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(54) Titre : **SYSTEME D'ENTRAINEMENT SUPERIEUR MODULAIRE**
(54) Title: **MODULAR TOP DRIVE SYSTEM**

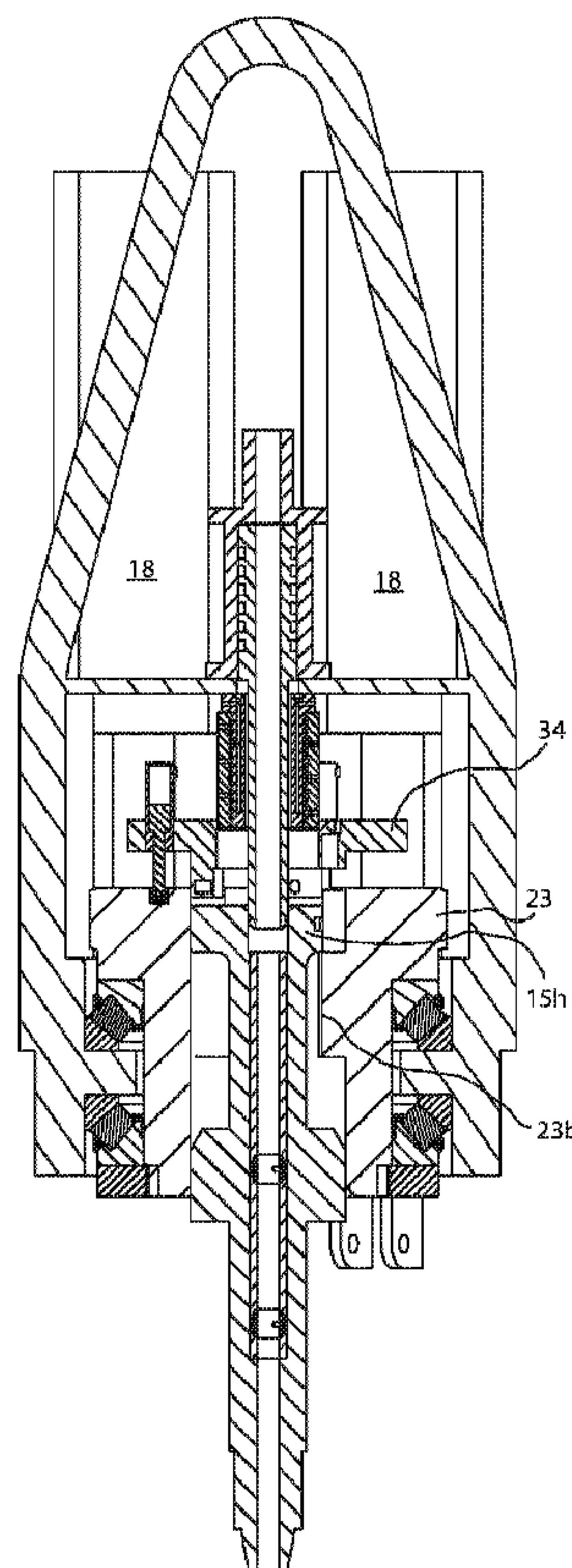


FIG. 4F

(57) **Abrégé/Abstract:**

A modular top drive system for construction of a wellbore includes a motor unit. The motor unit includes: a drive body; a drive motor having a stator connected to the drive body; a trolley for connecting the drive body to a rail of a drilling rig; and a drive ring



(57) **Abrégé(suite)/Abstract(continued):**

torsionally connected to a rotor of the drive motor and having a latch profile for selectively connecting one of: a drilling unit, a casing unit, and a cementing unit to the motor unit.

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[Continued on next page]

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tor unit. The motor unit includes: a drive body; a drive motor having a stator connected to
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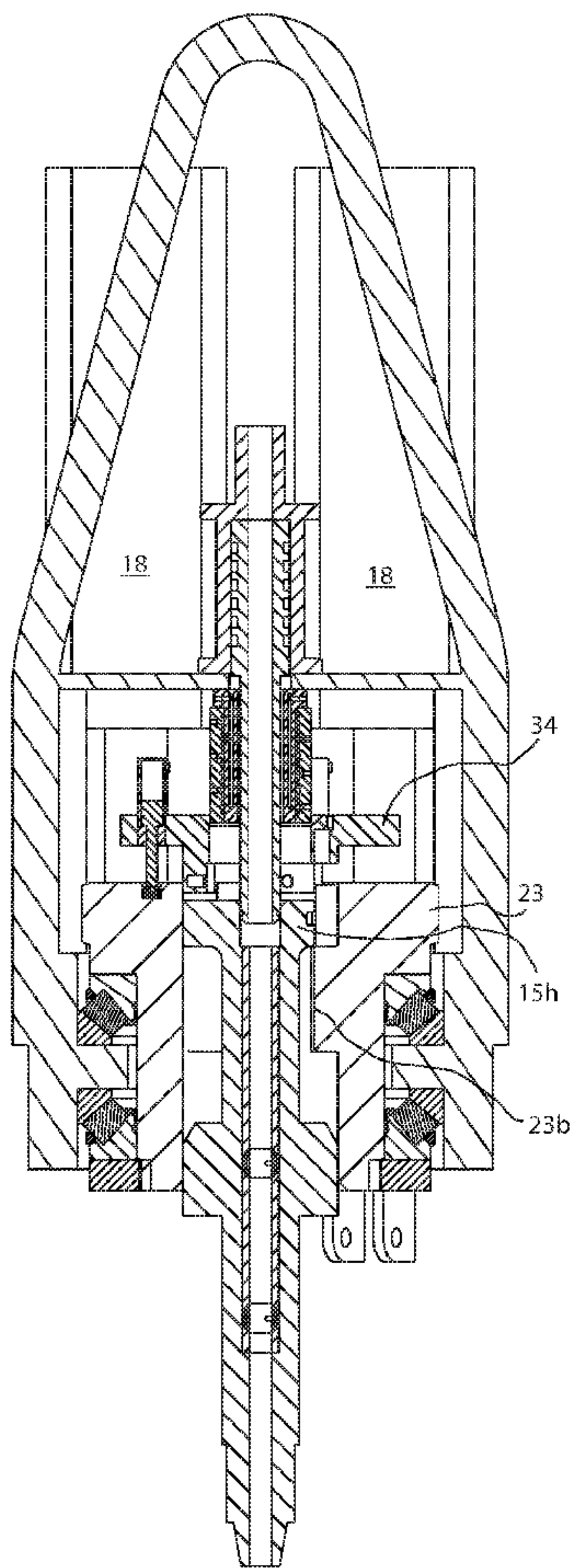


FIG. 4F

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MODULAR TOP DRIVE SYSTEM

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

[0001] The present disclosure generally relates to a modular top drive system.

Description of the Related Art

[0002] A wellbore is formed to access hydrocarbon-bearing formations (e.g., crude oil and/or natural gas) or for geothermal power generation by the use of drilling. Drilling is accomplished by utilizing a drill bit that is mounted on the end of a drill string. To drill within the wellbore to a predetermined depth, the drill string is often rotated by a top drive on a surface rig. After drilling to a predetermined depth, the drill string and drill bit are removed and a section of casing is lowered into the wellbore. An annulus is thus formed between the string of casing and the formation. The casing string is hung from the wellhead. A cementing operation is then conducted in order to fill the annulus with cement. The casing string is cemented into the wellbore by circulating cement into the annulus defined between the outer wall of the casing and the borehole. The combination of cement and casing strengthens the wellbore and facilitates the isolation of certain areas of the formation behind the casing for the production of hydrocarbons.

[0003] Top drives are equipped with a motor for rotating the drill string. The quill of the top drive is typically threaded for connection to an upper end of the drill pipe in order to transmit torque to the drill string. The top drive may also have various accessories to facilitate drilling. For adapting to the larger casing string, the drilling accessories are removed from the top drive and a gripping head is added to the top drive. The gripping head has a threaded adapter for connection to the quill and grippers for engaging an upper end of the casing string. This shifting of the top drive between drilling and casing modes is time consuming and dangerous requiring rig personnel to work at heights. The threaded connection between the quill and the gripping head also unduly limits the load capacity of the top drive in the casing mode.

SUMMARY OF THE DISCLOSURE

[0004] The present disclosure generally relates to a modular top drive system. One embodiment provides a top drive comprising a drive body, a drive motor, wherein a stator of the drive motor is connected to the drive body, and a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a tool.

[0005] Another embodiment provides a modular top drive system comprising a motor unit, a rack and a unit handler. The motor unit includes a drive body, a drive motor, wherein a stator of the drive motor is connected to the drive body, and a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a tool. The rack includes a parking spot for receiving the tool. The unit handler retrieves the tool from the rack and delivers the tool to the drive unit.

[0006] Another embodiment provides a method of operating a modular top drive system. The method includes aligning a latch profile of a tool with an internal latch profile formed on a drive ring of a motor unit, inserting the tool into the motor unit, and engaging the latch profiles to connect the tool to the motor unit.

[0007] In one embodiment, a modular top drive system for construction of a wellbore includes a motor unit. The motor unit includes: a drive body; a drive motor having a stator connected to the drive body; a trolley for connecting the drive body to a rail of a drilling rig; and a drive ring torsionally connected to a rotor of the drive motor and having a latch profile for selectively connecting one of: a drilling unit, a casing unit, and a cementing unit to the motor unit.

[0008] In another embodiment, a method of operating a modular top drive system includes: retrieving a drilling unit from a unit rack; raising the retrieved drilling unit to or above the rig floor; delivering the retrieved drilling unit to a motor unit connected to a rail of the drilling rig; aligning a latch profile of the motor unit with a latch profile of the drilling unit; inserting the drilling unit into the motor unit; and engaging the latch profiles, thereby connecting the drilling unit to the motor unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0010] Figure 1A illustrates a modular top drive system, according to one embodiment of the present disclosure. Figure 1B illustrates a unit rack of the modular top drive.

[0011] Figure 2A illustrates a motor unit of the modular top drive system. Figure 2B illustrates a drilling unit of the modular top drive system. Figure 2C illustrates a casing unit of the modular top drive system. Figure 2D illustrates a cementing unit of the modular top drive system.

[0012] Figure 3 is a control diagram of the modular top drive system in a drilling mode.

[0013] Figures 4A-4M illustrate shifting of the modular top drive system from a standby mode to the drilling mode.

[0014] Figures 5A-5H illustrate extension of a drill string using the modular top drive system in the drilling mode. Figure 5I illustrates drilling a wellbore using the extended drill string and the modular top drive system.

[0015] Figure 6A illustrates shifting of the modular top drive system from the drilling mode to the casing mode. Figures 6B-6F illustrate extension of a casing string using the modular top drive system in the casing mode. Figure 6G illustrates running of the extended casing string into the wellbore using the modular top drive system.

[0016] Figure 7 illustrates cementing of the casing string using the modular top

drive system in a cementing mode.

[0017] Figure 8 illustrates the modular top drive system in a cargo mode.

[0018] Figures 9A and 9B illustrates an alternative modular top drive system, according to another embodiment of the present disclosure.

[0019] Figures 10A and 10B illustrate an alternative unit rack for the modular top drive system, according to another embodiment of the present disclosure. Figure 10C illustrates a second alternative unit rack for the modular top drive system, according to another embodiment of the present disclosure.

[0020] Figures 11A-11C illustrate an alternative unit handler for the modular top drive system, according to another embodiment of the present disclosure.

[0021] Figure 12 illustrates a torque sub accessory for the modular top drive system, according to another embodiment of the present disclosure.

[0022] Figures 13A and 13B schematically illustrate a top drive unit having a movable latch profile according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

[0023] Figure 1A illustrates a modular top drive system 1, according to one embodiment of the present disclosure. The modular top drive system 1 may include a linear actuator 1a (Figure 4L), a casing unit 1c, a drilling unit 1d, a pipe handler 1p, a unit rack 1k, a motor unit 1m, a rail 1r, a cementing unit 1s, and a unit handler 1u. The unit handler 1u may include a post 2, a slide hinge 3, an arm 4, a holder 5, a base 6, and one or more actuators (not shown).

[0024] The modular top drive system 1 may be assembled as part of a drilling rig 7 by connecting a lower end of the rail 1r to a floor 7f of the rig and an upper end of the rail to a derrick 7d of the rig such that a front of the rail is adjacent to a drill string opening in the rig floor. The rail 1r may have a length sufficient for the top drive system 1 to handle stands 8s of two to four joints of drill pipe 8p. It should be noted that the rail 1r may have a length for the top drive system 1 to hand more joints of drill pipe 8p. The rail length may be greater than or equal to twenty-five

meters and less than or equal to one hundred meters.

[0025] Alternatively, the modular top drive system 1 may include twin rails instead of the monorail 1r. Alternatively, the lower end of the rail 1r may be connected to the derrick 7d instead of the floor 7f.

[0026] The base 6 may mount the post 2 on or adjacent to a structure of the drilling rig 7, such as a subfloor structure, such as a catwalk (not shown) or pad. . Alternatively, the base 6 may a standalone structure. The unit rack 1k may also be located on or adjacent to the rig structure. The post 2 may extend vertically from the base 6 to a height above the rig floor 7f such that the unit handler 1u may retrieve any of the units 1c,d,s from the rack 1k and deliver the retrieved unit to the motor unit 1m.

[0027] The arm 4 may be connected to the slide hinge 3, such as by fastening. The slide hinge 3 may be transversely connected to the post 2, such as by a slide joint, while being free to move longitudinally along the post. Alternatively, the slide hinge 3 may be connected to the post 2 by any suitable structures, for example, by a friction bearing or a roller/ball bearing. The slide hinge 3 may also be pivotally connected to a linear actuator (not shown), such as by fastening. The slide hinge 3 may longitudinally support the arm 4 from the linear actuator while allowing pivoting of the arm relative to the post 2. The unit handler 1u may further include an electric, pneumatic, or hydraulic slew motor (not shown) for pivoting the arm 4 about the slide hinge 3.

[0028] The linear actuator may have a lower end pivotally connected to the base 6 and an upper end pivotally connected to the slide hinge 3. The linear actuator may include a cylinder and a piston disposed in a bore of the cylinder. The piston may divide the cylinder bore into a raising chamber and a lowering chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with a manifold 60m of a hydraulic power unit (HPU) 60 (both in Figure 3) via a control line (not shown). Supply of hydraulic fluid to the raising port may move the slide hinge 3 and arm 4 upward to the rig floor 7f. Supply of

hydraulic fluid to the lowering port may move the slide hinge 3 and arm 4 downward toward the base 6.

[0029] Alternatively, the linear actuator may include an electro-mechanical linear actuator, such as a motor and lead screw or pinion and gear rod, instead of the piston and cylinder assembly. For example, a gear rod connected to the post 2 may be meshed with a motor with gears at the location of the slide hinge 3. Alternatively, a rope may be used to move the slide hinge 3 up and down along the post 2

[0030] The arm 4 may include a forearm, an aft-arm, and an actuated joint, such as an elbow, connecting the arm segments. The holder 5 may be releasably connected to the forearm, such as by fastening. The arm 4 may further include an actuator (not shown) for selectively curling and extending the forearm and relative to the aft-arm. The arm actuator may have an end pivotally connected to the forearm and another end pivotally connected to the aft-arm. The arm actuator may include a cylinder and a piston disposed in a bore of the cylinder. The piston may divide the cylinder bore into an extension chamber and a curling chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with the HPU manifold 60m via a control line (not shown). Supply of hydraulic fluid to the respective ports may articulate the forearm and holder 5 relative to the aft-arm toward the respective positions.

[0031] Alternatively, the arm actuator may include an electro-mechanical linear actuator, such as a motor and lead screw or pinion and gear rod, instead of the piston and cylinder assembly. Alternatively, the actuated joint may be a telescopic joint instead of an elbow. Alternatively, the arm 4 may include more than two arm segments, joined together by linear joints, telescopic joints, or a combination of telescopic and linear joints. Additionally, the holder 5 may include a safety latch for retaining any of the units 1c,d,s thereto after engagement of the holder therewith to prevent unintentional release of the units during handling thereof. Additionally, the holder 5 may include a brake for torsionally connecting any of the units 1c,d,s thereto after engagement of the holder therewith to facilitate connection to the

motor unit 1m.

[0032] Referring to Figure 4L, the pipe handler 1p may include a drill pipe elevator 9d (Figure 5A) or casing elevator 9c (Figure 6C) and adapters (not shown), a pair of bails 10, a link tilt 11, and a slide hinge 12. The slide hinge 12 may be transversely connected to the rail 1r such as by a slide joint, while being free to move longitudinally along the rail. Each bail 10 may have an eyelet formed at each longitudinal end thereof. An upper eyelet of each bail 10 may be received by a respective pair of knuckles of the slide hinge 12 and pivotally connected thereto, such as by fastening. In the drilling mode, the adapters may be removed from the lower eyelets and a lower eyelet of each bail 10 may be received by a respective ear of the drill pipe elevator 9d and pivotally connected thereto, such as by fastening. Alternatively, an adaptor connected to the bail 10 may be used to supply a connection position for the casing elevator 9c. Width adjustment may be provided by sideways tilting of the bails 10.

[0033] In the casing mode, each adapter may be inserted into the respective lower eyelet and connected to the respective bail 10. Each adapter may include a base, an upper collar, a lower collar, and a linkage. The upper collar may include a pair of bands disposed around a portion of the respective bail 10 adjacent to the lower eyelet. The bands may be connected together and one of the bands may be connected to the base, such as by fastening. The lower collar may extend around a bottom of the respective lower eyelet and be connected to the base, such as by fastening. The base may be disposed through the respective eyelet and have a shape conforming to the interior thereof. The linkage may include a pair of triangular arms pivotally connected to an upper portion of the base, such as by fastening. The linkage may further include a straight arm pivotally connected to the triangular arms and pivotally connected to the base, such as fastening. The straight arm may have a plurality of holes formed therethrough and the base may have a slot formed therein for receiving the straight arm at various positions to provide adjustability to suit various casing elevators 9c. A lower portion of the triangular arms may receive a respective ear of the casing elevator 9c and be pivotally connected thereto, such as by fastening.

[0034] The link tilt 11 may include a pair of piston and cylinder assemblies for swinging either elevator 9c,d (Figures 6C, 5A) relative to the slide hinge 12. Each piston and cylinder assembly may have a coupling, such as a hinge knuckle, formed at each longitudinal end thereof. An upper hinge knuckle of each piston and cylinder assembly may be received by the respective lifting lug of the slide hinge 12 and pivotally connected thereto, such as by fastening. A lower hinge knuckle of each PCA may be received by a complementary hinge knuckle of the respective bail 10 and pivotally connected thereto, such as by fastening. A piston of each piston and cylinder assembly may be disposed in a bore of the respective cylinder. The piston may divide the cylinder bore into a raising chamber and a lowering chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with the HPU manifold 60m via a respective control line 66b,c (Figure 3). Supply of hydraulic fluid to the raising port may lift either elevator 9c,d (Figures 6C and 5A) by increasing a tilt angle (measured from a longitudinal axis of the rail 1r). Supply of hydraulic fluid to the lowering port may drop either elevator 9c,d (Figures 6D and 5C) by decreasing the tilt angle.

[0035] The drill pipe elevator 9d may be manually opened and closed or the pipe handler 1p may include an actuator (not shown) for opening and closing the elevator. The actuator may be controlled locally or remotely. The drill pipe elevator 9d may include a bushing having a profile, such as a bottleneck, complementary to an upset formed in an outer surface of a joint of the drill pipe 8p adjacent to the threaded coupling thereof. The bushing may receive the drill pipe 8p for hoisting one or more joints thereof, such as the stand 8s. The bushing may allow rotation of the stand 8s relative to the pipe handler 1p. The pipe handler 1p may deliver the stand 8s to a drill string 8 (Figure 5A) where the stand 8s may be assembled therewith to extend the drill string during a drilling operation. When connected to the motor unit 1m, the pipe handler 1p may be capable of supporting the weight of the drill string 8 (as opposed to a single joint elevator which is only capable of supporting the weight of the stand 8s) to expedite tripping of the drill string.

[0036] The casing elevator 9c may be similar to the drill pipe elevator 9d except

for being sized to handle a joint 90j (Figure 6B) of casing. The pipe handler 1p may be used to assemble the casing joint 90j with a casing string 90 (Figure 6C) in a similar fashion as with the drill string 8, discussed above, with a few exceptions.

[0037] Alternatively, a remote controlled drilling elevator of the rig 7 may be used instead of the pipe handler 1p to assemble or disassemble the drill string 8 and/or a remote controlled single joint elevator of the rig may be used assemble or disassemble the casing string 90 instead of the pipe handler. Alternatively, the slide hinge 12 and linear actuator 1a may be omitted and the link tilt 11 and bails 10 may instead be pivotally connected to the motor unit 1m.

[0038] Alternatively, the drill pipe elevator 9d may have a gripper, such as slips and a cone, capable of engaging an outer surface of the drill pipe 8p at any location therealong. Alternatively, the casing elevator 9c may have a gripper, such as slips and a cone, capable of engaging an outer surface of the casing joint 90j at any location therealong.

[0039] The linear actuator 1a may include a gear rack, one or two pinions (not shown), and one or two pinion motors (not shown). The linear actuator 1a may include more than two pinions and pinion motors. The gear rack may be a bar having a geared upper portion and a plain lower portion. The gear rack may have a knuckle formed at a bottom thereof for pivotal connection with a lifting lug of the slide hinge 12, such as by fastening. Each pinion may be meshed with the geared upper portion and torsionally connected to a rotor of the respective pinion motor. A stator of each pinion motor may be connected to the motor unit 1m and be in electrical communication with a motor driver 61 via a cable 67b (both shown in Figure 3). The pinion motors may share a cable via a splice (not shown). Each pinion motor may be reversible and rotation of the respective pinion in a first direction, such as counterclockwise, may raise the slide hinge 12 relative to the motor unit 1m and rotation of the respective pinion in a second opposite direction, such as clockwise, may lower the slide hinge relative to the motor unit. Each pinion motor may include a brake (not shown) for locking position of the slide hinge once the pinion motors are shut off. The brake may be disengaged by supply of electricity to the pinion motors and engaged by shut off of electricity to the pinion

motors.

[0040] The linear actuator 1a may be capable of hoisting the stand 8s and the casing joint 90j. A stroke of the linear actuator 1a may be sufficient to stab a top coupling of the stand 8s into a quill 37 of the motor unit 1m and sufficient to stab an upper portion of the casing joint 90j into a spear 40 of the casing unit 1c.

[0041] Alternatively, the pinion motors and brake may be hydraulic or pneumatic instead of electric. Alternatively, the linear actuator 1a may include a braking system separate from the pinion motor and having a separate control line for operation thereof, such as a sliding brake or as a transverse gear rack stub extendable into engagement with the gear rack. Alternatively, the linear actuator 1a may include a gear box torsionally connecting each pinion motor to the respective pinion.

[0042] Figure 1B illustrates the unit rack 1k. The unit rack 1k may include a base 13b, a beam 13m, two or more (three shown) columns 13c connecting the base to the beam, such as by welding or fastening, and a parking spot 14 for each of the units 1c,d,s (four spots shown). Alternative, the unit rack 1k may include on or more columns 13c. A length of the columns 13c may correspond to a length of the longest one of the units 1c,d,s, such as being slightly greater than the longest length. The columns 13c may be spaced apart to form parking spots (four shown) between adjacent columns. The units 1c,d,s may be hung from the beam by engagement of the parking spots 14 with respective couplings 15 of the units. Each parking spot 14 may include an opening formed through the beam 13m, a ring gear 14g, and a motor 14m. Each ring gear 14g may be supported from and transversely connected to the beam 13b by a bearing (not shown) such that the ring gear 14g may rotate relative to the beam 13b. Each bearing may be capable supporting the weight of any of the units 1c,d,s and placement of a particular unit in a particular parking spot 14 may be arbitrary. In one embodiment, each parking spot 14 of the unit rack 1k may include a latch profile that is the same as a latch profile 23b in the top drive unit 1m. In one embodiment, the unit rack 1k may include an integrated tool handler. The integrated tool handler may be used to deliver a tool to and/or receive a tool from the unit handler 1u.

[0043] Each motor 14m may include a stator connected to the beam 13m and may be in electrical communication with a motor driver 61 (Figure 3) via a cable (not shown). A rotor of each motor 14m may be meshed with the respective ring gear 14g for rotation thereof between a disengaged position (Figure 4A) and an engaged position. Each ring gear 14g may have an internal latch profile, such as a bayonet profile, and each coupling may 15 may include a head 15h having an external latch profile, such as a bayonet profile. The bayonet profiles may each have one or more (three shown) prongs and prong-ways spaced around the respective ring gears 14g and heads 15h at regular intervals. When the prongs of the respective bayonet profiles are aligned, the external prongs of the heads 15h may be engaged with the internal prongs of the respective ring gears 14g, thereby supporting the units 1c,d,s from the beam 13m. When the external prongs of the heads 15h are aligned with the internal prong-ways of the ring gears 14g (and vice versa), the heads may be free to pass through the respective ring gears.

