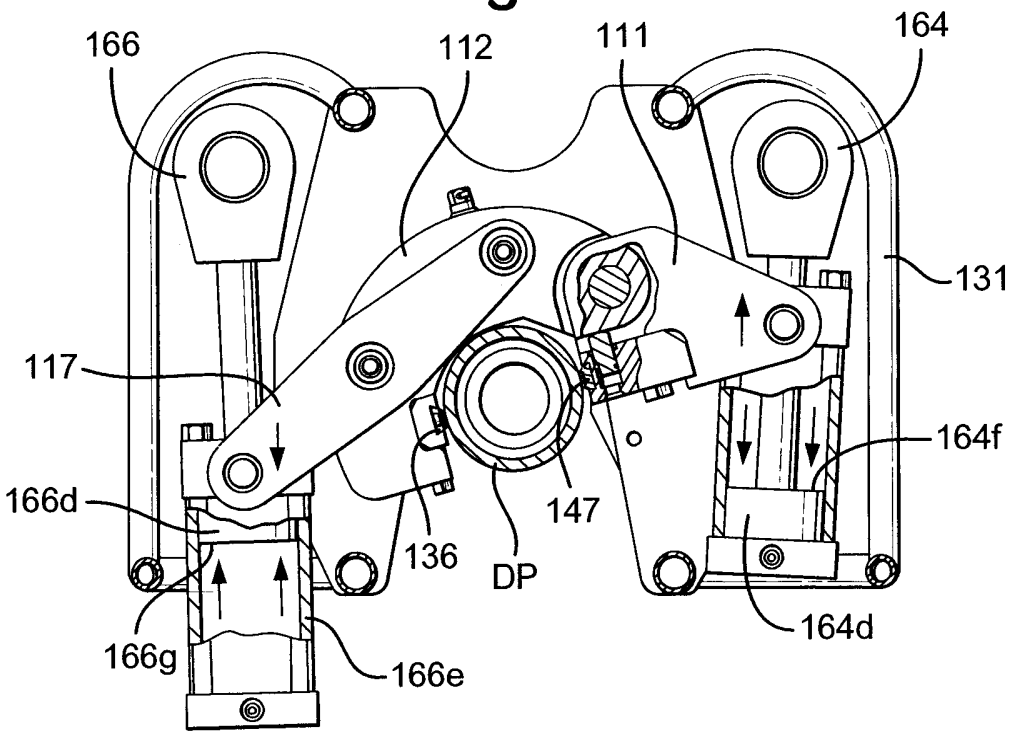
170c

Fig.4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164
131
117
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166d
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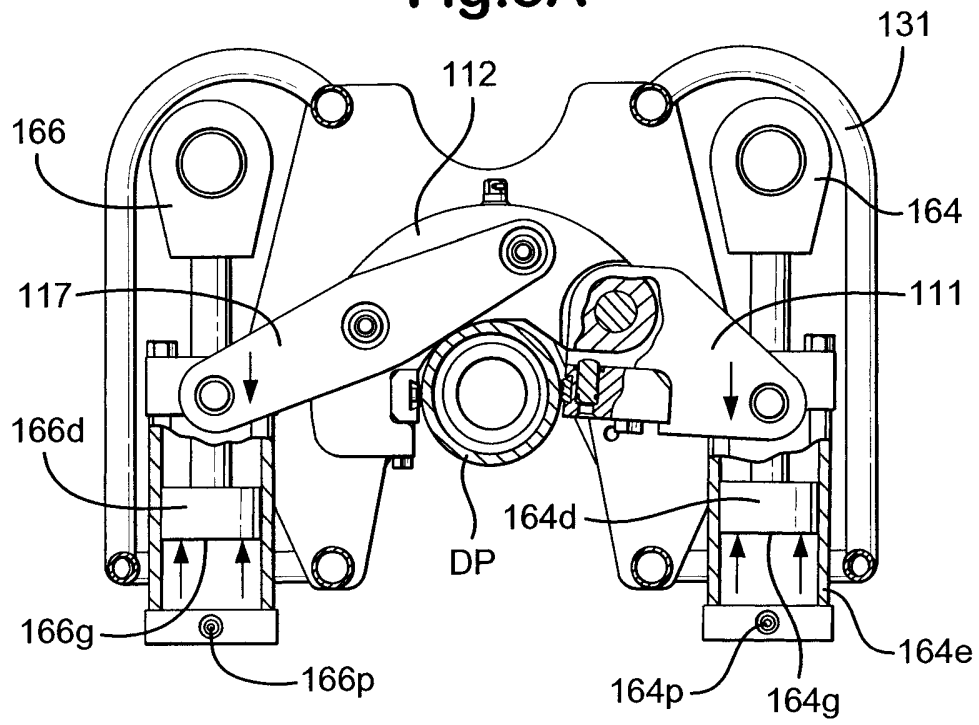
136
DP
164d
166g
166e