[0044] Alternatively, the ring gear motors may be pneumatic or hydraulic instead of electric.

[0045] Each coupling 15 may further include a neck 15n extending from the head 15h and having a reduced diameter relative to a maximum outer diameter of the head for extending through the respective beam opening and respective ring gear 14g. Each coupling 15 may further include a lifting shoulder 15s connected to a lower end of the neck 15n and having an enlarged diameter relative to the reduced diameter of the neck and a torso 15r extending from the lifting shoulder 15s and having a reduced diameter relative to the enlarged diameter of the lifting shoulder. The torso 15r may have a length corresponding to a length of the holder 5 for receipt thereof and a bottom of the lifting shoulder 15s may seat on a top of the holder for transport from the unit rack 1k to the motor unit 1m.

[0046] The unit rack 1k may further include a side bar 13r for holding one or more accessories for connection to the forearm instead of the holder 5, such as a cargo hook 16 and a pipe clamp 17. The side bar 13r may also hold the holder 5 when the unit handler 1u is equipped with one of the accessories.

[0047] Advantageously, the unit rack 1k may be used to load or unload any of the units 1c,d,s from either side thereof. The units 1c,d,s may be initially loaded onto the rack 1k, such as by a forklift (not shown).

[0048] Alternatively, the accessories may be stowed in a separate rack. Alternatively, the unit handler 1u, side bar 13r, and/or separate accessory rack may include an automated quick connect system for connecting any of the holder 5, cargo hook 16, and pipe clamp 17 to the arm 4 and for releasing any of the members therefrom and the quick connect system may be remotely operated by a technician to switch the members.

[0049] Figure 2A illustrates the motor unit 1m. The motor unit 1m may include one or more (pair shown) drive motors 18, a becket 19, a hose nipple 20, a mud swivel 21, a drive body 22, a drive ring, such as gear 23, a trolley 24 (Figure 3), a thread compensator 25, a control, such as hydraulic, swivel 26, a down thrust bearing 27, an up thrust bearing 28, a backup wrench 29 (Figure 4L), a swivel frame 30, a bearing retainer 31, a motor gear 32 (Figure 3), and a latch 57 (Figure 3). The drive body 22 may be rectangular, may have thrust chambers formed therein, may have an inner rib dividing the thrust chambers, and may have a central opening formed therethrough and in communication with the chambers. The drive gear 23 may be cylindrical, may have a bore therethrough, may have an outer flange 23f formed in an upper end thereof, may have an outer thread formed at a lower end thereof, may have an inner locking profile 23k formed at an upper end thereof, and may have an inner latch profile, such as a bayonet profile 23b, formed adjacently below the locking profile. The inner bayonet profile 23b may be similar to the inner bayonet profile of the ring gears 14g except for having a substantially greater thickness for sustaining weight of either the casing string 90 or drill string 8. The bearing retainer 31 may have an inner thread engaged with the outer thread of the drive gear 23, thereby connecting the two members.

[0050] The drive motors 18 may be electric (shown) or hydraulic (not shown) and have a rotor and a stator. A stator of each drive motor 18 may be connected to the trolley 24, such as by fastening, and be in electrical communication with the motor driver 61 via a cable 67c (Figure 3). The motors 18 may be operable to rotate

the rotor relative to the stator which may also torsionally drive respective motor gears 32. The motor gears 32 may be connected to the respective rotors and meshed with the drive gear 23 for torsional driving thereof.

[0051] Alternatively, the motor unit 1m may instead be a direct drive unit having the drive motor 18 centrally located. Alternatively, the hydraulic swivel 26 may be pneumatic, electric, or the combinations thereof.

[0052] Each thrust bearing 27, 28 may include a shaft washer, a housing washer, a cage, and a plurality of rollers extending through respective openings formed in the cage. The shaft washer of the down thrust bearing 27 may be connected to the drive gear 23 adjacent to a bottom of the flange thereof. The housing washer of the down thrust bearing 27 may be connected to the drive body 22 adjacent to a top of the rib thereof. The cage and rollers of the down thrust bearing 27 may be trapped between the washers thereof, thereby supporting rotation of the drive gear 23 relative to the drive body 22. The down thrust bearing 27 may be capable of sustaining weight of either the drill string 8 or the casing string 90 during rotation thereof. The shaft washer of the up thrust bearing 28 may be connected to the drive gear 23 adjacent to the bearing retainer 31. The housing washer of the up thrust bearing 28 may be connected to the drive body 22 adjacent to a bottom of the rib thereof. The cage and rollers of the up thrust bearing 28 may be trapped between the washers thereof. The up thrust bearing 28 functions to preload the connection thus avoiding chattering along the vertical direction. The up thrust bearing 28 also transfers a downward load from the motor unit 1m to the work string.

[0053] The trolley 24 may be connected to a back of the drive body 22, such as by fastening. The trolley 24 may be transversely connected to the rail 1r and may ride along the rail, thereby torsionally restraining the drive body 22 while allowing vertical movement of the motor unit 1m with a travelling block 73t (Figure 5A) of a rig hoist 73. The becket 19 may be connected to the drive body 22, such as by fastening, and the becket may receive a hook of the traveling block 73t to suspend the motor unit 1m from the derrick 7d.

[0054] The hose nipple 20 may be connected to the mud swivel 21 and receive an end of a mud hose (not shown). The mud hose may deliver drilling fluid 87 (Figure 5A) from a standpipe 79 (Figure 5A) to the hose nipple 20. The mud swivel 21 may have an outer non-rotating barrel 21o connected to the hose nipple 20 and an inner rotating barrel 21n. The mud swivel 21 may have a bearing (not shown) and a dynamic seal (not shown) for accommodating rotation of the rotating barrel relative to the non-rotating barrel. The outer non-rotating barrel 21o may be connected to a top of the swivel frame 30, such as by fastening. The swivel frame 30 may be connected to a top of the drive body 22, such as by fastening. The inner rotating barrel 21n may have an upper portion disposed in the outer non-rotating barrel 21o and a stinger portion extending therefrom, through the hydraulic swivel 26, and through the compensator 25. A lower end of the stinger portion may carry a stab seal for engagement with an inner seal receptacle 15b of each coupling 15 when the respective unit 1c,d,s is connected to the motor unit 1m, thereby sealing an interface formed between the units.

[0055] The hydraulic swivel 26 may include a non-rotating inner barrel and a rotating outer barrel. The inner barrel may be connected to the swivel frame 30 and the outer barrel may be supported from the inner barrel by one or more bearings. The outer barrel may have hydraulic ports (six shown) formed through a wall thereof, each port in fluid communication with a respective hydraulic passage formed through the inner barrel (only two passages shown). An interface between each port and passage may be straddled by dynamic seals for isolation thereof. The inner barrel passages may be in fluid communication with the HPU manifold 60m via the control lines 64a-c (Figure 3) and the outer barrel ports may be in fluid communication with either the linear actuator 33 or lock ring 34 via jumpers (not shown). The outer barrel ports may be disposed along the outer barrel. The inner barrel may have a mandrel portion extending along the outer barrel and a head portion extending above the outer barrel. The head portion may connect to the swivel frame 30 and have the hydraulic ports extending therearound.

[0056] The compensator 25 may include a linear actuator 33, the lock ring 34, and one or more (such as three, but only one shown) lock pins 35. The lock ring 34

may have an outer flange 34f formed at an upper end thereof, a bore formed therethrough, one or more chambers housing the lock pins 35 formed in an inner surface thereof, a locking profile 34k formed in a lower end thereof, members, such as males 34m, of a control, such as hydraulic, junction 36 (Figure 4J) formed in the lower end thereof, and cables or passages, such as hydraulic passages (two shown) formed through a wall thereof. The locking profile 34k may include a lug for each prong-way of the external bayonet profiles of the heads 15h.

[0057] Each lock pin 35 may be a piston dividing the respective chamber into an extension portion and a retraction portion and the lock ring 34 may have passages formed through the wall thereof for the chamber portions. Each passage may be in fluid communication with the HPU manifold 60m via a respective control line 64a (Figure 3, only one shown). The lock pins 35 may share an extension control line and a retraction control line via a splitter (not shown). Supply of hydraulic fluid to the extension passages may move the lock pins 35 to an engaged position (Figure 4J) where the pins extend into respective slots 15t formed in the prong-ways of the heads 15h, thereby longitudinally connecting the lock ring 34 to a respective unit 1c,d,s. Supply of hydraulic fluid to the retraction passages may move the lock pins 35 to a release position (shown) where the pins are contained in the respective chambers of the lock ring 34. Alternatively, one or more lock members of other form may be used in place of the lock pins 35. For example, a ratchet may be used in place of the lock pins 35 to secure the lock ring 23 and a coupling on a unit 1c,d,s.

[0058] The linear actuator 33 may include one or more, such as three, piston and cylinder assemblies 33a,b for vertically moving the lock ring 34 relative to the drive gear 23 between a lower hoisting position (Figure 4J) and an upper ready position (shown). A bottom of the lock ring flange 34f may be seated against a top of the drive gear flange 23f in the hoisting position such that string weight carried by either the drilling module 1d or the casing module 1c may be transferred to the drive gear 23 via the flanges and not the linear actuator 33 which may be only capable of supporting stand weight or joint weight. String weight may be one hundred (or more) times that of stand weight or joint weight. A piston of each

assembly 33a,b may be seated against the respective cylinder in the ready position.

[0059] Each cylinder of the linear actuator 33 may be disposed in a respective peripheral socket formed through the lock ring flange 34f and be connected to the lock ring 34, such as by threaded couplings. Each piston of the linear actuator 33 may extend into a respective indentation formed in a top of the drive gear flange 23f and be connected to the drive gear 23, such as by threaded couplings. Each socket of the lock ring flange 34f may be aligned with the respective lug of the locking profile 34k and each indentation of the drive gear flange 23f may be aligned with a receptacle of the locking profile 23k such that connection of the linear actuator 33 to the lock ring 34 and drive gear 23 ensures alignment of the locking profiles.

[0060] Each piston of the linear actuator 33 may be disposed in a bore of the respective cylinder. The piston may divide the cylinder bore into a raising chamber and a lowering chamber and the cylinder may have ports (only one shown) formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with the manifold 60m via a respective control line 64b (only one shown in Figure 3). Supply of hydraulic fluid to the raising port may lift the lock ring 34 toward the ready position. Supply of hydraulic fluid to the lowering port may drop the lock ring 34 toward the hoisting position. A stroke length of the linear compensator 25 between the ready and hoisting positions may correspond to, such as being equal to or slightly greater than, a makeup length of the drill pipe 8p and/or casing joint 90j. One advantage of the linear compensator 25 is that the linear compensator 25 is more sensitive than a top drive compensation because the linear compensator 25 only compensates for weight of the stand and tool weight and the mass of the top drive has no impact. Alternatively, the top drive compensation and the connection compensation may be combined. For example, the top drive compensation supplies the stroke while the connection compensation reduces the impacts. Additionally, the connection compensation may send a signal to the top drive compensation when the connection compensation is close to an end position. The top drive compensation

may extend or retract after receiving the signal from the connection compensation.

[0061] Alternatively, the linear actuator 33 may be electric or pneumatic instead of hydraulic. Alternatively, the junction 36 may be electric or pneumatic instead of hydraulic. Alternatively the lock pin 35 may be activated by electric or pneumatic.

[0062] Each coupling 15 may further include mating members, such as females 15f, of the junction 36 formed in a top of the prongs of the head 15h. The male members 34m may each have a nipple for receiving a respective jumper from the hydraulic swivel 26, a stinger, and a passage connecting the nipple and the stinger. Each stinger may carry a respective seal. The female member 15f may have a seal receptacle for receiving the respective stinger. The junction members 34m, 15f may be asymmetrically arranged to ensure that the male member 34m is stabbed into the correct female member 15f.

[0063] Referring to Figure 4L, the backup wrench 29 may include a hinge 29h, a tong 29t, a guide 29g, an arm 29a, a tong actuator (not shown), a tilt actuator (not shown), and a linear actuator (not shown). The tong 29t may be transversely connected to the arm 29a while being longitudinally movable relative thereto subject to engagement with a stop shoulder thereof. The hinge 29h may pivotally connect the arm 29a to a bottom of the drive body 22. The hinge 29h may include a pair of knuckles fastened or welded to the drive body 22 and a pin extending through the knuckles and a hole formed through a top of the arm 29a. The tilt actuator may include a piston and cylinder assembly having an upper end pivotally connected to the bottom of the drive body 22 and a lower end pivotally connected to a back of the arm 29a. The piston may divide the cylinder bore into an activation chamber and a stowing chamber and the cylinder may have ports (only one shown) formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with the HPU manifold 60m via a respective control line (not shown). Supply of hydraulic fluid to the activation port may pivot the tong 29t about the hinge 29h toward the quill 37. Supply of hydraulic fluid to the stowing port may pivot the tong 29t about the hinge 29h away from the quill 37.

[0064] The tong 29t may include a housing having an opening formed therethrough and a pair of jaws (not shown) and the tong actuator may move one of the jaws radially toward or away from the other jaw. The guide 29g may be a cone connected to a lower end of the tong housing, such as by fastening, for receiving a threaded coupling, such as a box, of the drill pipe 8p. The quill 37 may extend into the tong opening for stabbing into the drill pipe box. Once stabbed, the tong actuator may be operated to engage the movable jaw with the drill pipe box, thereby torsionally connecting the drill pipe box to the drive body 22. The tong actuator may be hydraulic and operated by the HPU 60 via a control line 66d (Figure 3).

[0065] The backup wrench linear actuator may include a gear rack (not shown) formed along a straight lower portion of the arm 29a, one or two pinions (not shown), and one or two pinion motors (not shown). The arm 29a may have a deviated upper portion engaged with the hinge 29h. Each pinion may be meshed with the gear rack of the arm 29a and torsionally connected to a rotor of the respective pinion motor. A stator of each pinion motor may be connected to the housing of the tong 29t and be in electrical communication with the motor driver 61 via a cable 67a (Figure 3). The pinion motors may share a cable via a splice (not shown). Each pinion motor may be reversible and rotation of the respective pinion in a first direction, such as counterclockwise, may raise the tong 29t along the arm 29a and rotation of the respective pinion in a second opposite direction, such as clockwise, may lower the tong along the arm. Each pinion motor may include a brake (not shown) for locking position of the tong 29t once the pinion motors are shut off. The brake may be disengaged by supply of electricity to the pinion motors and engaged by shut off of electricity to the pinion motors.

[0066] Alternatively, the pinion motors and brake may be hydraulic or pneumatic instead of electric. Alternatively, the linear actuator may include a braking system separate from the pinion motor and having a separate control line for operation thereof, such as a sliding brake or as a transverse gear rack stub extendable into engagement with the gear rack. Alternatively, the linear actuator may include a gear box torsionally connecting each pinion motor to the respective pinion.

[0067] Referring to Figure 3, the latch 57 may include a one or more (pair shown) units disposed at sides of the drive body 22. Each latch unit may include a lug connected, such as by fastening or welding, to the drive body 22 and extending from a bottom thereof, a fastener, such as a pin, and an actuator. Each lug may have a hole formed therethrough and aligned with a respective actuator. Each interior knuckle of the slide hinge 12 may have a hole formed therethrough for receiving the respective latch pin. Each actuator may include a cylinder and piston (not shown) connected to the latch pin and disposed in a bore of the cylinder. Each cylinder may be connected to the drive body 22, such as by fastening, adjacent to the respective lug. The piston may divide the cylinder bore into an extension chamber and a retraction chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber. Each port may be in fluid communication with the HPU manifold 60m via a control line 66a (Figure 3, only one shown). The latch units may share an extension control line and a retraction control line via a splitter (not shown). Supply of hydraulic fluid to the extension port may move the pin to an engaged position (shown) where the pin extends through the respective lug hole and the respective interior knuckle hole of the slide hinge 12, thereby connecting the pipe handler 1p to the drive body 22. Supply of hydraulic fluid to the retraction port may move the pin to a release position (not shown) where the pin is clear of the interior slide hinge knuckle.

[0068] Figure 2B illustrates a drilling unit 1d. The drilling unit 1d may further include the quill 37, one or more internal blowout preventers (IBOP) 38, and one or more, such as four (only one shown), hydraulic passages 39. The quill 37 may be a shaft, may have an upper end connected to the torso 15r, may have a bore formed therethrough, may have a threaded coupling, such as a pin, formed at a lower end thereof.

[0069] The IBOP 38 may include an internal sleeve 38v and one or more shutoff valves 38u,b. Each shutoff valve 38u,b may be actuated. Each shutoff valve 38u,b may be connected to the sleeve 38v and the sleeve may be received in a recessed portion of the quill 37 and/or coupling 15. The IBOP valve actuators may be

disposed in sockets formed through a wall of the quill 37 and/or coupling 15 and may each include an opening port and/or a closing port and each port may be in fluid communication with the HPU manifold 60m via a respective hydraulic passage 39, respective male 34m and female 15f members, respective jumpers, the hydraulic swivel 26, and respective control lines 64c (only one shown in Figure 3).

[0070] Alternatively, each IBOP valve 38u,b may have an electrical or pneumatic actuator instead of the hydraulic actuator. The IBOP 38 may be located on the motor unit 1m, the drilling unit 1d, or both.

[0071] Figure 2C illustrates the casing unit 1c. The casing unit 1c may further include a clamp, such as a spear 40, an adapter 48, one or more, such as two (only one shown), hydraulic passages 49, and a fill up tool 50. The adapter 48 may have a bore formed therethrough, may have an upper end connected to the torso 15r, and may have an outer thread and an inner receptacle formed at a lower end thereof.

[0072] The spear 40 may include a linear actuator 41, a bumper 42, a collar 43, a mandrel 44, a set of grippers, such as slips 45, a seal joint 46, and a sleeve 47. The collar 43 may have an inner thread formed at each longitudinal end thereof. The collar upper thread may be engaged with the outer thread of the adapter 48, thereby connecting the two members. The collar lower thread may be engaged with an outer thread formed at an upper end of the mandrel 44 and the mandrel may have an outer flange formed adjacent to the upper thread and engaged with a bottom of the collar 43, thereby connecting the two members.

[0073] The seal joint 46 may include the inner barrel, an outer barrel, and a nut. The inner barrel may have an outer thread engaged with a threaded portion of the shaft receptacle and an outer portion carrying a seal engaged with a seal bore portion of the shaft receptacle. The mandrel 44 may have a bore formed therethrough and an inner receptacle formed at an upper portion thereof and in communication with the bore. The mandrel receptacle may have an upper conical portion, a threaded mid portion, and a recessed lower portion. The outer barrel may be disposed in the recessed portion of the mandrel 44 and trapped therein by

engagement of an outer thread of the nut with the threaded mid portion of the mandrel receptacle. The outer barrel may have a seal bore formed therethrough and a lower portion of the inner barrel may be disposed therein and carry a stab seal engaged therewith.

[0074] The linear actuator 41 may include a housing, an upper flange, a plurality of piston and cylinder assemblies, and a lower flange. The housing may be cylindrical, may enclose the cylinders of the assemblies, and may be connected to the upper flange, such as by fastening. The collar 43 may also have an outer thread formed at the upper end thereof. The upper flange may have an inner thread engaged with the outer collar thread, thereby connecting the two members. Each flange may have a pair of lugs for each piston and cylinder assembly connected, such as by fastening or welding, thereto and extending from opposed surfaces thereof.

[0075] Each cylinder of the linear actuator 41 may have a coupling, such as a hinge knuckle, formed at an upper end thereof. The upper hinge knuckle of each cylinder may be received by a respective pair of lugs of the upper flange and pivotally connected thereto, such as by fastening. Each piston of the linear actuator 41 may have a coupling, such as a hinge knuckle, formed at a lower end thereof. Each piston of the linear actuator 41 may be disposed in a bore of the respective cylinder. The piston may divide the cylinder bore into a raising chamber and a lowering chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber.

[0076] Each port may be in fluid communication with the HPU manifold 60m via a respective hydraulic passage 49, respective male 34m and female 15f members, respective jumpers, the hydraulic swivel 26, and respective control lines. Supply of hydraulic fluid to the raising port may lift the lower flange to a retracted position (shown). Supply of hydraulic fluid to the lowering port may drop the lower flange toward an extended position (not shown). The piston and cylinder assemblies may share an extension control line and a retraction control line via a splitter (not shown).

[0077] The sleeve 47 may have an outer shoulder formed in an upper end thereof trapped between upper and lower retainers. A washer may have an inner shoulder formed in a lower end thereof engaged with a bottom of the lower retainer. The washer may be connected to the lower flange, such as by fastening, thereby longitudinally connecting the sleeve 47 to the linear actuator 41. The sleeve 47 may also have one or more (pair shown) slots formed through a wall thereof at an upper portion thereof. The bumper 42 may be connected to the mandrel, such as by one or more threaded fasteners, each fastener extending through a hole thereof, through a respective slot of the sleeve 47, and into a respective threaded socket formed in an outer surface of the mandrel 44, thereby also torsionally connecting the sleeve to the mandrel while allowing limited longitudinal movement of the sleeve relative to the mandrel to accommodate operation of the slips 45. A lower portion of the spear 40 may be stabbed into the casing joint 90j (Figure 6E) until the bumper 42 engages a top of the casing joint. The bumper 42 may cushion impact with the top of the casing joint 90j to avoid damage thereto.

[0078] The sleeve 47 may extend along the outer surface of the mandrel from the lower flange of the linear actuator 41 to the slips 45. A lower end of the sleeve 47 may be connected to upper portions of each of the slips 45, such as by a flanged (i.e., T-flange and T-slot) connection. Each slip 46 may be radially movable between an extended position and a retracted position by longitudinal movement of the sleeve 47 relative to the slips. A slip receptacle may be formed in an outer surface of the mandrel 44 for receiving the slips 45. The slip receptacle may include a pocket for each slip 46, each pocket receiving a lower portion of the respective slip. The mandrel 44 may be connected to lower portions of the slips 45 by reception thereof in the pockets. Each slip pocket may have one or more (three shown) inclined surfaces formed in the outer surface of the mandrel 44 for extension of the respective slip. A lower portion of each slip 46 may have one or more (three shown) inclined inner surfaces corresponding to the inclined slip pocket surfaces.

[0079] Downward movement of the sleeve 47 toward the slips 45 may push the slips along the inclined surfaces, thereby wedging the slips toward the extended

position. The lower portion of each slip 46 may also have a guide profile, such as tabs, extending from sides thereof. Each slip pocket may also have a mating guide profile, such as grooves, for retracting the slips 45 when the sleeve 47 moves upward away from the slips. Each slip 46 may have teeth formed along an outer surface thereof. The teeth may be made from a hard material, such as tool steel, ceramic, or cermet for engaging and penetrating an inner surface of the casing joint 90j, thereby anchoring the spear 40 to the casing joint.

[0080] The fill up tool 50 may include a flow tube, a stab seal, such as a cup seal, a release valve, and a mud saver valve. The cup seal may have an outer diameter slightly greater than an inner diameter of the casing joint to engage the inner surface thereof during stabbing of the spear 40 therein. The cup seal may be directional and oriented such that pressure in the casing bore energizes the seal into engagement with the casing joint inner surface. An upper end of the flow tube may be connected to a lower end of the mandrel 44, such as by threaded couplings. The mud saver valve may be connected to a lower end of the flow tube, such as by threaded couplings. The cup seal and release valve may be disposed along the flow tube and trapped between a bottom of the mandrel and a top of the mudsaver valve.

[0081] The spear 40 may be capable of supporting weight of the casing string 90. The string weight may be transferred to the becket 19 via the slips 45, the mandrel 44, the collar 43, the adapter 48, the coupling 15, the bayonet profile 23b, the down thrust bearing 27, the drive body 22. Fluid may be injected into the casing string 90 via the hose nipple 20, the mud swivel 21, the coupling 15, the adapter 48, the seal joint 46, the mandrel 44, the flow tube, and the mud saver valve. The spear 40 may thus have a load path separated from a flow path at the interface between the adapter 48 and the collar 43 and at the interface between the collar and the mandrel 44. This separation allows for more robust connections between the adapter 48 and the collar 43 and between the collar and the mandrel 44 than if the connections therebetween had to serve both load and isolation functions.

[0082] Alternatively, the clamp may be a torque head instead of the spear 40.

The torque head may be similar to the spear except for receiving an upper portion of the casing joint 90 therein and having the grippers for engaging an outer surface of the casing joint instead of the inner surface of the casing joint. Alternatively, the compensator 25 may be configured for compensation of drill pipe 8p and the casing unit 1c may include an additional compensator configured for compensation of casing joints 90j.

[0083] Figure 2D illustrates the cementing unit 1s. The cementing unit 1s may further include the quill 37, the IBOP 38, the hydraulic passages (not shown) and a cementing head 51. The cementing head 51 may include a cementing swivel 53, a launcher 54, and a release plug, such as a dart 55.

[0084] The cementing swivel 53 may include a housing torsionally connected to the drive body 22, such as by a bar 52. The cementing swivel 53 may further include a mandrel and bearings for supporting the housing from the mandrel while accommodating rotation of the mandrel. An upper end of the mandrel may be connected to a lower end of the quill 37, such as by threaded couplings. The cementing swivel 53 may further include an inlet formed through a wall of the housing and in fluid communication with a port formed through the mandrel and a seal assembly for isolating the inlet-port communication. The mandrel port may provide fluid communication between a bore of the cementing head 51 and the housing inlet.

[0085] The launcher 54 may include a body, a deflector, a canister, a gate, the actuator, and an adapter. The body may be tubular and may have a bore therethrough. An upper end of the body may be connected to a lower end of the cementing swivel 53, such as by threaded couplings, and a lower end of the body may be connected to the adapter, such as by threaded couplings. The canister and deflector may each be disposed in the body bore. The deflector may be connected to the cementing swivel mandrel, such as by threaded couplings. The canister may be longitudinally movable relative to the body. The canister may be tubular and have ribs formed along and around an outer surface thereof. Bypass passages (only one shown) may be formed between the ribs. The canister may further have a landing shoulder formed in a lower end thereof for receipt by a landing shoulder

of the adapter. The deflector may be operable to divert fluid received from a cement line 92 (Figure 7) away from a bore of the canister and toward the bypass passages. The adapter may have a threaded coupling, such as a threaded pin, formed at a lower end thereof for connection to a work string 91 (Figure 7).

[0086] The dart 55 may be disposed in the canister bore. The dart 55 may be made from one or more drillable materials and include a finned seal and mandrel. The mandrel may be made from a metal or alloy and may have a landing shoulder and carry a landing seal for engagement with the seat and seal bore of a wiper plug (not shown) of the work string 91.

[0087] The gate of the launcher 54 may include a housing, a plunger, and a shaft. The housing may be connected to a respective lug formed in an outer surface of the body, such as by threaded couplings. The plunger may be radially movable relative to the body between a capture position and a release position. The plunger may be moved between the positions by a linkage, such as a jackscrew, with the shaft. The shaft may be connected to and rotatable relative to the housing. The actuator may be a hydraulic motor operable to rotate the shaft relative to the housing. The actuator may include a reservoir (not shown) for receiving the spent hydraulic fluid or the cementing head 51 may include a second actuator swivel and hydraulic conduit (not shown) for returning the spent hydraulic fluid to the HPU 60.

[0088] In operation, when it is desired to launch the dart 55, the console 62 (Figure 3) may be operated to supply hydraulic fluid to the launcher actuator via a control line 56 extending to the hydraulic swivel 26 and a control line extending from the hydraulic swivel to the manifold 60m. The launcher actuator may then move the plunger to the release position. The canister and dart 55 may then move downward relative to the launcher body until the landing shoulders engage. Engagement of the landing shoulders may close the canister bypass passages, thereby forcing chaser fluid 98 (Figure 7) to flow into the canister bore. The chaser fluid 98 may then propel the dart 55 from the canister bore, down a bore of the adapter, and onward through the work string 91.

[0089] Alternatively, the actuator swivel 52 and launcher actuator may be pneumatic or electric. Alternatively, the launcher actuator may be linear, such as a piston and cylinder. Alternatively, the launcher 54 may include a main body having a main bore and a parallel side bore, with both bores being machined integral to the main body. The dart 55 may be loaded into the main bore, and a dart releaser valve may be provided below the dart to maintain it in the capture position. The dart releaser valve may be side-mounted externally and extend through the main body. A port in the dart releaser valve may provide fluid communication between the main bore and the side bore. In a bypass position, the dart 55 may be maintained in the main bore with the dart releaser valve closed. Fluid may flow through the side bore and into the main bore below the dart via the fluid communication port in the dart releaser valve. To release the dart 55, the dart releaser valve may be turned, such as by ninety degrees, thereby closing the side bore and opening the main bore through the dart releaser valve. The chaser fluid 98 may then enter the main bore behind the dart 55, thereby propelling the dart into the work string 91.

[0090] Figure 3 is a control diagram of the modular top drive system 1 in the drilling mode. The HPU 60 may include a pump 60p, a check valve 60k, an accumulator 60a, a reservoir 60r of hydraulic fluid, and the manifold 60m. The motor driver 61 may be one or more (three shown) phase and include a rectifier 61r and an inverter 61i. The inverter 61i may be capable of speed control of the drive motors 18, such as being a pulse width modulator. Each of the HPU manifold 60m and motor driver 61 may be in data communication with the control console 62 for control of the various functions of the modular top drive system 1. The modular top drive system 1 may further include a video monitoring unit 63 having a video camera 63c and a light source 63g such that a technician (not shown) may visually monitor operation thereof from the rig floor 7f or control room (not shown) especially during shifting of the modes. The video monitoring unit 63 may be mounted on the motor unit 1m.

[0091] The pipe handler control lines 66b,c may flexible control lines such that the pipe handler 1p remains connected thereto in any position thereof.

[0092] The motor unit 1m may further include a proximity sensor 68 connected

to the swivel frame 30 for monitoring a position of the lock ring flange 34f. The proximity sensor 68 may include a transmitting coil, a receiving coil, an inverter for powering the transmitting coil, and a detector circuit connected to the receiving coil. A magnetic field generated by the transmitting coil may induce eddy current in the turns gear lock ring flange 34f which may be made from an electrically conductive metal or alloy. The magnetic field generated by the eddy current may be measured by the detector circuit and supplied to the control console 62 via control line 65.

[0093] Alternatively, the proximity sensor 68 may be Hall effect, ultrasonic, or optical.

[0094] Alternatively, the motor unit 1m and/or casing unit 1c have a hydraulic manifold instead of the manifold 60m being part of the HPU 60 and the swivel 26 and/or a swivel of the casing unit may further include wireless power and/or data couplings for operation of the manifold. The swivels may be hydraulic, pneumatic, or combination of hydraulic and pneumatic. In one embodiment, pneumatic lines of the swivels may be used to transfer signals.

[0095] Alternatively, the swivel 26 may have additional hydraulic and/or pneumatic couplings for additional functionality of the casing 1c, drilling 1d, and/or cementing units 1s. For example, the casing unit 1c may have an IBOP.

[0096] Figures 4A-4M illustrate shifting of the modular top drive system 1 from a standby mode to the drilling mode. Referring specifically to Figures 1 and 4A, the unit handler 1u may be operated to engage the holder 5 with the torso 15r of the drilling unit 1d. Once engaged, the arm 4 may be raised slightly to shift weight of the drilling unit 1d from the unit rack 1k to the holder 5. The respective motor 14m may then be operated to rotate the respective ring gear 14g until the external prongs of the respective head 15h are aligned with the internal prong-ways of the ring gear (and vice versa), thereby freeing the head for passing through the ring gear. The arm 4 may then be lowered, thereby passing the drilling unit 1d through the respective ring gear 14g.

[0097] Referring specifically to Figure 4B, the unit handler 1u may be operated

to move the drilling unit 1d away from the unit rack 1k until the drilling unit is clear of the unit rack. Referring specifically to Figure 4C, the arm 4 may be raised to lift the drilling unit 1d above the rig floor 7f. Referring specifically to Figure 4D, the unit handler 1u may be operated to horizontally move the drilling unit 1d into alignment with the motor unit 1m.

[0098] Referring specifically to Figures 4E-4G, the arm 4 may then be raised to lift the drilling unit 1d until the respective head 15h is adjacent to the bottom of the drive gear 23. The drive motors 18 may then be operated to rotate the drive gear 23 until the external prongs of the respective head 15h are aligned with the internal prong-ways of the bayonet profile 23b and at a correct orientation so that when the drive gear is rotated to engage the bayonet profile with the respective head 15h, the asymmetric profiles of the hydraulic junction 36 will be aligned. The drive gear 23 may have visible alignment features (not shown) on the bottom thereof to facilitate use of the camera 63c for obtaining the alignment and the orientation. Once aligned and oriented, the arm 4 may be raised to lift the coupling 15 of the drilling unit 1d into the drive gear 23 until the respective head 15h is aligned with the locking profile 23k thereof. The lock ring 34 may be in a lower position, such as the hoisting position, such that the top of the respective head 15h contacts the lock ring and pushes the lock ring upward. The proximity sensor 68 may then be used to determine alignment of the respective head 15h with the locking profile 23k by measuring the vertical displacement of the lock ring 34. Once alignment has been achieved, the compensator actuator 33 may be operated to move the lock ring 34 to the ready position.

[0099] Referring specifically to Figures 4H and 4I, the drive motors 18 may then be operated to rotate the drive gear 23 until sides of the external prongs of the respective head 15h engage respective stop lugs of the locking profile 23k, thereby aligning the external prongs of the respective head with the internal prongs of the bayonet profile 23b and correctly orienting the profiles of the hydraulic junction 36.

[0100] Referring specifically to Figures 4J and 4K, the compensator actuator 33 may then be operated to move the lock ring 34 to the hoisting position, thereby moving the lugs of the locking profile 34k into the external prong-ways of the

respective head 15h and aligning the lock pins 35 with the respective slots 15t. Movement of the lock ring 34 also stabs the male members 34m into the respective female members 15f, thereby forming the hydraulic junction 36. The proximity sensor 68 may again be monitored to ensure that the bayonet profiles 23b have properly engaged and are not jammed. Hydraulic fluid may then be supplied to the extension portions of the chambers housing the lock pins 35 via the control line 64a, thereby moving the lock pins radially inward and into the respective slots 15t. The locking profile 23k may have a sufficient length to maintain a torsional connection between the drilling unit 1d and the drive gear 23 in and between the ready and hoisting positions of the compensator 25. The drilling unit 1d is now longitudinally and torsionally connected to the drive gear 23, thereby forming a top drive.

[0101] Referring specifically to Figures 4L and 4M, the tilt actuator of the backup wrench 29 may then be operated to pivot the arm 29a and tong 29t about the hinge 29h and into alignment with the drilling unit 1d. The linear actuator of the backup tong 29 may then be operated via the cable 67a to move the tong 29t upward along the arm 29a until the tong is positioned adjacent to the quill 37. The modular top drive system 1 is now in the drilling mode.

[0102] Alternatively, the tong 29t may be in alignment with the quill 37 during installation and removal of the drilling unit 1d and the tilt actuator used only for installation and removal of the casing unit 1c. Alternatively, the unit handler 1u may raise the drilling unit 1d to the rig floor 7f and the pipe handler 1p may deliver the drilling unit to the motor unit 1m.

[0103] Figures 5A-5H illustrate extension of the drill string 8 using the modular top drive system 1 in the drilling mode. Referring specifically to Figure 5A, the drilling rig 7 may be part of a drilling system. The drilling system may further include a fluid handling system 70, a blowout preventer (BOP) 71, a flow cross 72 and the drill string 8. The drilling rig 7 may further include a hoist 73, a rotary table 74, and a spider 75. The rig floor 7f may have the opening through which the drill string 8 extends downwardly through the flow cross 72, BOP 71, and a wellhead 76h, and into a wellbore 77.

[0104] The hoist 73 may include the drawworks 73d wire rope 73w, a crown block 73c, and the traveling block 73t. The traveling block 73t may be supported by wire rope 73w connected at its upper end to the crown block 73c. The wire rope 73w may be woven through sheaves of the blocks 73c,t and extend to the drawworks 73d for reeling thereof, thereby raising or lowering the traveling block 73t relative to the derrick 7d.

[0105] The fluid handling system 70 may include a mud pump 78, the standpipe 79, a return line 80, a separator, such as shale shaker 81, a pit 82 or tank, a feed line 83, and a pressure gauge 84. A first end of the return line 80 may be connected to the flow cross 72 and a second end of the return line may be connected to an inlet of the shaker 81. A lower end of the standpipe 79 may be connected to an outlet of the mud pump 78 and an upper end of the standpipe may be connected to the mud hose. A lower end of the feed line 83 may be connected to an outlet of the pit 82 and an upper end of the feed line may be connected to an inlet of the mud pump 78.

[0106] The wellhead 76h may be mounted on a conductor pipe 76c. The BOP 71 may be connected to the wellhead 76h and the flow cross 72 may be connected to the BOP, such as by flanged connections. The wellbore 77 may be terrestrial (shown) or subsea (not shown). If terrestrial, the wellhead 76h may be located at a surface 85 of the earth and the drilling rig 7 may be disposed on a pad adjacent to the wellhead. If subsea, the wellhead 76h may be located on the seafloor or adjacent to the waterline and the drilling rig 7 may be located on an offshore drilling unit or a platform adjacent to the wellhead.

[0107] The drill string 8 may include a bottomhole assembly (BHA) 8b and a stem. The stem may include joints of the drill pipe 8p connected together, such as by threaded couplings. The BHA 8b may be connected to the stem, such as by threaded couplings, and include a drill bit and one or more drill collars (not shown) connected thereto, such as by threaded couplings. The drill bit may be rotated by the motor unit 1m via the stem and/or the BHA 8b may further include a drilling motor (not shown) for rotating the drill bit. The BHA 8b may further include an instrumentation sub (not shown), such as a measurement while drilling (MWD)

and/or a logging while drilling (LWD) sub.

[0108] The drill string 8 may be used to extend the wellbore 77 through an upper formation 86 and/or lower formation (not shown). The upper formation may be non-productive and the lower formation may be a hydrocarbon-bearing reservoir. During the drilling operation, the mud pump 78 may pump the drilling fluid 87 from the pit 82, through the standpipe 79 and mud hose to the motor unit 1m. The drilling fluid may include a base liquid. The base liquid may be refined or synthetic oil, water, brine, or a water/oil emulsion. The drilling fluid 87 may further include solids dissolved or suspended in the base liquid, such as organophilic clay, lignite, and/or asphalt, thereby forming a mud.

[0109] The drilling fluid 87 may flow from the standpipe 79 and into the drill string 8 via the motor 1m and drilling 1d units. The drilling fluid 87 may be pumped down through the drill string 8 and exit the drill bit, where the fluid may circulate the cuttings away from the bit and return the cuttings up an annulus formed between an inner surface of the wellbore 77 and an outer surface of the drill string 8. The drilling fluid 87 plus cuttings, collectively returns 88 (Figure 5I), may flow up the annulus to the wellhead 76h and exit via the return line 80 into the shale shaker 81. The shale shaker 81 may process the returns to remove the cuttings and discharge the processed fluid into the mud pit 82, thereby completing a cycle. As the drilling fluid 87 and returns 88 circulate, the drill string 8 may be rotated by the motor unit 1m and lowered by the traveling block 73t, thereby extending the wellbore 77.

[0110] Referring also to Figure 5B, during drilling of the wellbore 77, once a top of the drill string 8 reaches the rig floor 7f, the drill string must be extended to continue drilling. Drilling may be halted by stopping rotation of the motor unit 1m, stopping lowering of the traveling block 73t, stopping injection of the drilling fluid 87, and removing weight from the drill bit. The spider 75 may then be installed into the rotary table 74, thereby longitudinally supporting the drill string 8 from the rig floor 7f. The tong actuator of the backup wrench 29 may be operated via control line 66d to engage the backup wrench tong 29t with a top coupling of the drill string 8.

[0111] The compensator 25 may be in the hoisting position and the linear

actuator 33 thereof activated while the drive motors 18 are operated to loosen and counter-spin the connection between the quill 37 and the top coupling of the drill string 8. The compensator 25 may stroke from the hoisting position to the ready position during unscrewing of the connection between the top coupling and the quill 37. Hydraulic pressure may be maintained in the linear actuator 33 corresponding to the weight of the drilling module 1d and lock ring 34 so that the threaded connection between the top coupling and the quill 37 is maintained in a neutral condition during unscrewing. A pressure regulator of the manifold 60m may increase fluid pressure to the linear actuator 33 as the connection is being unscrewed to maintain the neutral condition while the compensator 25 strokes upward to accommodate the longitudinal displacement of the threaded connection.

[0112] Referring specifically to Figure 5C, once the connection between the quill 37 and the top coupling has been unscrewed the compensator 25 may be stroked back to the hoisting position and the motor 1m and drilling 1d units and the pipe handler 1p may then be raised by the hoist 73 until the elevator 9d is above a top of the stand 8s. The motor unit 1m may be positioned at a location with enough space to allow subsequent operations. For example, the motor unit 1m may be raised slightly upward before extending the compensator 25. The latch 57 of the motor unit 1m may then be operated via the control line 66a to release the slide hinge 12 from the drive body 22 and the linear actuator 1a operated via the cable 67b to lower the slide hinge until the elevator 9d is adjacent to the top of the stand 8s. The elevator 9d may be opened (or already open) and the link tilt 11 operated to swing the elevator into engagement with the top coupling of the stand 8s. The elevator 9d may then be closed to securely grip the stand 8s.

[0113] Alternatively, the stand 8s may be located on a ramp 7r (Figure 4E) adjacent to the rig floor 7f and the pipe handler 1p operated to locate the elevator 9d adjacent to the top of the stand at or through a V-door (not shown) of the rig 7. Alternatively, the stand 8s may be supported by a pipe handler.

[0114] Referring specifically to Figure 5D, the motor 1m and drilling 1d units, pipe handler 1p, and stand 8s may then be raised by the hoist 73 and the link tilt 11 operated to swing the stand over and into alignment with quill 37. The compensator

25 may then be stroked to the ready position and the proximity sensor 68 calibrated by a controller of the console 62 reading the proximity sensor at the hoisting position. The pressure regulator of the manifold 60m may be operated to maintain the compensator actuator 33 at a sensing pressure, such as slightly less than the pressure required to support weight of the lock ring 34 and drilling unit 1d, such that the compensator 25 drifts to the hoisting position. The linear actuator of the backup wrench 29 may be operated to raise the tong 29t such that the camera 63c may observe stabbing of the quill 37 into the top coupling of the stand 8s.

[0115] Referring specifically to Figure 5E, the linear actuator 1a may be operated via the cable 67b to raise the slide hinge 12, elevator 9d, and stand 8s until the quill 37 is stabbed into the top coupling of the stand 8s. During stabbing, the proximity sensor 68 may be monitored by the control console 53 to detect stroking of the compensator 25 to the ready position and the linear actuator 1a may be locked at the ready position.

[0116] Referring specifically to Figure 5F, the linear actuator of the backup wrench 29 may be operated to lower the tong 29t into alignment with the top coupling of the stand 8s. The tong actuator of the backup wrench 29 may then be operated to engage the tong 29t with the top coupling of the stand 8s. The drive motors 18 may then be operated to spin and tighten the threaded connection between the quill 37 and the stand 8s. The hydraulic pressure may be maintained in the linear actuator 33 corresponding to the weight of the lock ring 34 and drilling unit 1d so that the threaded connection is maintained in a neutral condition during makeup. The pressure regulator of the manifold 60m may relieve fluid pressure from the linear actuator 33 as the quill 37 is being madeup to the stand 8s to maintain the neutral condition while the compensator 25 strokes downward to accommodate the longitudinal displacement of the threaded connection.

[0117] Referring specifically to Figure 5G, the elevator 9d may be opened to release the stand 8s and the link tilt 11 operated to swing the elevator to a position clear of the stand. The tong actuator of the backup wrench 29 may then be operated to release the tong 29t from the top coupling of the stand 8s. The linear actuator 1a may be operated to raise the slide hinge 12 until the slide hinge is

aligned with the latch 57 of the motor unit 1m. The latch 57 of the motor unit 1m may then be operated via the control line 66a to fasten the slide hinge 12 to the motor unit 1m. Alternatively, particularly when the elevator 9d is not used to lift the string, involvement of the latch 57 may be omitted. The compensator 25 may be stroked upward and the pressure regulator of the manifold 60m may be operated to maintain the compensator actuator 33 at a second sensing pressure, such as slightly less than the pressure required to support weight of the lock ring 34, drilling unit 1d, and stand 8s, such that the compensator 25 drifts to the hoisting position. Alternatively, the compensator 25 may be driven to the hoisting position first and the pressure regulator may be used to set a pressure at the hoisting position. The motor 1m and drilling 1d units, pipe handler 1p, and stand 8s may be lowered by operation of the hoist 73 and a bottom coupling of the stand stabbed into the top coupling of the drill string 8. During stabbing, the proximity sensor 68 may be monitored by the control console 53 to detect stroking of the compensator 25 to the ready position and the hoist 73 may be locked at the ready position.

[0118] Referring specifically to Figure 5H, the rotary table 74 may be locked or a backup tong (not shown) may be engaged with the top coupling of the drill string 8 and the drive motors 18 may be operated to spin and tighten the threaded connection between the stand 8s and the drill string 8. The hydraulic pressure may be maintained in the linear actuator 33 corresponding to the weight of the lock ring 34, drilling unit 1d, and stand 8s so that the threaded connection is maintained in a neutral condition during makeup. The pressure regulator of the manifold 60m may relieve fluid pressure from the linear actuator 33 as the stand 8s is being madeup to the drill string 8 to maintain the neutral condition while the compensator 25 strokes downward to accommodate the longitudinal displacement of the threaded connection.

[0119] Alternatively, a spinner and drive tong may be engaged with the stand 8s and operated to spin and tighten the threaded connection between the stand 8s and the drill string 8. Alternatively, the a spinner and drive tong may be used for unscrewing the quill 37 from the top coupling of the drill string 8 by swinging the backup wrench 29 out of the way.

[0120] Figure 5I illustrates drilling the wellbore 77 using the extended drill string 8, 8s and the modular top drive system 1. The manifold 60m may be operated to pressurize the linear actuator 33 to exert a downward preload onto the lock ring 34. During drilling or running, the preload may prevent or mitigate vibration and/or impact from the drilling or running operation from damaging the bayonet connection between the drilling unit 1d and the motor unit 1m. The spider 75 may then be removed from the rotary table 74 to release the extended drill string 8, 8s and drilling may continue therewith.

[0121] Alternatively, the stand 8s may be connected to the drill string 8 before the quill 37 is connected to the stand, such as by using tongs.

[0122] Figure 6A illustrates shifting of the modular top drive system 1 from the drilling mode to the casing mode. Once drilling the formation 86 has been completed, the drill string 8 may be tripped out from the wellbore 77 by reversing the steps of Figures 5A-5I. Once the drill string 8 has been retrieved to the rig 7, the drilling unit 1d may be released from the motor unit 1m and loaded onto the unit rack 1k by reversing the steps of Figures 1A and 4A-4M. The top drive system 1 may then be shifted into the casing mode by repeating the steps of Figures 1A and 4A-4K for the casing unit 1c. The locking profile 23k may have a sufficient length to maintain a torsional connection between the casing unit 1c and the drive gear 23 in and between the ready and hoisting positions of the compensator 25. The drill pipe elevator 9d may be disconnected and removed from the lower eyelets of the bails 10. Each adapter may then be inserted into the respective lower eyelet and connected to the respective bail 10 and the casing elevator 9c may be connected to the adapters.

[0123] Figures 6B-6F illustrate extension of a casing string 90 using the modular top drive system 1 in the casing mode. Referring specifically to Figure 6B, once the casing unit 1c has been connected to the motor unit 1m, the holder 5 may be disconnected from the arm 4 and stowed on the side bar 13r. The pipe clamp 17 may then be connected to the arm 4 and the unit handler 1u operated to engage the pipe clamp with the casing joint 90j. The pipe clamp 17 may be manually actuated between an engaged and disengaged position or include an actuator,

such as a hydraulic actuator, for actuation between the positions. The casing joint 90j may initially be located on the subfloor structure and the unit handler 1u may be operated to raise the casing joint to the rig floor 7f. The pipe clamp 17 may release the casing joint onto the rig floor 7f or hold the casing joint 90j until the casing elevator 9c is engaged therewith and then release the casing joint.

[0124] Alternatively, the casing joint 90j may be located on the ramp 7r adjacent to the rig floor 7f and the pipe handler 1p operated to locate the elevator 9c adjacent to the top of the casing joint at or through the V-door. Alternatively, the unit handler 1h may deliver the casing joint 90j to the rig floor 7f and into alignment with the casing unit 1c and the unit handler 1h may hold the casing joint while the spear 40 and fill up tool 50 are stabbed into the casing joint, thereby obviating the need to use the pipe handler 1p for extension of the casing string 90.

[0125] Referring specifically to Figure 6C, during deployment of the casing string 90 into the wellbore 77, once a top of the casing string reaches the rig floor 7f, the casing string must be extended to continue deployment. Deployment may be halted by stopping rotation of the motor unit 1m, stopping injection of the drilling fluid 87, and stopping lowering of the traveling block 73t. The spider 75 may then be installed into the rotary table 74, thereby longitudinally supporting the casing string 90 from the rig floor 7f. The spear slips 45 may be released from a top joint of the casing string 90 by operating the linear actuator 41. Once the spear 40 has been released, the motor 1m and casing 1c units and pipe handler 1p may then be raised by the hoist 73 until the elevator 9c is above a top of the casing joint 90j. The latch 57 of the motor unit 1m may then be operated via the control line 66a to release the slide hinge 12 from the drive body 22 and the linear actuator 1a operated via the cable 67b to lower the slide hinge until the elevator 9c is adjacent to the top of the casing joint 90j. The elevator 9c may be opened (or already open) and the link tilt 11 operated to swing the elevator into engagement with a top coupling of the casing joint 90j. The elevator 9c may then be closed to securely grip the casing joint 90j.