Fig.5A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112
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164d
DP
166g
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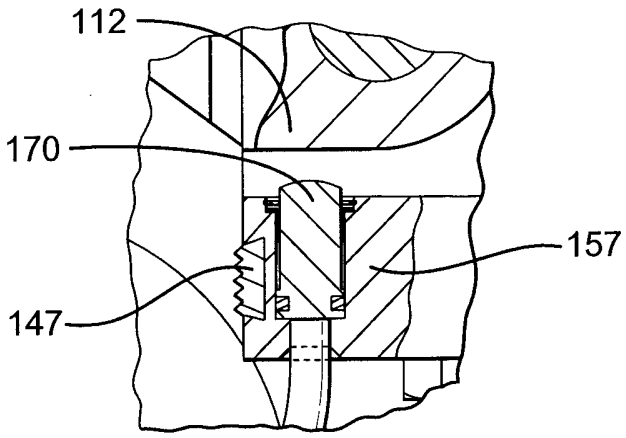
164p
164g
164e

Fig.5B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170
157
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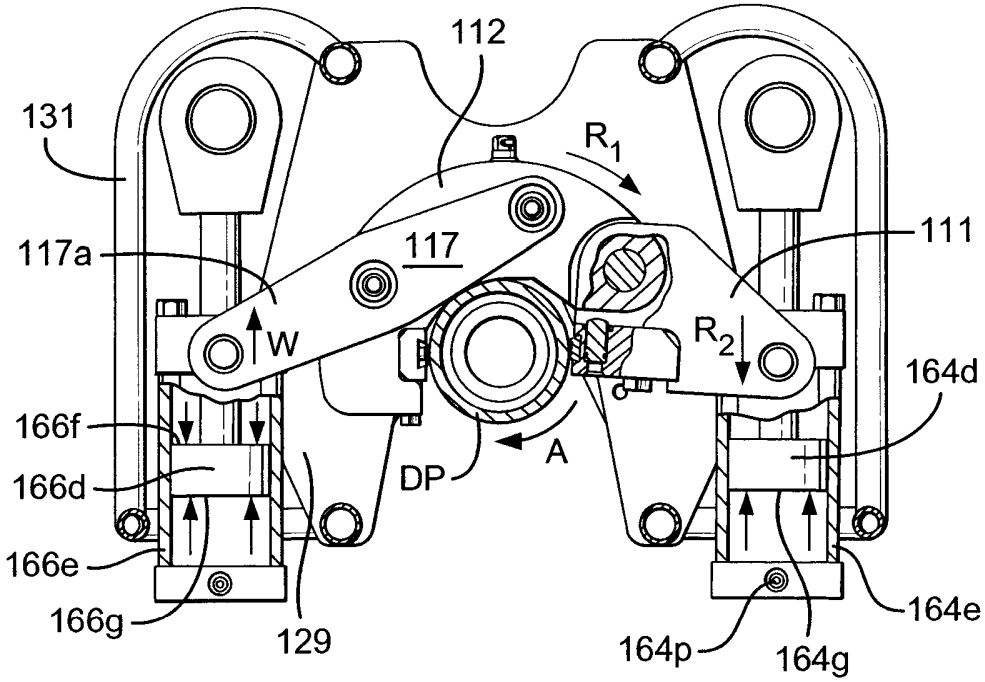