[0126] Referring specifically to Figure 6D, the motor 1m and casing 1c units, pipe handler 1p, and casing joint 90j may then be raised by the hoist 73 and the link

tilt 11 operated to swing the casing joint over and into alignment with the spear 40. The compensator 25 may be stroked upward and the pressure regulator of the manifold 60m may be operated to maintain the compensator actuator 33 at a sensing pressure, such as slightly less than the pressure required to support weight of the lock ring 34 and casing unit 1c, such that the compensator 25 drifts to the hoisting position. Alternatively, the compensator 25 may be driven to the hoisting position first and the pressure regulator may be used to set a pressure at the hoisting position.

[0127] Referring specifically to Figure 6E, the linear actuator 1a may be operated via the cable 67b to raise the slide hinge 12, elevator 9c, and casing joint 90j until the spear 40 and fill up valve 50 are stabbed into the casing joint. During stabbing, the bumper 42 may engage a top of the casing joint 90j and the proximity sensor 68 may be monitored by the control console 53 to detect stroking of the compensator 25 to the ready position. The camera 63c may also observe stabbing of the spear 40 into the casing joint 90j. Once stabbed, the spear slips 45 may be engaged with the casing joint 90j by operating the linear actuator 41.

[0128] Referring specifically to Figure 6F, the elevator 9c may be opened to release the casing joint 90j and the link tilt 11 operated to swing the elevator to a position clear of the casing joint. The linear actuator 1a may be operated to raise the slide hinge 12 until the slide hinge is aligned with the latch 57 of the motor unit 1m. The latch 57 of the motor unit 1m may then be operated via the control line 66a to fasten the slide hinge 12 to the motor unit 1m. The compensator 25 may be stroked upward and the pressure regulator of the manifold 60m may be operated to maintain the compensator actuator 33 at a second sensing pressure, such as slightly less than the pressure required to support weight of the lock ring 34, casing unit 1c, and casing joint 90j, such that the compensator 25 drifts to the hoisting position. Alternatively, the compensator 25 may be driven to the hoisting position first and the pressure regulator may be used to set a pressure at the hoisting position. The motor 1m and casing 1c units, pipe handler 1p, and casing joint 90j may be lowered by operation of the hoist 73 and a bottom coupling of the casing joint stabbed into the top coupling of the casing string 90. During stabbing, the

proximity sensor 68 may be monitored by the control console 53 to detect stroking of the compensator 25 to the ready position and the hoist 73 may be locked at the ready position.

[0129] The rotary table 74 may be locked or a backup tong (not shown) may be engaged with the top coupling of the casing string 90 and the drive motors 18 may be operated to spin and tighten the threaded connection between the casing joint 90j and the casing string 90. The hydraulic pressure may be maintained in the linear actuator 33 corresponding to the weight of the lock ring 34, casing unit 1c, and casing joint 90j so that the threaded connection is maintained in a neutral condition during makeup. The pressure regulator of the manifold 60m may relieve fluid pressure from the linear actuator 33 as the casing joint 90j is being madeup to the casing string 90 to maintain the neutral condition while the compensator 25 strokes downward to accommodate the longitudinal displacement of the threaded connection.

[0130] Figure 6G illustrates running of the extended casing string 90, 90j into the wellbore 77 using the modular top drive system 1. The manifold 60m may be operated to pressurize the linear actuator 33 to exert the downward preload onto the lock ring 34. The spider 75 may then be removed from the rotary table 74 to release the extended casing string 90, 90j and running thereof may continue. Injection of the drilling fluid 87 into the extended casing string 90, 90j and rotation thereof by the drive motors 18 allows the casing string to be reamed into the wellbore 77.

[0131] Alternatively, the pipe handler 1p may remain connected to the motor unit 1m and the casing joint 90j instead stabbed into the casing string 90 before stabbing of the spear 40 into the casing joint. Alternatively, the casing joint 90j may be delivered to the central axis of the well by the pipe handler 1p directly, held above the casing string 90, and stabbed in the spear 40 before making up the casing joint 90j to the casing string 90. Alternatively, the steps of Figures 1A, 4A-4M and 5A-5I may be omitted and the casing string 90 may be drilled into the formation 86, thereby simultaneously extending the wellbore 77 and deploying the casing string into the wellbore.

[0132] Figure 7 illustrates cementing of the casing string 90 using the modular top drive system 1 in a cementing mode. As a shoe (not shown) of the casing string 90 nears a desired deployment depth of the casing string, such as adjacent a bottom of the formation 86, the casing unit 1c and pipe handler 1p may be used to assemble a casing hanger 90h with the casing string. Once the casing hanger 90h reaches the rig floor 7f, the spider 75 may be set.

[0133] The casing unit 1c may be released from the motor unit 1m and loaded onto the unit rack 1k by reversing the steps of Figures 1A and 4A-4M for the casing unit 1c. The top drive system 1 may then be shifted into the cementing mode by repeating the steps of Figures 1A and 4A-4K for the cementing unit 1s. The pipe handler 1p (not shown) may then be used to connect a work string 91 to the casing hanger 90h and to extend the work string until the casing hanger 90h seats in the wellhead 76h.

[0134] The work string 91 may include a casing deployment assembly (CDA) 91d and a work stem 91s, such as such as one or more joints of drill pipe 8p connected together, such as by threaded couplings. An upper end of the CDA 91d may be connected a lower end of the work stem 91s, such as by threaded couplings. The CDA 91d may be connected to the casing hanger 90h, such as by engagement of a bayonet lug (not shown) with a mating bayonet profile (not shown) formed the casing hanger. The CDA 91d may include a running tool, a plug release system (not shown), and a packoff. The plug release system may include an equalization valve and a wiper plug. The wiper plug may be releasably connected to the equalization valve, such as by a shearable fastener.

[0135] Once the casing hanger 90h has seated in the wellhead 76h, an upper end of the cement line 92 may be connected to an inlet of a cement swivel 53. A lower end of the cement line 92 may be connected to an outlet of a cement pump 93. A cement shutoff valve 92v and a cement pressure gauge 92g may be assembled as part of the cement line 92. An upper end of a cement feed line 94 may be connected to an outlet of a cement mixer 95 and a lower end of the cement feed line may be connected to an inlet of the cement pump 93.

[0136] Once the cement line 92 has been connected to the cementing swivel 53, the IBOP 38 may be closed and the drive motors 18 may be operated to rotate the work string 91 and casing string 90 during the cementing operation. The cement pump 93 may then be operated to inject conditioner 96 from the mixer 95 and down the casing string 90 via the feed line 94, the cement line 92, the cementing head 51, and a bore of the work string 91. Once the conditioner 96 has circulated through the wellbore 77, cement slurry 97 may be pumped from the mixer 95 into the cementing swivel 53 by the cement pump 93. The cement slurry 97 may flow into the launcher 54 and be diverted past the dart 55 (not shown) via the diverter and bypass passages. Once the desired quantity of cement slurry 97 has been pumped, the dart 55 may be released from the launcher 54 by operating the launcher actuator. The chaser fluid 98 may be pumped into the cementing swivel 53 by the cement pump 93. The chaser fluid 98 may flow into the launcher 54 and be forced behind the dart 55 by closing of the bypass passages, thereby launching the dart.

[0137] Pumping of the chaser fluid 98 by the cement pump 93 may continue until residual cement in the cement line 92 has been purged. Pumping of the chaser fluid 98 may then be transferred to the mud pump 78 (not shown) by closing the valve 92v and opening the IBOP 38. The dart 55 and cement slurry 97 may be driven through the work string bore by the chaser fluid 98. The dart 55 may land onto the wiper plug and continued pumping of the chaser fluid 98 may increase pressure in the work string bore against the seated dart 55 until a release pressure is achieved, thereby fracturing the shearable fastener. Continued pumping of the chaser fluid 98 may drive the dart 55, wiper plug, and cement slurry 97 through the casing bore. The cement slurry 97 may flow through a float collar (not shown) and the shoe of the casing string 90, and upward into the annulus.

[0138] Pumping of the chaser fluid 98 may continue to drive the cement slurry 97 into the annulus until the wiper plug bumps the float collar. Pumping of the chaser fluid 98 may then be halted and rotation of the casing string 90 may also be halted. The float collar may close in response to halting of the pumping. The work string 91 may then be lowered set a packer of the casing hanger 90h. The bayonet

connection may be released and the work string 91 may be retrieved to the rig 7.

[0139] Additionally, the cementing head 51 may include a second launcher located below the launcher 54 and having a bottom dart and the plug release system may include a bottom wiper plug located below the wiper plug and having a burst tube. The bottom dart may be launched just before pumping of the cement slurry 97 and release the bottom wiper plug. Once the bottom wiper plug bumps the float collar, the burst tube may rupture, thereby allowing the cement slurry 97 to bypass the seated bottom plug. In a further addition to this alternative, a third dart and third wiper plug, each similar to the bottom dart and bottom plug may be employed to pump a slug of spacer fluid just before pumping of the cement slurry 97

[0140] Alternatively, the dart 55 and plug release system may be omitted, the work stem 91s may be made of casing instead of drill pipe, and the wiper plug may be disposed in the launcher 54. In a further variant of this alternative, the actuator swivel 53 may be omitted and the launcher may have a manual actuator, such as a release pin, instead of a hydraulic one.

[0141] Alternatively, for a liner operation (not shown) or a subsea casing operation, the drilling unit 1d may be used again after the casing or liner string is assembled for assembling a work string (not shown) used to deploy the assembled casing or liner string into the wellbore. The top drive system 1 may be shifted back to the drilling mode for assembly of the work string. The work string may include a casing or liner deployment assembly and a work stem of drill pipe 8p such that the drilling unit 1d may be employed to assemble the work stem by repeating the steps of Figures 5A-5H. The drilling step of Figure 5I may be repeated for reaming the casing or liner string into the wellbore.

[0142] Figure 8 illustrates the modular top drive system 1 in a cargo mode. In the event that cargo 100 needs to be transported from the subfloor structure to the rig floor 7f, the holder 5 or pipe clamp 17 may be disconnected from the arm 4 and stowed on the side bar 13r. The cargo hook 16 may then be connected to the arm 4 and the unit handler 1u operated to engage the cargo hook with a sling wrapped

about the cargo 100. The unit handler 1u may then be operated to raise the cargo to the rig floor 7f. The unit handler 1u may then be operated to release the cargo 100 onto the rig floor 7f. The cargo 100 may be spare parts for the motor unit 1m.

[0143] Figures 9A and 9B illustrates an alternative modular top drive system 101, according to another embodiment of the present disclosure. The alternative modular top drive system 101 may be similar to the modular top drive system except for having an alternative motor unit 101m and alternative couplings 102 for each of the casing, drilling, and cementing units. The alternative motor unit 101m may include the drive motors 18, the becket 19, the hose nipple 20, the mud swivel 21, the drive body 22, the drive gear 23, the trolley 24, an alternative thread compensator 103, the hydraulic swivel 26, the down thrust bearing 27, the up thrust bearing 28, the backup wrench 29, the swivel frame 30, the bearing retainer 31, the motor gear 32, and the latch 57.

[0144] Each alternative coupling 102 may include a head 102h having an external latch profile, such as a bayonet profile, an alternative control, such as hydraulic, junction member, such as a male conical top 105m, the slot 15t (not shown) and the hydraulic passages 39/49. Each alternative coupling 102 may further include the neck 15n, the lifting shoulder 15s, and the torso 15r.

[0145] The alternative compensator 103 may include the linear actuator 33, an alternative lock ring 104, an alternative hydraulic junction member, such as a female member 105f, and the lock pins 35 (not shown). The alternative lock ring 104 may have the outer flange 34f formed at an upper end thereof, a bore formed therethrough, one or more chambers (not shown) housing the lock pins 35 formed in an inner surface thereof, the locking profile 34k formed in a lower end thereof, and passages formed through the wall thereof for the chambers. The female junction member 105f may be connected to the alternative lock ring 104, such as by fastening.

[0146] The alternative female junction member 105f may have a conical inner surface for mating with the conical top 105m of the respective alternative coupling 102, thereby forming an alternative hydraulic junction 105m,f. The alternative

female member 105f may have nipples for receiving respective jumpers from the hydraulic swivel 26 and passages connecting the nipples and the conical inner surface. The conical top 105m may have seals disposed therealong for straddling the passages 39/49 and, upon mating, the passages 39/49 may be aligned with the respective passages of the female member 105f. The alternative hydraulic junction 105m,f may be formed as the alternative lock ring 104 is moved to the hoisting position by the compensator actuator 33. The alternative hydraulic junction 105m,f obviates the need for orientation as compared to the hydraulic junction 36.

[0147] Figures 10A and 10B illustrate an alternative unit rack 106 for the modular top drive system 1, according to another embodiment of the present disclosure. The alternative unit rack 106 may be a carousel and may include a lower turntable, an upper disk, a shaft connecting the turntable and the disk, and a motor (not shown) for rotating the turntable. A length of the shaft may correspond to a length of the longest one of the units 1c,d,s, such as being slightly greater than the longest length. The disk may have parking spots (eight shown) formed therein for receiving the units 1c,d,s. Each unit 1c,d,s may be hung from the disk by engagement of a parking spot with the respective coupling 15. The carousel rack 106 may allow one of the units 1c,d,s to be in a maintenance/initial loading position on a back side of the carousel rack while another one of the units is in a deployment position on a front side of the carousel rack facing the unit handler 1u.

[0148] Alternatively, the lower turntable may be a fixed base and the upper disk may be a turntable instead.

[0149] Additionally, the alternative unit rack 106 may include a gate 109 for each parking spot. Each gate 109 may be connected to the upper disk, such as by a hinge, and may pivot relative thereto between an open position and a closed position. The alternative unit rack 106 may further include actuators (not shown) for swinging the gates 109 between the positions and each actuator may be electrically, hydraulically, mechanically (for example by weight control), or pneumatically operated. In the open position, each gate 109 may allow deposit or removal of one of the units 1c,d,s into the respective parking spot and in the closed position, each gate may trap the deposited unit within the parking spot to secure

against escape of the deposited unit therefrom, such as due to heave of an offshore drilling unit. In one embodiment, each parking spot may include a latch profile, identical or similar to the latch profile in the latch ring 23, to secure a tool within. In one embodiment, the unit rack 106 may include an integrated tool handler. The integrated tool handler may be used to deliver a tool to and/or receive a tool from the unit handler 1u.

[0150] Figure 10C illustrates a second alternative unit rack 107 for the modular top drive, according to another embodiment of the present disclosure. The second alternative unit rack 107 may include a base, a beam, two or more (three shown) columns connecting the base to the beam, such as by welding or fastening, and a unit lift. A length of the columns may correspond to a length of the longest one of the units 1c,d,s, such as being slightly greater than the longest length. The columns may be spaced apart and parking spots (four shown) may be formed in the beam between adjacent columns. The units 1c,d,s may be hung from the beam by engagement of the parking spots with respective couplings 15 of the units. In one embodiment, each parking spot may include a latch profile, identical or similar to the latch profile in the latch ring 23, to secure a tool within. In one embodiment, the unit rack 107 may include an integrated tool handler. The integrated tool handler may be used to deliver a tool to and/or receive a tool from the unit handler 1u. The unit lift may include a slider transversely connected to one of the columns, a linear actuator (not shown) for raising and lowering the slider along the column, and an opening formed through the base for receiving a lower portion of one of the units 1c,d,s (casing unit 1c shown extending through opening). The slider may have a parking spot so one of the units 1c,d,s may be hung therefrom and raised and lowered as necessary to facilitate access by a technician 108 (pair shown) standing on the base or subfloor structure. The technician 108 may access the unit 1c,d,s for initial assembly thereof or maintenance thereof.

[0151] Additionally, the second alternative unit rack 107 may also have the side bar 13r. Alternatively, the unit lift may be located in a separate rack.

[0152] Figures 11A-11C illustrates an alternative unit handler 110 for the modular top drive system 1, according to another embodiment of the present

disclosure. The alternative unit handler 110 may include the rail 1r, a crane 111, a sling 112, an upper bracket 113, a lower bracket 114, and a linear actuator 115.

[0153] The crane 111 may include a boom, a hinge, a winch, and a hook. The winch may include a housing, a drum (not shown) having a load line (not shown) wrapped therearound, and a motor (not shown) for rotating the drum to wind and unwind the load line. The load line may be wire rope. The winch motor may be electric, hydraulic, or pneumatic. The winch housing may be connected to the boom, such as by fastening. The hook may be fastened to an eye splice formed in an end of the load line. The boom may be connected to the hinge, such as by fastening. The hinge may be connected to a back of the rail 1r, such as by fastening. The hinge may longitudinally support the boom from the rail 1r while allowing pivoting of the boom relative to the rail between a standby position (shown) and a transfer position (not shown) one-quarter turn or so toward the motor unit 1m. The sling 112 may include a becket, a frame, and a parking spot similar to the parking spot 14.

[0154] Alternatively, the hinge may be connected to the derrick 7d for supporting the boom from the derrick instead of the rail 1r. Additionally, the crane 111 may further include an electric or hydraulic slew motor (not shown) for pivoting the boom about the hinge. Additionally, the crane 111 may further include a guide rail (not shown) connected, such as by fastening, to the boom and the sling frame may have a groove (not shown) engaged with the guide rail, thereby preventing swinging of the sling 112 relative to the crane.

[0155] The upper bracket 113 may include a holder and a hinge. In a standby position, one of the units (cementing unit 1s shown) may be seated on the holder clear from the motor unit 1m. The holder may be connected to the hinge, such as by fastening. The hinge may be connected to the back of the rail 1r, such as by fastening. The hinge may longitudinally support the holder from the rail while allowing pivoting of the holder relative to the rail between the standby position (shown), a loading position (not shown) in alignment with the motor unit 1m, and a transfer position midway between the standby position and the loading position (corresponding to the crane transfer position). The upper bracket 113 may further

include an electric or hydraulic slew motor (not shown) for pivoting the holder about the hinge.

[0156] The lower bracket 114 may include a holder and a slide hinge. In the standby position, one of the units (drilling unit 1d shown) may be seated on the holder clear from the motor unit 1m. The holder may be connected to the slide hinge, such as by fastening. The slide hinge may be transversely connected to the back of the rail 1r such as by a slide joint, while being free to move longitudinally along the rail between the standby position (shown) and a maintenance position similar to that shown in Figure 10B. The slide hinge may also be pivotally connected to the linear actuator 115, such as by fastening. The slide hinge may longitudinally support the holder from the linear actuator 115 while allowing pivoting of the holder relative to the rail between the standby position (shown), a loading position (not shown) in alignment with the motor unit 1m, and a transfer position midway between the standby position and the loading position (corresponding to the crane transfer position). The lower bracket 114 may further include an electric or hydraulic slew motor (not shown) for pivoting the holder about the slide hinge.

[0157] Alternatively, the rail 1r may be twin rails instead of the monorail 2 and each bracket 113, 114 may be located in a space between the twin rails. Each bracket 113, 114 in this alternative may have a linear actuator instead of the respective hinge. Each alternative linear actuator may be connected to the twin rails or to the derrick 7d for supporting the respective holder therefrom and be operable to transversely move the respective holder between an online position aligned with the motor unit 1m and an offline position clear of the motor unit. The crane 111 in this alternative may also have a linear actuator for transverse movement. Alternatively, the linear actuator may move sideways.

[0158] The linear actuator 115 may include a base connected to the back of the rail 1r, such as by fastening, a cylinder (not shown) pivotally connected to the base, and a piston (not shown) pivotally connected to the slide hinge and disposed in a bore of the cylinder. The piston may divide the cylinder bore into a raising chamber and a lowering chamber and the cylinder may have ports formed through a wall thereof and each port may be in fluid communication with a respective chamber.

Each port may be in fluid communication with the HPU manifold 60m via a control line (not shown). Supply of hydraulic fluid to the raising port may move the drilling unit 1d to the standby position. Supply of hydraulic fluid to the lowering port may move the drilling unit 1d to the maintenance position. The rig floor 7f may have an opening formed therethrough for receiving the lower portion of the drilling unit 1d in the maintenance position for accessibility thereof by the rig technician 108.

[0159] Additionally, the linear actuator 115 may be movable to a second maintenance position (not shown) for the casing unit 1c and a third maintenance position (not shown) for the cementing unit 1s. Additionally, the linear actuator 115 may be movable to more than one maintenance position for any or all of the casing 1c, drilling 1d, and cementing 1s units and may be able to stop at each maintenance position. For example, when the lower bracket 114 is holding the casing unit 1c, the linear actuator 115 may be movable to an upper maintenance position for servicing or replacing a fill up tool 50 of the casing unit, a mid maintenance position for servicing or replacing slips 45 of the casing unit, and/or a lower maintenance position for accessing a linear actuator 41 of the casing unit.

[0160] Alternatively, the linear actuator 115 may include an electro-mechanical linear actuator, such as a motor and lead screw or pinion and gear rod, instead of the piston and cylinder assembly. Alternatively, the linear actuator 115 may include a hydraulic and/or a pneumatic linear actuator.

[0161] The crane 111 may be operable to transfer any of the units 1c,d,s on either one the brackets 113, 114 to the other bracket by moving the crane and the bracket holding the unit to the transfer position, engaging the sling 112 with the coupling 15, and raising or lowering the unit to a position in alignment with the other bracket 113, 114. The other bracket may then be moved to the transfer position, and the sling operated to release the unit 1c,d,s onto the other bracket.

[0162] Alternatively, the alternative unit handler 110 may be used in conjunction with the unit handler 1u as follows. Instead of the unit handler 1u delivering or retrieving one of the units 1c,d,s directly to/from the motor unit 1m, the unit handler may instead deliver or retrieve the unit to/from one of the brackets 113, 114 and the

bracket may be operated to deliver or retrieve the unit to/from the motor unit. In a further variant of this alternative, one of the brackets 113, 114 may be used with the unit handler 1u as follows. The unit handler 1u may deliver one of the units 1c,d,s to the bracket 113, 114 while the motor unit 1m is using another one of the units. The unit handler 1h may then retrieve the used unit from the motor unit 1m and deliver the used unit to the rack 1k. As soon as the unit handler 1h has retrieved the used unit, the bracket 113, 114 may be operated to deliver the currently held unit to the motor unit 1m.

[0163] Additionally, the alternative unit handler 110 may include a gate 116 for each bracket 113, 114. Each gate 116 may be connected to the respective bracket 113, 114, such as by a hinge, and may pivot relative thereto between an open position and a closed position. The alternative unit handler 110 may further include actuators (not shown) for swinging the gates 116 between the positions and each actuator may be electrically, hydraulically, or pneumatically operated. In the open position, each gate 116 may allow deposit or removal of one of the units 1c,d,s into the holder and in the closed position, each gate may trap the deposited unit within the holder to secure against escape of the deposited unit therefrom, such as due to heave of an offshore drilling unit.

[0164] Alternatively, each gate 116 may be mechanically operated, the hinge thereof may have a torsion spring biasing the gate toward the open position, and the alternative unit handler 110 may include latches operable to fasten the gates in the closed position. Each latch may be released by: a pin on the motor unit 1m that releases the latch if the respective bracket 113, 114 is proximate thereto, a linkage that is operated by rotation of the respective bracket toward the motor unit (opens when bracket is aligned with motor unit), and/or a pin on the sling 112 that releases the latch if the respective bracket 113, 114 is proximate thereto.

[0165] Figure 12 illustrates a torque sub accessory 120 for the modular top drive system 1, according to another embodiment of the present disclosure. The torque sub 120 may include an outer non-rotating interface 121, an interface frame 122, an inner torque shaft 123, one or more load cells 124a,t, one or more wireless couplings 125r,s, 126r,s, a shaft electronics package 127r, an interface electronics

package 127s, a turns counter 128, and a shield 129.

[0166] The torque shaft 123 may be tubular, may have a bore formed therethrough, and may have couplings, such as a threaded box or pin, formed at each end thereof. The torque shaft 123 may have a reduced diameter outer portion forming a recess in an outer surface thereof. The load cell 124t may include a circuit of one or more torsional strain gages and the load cell 124a may include a circuit of one or more longitudinal strain gages, each strain gage attached to an outer surface of the reduced diameter portion, such as by adhesive. The strain gages may each be made from metallic foil, semiconductor, or optical fiber.

[0167] Additionally, the load cell 124a may include a set of strain gages disposed around the torque shaft 123 such that one or more bending moments exerted on the torque shaft may be determined from the strain gage measurements.

[0168] The wireless couplings 125r,s, 126r,s may include wireless power couplings 125r,s and wireless data couplings 126r,s. Each set of couplings 125r,s, 126r,s may include a shaft member 125s, 126s connected to the torque shaft 123 and an interface member housed in an encapsulation 130s connected to the frame 122. The wireless power couplings 125r,s may each be inductive coils and the wireless data couplings 126r,s may each be antennas. The shaft electronics may be connected by leads and the electronics package 127r, load cells 124a,t, and antenna 126r may be encapsulated 130r into the recess. The shield 129 may be located adjacent to the recess and may be connected to the frame 122 (shown) or connected to the shaft 123 (not shown). The frame 122 may be may be connected to the top drive frame by a bracket (not shown).

[0169] Alternatively, the torque shaft 123 may carry a power source, such as a battery, capacitor, and/or inductor, and the wireless power couplings 125r,s may be omitted or used only to charge the power source.

[0170] The shaft electronics package 127r may include a microcontroller, a power converter, an ammeter and a transmitter. The power converter may receive

an AC power signal from the power coupling and convert the signal to a DC power signal for operation of the shaft electronics. The DC power signal may be supplied to the load cells 124a,t and the ammeter may measure the current. The microcontroller may receive the measurements from the ammeter and digitally encode the measurements. The transmitter may receive the digitally encoded measurements, modulate them onto a carrier signal, and supply the modulated signal to the antenna 126r.

[0171] The interface antenna 126s may receive the modulated signal and the interface electronics package 127s may include a receiver for demodulating the signal. The interface package 127s may further include a microcontroller for digitally decoding the measurements and converting the measurements to torque and longitudinal load. The interface package 127s may send the converted measurements to the control console 62 via a data cable (not shown). The interface package 127s may further include a power converter for supplying the interface data coupling with the AC power signal. The interface package 127s may also be powered by the data cable or include a battery.

[0172] The turns counter 128 may include a base 128h torsionally connected to the shaft, a turns gear 128g connected to the base, and a proximity sensor 128s connected to the frame 122 and located adjacent to the turns gear. The turns gear 128g may be made from an electrically conductive metal or alloy and the proximity sensor 128s may be inductive. The proximity sensor 128s may include a transmitting coil, a receiving coil, an inverter for powering the transmitting coil, and a detector circuit connected to the receiving coil. A magnetic field generated by the transmitting coil may induce an eddy current in the turns gear 128g. The magnetic field generated by the eddy current may be measured by the detector circuit and supplied to the interface controller. The interface controller may then convert the measurement to angular movement and/or speed and supply the converted measurement to the control console 53.

[0173] Alternatively, the proximity sensor 128s may be Hall effect, ultrasonic, or optical. Alternatively, the turns counter 128 may include a gear box instead of a single turns gear 128g to improve resolution.

[0174] A torque sub 120 may be added to any or all of: the drilling unit 1d, casing unit 1c, and cementing unit 1s. If added to the drilling unit 1d or the cementing unit 1c, the torque shaft 123 may be connected to the quill 37 or and the interface frame 122 may be hung from a bottom of the drive body 22. If added to the casing unit 1c, the torque shaft 123 may be connected between the coupling 15 and the collar 43 and the interface frame 122 may be hung from the bottom of the drive body 22.

[0175] Alternatively, the torque sub 120 may be added to the motor unit 1m instead of the drilling 1d, casing 1c, and/or cementing 1s units.

[0176] During the drilling operation, the torque sub 120 may be used to monitor torque, longitudinal load, and angular velocity for instability, such as sticking of the drill string 8 or collapse of the formation 86. The torque sub 120 may also be used to monitor make up of the threaded connections between the stands 8s whether for drilling or for a work string. During the casing operation, the torque sub 120 may be used to monitor torque, turns, and the derivative of torque with respect to turns to ensure that the threaded connections between the casing joints 90j are properly made up. During the cementing operation, the torque sub 120 may be used to monitor curing of the cement slurry 97 by measuring the torsional resistance thereof.

[0177] Latch profiles between a motor unit and a tool unit of the present disclosure may be any suitable profiles. Instead of bayonet profiles, movable latch profiles, enabled by bolts, locking blocks, or other suitable structures, may be used to joined a top drive unit and a tool unit. In one embodiment, the latch profile in the motor unit and/or in the tool unit may be a movable latch profile. The latch profile may move between an open position to allow inserting and removal of a tool and a closed position to transfer torsional and/or torsional loads.

[0178] Figures 13A and 13B schematically illustrate a top drive unit 1m' having a movable latch profile to connect with a tool unit 1d'. In Figure 13A, the top drive unit 1m' is in an open position. In Figure 13B, the top drive unit 1m' is in a closed position. The top drive unit 1m' may include a drive ring 23'. In one embodiment,

the drive ring 23' may be connected to a rotor of a drive motor. The drive ring 23' may include a plurality of locking blocks 23l' disposed along an inner surface of the drive ring 23'. In the open position, the plurality of locking blocks 23l' may be in an upper right position to allow a coupling 15' of the tool unit 1d' to enter drive ring 23'. In the closed position, the plurality of locking blocks 23l' may be tilted radially inward forming a latch profile to lock with a latch profile 15l' of on the coupling 15'. In one embodiment, the locking block 23l' may be moved between the open position and the closed position by one or more actuators 23p'. In one embodiment, the actuator 23p' may be a linear actuator. In one embodiment, control junctions, such as hydraulic junctions, electric junctions, pneumatic junctions, data junctions, and/or signal junctions may be formed in the drive ring 23' and the coupling 15' to connect pressured fluids, electrical power or signals, and/or data between the top drive unit 1m' and the tool unit 1d'. In one embodiment, the top drive unit 1m' does not include a thread compensator, such as the compensator 25 in the motor unit 1m. Alternatively, a compensator, similar to the compensator 25 may be connected to the drive ring 23'.

[0179] It should be noted that the various embodiments to the top drive units, the rack units, the handler units, and the tool units may be exchanged, mixed, and/or combined to achieve desired results.

[0180] Even though embodiments described above relate to connecting a tool to a top drive unit, latch profiles according to the present disclosure may be used to connect any tubulars, such as connecting a tool to a suitable devices or an adaptor, connecting an adaptor to a top drive unit, connecting a tool to a handler, connecting a tool to a storage unit, and the like.

[0181] One embodiment of the present disclosure may include a top drive comprising a drive body, and a drive ring rotationally coupled the drive body, wherein the drive ring has an internal latch profile for selectively receiving a tool.

[0182] One embodiment of the present disclosure may include a top drive comprising a drive motor, and a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a

tool.

[0183] One embodiment of the present disclosure provides a modular top drive system for construction of a wellbore. The system includes a motor unit comprising a drive body, a drive motor having a stator connected to the drive body, a trolley for connecting the drive body to a rail of a drilling rig, and a drive ring torsionally connected to a rotor of the drive motor and having a latch profile for selectively connecting one of: a drilling unit, a casing unit, and a cementing unit to the motor unit.

[0184] In one or more embodiment, the system further includes a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit.

[0185] In one or more embodiment, the unit handler comprises a base for mounting the unit handler to a subfloor structure of the drilling rig, a post extending from the base to a height above a floor of the drilling rig, a slide hinge transversely connected to the post, and an arm connected to the slide hinge.

[0186] In one or more embodiment, the arm comprises a forearm segment, an aft-arm segment, and an actuated joint connecting the arm segments, and the unit handler further comprises a holder connected to the forearm segment and operable to engage a torso of each of the drilling, casing, and cementing units.

[0187] In one or more embodiment, the system further comprises the drilling, casing, and cementing units, each unit having a coupling and each coupling having a head with a latch profile for mating with the latch profile of the drive ring.

[0188] In one or more embodiment, the latch profiles are bayonet profiles.

[0189] In one or more embodiment, the couplings of the drilling, casing, and cementing units each further have a neck extending from the head, a lifting shoulder connected to a lower end of the neck, and a torso extending from the lifting shoulder.

[0190] In one or more embodiment, wherein the motor unit further comprises a thread compensator. The thread compensator includes a lock ring torsionally connected to the drive ring, a linear actuator for moving the lock ring relative to the drive ring between a ready position and a hoisting position, and a lock pin for selectively connecting any one of the drilling, casing, and cementing units to the lock ring.

[0191] In one or more embodiment, a flange of the lock ring is engaged with the drive ring in the hoisting position, each of the drive ring and lock ring has a locking profile for locking the mated latch profiles together, and the linear actuator is also for moving the selectively connected unit to the ready position.

[0192] In one or more embodiment, the lock ring and each coupling head each have a stab connector of a control junction.

[0193] In one or more embodiment, the thread compensator further comprises a stab connector of a control junction connected to the lock ring and having a plurality of passages formed therethrough, each coupling head has a stab connector of the control junction having a plurality of passages formed therethrough, and each stab connector is at least partially conical.

[0194] In one or more embodiment, the motor unit further comprises a proximity sensor connected to the drive body for monitoring a position of the lock ring.

[0195] In one or more embodiment, the motor unit further comprises a becket connected to the drive body for receiving a hook of a traveling block, a swivel frame connected to the drive body, a mud swivel comprising an outer barrel connected to the swivel frame and an inner barrel having an upper portion disposed in the outer barrel and a stinger portion for stabbing into a seal into a seal receptacle of any of the couplings, a nipple connected to the outer barrel for receiving a mud hose, a down thrust bearing for supporting the drive ring for rotation relative to the drive body.

[0196] In one or more embodiment, the motor unit further comprises a control swivel, the control swivel comprises an outer barrel and an inner barrel having a

head portion connected to the swivel frame and a mandrel portion extending along the outer barrel, and the stinger portion of the mud swivel extends through the control swivel.

[0197] In one or more embodiment, the motor unit further comprises a backup wrench, and the backup wrench comprises: an arm, a hinge connecting the arm to the drive body, and a tong connected to the arm and movable along the arm.

[0198] In one or more embodiment, the system further includes the rack having a parking spot for each of the drilling, casing, and cementing units.

[0199] In one or more embodiment, the system further comprises a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit, and the rack further comprises a side bar for holding accessories of the unit handler.

[0200] In one or more embodiment, the rack comprises a turntable, a disk, and a shaft, and the disk has the parking spots formed therein.

[0201] In one or more embodiment, the rack further comprises a gate for each parking spot, each gate hinged to the disk for pivoting between an open position and a closed position for trapping one of the drilling, casing, and cementing units in the respective parking spot.

[0202] In one or more embodiment, the system further includes a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit, and an accessory rack for holding accessories of the unit handler.

[0203] In one or more embodiment, the rack comprises a base, a beam, two or more columns connecting the base to the beam, and a unit lift, the parking spots are formed in the beam, and the unit lift comprises a slider connected to one of the columns and having an additional parking spot and an opening formed through the

base for receiving a lower portion of any of the drilling, casing, and cementing units.

[0204] In one or more embodiment, each of the drilling and cementing units comprises an internal blowout preventer (IBOP) disposed in a bore of the respective unit, a quill connected to the respective coupling, and a passage extending from the head to an actuator of the IBOP.

[0205] In one or more embodiment, the cementing unit further comprises a cementing swivel. The cementing swivel comprises a housing having an inlet formed through a wall thereof for connection of a cement line, a mandrel connected to the respective quill and having a port formed through a wall thereof in fluid communication with the inlet, a bearing for supporting rotation of the mandrel relative to the housing, and a seal assembly for isolating the inlet-port communication.

[0206] In one or more embodiment, the cementing unit further comprises a launcher. The launcher comprises a body connected to the mandrel of the cementing swivel, a dart disposed in the launcher body, and a gate having a portion extending into the launcher body for capturing the dart therein and movable to a release position allowing the dart to travel past the gate.

[0207] In one or more embodiment, the casing unit comprises a clamp. The clamp comprises a set of grippers for engaging a surface of a joint of casing, thereby anchoring the casing joint to the casing unit, and an actuator for selectively engaging and disengaging the clamp with a casing joint, and a stab seal for engaging an inner surface of the casing joint.

[0208] In one or more embodiment, the clamp further comprises a mandrel having the grippers disposed thereon, a collar longitudinally and torsionally connecting the mandrel to the respective coupling, and a seal tube fluidly connecting the mandrel and the respective coupling.

[0209] In one or more embodiment, the casing unit further comprises a fill up tool comprising a stab seal, a mud saver valve, and a release valve.

[0210] In one or more embodiment, the system further comprises a video camera mounted to the motor unit for monitoring alignment of the latch profiles.

[0211] In one or more embodiment, the system further comprises a pipe handler. The pipe handler includes a pair of bails, a slide hinge for connecting the bails to the rail, a link tilt pivotally connected to the slide hinge and each bail for swinging the bails relative to the slide hinge, and a linear actuator for moving the slide hinge relative to the motor unit, wherein the motor unit further comprises a latch for selectively connecting the slide hinge to the drive body.

[0212] In one or more embodiment, a linear motor is coupled to the pipe handler.

[0213] In one or more embodiment, the linear actuator comprises a gear rack pivotally connected to the slide hinge, and a pinion motor comprising a stator connected to the drive body and a rotor meshed with the rack.

[0214] In one or more embodiment, the system further comprises the rail for connection to at least one of: a floor and a derrick of the drilling rig.

[0215] In one or more embodiment, the system further comprises a torque sub for assembly with one of the units. The torque sub comprises a non-rotating interface, a torque shaft, a strain gage disposed on the torque shaft and oriented to measure torque exerted on the torque shaft, a transmitter disposed on the torque shaft and in communication with the strain gage, the transmitter operable to wirelessly transmit the torque measurement to the interface, a turns gear torsionally connected to the torque shaft, and a proximity sensor connected to the interface and located adjacent to the turns gear.

[0216] In one or more embodiment, the system further includes a set of strain gages. Each strain gage is disposed on the torque shaft and oriented to measure longitudinal load exerted on the torque shaft, and the set is spaced around the torque shaft for measurement of a bending moment exerted on the torque shaft.

[0217] In one or more embodiment, the system further includes at least one rail

for connection to at least one of: a floor and a derrick of a drilling rig, a bracket for holding any one of the drilling, casing, and cementing units and movable relative to the rail between a standby position and a connection position, wherein the unit held by the bracket is aligned with the motor unit in the connection position and clear of the motor unit in the standby position.

[0218] In one or more embodiment, the system further includes a unit handler locatable on or adjacent to a subfloor structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the bracket, and retrieve any one of the drilling, casing, and cementing units from the motor unit and deliver the retrieved unit to the rack.

[0219] In one or more embodiment, the system further includes a gate hinged to the bracket for pivoting between an open position and a closed position for trapping one of the drilling, casing, and cementing units in a holder of the bracket.

[0220] Another embodiment of the present disclosure provides a method for operating a modular top drive system. The method includes retrieving a drilling unit from a unit rack located below a floor of a drilling rig, raising the retrieved drilling unit to or above the rig floor, delivering the retrieved drilling unit to a motor unit connected to a rail of the drilling rig, aligning a latch profile of the motor unit with a latch profile of the drilling unit, inserting the drilling unit into the motor unit, and engaging the latch profiles, thereby connecting the drilling unit to the motor unit.

[0221] In one or more embodiment, the method further includes operating a compensator of the motor unit to lower a lock ring thereof into engagement with the engaged latch profiles, thereby torsionally locking the profiles, and engaging one or more lock pins carried by the lock ring with the drilling unit, thereby connecting the drilling unit to the lock ring.

[0222] In one or more embodiment, lowering of the lock ring also assembles a control junction between the motor and drilling units.

[0223] In one or more embodiment, the method further includes operating a backup wrench of the motor unit to move a tong along an arm of the backup

wrench until the tong is positioned adjacent to a quill of the drilling unit.

[0224] In one or more embodiment, the method further includes releasing a pipe handler from the motor unit, lowering the released pipe handler to position an elevator adjacent to a top coupling of a stand of drill pipe, closing the elevator to grip the stand, raising the gripped stand and operating a link tilt of the pipe handler to swing the stand into alignment with the quill, raising the pipe handler and the gripped stand to engage the top coupling with the quill, engaging the backup tong with the top coupling, and operating the motor unit to screw the quill into the top coupling while operating the compensator to maintain a neutral condition.

[0225] In one or more embodiment, the method further includes the pipe handler and gripped stand are further raised after engagement of the top coupling with the quill to stroke the compensator from a hoisting position to a ready position.

[0226] In one or more embodiment, the method further includes releasing the elevator and backup tong from the stand, lowering the motor and drilling units to stab the connected stand into a drill or work string, and operating the motor unit to screw the stand into the drill or work string while operating the compensator to maintain a neutral condition, thereby extending the drill or work string.

[0227] In one or more embodiment, the method further includes replacing the drilling unit with a casing unit from the unit rack, releasing a pipe handler from the motor unit, lowering the released pipe handler to position an elevator adjacent to a top coupling of a casing or liner joint, closing the elevator to grip the casing or liner joint, raising the gripped casing or liner joint and operating a link tilt of the pipe handler to swing the stand into alignment with a clamp of the casing unit, raising the pipe handler and the gripped casing or liner joint to stab a seal of the casing unit into the casing or liner joint, and operating the clamp to anchor the sealed casing or liner joint to the casing unit.

[0228] In one or more embodiment, the pipe handler and anchored casing or liner joint are further raised after stabbing of the seal to stroke the compensator from a hoisting position to a ready position.

[0229] In one or more embodiment, the method further includes releasing the elevator and backup tong from the anchored casing or liner joint, lowering the motor and drilling units to stab the anchored casing or liner joint into a casing or liner string, and operating the motor unit to screw the joint into the casing or liner string while operating a compensator of the motor unit to maintain a neutral condition, thereby extending the casing or liner string.

[0230] In one or more embodiment, the method further includes replacing the drilling unit with a cementing unit from the unit rack, using a work string to set a hanger of a casing or liner string, connecting a cement line to a swivel of the cementing unit, operating the motor unit to rotate the work string and casing or liner string, and while rotating the strings, pumping cement slurry through the cement line and cementing unit, operating an actuator of the cementing unit to launch a dart from a launcher of the cementing unit, and pumping chaser fluid behind the dart, thereby driving the cement slurry through the work string, releasing a wiper plug therefrom, and driving the cement slurry through the casing or liner string and into an annulus formed between the casing or liner string and a wellbore.

[0231] In one or more embodiment, the drilling unit is retrieved, raised, and delivered by operating a unit handler having a holder connected to an arm thereof.

[0232] In one or more embodiment, the method further includes removing the holder from the arm of the unit handler, and connecting a pipe clamp to the arm, operating the unit handler to engage the pipe clamp with a joint of casing or liner located below the rig floor, and operating the unit handler to raise the casing or liner joint to the rig floor.

[0233] In one or more embodiment, the method further includes replacing the drilling unit with a casing unit from the unit rack, wherein the unit handler is further operated to deliver the casing or liner joint into alignment with the casing unit and to hold the casing or liner joint while the casing unit is stabbed into the casing or liner joint.

[0234] In one or more embodiment, the method further includes removing the

holder from the arm of the unit handler, and connecting a cargo hook to the arm, operating the unit handler to engage the cargo hook with cargo located below the rig floor, and operating the unit handler to raise the cargo to the rig floor.

[0235] In one or more embodiment, the holder is removed and the pipe clamp or cargo hook is connected by remote operation of a quick connect system.

[0236] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope of the invention is determined by the claims that follow.

Claims:

1. A top drive, comprising:
 - a drive body;
 - a drive motor, wherein a stator of the drive motor is connected to the drive body; and
 - a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a tool.
2. The top drive of claim 1, wherein the drive ring has a central bore, a locking profile is formed on an upper portion of the central bore, and the internal latch profile is formed on a lower portion of the central bore.
3. The top drive of claim 2, wherein the internal latch profile comprises a bayonet profile.
4. The top drive of claim 2, further comprising a thread compensator, wherein the thread compensator includes:
 - a lock ring torsionally connected to the drive ring; and
 - a linear actuator for moving the lock ring relative to the drive ring between a ready position and a hoisting position.
5. The top drive of claim 4, wherein the thread compensator further comprises a lock member for selectively connecting to the lock ring to the tool received in the drive ring, and the linear actuator moves the tool and the lock ring together when the lock member connects the locking ring to the tool.
6. The top drive of claim 4, wherein the lock ring includes a locking profile, wherein the locking profile of the drive ring and the locking profile of the lock ring lock the tool at a mated position with the internal latch profile of the drive ring.
7. The top drive of claim 4, further comprising a control junction.

8. The top drive of claim 7, wherein the control junction comprises a stab connector having a plurality of cable or a plurality of passages formed through the locking ring.
9. The top drive of claim 4, further comprising a proximity sensor connected to the drive body for monitoring a position of the lock ring.
10. The top drive of claim 1, further comprising a video camera for monitoring alignment of the tool with the internal latching profile.
11. The top drive of claim 1, further comprising one or more thrust bearing disposed between the drive body and the driving ring.
12. A modular top drive system, comprising:
 - a motor unit, comprising:
 - a drive body;
 - a drive motor, wherein a stator of the drive motor is connected to the drive body; and
 - a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a tool;
 - a rack having a parking spot for receiving the tool; and
 - a unit handler for retrieving the tool from the rack and delivering the tool to the drive unit.
13. The system of claim 12, wherein the unit handler comprises:
 - a base;
 - a post extending from the base;
 - a slide hinge transversely connected to the post; and
 - an arm connected to the slide hinge, wherein the arm comprises a holder to engage the tool.
14. The system of claim 12, further comprising one or more tools, wherein each

of the one or more tools comprises: a coupling head with an outer latch profile for matching the internal latch profile of the drive ring.

15. The system of claim 14, wherein the latch profiles are bayonet profiles.
16. The system of claim 14, wherein the coupling head has a control junction.
17. A method of operating a modular top drive system, comprising:
 - aligning a latch profile of a tool with an internal latch profile formed on a drive ring of a motor unit;
 - inserting the tool into the motor unit; and
 - engaging the latch profiles to connect the tool to the motor unit.
18. The method of claim 17, further comprising:
 - lowering a lock ring between the engaged latch profiles of the tool and the drive ring to torsionally lock the latch profiles; and
 - engaging one or more lock members carried by the lock ring with the tool.
19. The method of claim 18, wherein lowering the lock ring connecting a control junction between the lock ring and the tool.
20. The method of claim 18, further comprising:
 - moving the engaged lock ring and tool between a hoisting position and a ready position; and
 - performing one of a drilling operation, casing operation, and cementing operation with the tool.
21. The method of claim 18, further comprising using a linear actuator connected to the motor unit to lift a work string attached to the tool.
22. A top drive, comprising:
 - a drive body; and

a drive ring rotationally coupled the drive body, wherein the drive ring has an internal latch profile for selectively receiving a tool.

23. A top drive, comprising:

a drive motor; and

a drive ring torsionally coupled to a rotor of the drive motor, wherein the drive ring has an internal latch profile for selectively receiving a tool.

24. The top drive of claim 1, wherein the internal latch profile is a movable profile.

25. A modular top drive system for construction of a wellbore, comprising:
a motor unit, comprising:

a drive body;

a drive motor having a stator connected to the drive body;

a trolley for connecting the drive body to a rail of a drilling rig; and

a drive ring torsionally connected to a rotor of the drive motor and

having a latch profile for selectively connecting one of: a drilling unit, a casing unit, and a cementing unit to the motor unit.

26. The system of claim 1, further comprising a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit.

27. The system of claim 2, wherein the unit handler comprises:

a base for mounting the unit handler to a subfloor structure of the drilling rig;

a post extending from the base to a height above a floor of the drilling rig;

a slide hinge transversely connected to the post; and

an arm connected to the slide hinge.

28. The system of claim 3, wherein:

the arm comprises a forearm segment, an aft-arm segment, and an actuated joint connecting the arm segments, and

the unit handler further comprises a holder connected to the forearm segment and operable to engage a torso of each of the drilling, casing, and cementing units.

29. The system of any preceding claim, further comprising the drilling, casing, and cementing units, each unit having a coupling and each coupling having a head with a latch profile for mating with the latch profile of the drive ring.

30. The system of claim 5, wherein the latch profiles are bayonet profiles.

31. The system of claims 5 or 6, wherein the couplings of the drilling, casing, and cementing units each further have a neck extending from the head, a lifting shoulder connected to a lower end of the neck, and a torso extending from the lifting shoulder.

32. The system of any of claims 5 to 7, wherein the motor unit further comprises a thread compensator, comprising:

a lock ring torsionally connected to the drive ring;

a linear actuator for moving the lock ring relative to the drive ring between a ready position and a hoisting position; and

a lock pin for selectively connecting any one of the drilling, casing, and cementing units to the lock ring.

33. The system of claim 8, wherein:

a flange of the lock ring is engaged with the drive ring in the hoisting position,

each of the drive ring and lock ring has a locking profile for locking the mated latch profiles together, and

the linear actuator is also for moving the selectively connected unit to the ready position.