Fig.6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R_2
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DP
A
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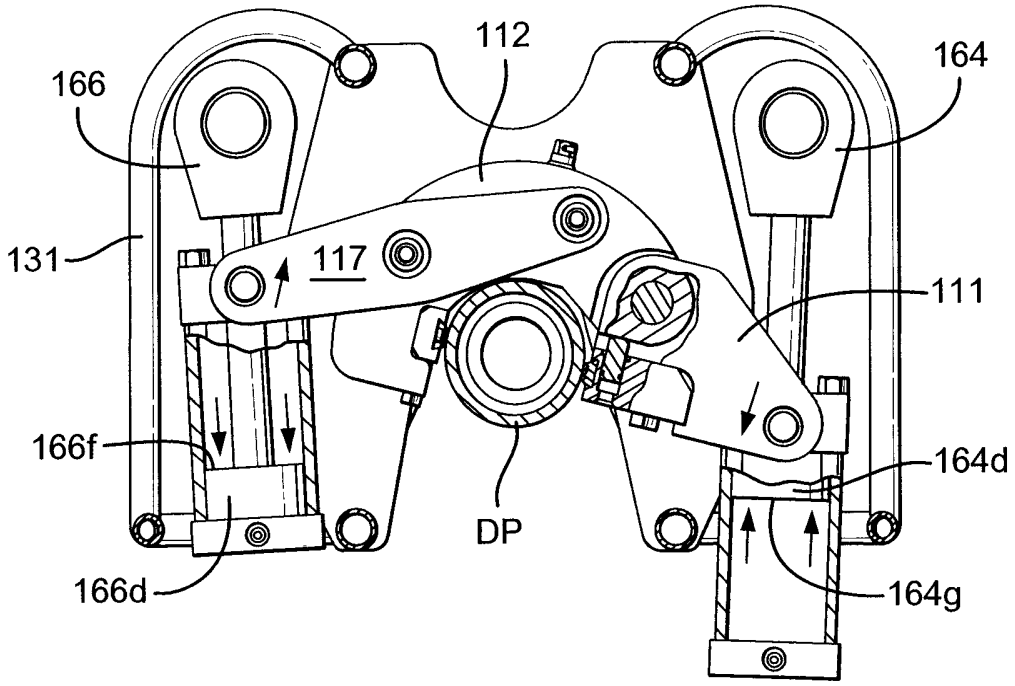
166g
129
164p
164g
164e

Fig.7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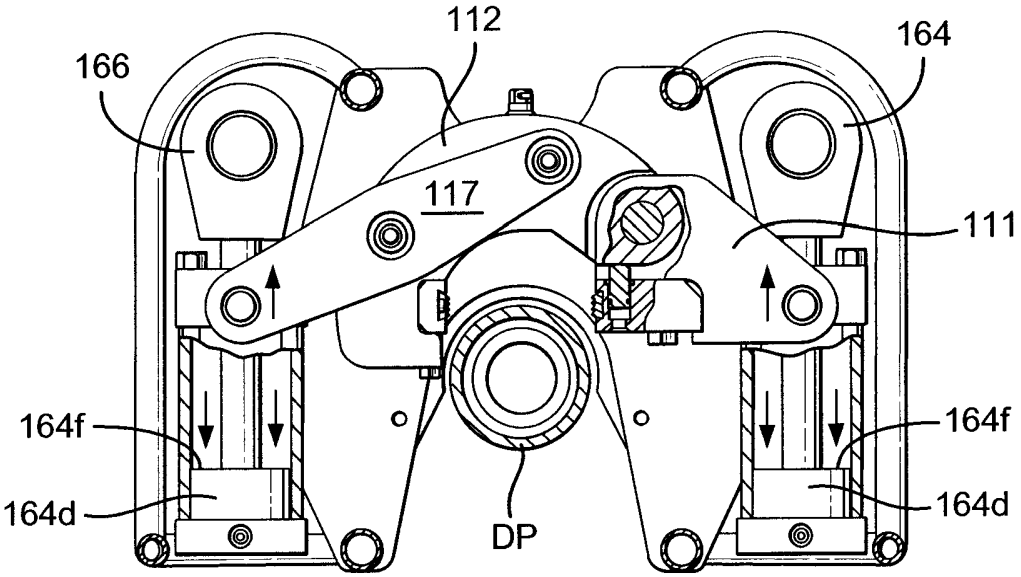
131
117
111
166f
164d
DP
166d
164g