34. The system of claim 8 or 9, wherein the lock ring and each coupling head each have a stab connector of a control junction.
35. The system of claim 8 or 9, wherein:
the thread compensator further comprises a stab connector of a control junction connected to the lock ring and having a plurality of passages formed therethrough,
each coupling head has a stab connector of the control junction having a plurality of passages formed therethrough, and
each stab connector is at least partially conical.
36. The system of any of claims 8 to 11, wherein the motor unit further comprises a proximity sensor connected to the drive body for monitoring a position of the lock ring.
37. The system of any of claims 5 to 12, wherein the motor unit further comprises:
a becket connected to the drive body for receiving a hook of a traveling block;
a swivel frame connected to the drive body;
a mud swivel comprising an outer barrel connected to the swivel frame and an inner barrel having an upper portion disposed in the outer barrel and a stinger portion for stabbing into a seal into a seal receptacle of any of the couplings;
a nipple connected to the outer barrel for receiving a mud hose;
a down thrust bearing for supporting the drive ring for rotation relative to the drive body.
38. The system of claim 13, wherein:
the motor unit further comprises a control swivel,
the control swivel comprises an outer barrel and an inner barrel having a head portion connected to the swivel frame and a mandrel portion extending along the outer barrel, and

the stinger portion of the mud swivel extends through the control swivel.

39. The system of any preceding claim, wherein:
the motor unit further comprises a backup wrench, and
the backup wrench comprises: an arm; a hinge connecting the arm to the drive body; and a tong connected to the arm and movable along the arm.
40. The system of any of claims 5 to 15, further comprising the rack having a parking spot for each of the drilling, casing, and cementing units.
41. The system of claim 16, wherein:
the system further comprises a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit, and
the rack further comprises a side bar for holding accessories of the unit handler.
42. The system of claim 16, wherein:
the rack comprises a turntable, a disk, and a shaft, and
the disk has the parking spots formed therein.
43. The system of claim 18, wherein the rack further comprises a gate for each parking spot, each gate hinged to the disk for pivoting between an open position and a closed position for trapping one of the drilling, casing, and cementing units in the respective parking spot.
44. The system of any of claims 3 to 16, further comprising:
a unit handler locatable on or adjacent to a structure of the drilling rig and operable to retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the motor unit, and
an accessory rack for holding accessories of the unit handler.

45. The system of claim 16, wherein:
the rack comprises a base, a beam, two or more columns connecting the base to the beam, and a unit lift,
the parking spots are formed in the beam, and
the unit lift comprises a slider connected to one of the columns and having an additional parking spot and an opening formed through the base for receiving a lower portion of any of the drilling, casing, and cementing units.
46. The system of any of claims 5 to 21, wherein each of the drilling and cementing units comprises:
an internal blowout preventer (IBOP) disposed in a bore of the respective unit,
a quill connected to the respective coupling, and
a passage extending from the head to an actuator of the IBOP.
47. The system of claim 22, wherein:
the cementing unit further comprises a cementing swivel, and
the cementing swivel comprises:
a housing having an inlet formed through a wall thereof for connection of a cement line;
a mandrel connected to the respective quill and having a port formed through a wall thereof in fluid communication with the inlet;
a bearing for supporting rotation of the mandrel relative to the housing; and
a seal assembly for isolating the inlet-port communication.
48. The system of claim 23, wherein:
the cementing unit further comprises a launcher, and
the launcher comprises:
a body connected to the mandrel of the cementing swivel;
a dart disposed in the launcher body; and
a gate having a portion extending into the launcher body for capturing

the dart therein and movable to a release position allowing the dart to travel past the gage.

49. The system of any of claims 5 to 24, wherein the casing unit comprises:
a clamp comprising:
a set of grippers for engaging a surface of a joint of casing, thereby anchoring the casing joint to the casing unit; and
an actuator for selectively engaging and disengaging the clamp with a casing joint; and
a stab seal for engaging an inner surface of the casing joint.
50. The system of claim 25, wherein the clamp further comprises:
a mandrel having the grippers disposed thereon;
a collar longitudinally and torsionally connecting the mandrel to the respective coupling; and
a seal tube fluidly connecting the mandrel and the respective coupling.
51. The system of claim 26, wherein the casing unit further comprises a fill up tool comprising a stab seal, a mud saver valve, and a release valve.
52. The system of any of claims 5 to 27, further comprising a video camera mounted to the motor unit for monitoring alignment of the latch profiles.
53. The system of any preceding claim, further comprising a pipe handler, comprising:
a pair of bails;
a slide hinge for connecting the bails to the rail;
a link tilt pivotally connected to the slide hinge and each bail for swinging the bails relative to the slide hinge; and
a linear actuator for moving the slide hinge relative to the motor unit,
wherein the motor unit further comprises a latch for selectively connecting the slide hinge to the drive body.

54. The system of claim 29, wherein the linear actuator comprises:
a gear rack pivotally connected to the slide hinge; and
a pinion motor comprising a stator connected to the drive body and a rotor meshed with the rack.
55. The system of any preceding claim, further comprising the rail for connection to at least one of: a floor and a derrick of the drilling rig.
56. The system of any preceding claim, further comprising a torque sub for assembly with one of the units, the torque sub comprising:
a non-rotating interface;
a torque shaft;
a strain gage disposed on the torque shaft and oriented to measure torque exerted on the torque shaft;
a transmitter disposed on the torque shaft and in communication with the strain gage, the transmitter operable to wirelessly transmit the torque measurement to the interface;
a turns gear torsionally connected to the torque shaft; and
a proximity sensor connected to the interface and located adjacent to the turns gear.
57. The system of claim 32, further comprising a set of strain gages, wherein:
each strain gage is disposed on the torque shaft and oriented to measure longitudinal load exerted on the torque shaft, and
the set is spaced around the torque shaft for measurement of a bending moment exerted on the torque shaft.
58. The system of any preceding claim, further comprising:
at least one rail for connection to at least one of: a floor and a derrick of a drilling rig;
a bracket for holding any one of the drilling, casing, and cementing units and

movable relative to the rail between a standby position and a connection position, wherein the unit held by the bracket is aligned with the motor unit in the connection position and clear of the motor unit in the standby position.

59. The system of claim 34, further comprising a unit handler locatable on or adjacent to a subfloor structure of the drilling rig and operable to:

retrieve any one of the drilling, casing, and cementing units from a rack and deliver the retrieved unit to the bracket, and

retrieve any one of the drilling, casing, and cementing units from the motor unit and deliver the retrieved unit to the rack.

60. The system of claim 34 or 35, further comprising a gate hinged to the bracket for pivoting between an open position and a closed position for trapping one of the drilling, casing, and cementing units in a holder of the bracket.

61. A method of operating a modular top drive system, comprising:

retrieving a drilling unit from a unit rack located below a floor of a drilling rig;
raising the retrieved drilling unit to or above the rig floor;
delivering the retrieved drilling unit to a motor unit connected to a rail of the drilling rig;

aligning a latch profile of the motor unit with a latch profile of the drilling unit;
inserting the drilling unit into the motor unit; and
engaging the latch profiles, thereby connecting the drilling unit to the motor unit.

62. The method of claim 37, further comprising:

operating a compensator of the motor unit to lower a lock ring thereof into engagement with the engaged latch profiles, thereby torsionally locking the profiles; and

engaging one or more lock pins carried by the lock ring with the drilling unit, thereby connecting the drilling unit to the lock ring.

63. The method of claim 38, wherein lowering of the lock ring also assembles a control junction between the motor and drilling units.
64. The method of claim 38 or 39, further comprising operating a backup wrench of the motor unit to move a tong along an arm of the backup wrench until the tong is positioned adjacent to a quill of the drilling unit.
65. The method of any of claims 38 to 40, further comprising:
releasing a pipe handler from the motor unit;
lowering the released pipe handler to position an elevator adjacent to a top coupling of a stand of drill pipe;
closing the elevator to grip the stand;
raising the gripped stand and operating a link tilt of the pipe handler to swing the stand into alignment with the quill;
raising the pipe handler and the gripped stand to engage the top coupling with the quill;
engaging the backup tong with the top coupling; and
operating the motor unit to screw the quill into the top coupling while operating the compensator to maintain a neutral condition.
66. The method of claim 41, wherein the pipe handler and gripped stand are further raised after engagement of the top coupling with the quill to stroke the compensator from a hoisting position to a ready position.
67. The method of claim 41 or 42, further comprising:
releasing the elevator and backup tong from the stand;
lowering the motor and drilling units to stab the connected stand into a drill or work string; and
operating the motor unit to screw the stand into the drill or work string while operating the compensator to maintain a neutral condition, thereby extending the drill or work string.

68. The method of any of claims claim 37 to 43, further comprising
replacing the drilling unit with a casing unit from the unit rack;
releasing a pipe handler from the motor unit;
lowering the released pipe handler to position an elevator adjacent to a top coupling of a casing or liner joint;
closing the elevator to grip the casing or liner joint;
raising the gripped casing or liner joint and operating a link tilt of the pipe handler to swing the stand into alignment with a clamp of the casing unit;
raising the pipe handler and the gripped casing or liner joint to stab a seal of the casing unit into the casing or liner joint; and
operating the clamp to anchor the sealed casing or liner joint to the casing unit.
69. The method of claim 44, wherein the pipe handler and anchored casing or liner joint are further raised after stabbing of the seal to stroke the compensator from a hoisting position to a ready position.
70. The method of claim 44 or 45, further comprising:
releasing the elevator and backup tong from the anchored casing or liner joint;
lowering the motor and drilling units to stab the anchored casing or liner joint into a casing or liner string; and
operating the motor unit to screw the joint into the casing or liner string while operating a compensator of the motor unit to maintain a neutral condition, thereby extending the casing or liner string.
71. The method of any of claims 37 to 46, further comprising:
replacing the drilling unit with a cementing unit from the unit rack;
using a work string to set a hanger of a casing or liner string;
connecting a cement line to a swivel of the cementing unit;
operating the motor unit to rotate the work string and casing or liner string;
and

while rotating the strings:

pumping cement slurry through the cement line and cementing unit;

operating an actuator of the cementing unit to launch a dart from a launcher of the cementing unit; and

pumping chaser fluid behind the dart, thereby driving the cement slurry through the work string, releasing a wiper plug therefrom, and driving the cement slurry through the casing or liner string and into an annulus formed between the casing or liner string and a wellbore.

72. The method of any of claims 37 to 47, wherein the drilling unit is retrieved, raised, and delivered by operating a unit handler having a holder connected to an arm thereof.

73. The method of claim 48, further comprising:

removing the holder from the arm of the unit handler; and

connecting a pipe clamp to the arm;

operating the unit handler to engage the pipe clamp with a joint of casing or liner located below the rig floor; and

operating the unit handler to raise the casing or liner joint to the rig floor.

74. The method of claim 49, further comprising:

replacing the drilling unit with a casing unit from the unit rack,

wherein the unit handler is further operated to deliver the casing or liner joint into alignment with the casing unit and to hold the casing or liner joint while the casing unit is stabbed into the casing or liner joint.

75. The method of claim 48, further comprising

removing the holder from the arm of the unit handler; and

connecting a cargo hook to the arm;

operating the unit handler to engage the cargo hook with cargo located below the rig floor; and

operating the unit handler to raise the cargo to the rig floor.

76. The method of any of claims 49 to 51, wherein the holder is removed and the pipe clamp or cargo hook is connected by remote operation of a quick connect system.

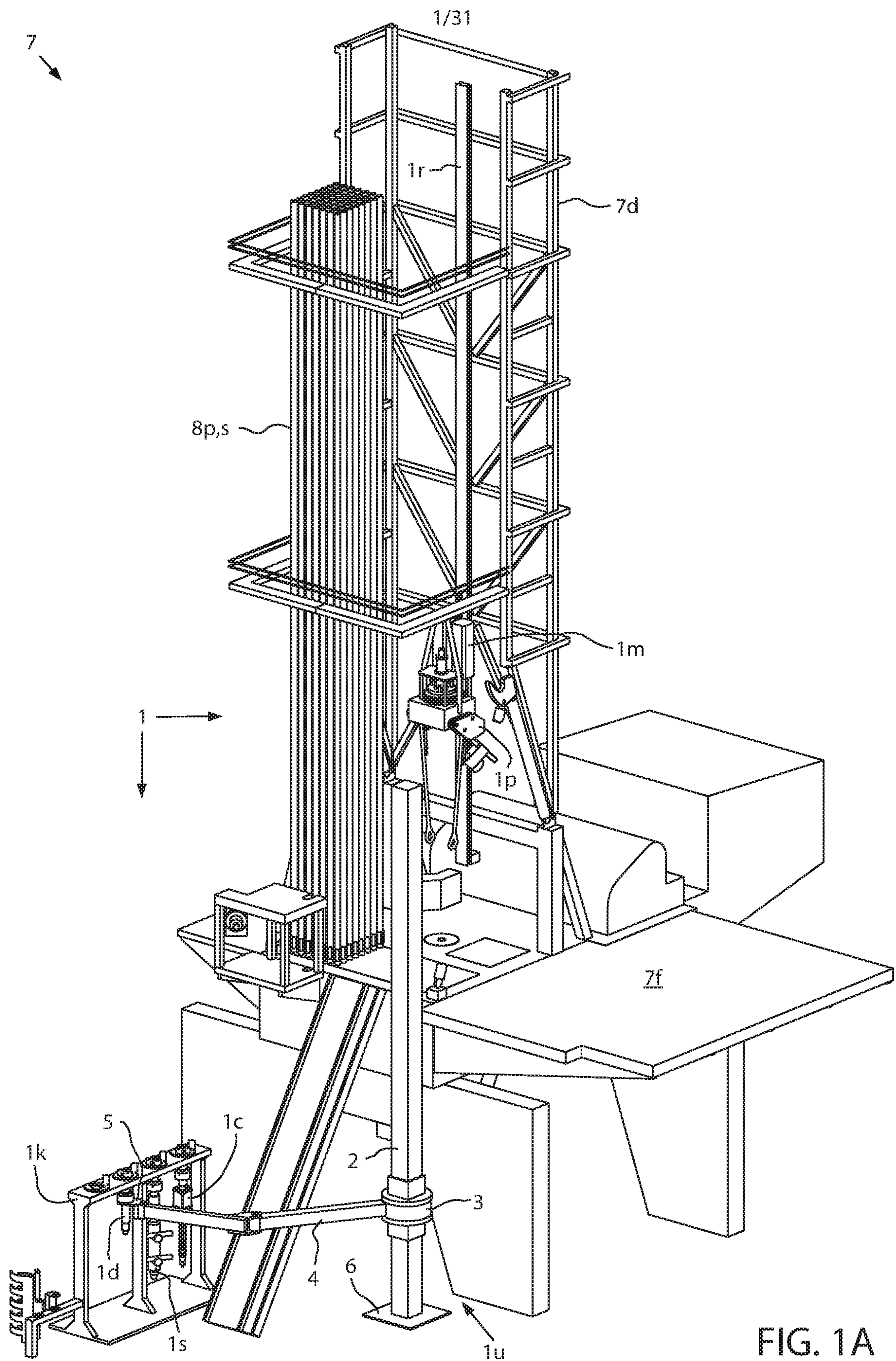


FIG. 1A

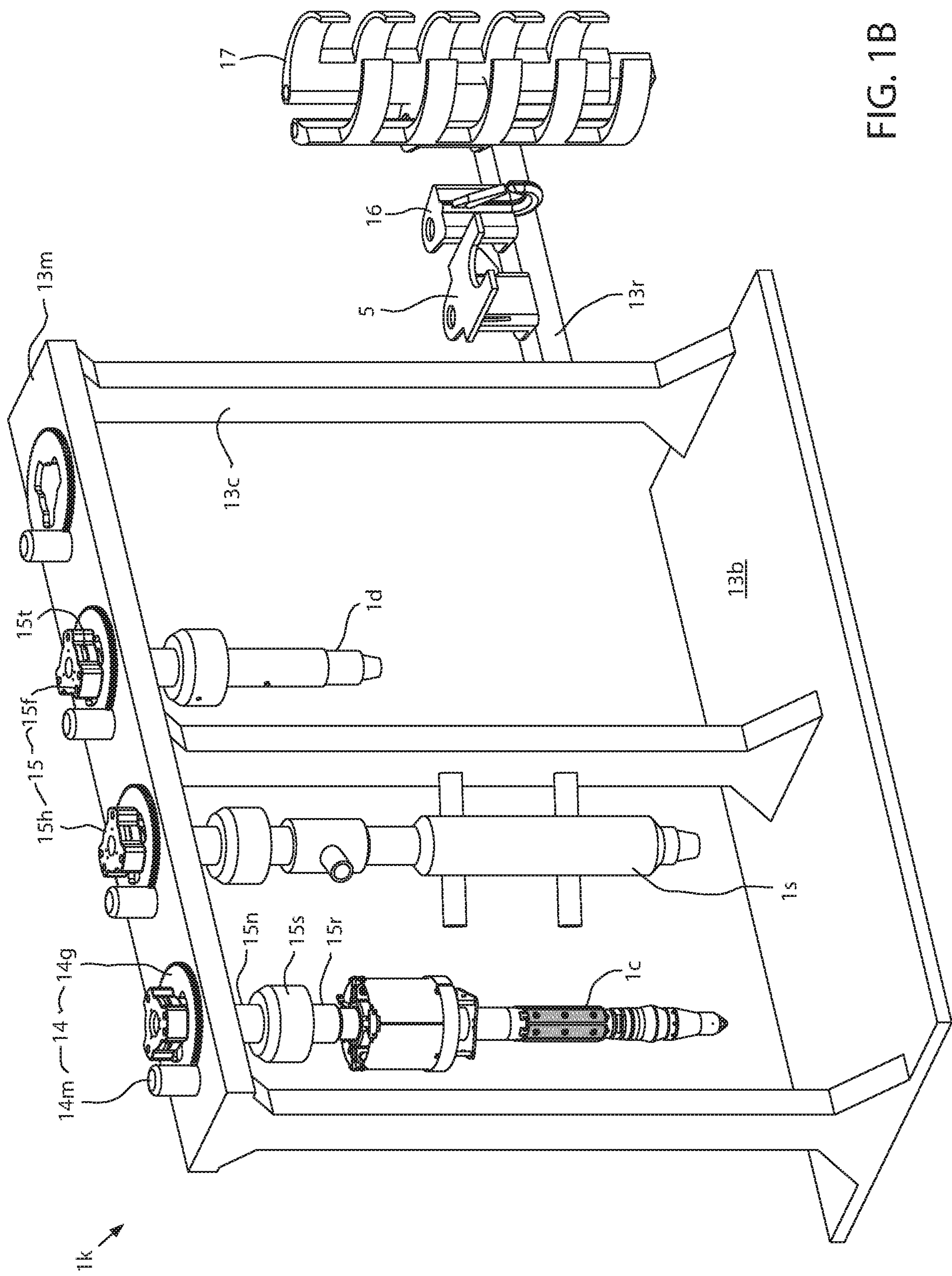
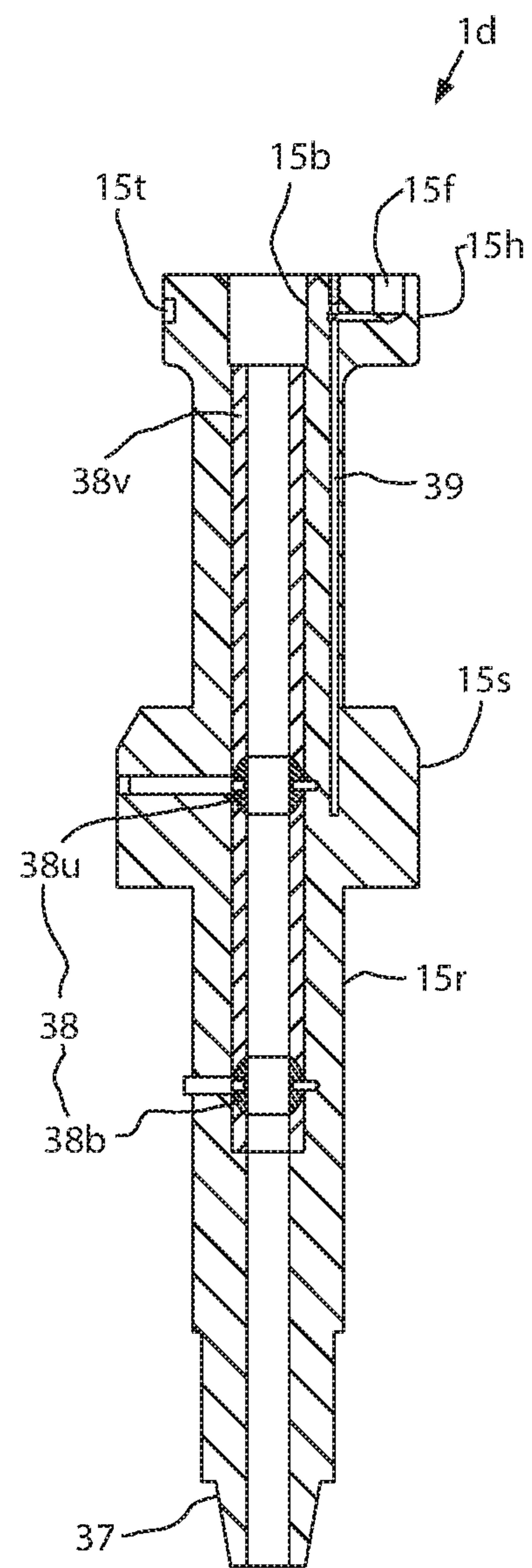
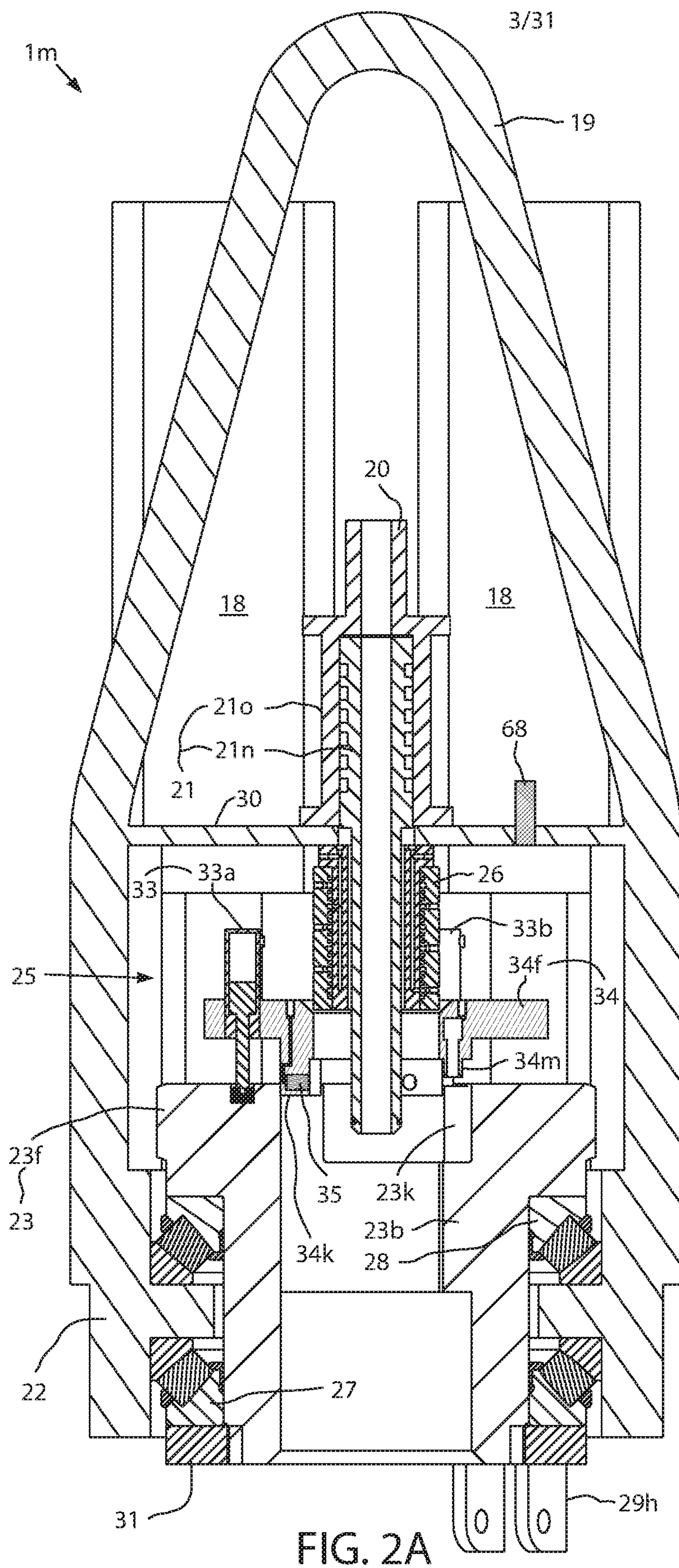
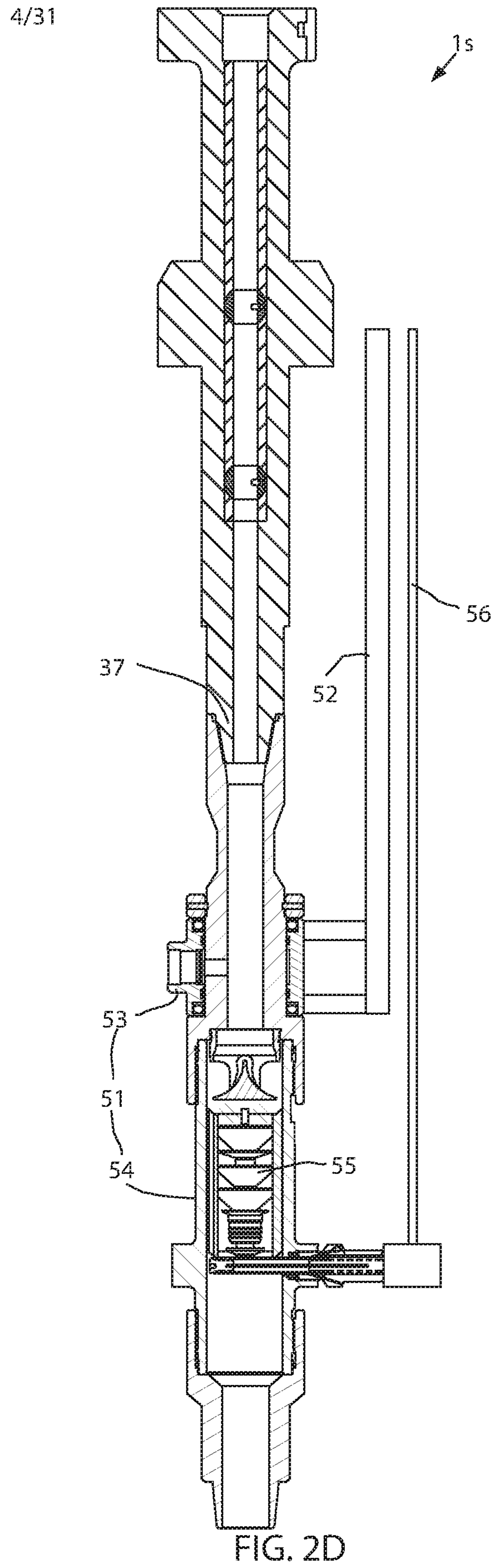
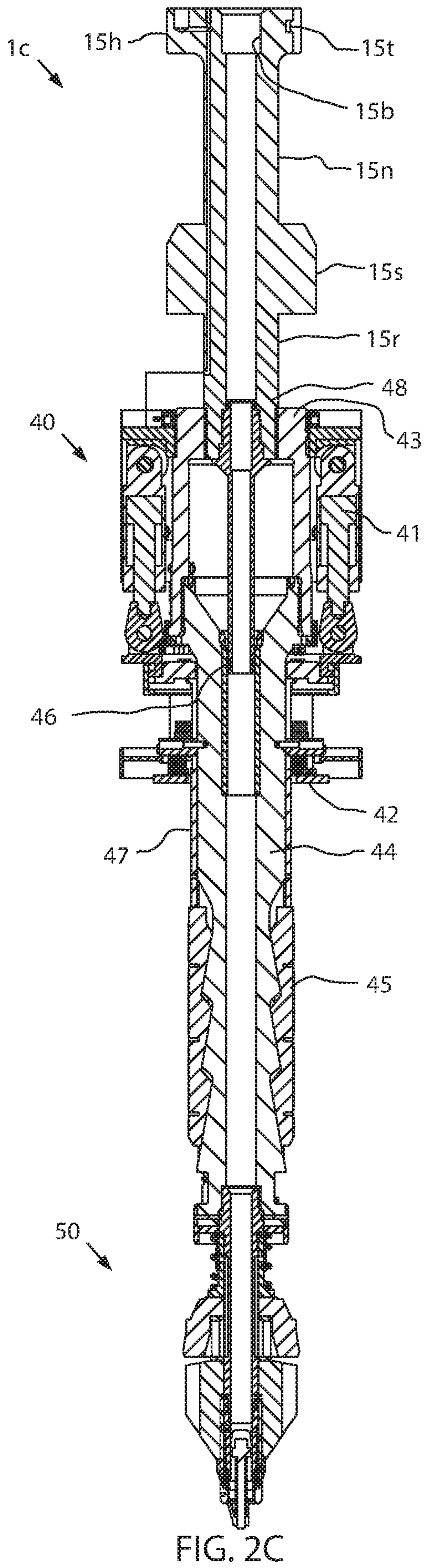


FIG. 1B





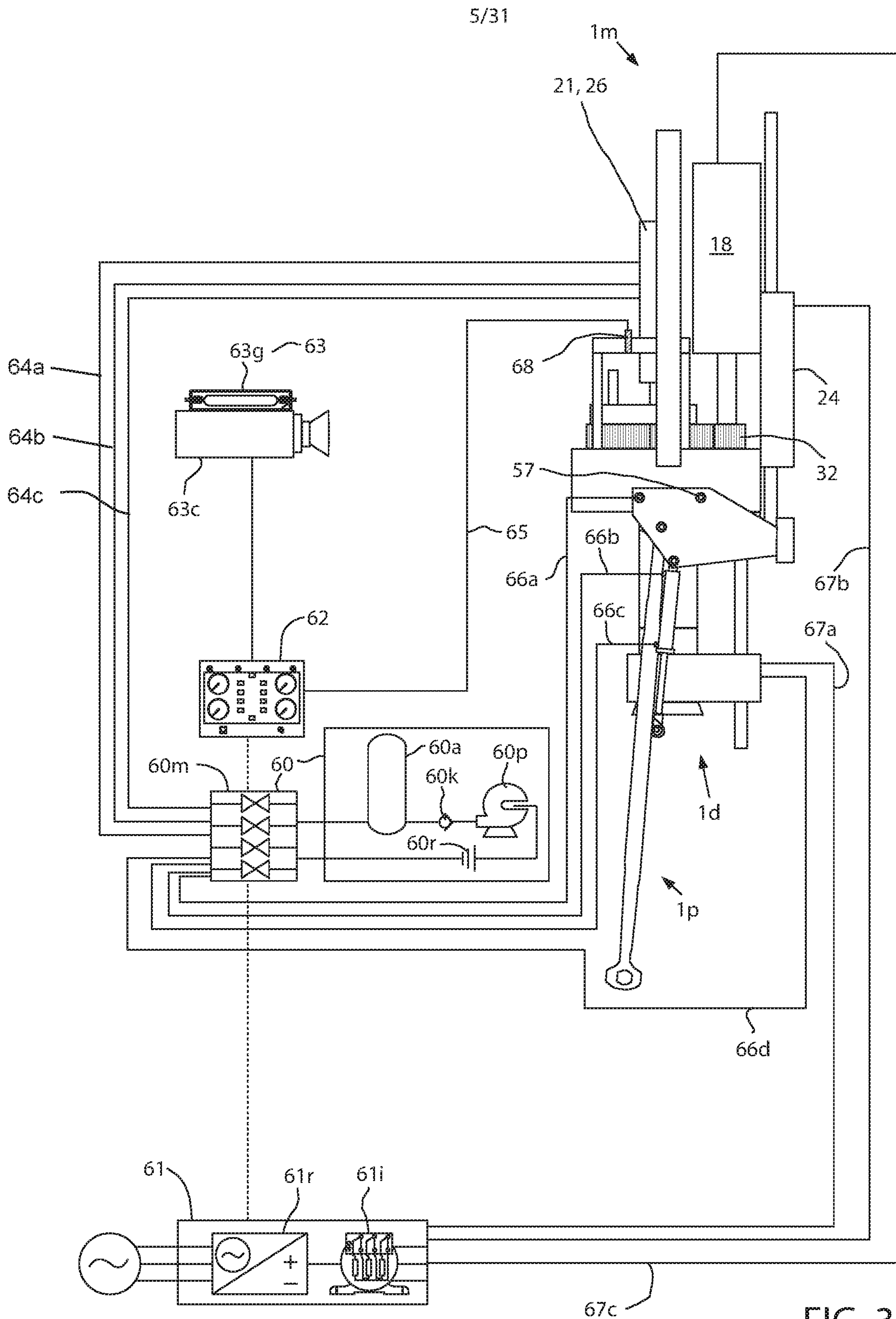
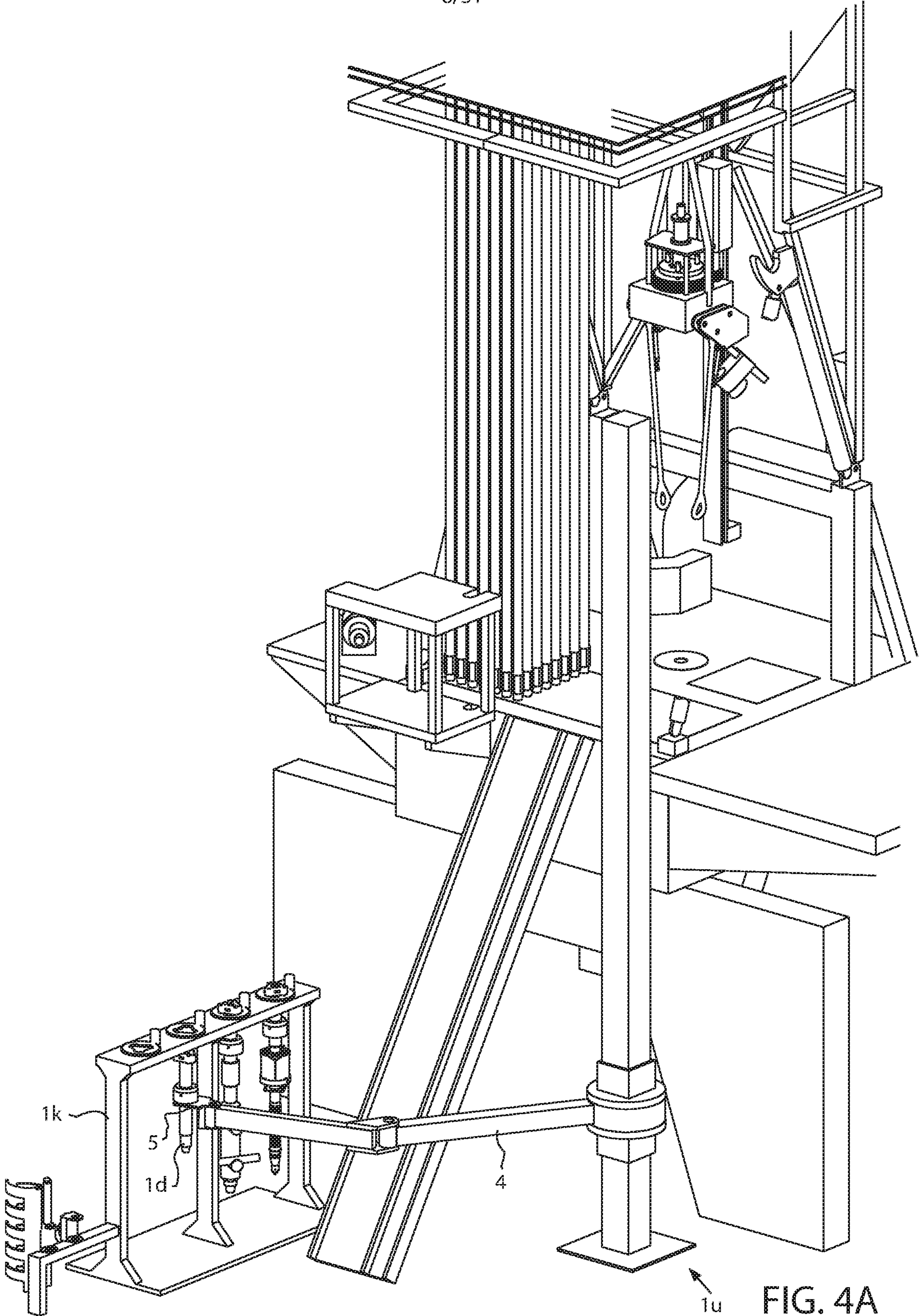
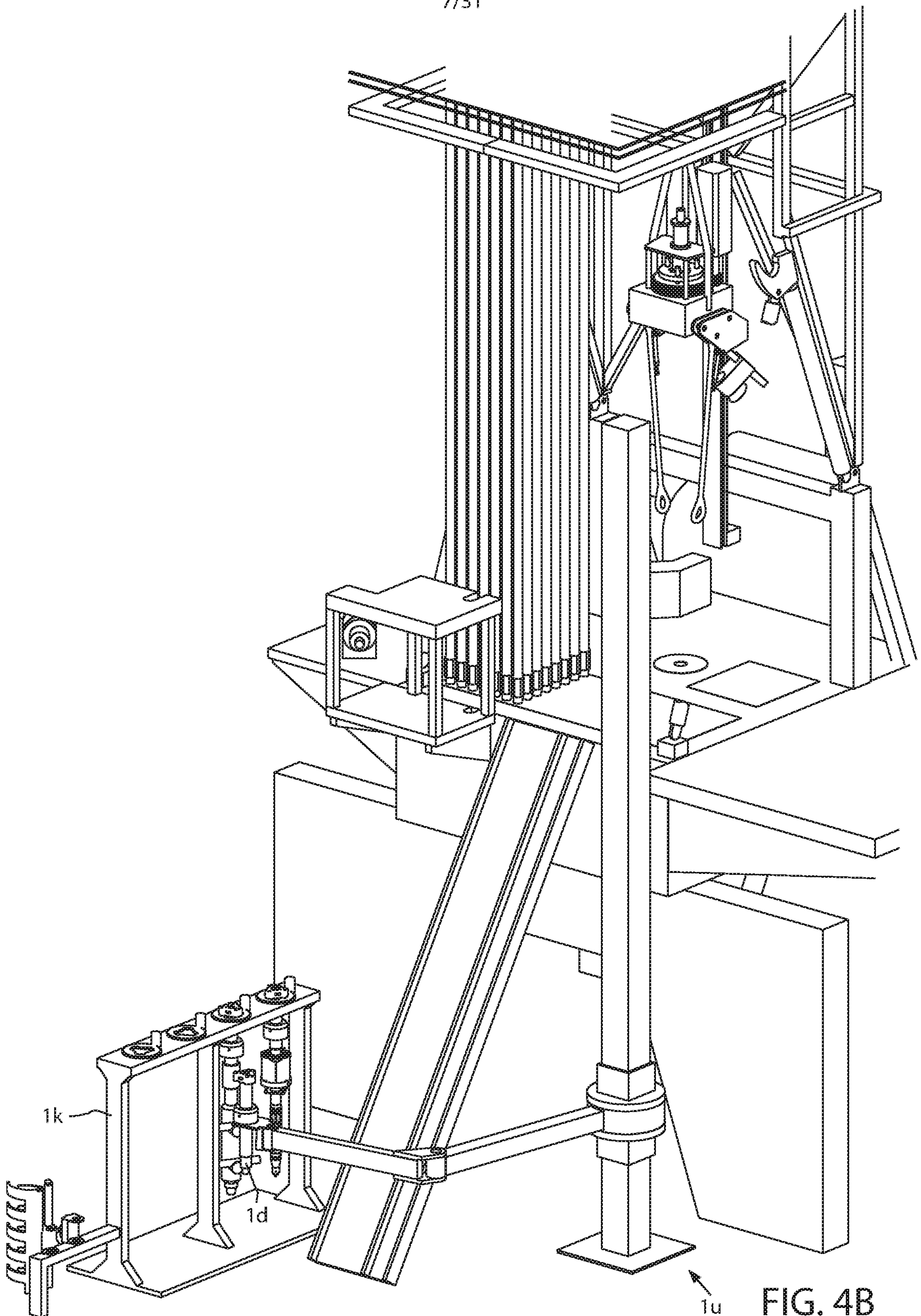


FIG. 3

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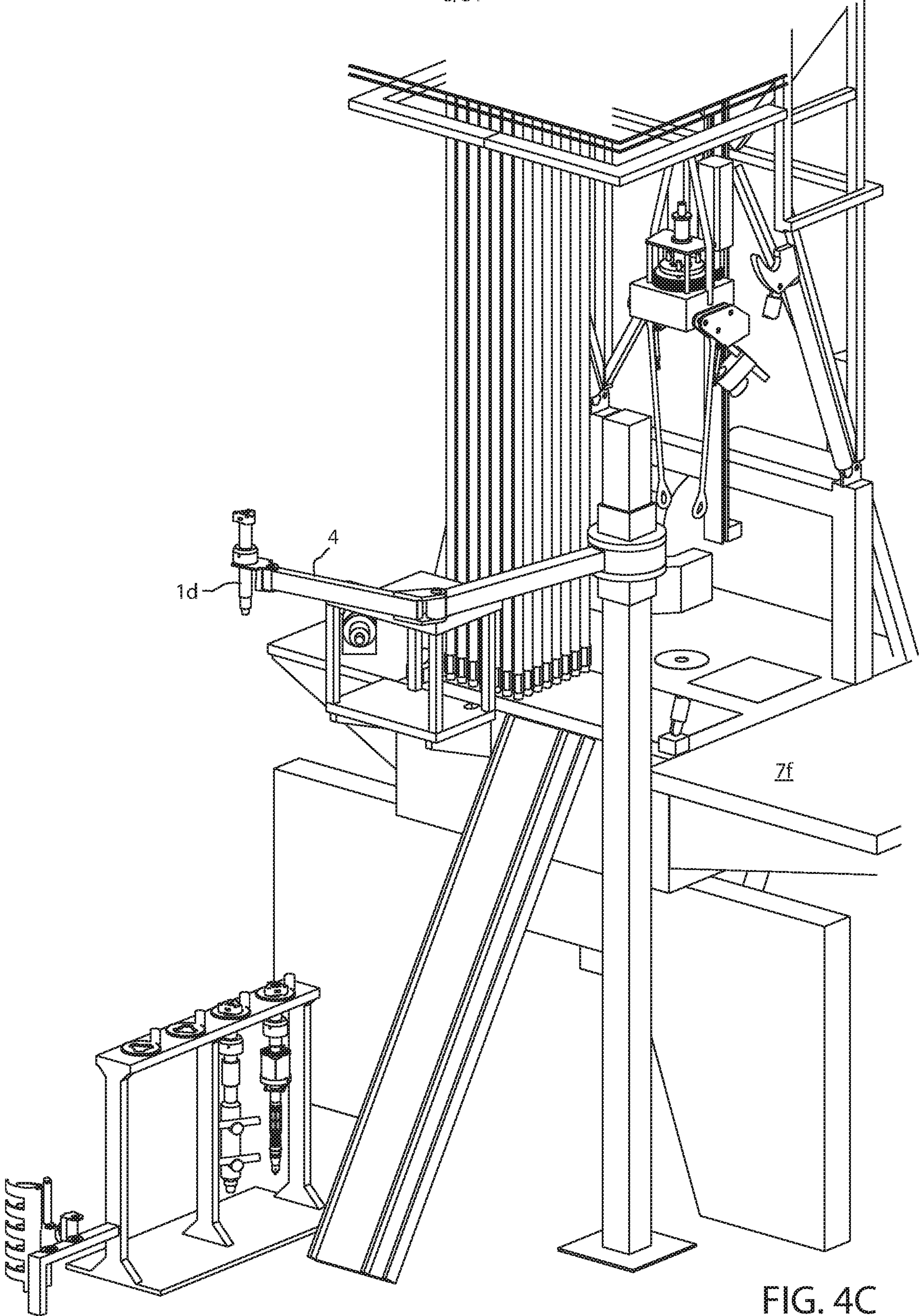
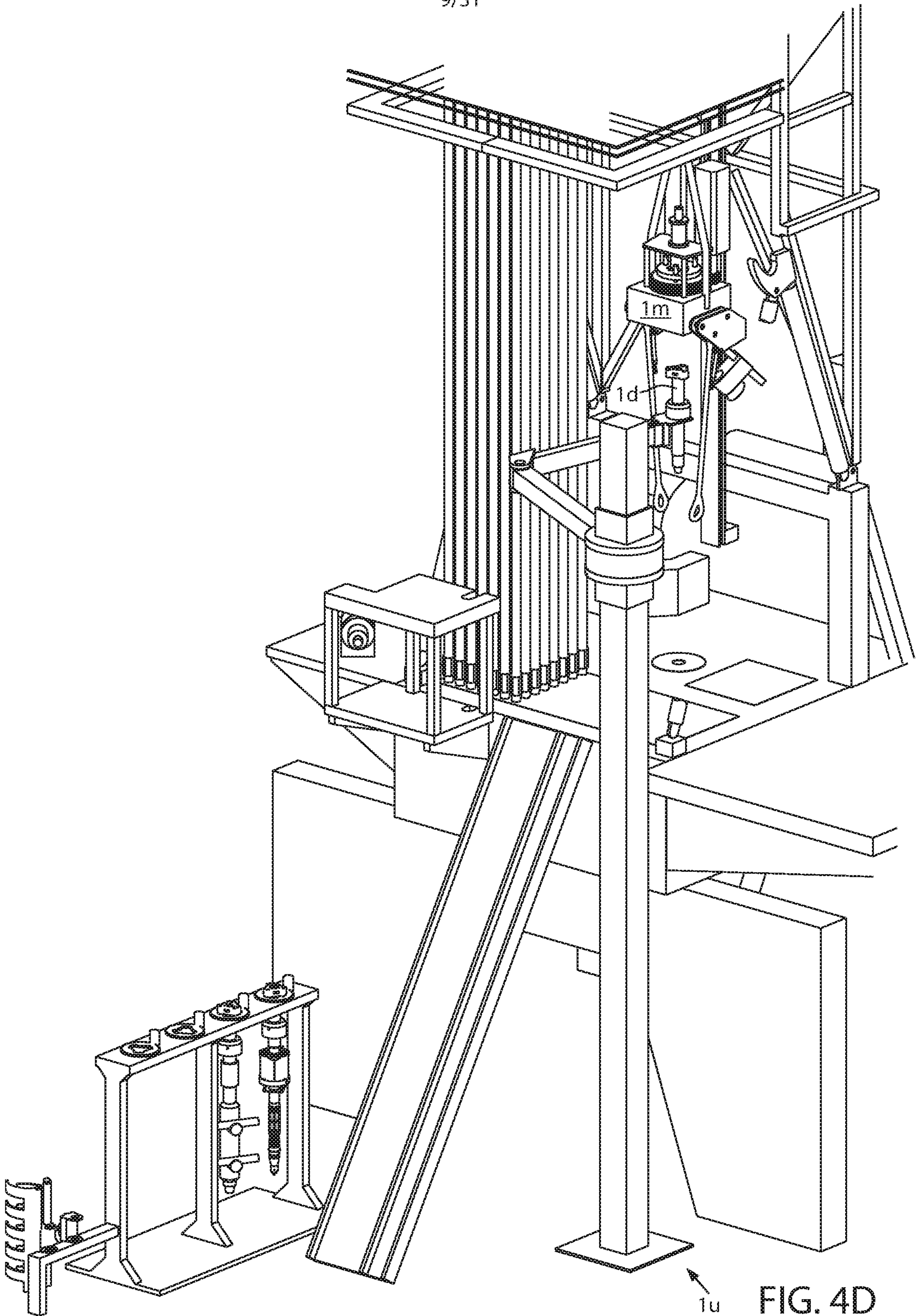