Fig.8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117
111
164f
164f
164d
164d
DP

Fig.9A

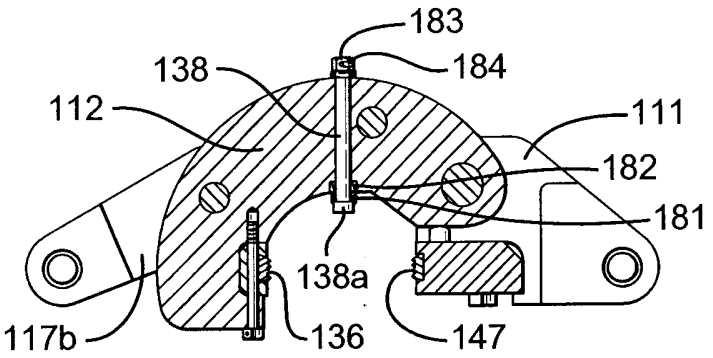


Fig.9B

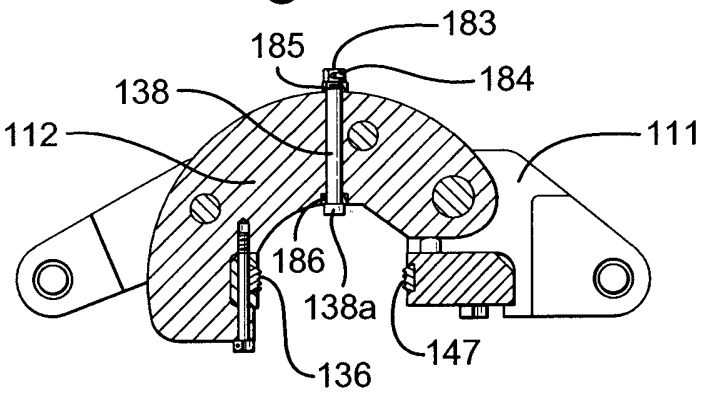


Fig.9C

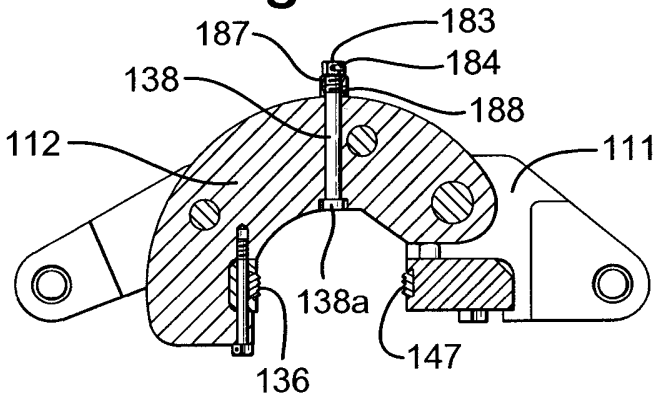


Fig.10

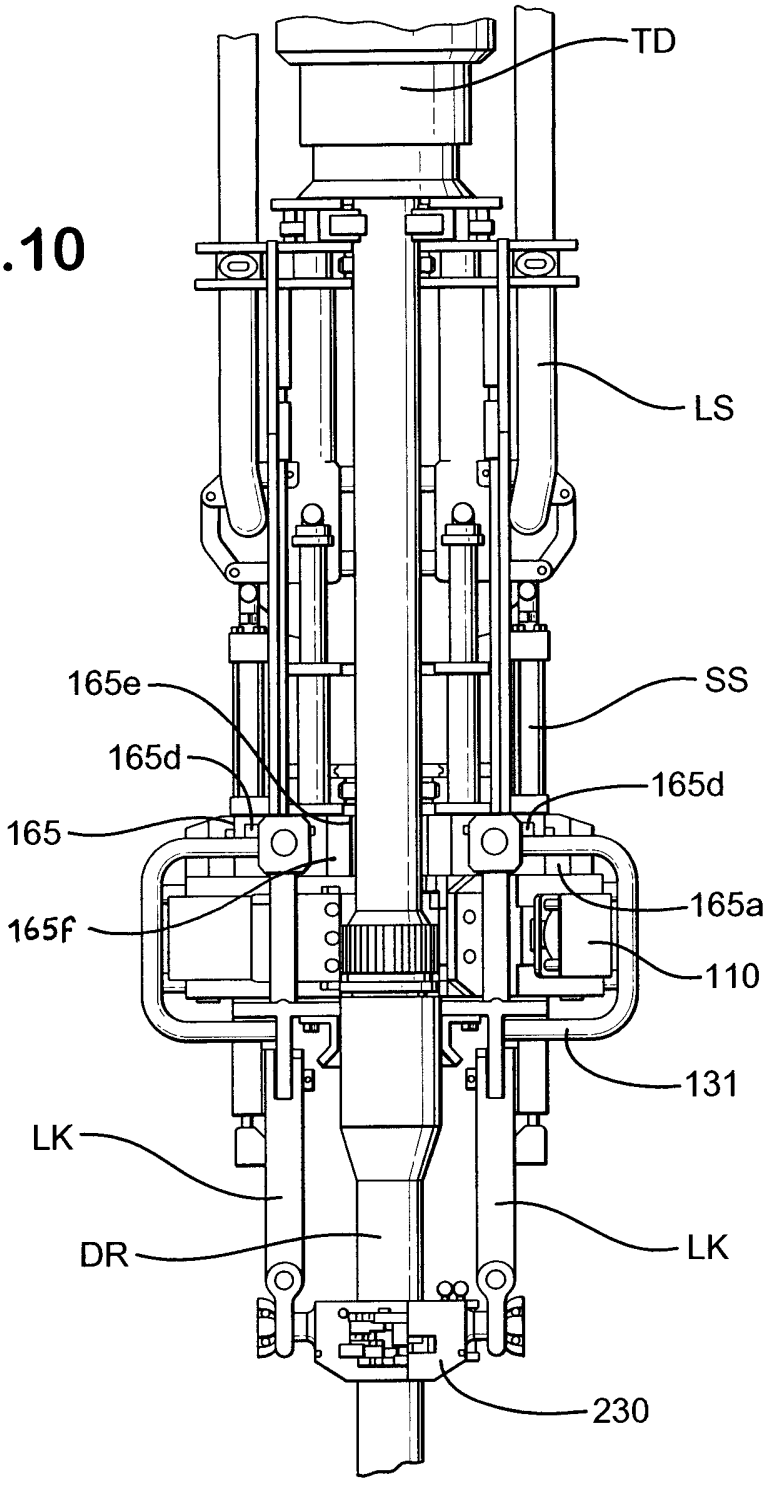


Fig.11

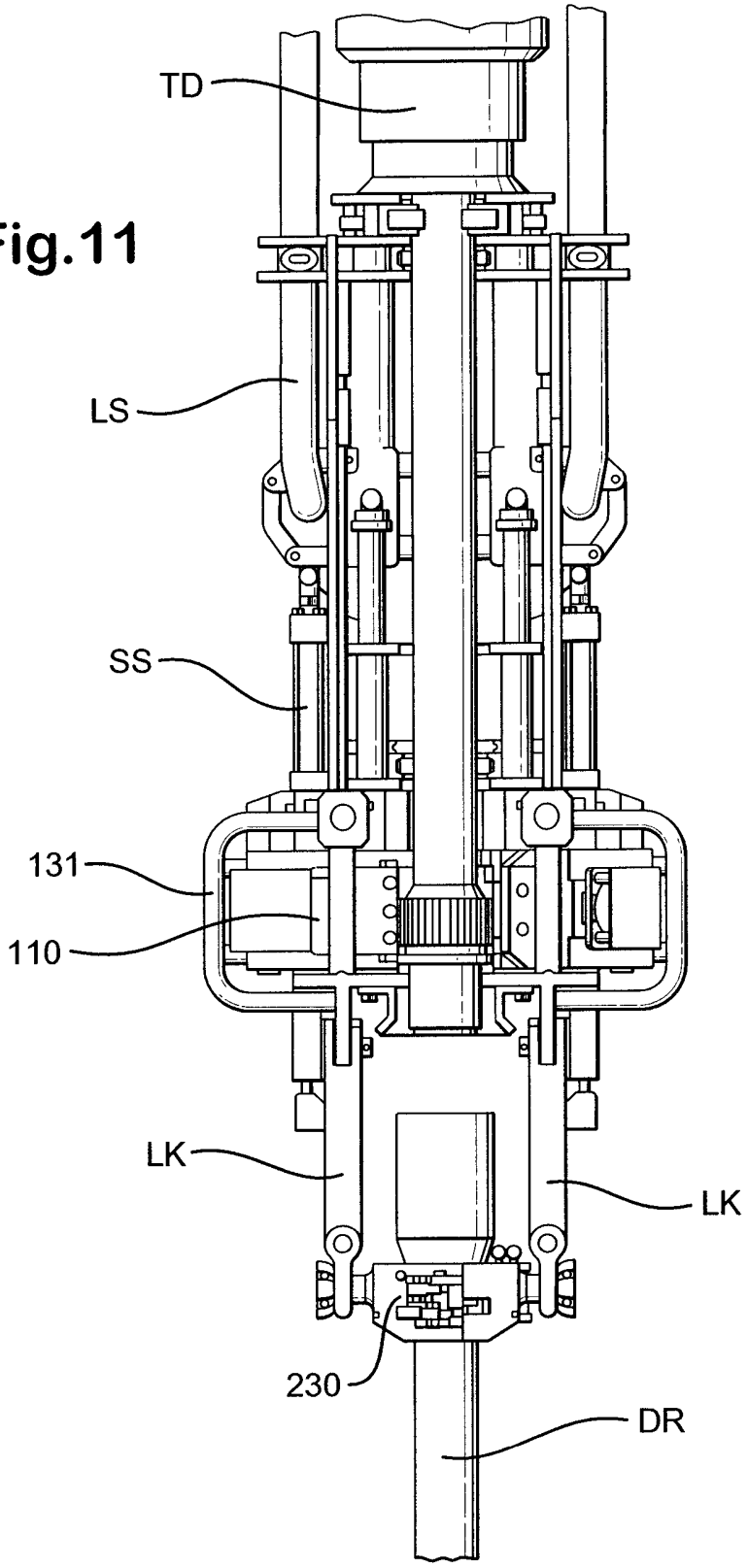
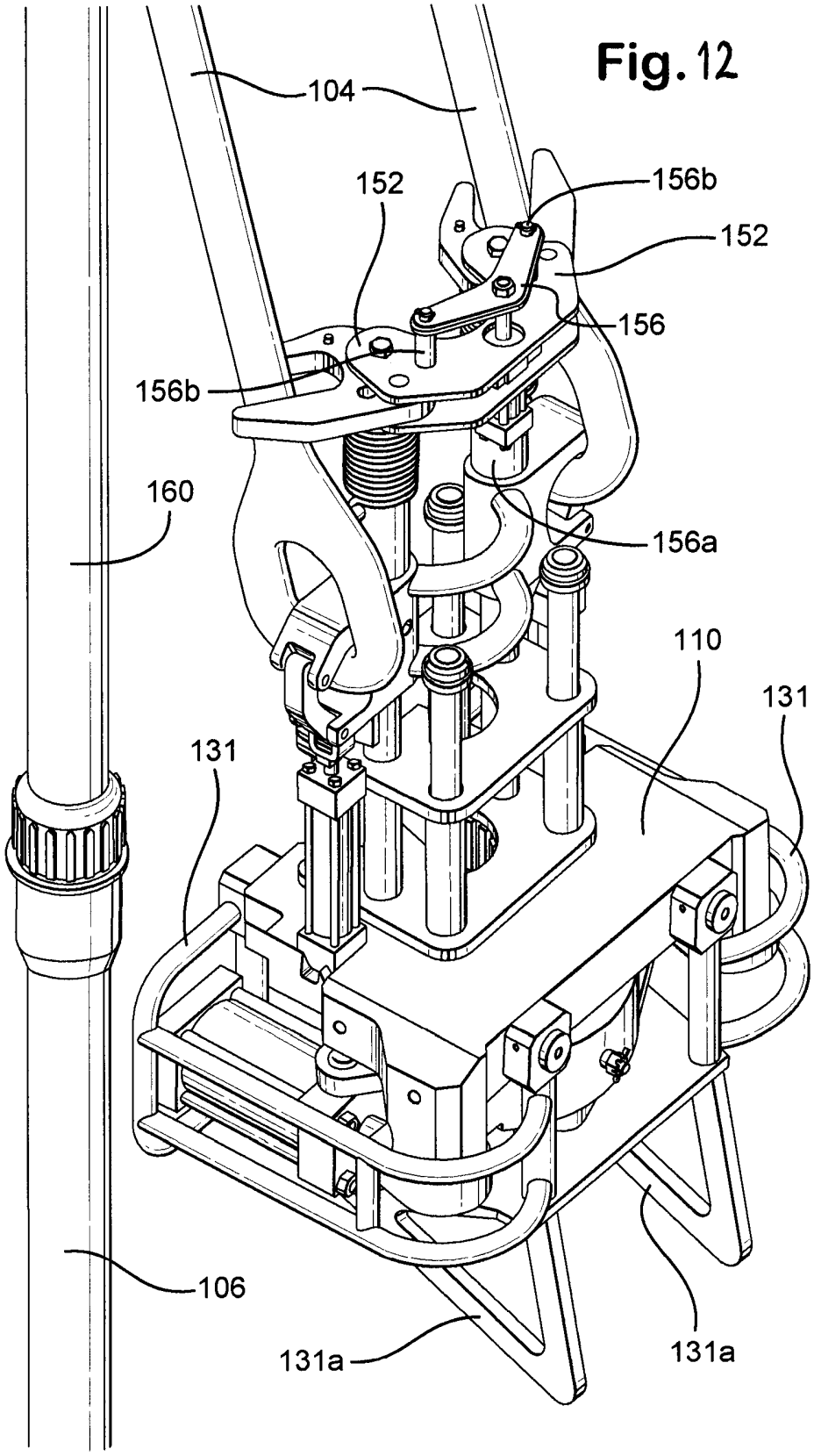


Fig. 12



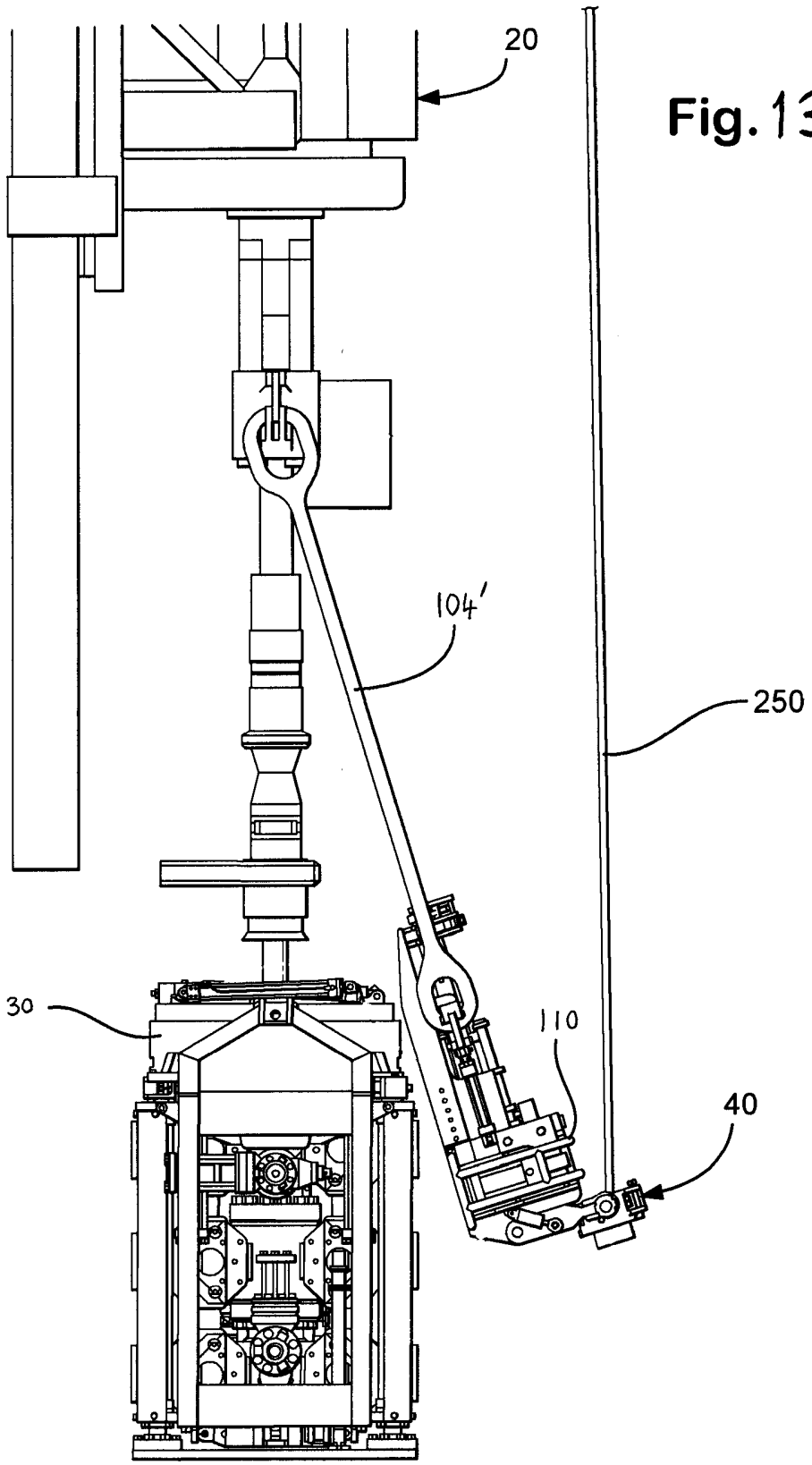


Fig. 13

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2005/050221

A. CLASSIFICATION OF SUBJECT MATTER
E21B19/20

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 575 344 A (WIREMAN ET AL) 19 November 1996 (1996-11-19) column 2, line 40 - column 4, line 24; figures 1,3,5	1-4,6-24
X	US 4 813 493 A (SHAW ET AL) 21 March 1989 (1989-03-21) column 3, line 43 - column 4, line 23 column 11, line 50 - column 12, line 22; figures 17-19	1-8, 17-24
X	US 4 696 207 A (BOYADJIEFF ET AL) 29 September 1987 (1987-09-29) abstract; figures 8-10	17

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2006	26/01/2006

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Tompouloglou, C

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB2005/050221

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5575344 A	19-11-1996	EP 0918916 A1 WO 9745621 A1	02-06-1999 04-12-1997
US 4813493 A	21-03-1989	WO 8808069 A2	20-10-1988
US 4696207 A	29-09-1987	NONE	