FIG. 4C

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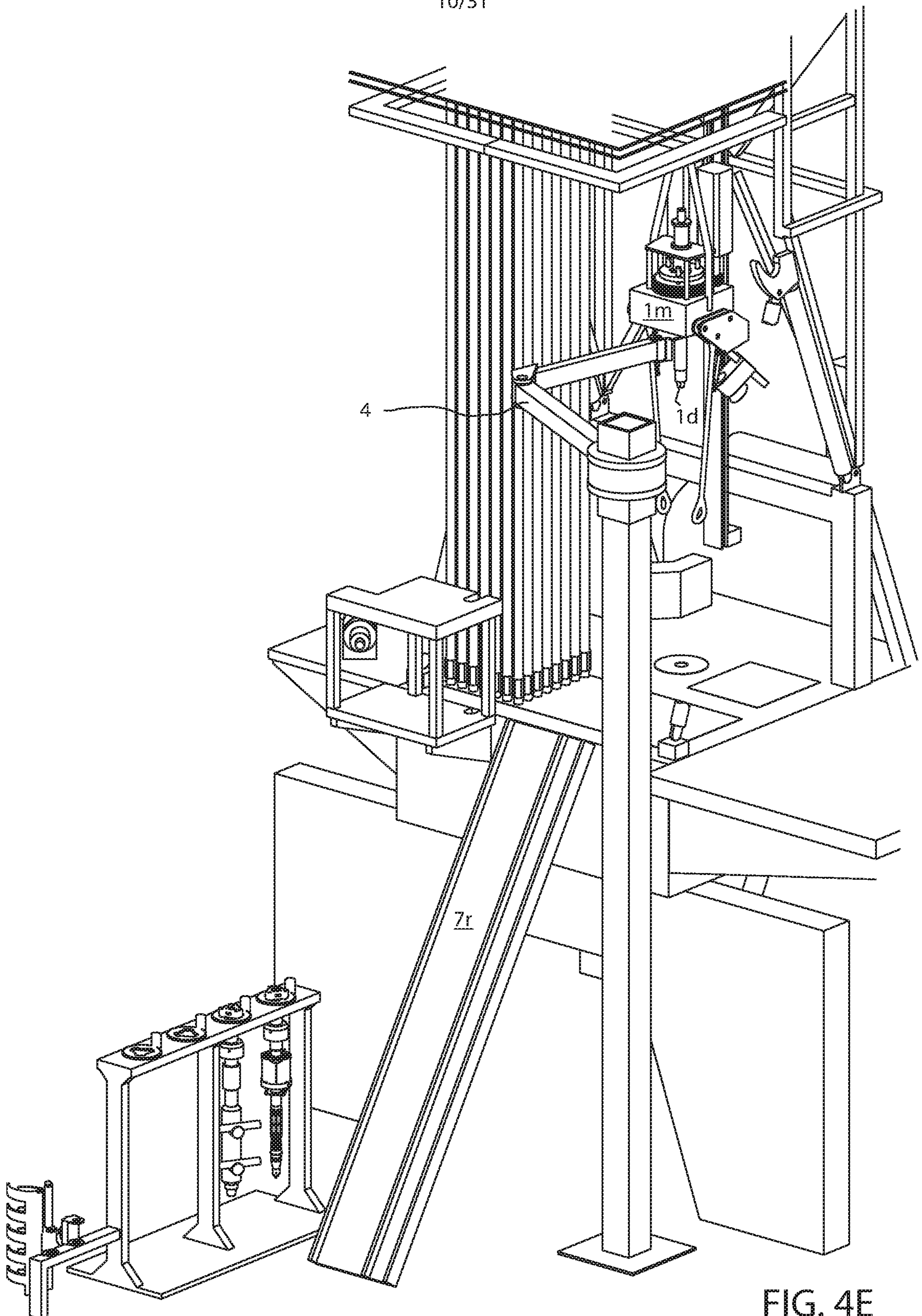


FIG. 4E

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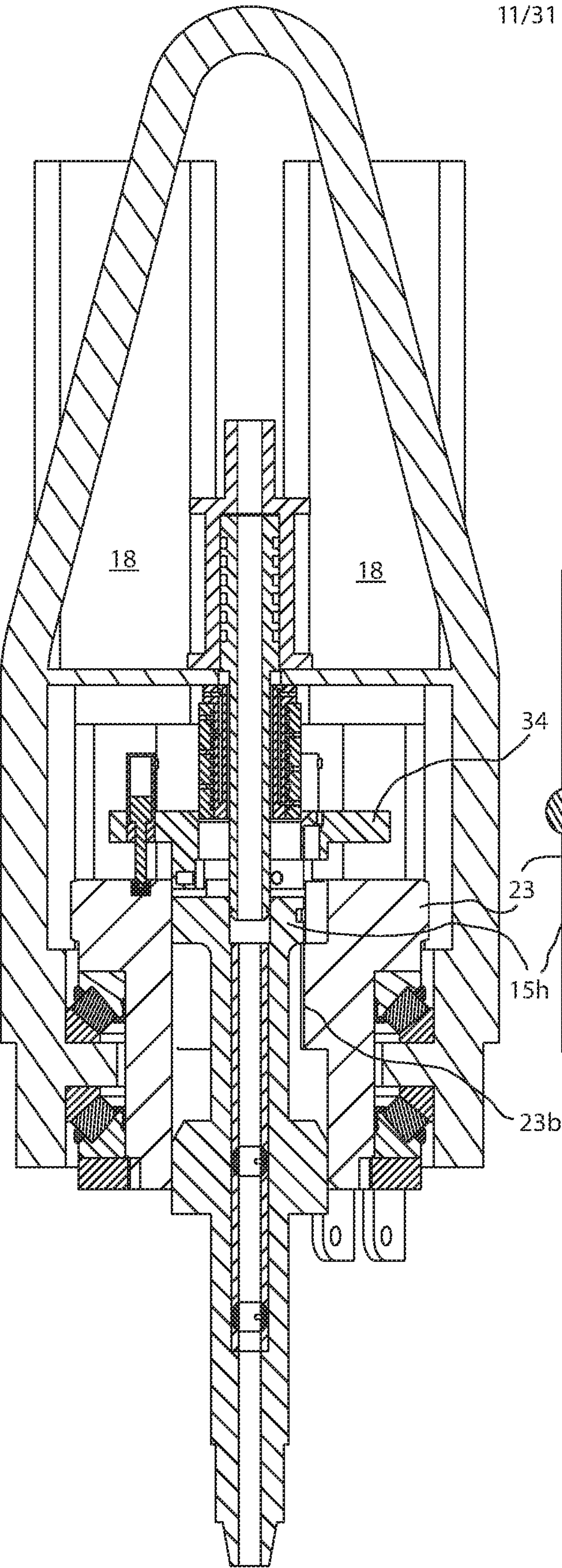


FIG. 4F

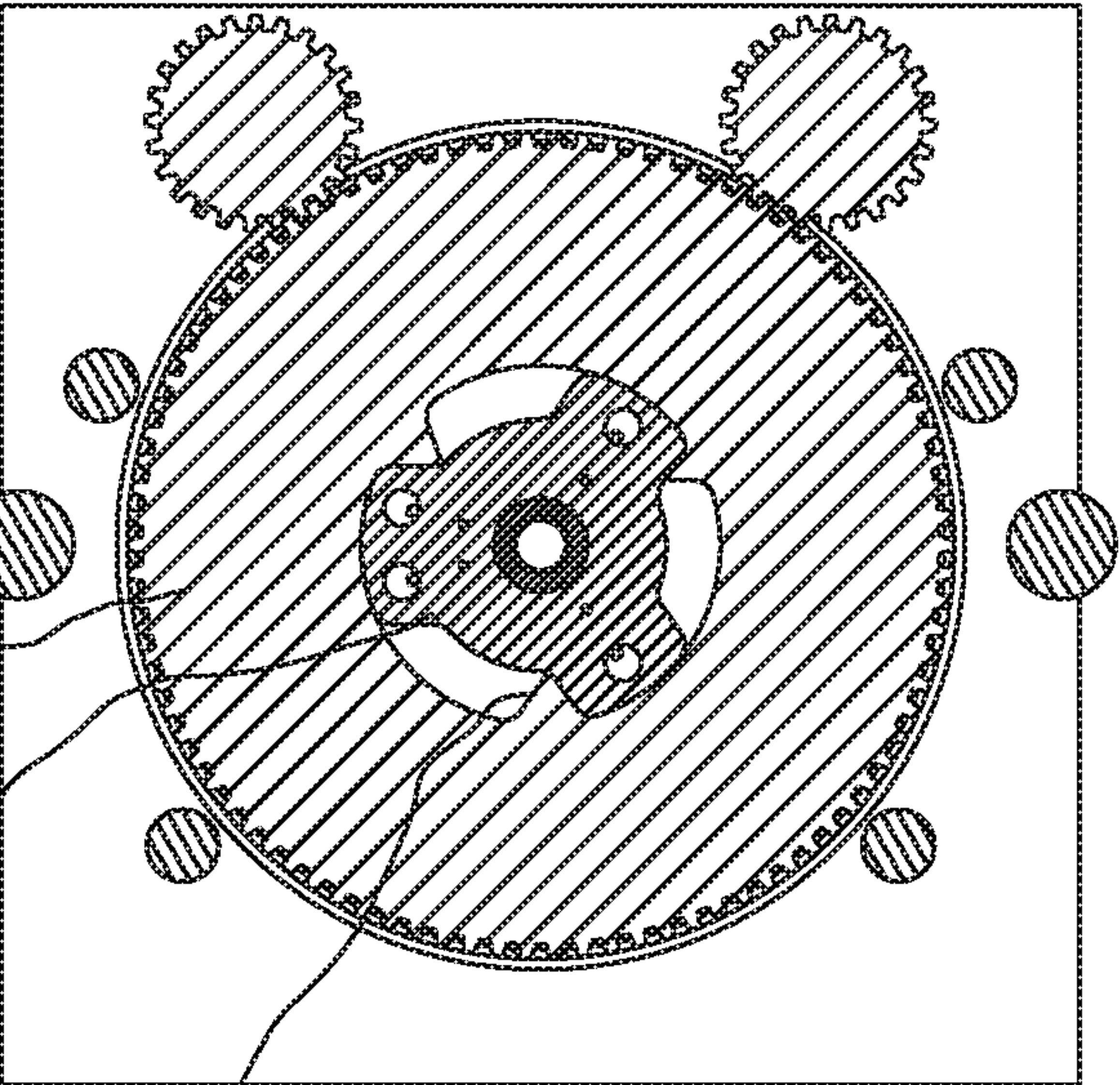


FIG. 4G

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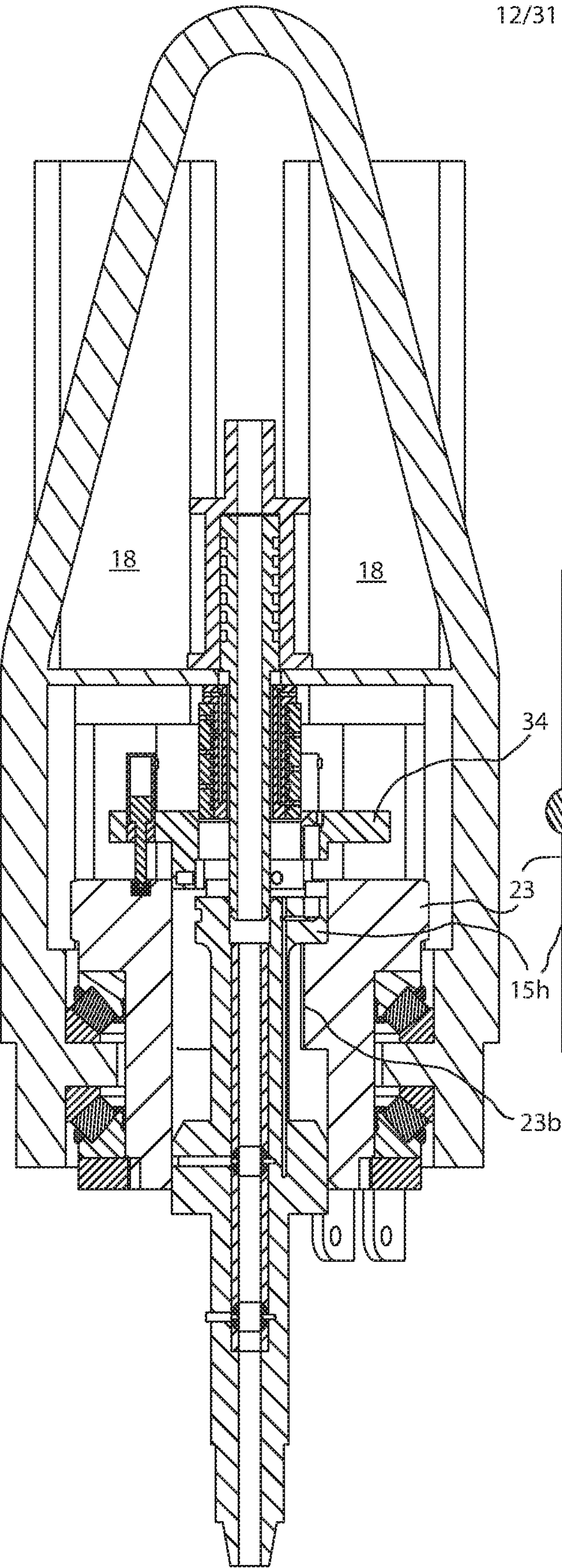


FIG. 4H

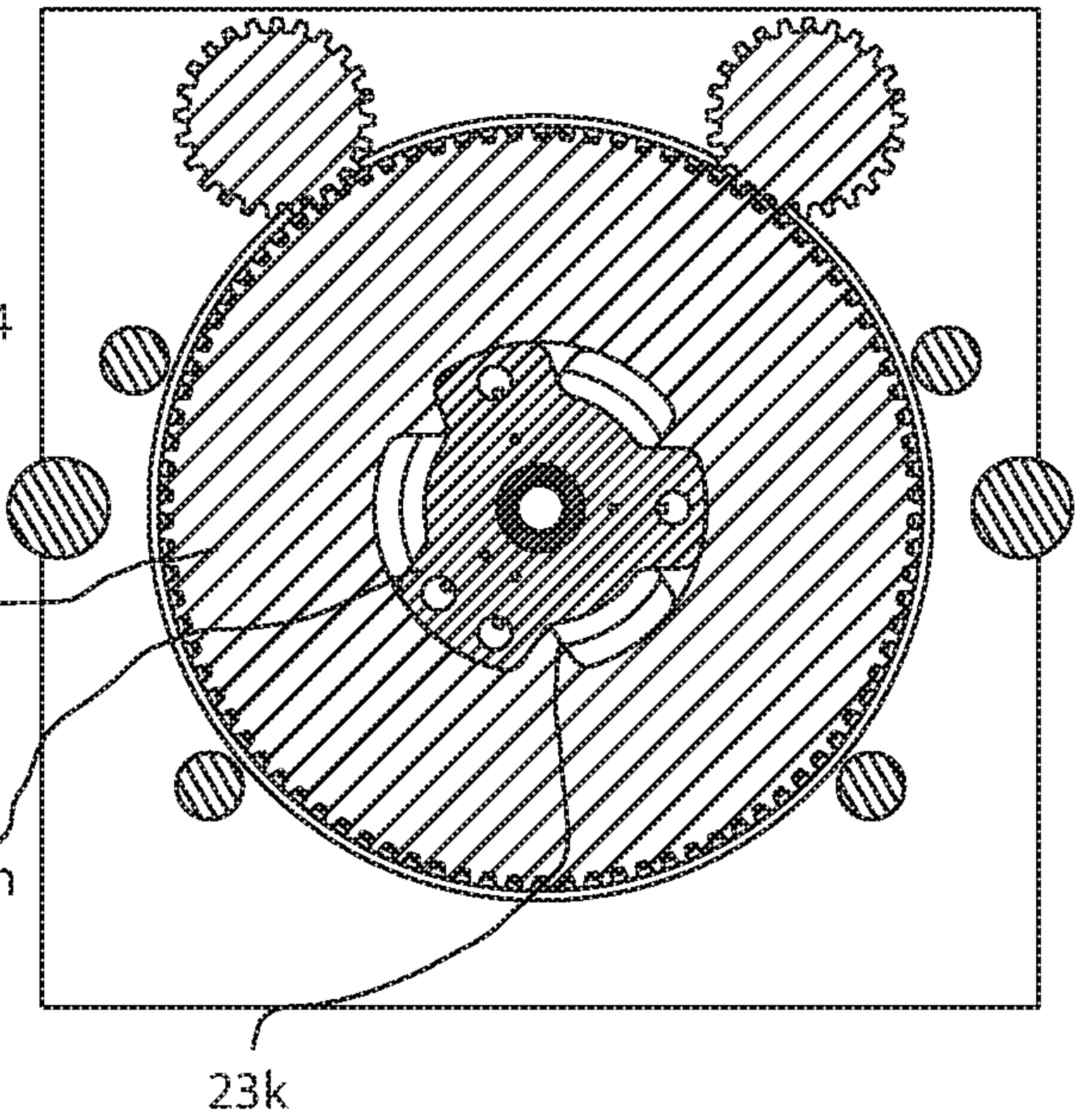


FIG. 4I

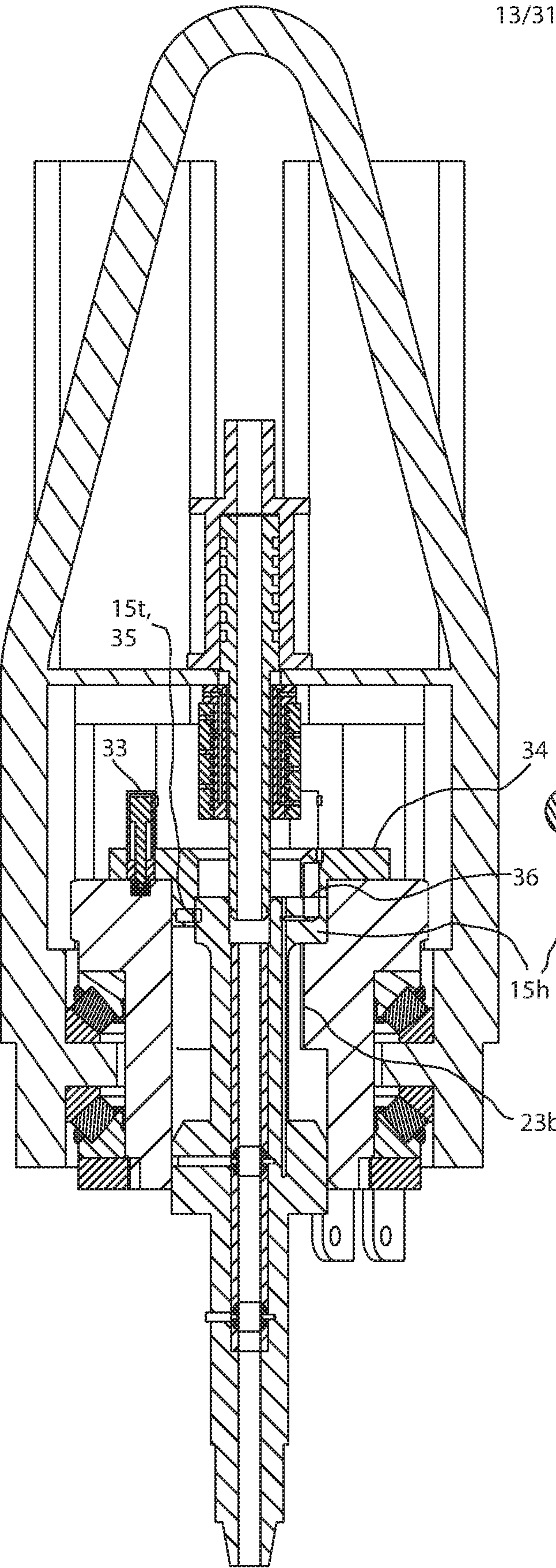


FIG. 4J

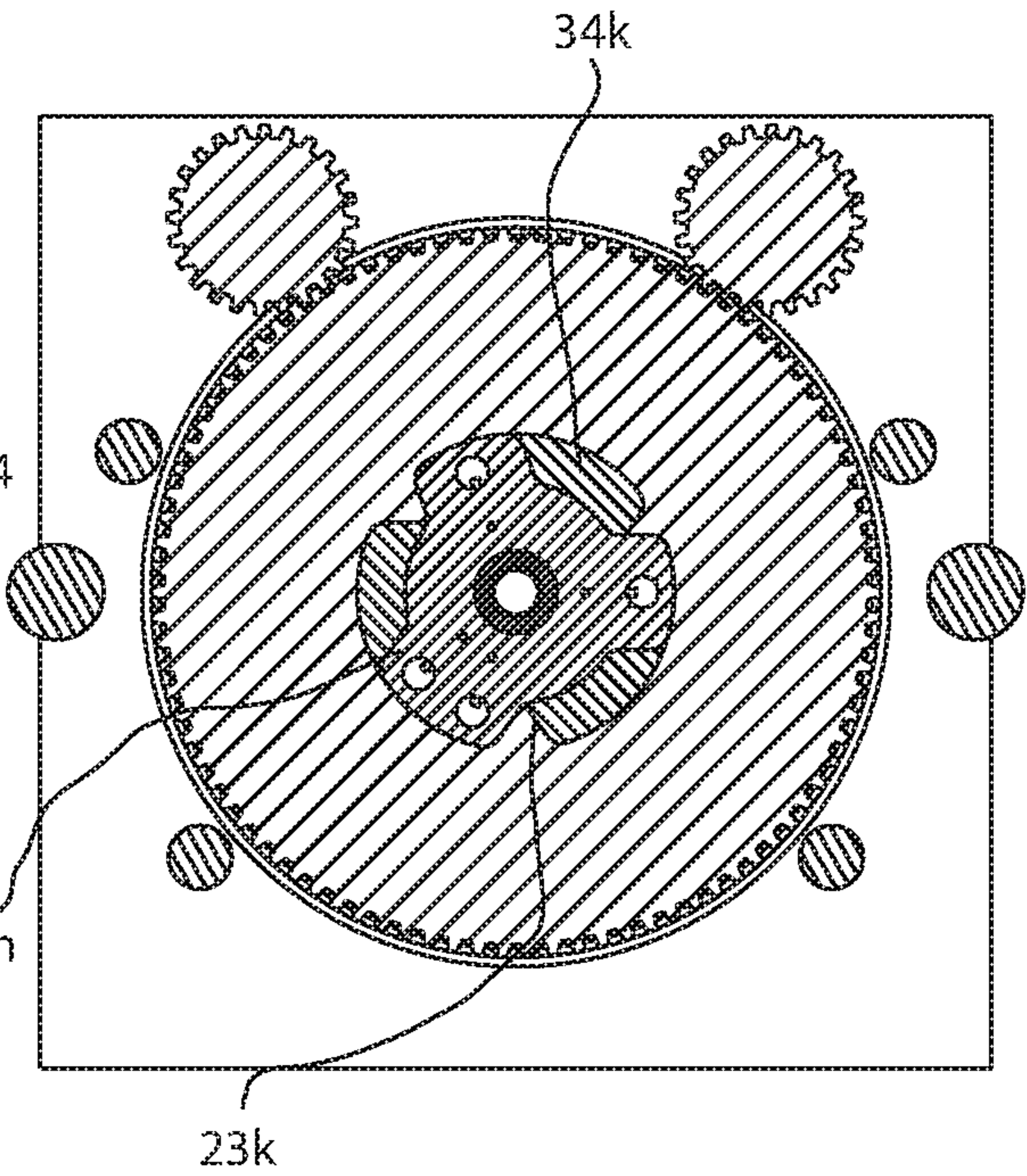


FIG. 4K

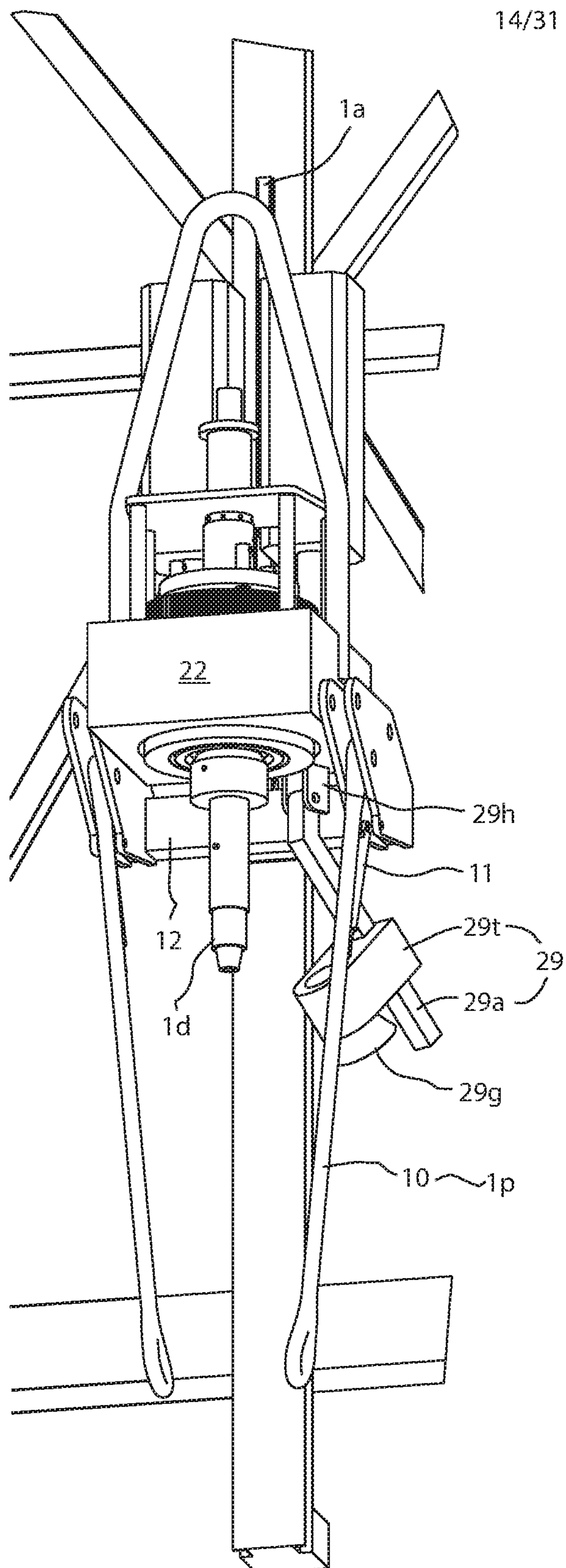


FIG. 4L

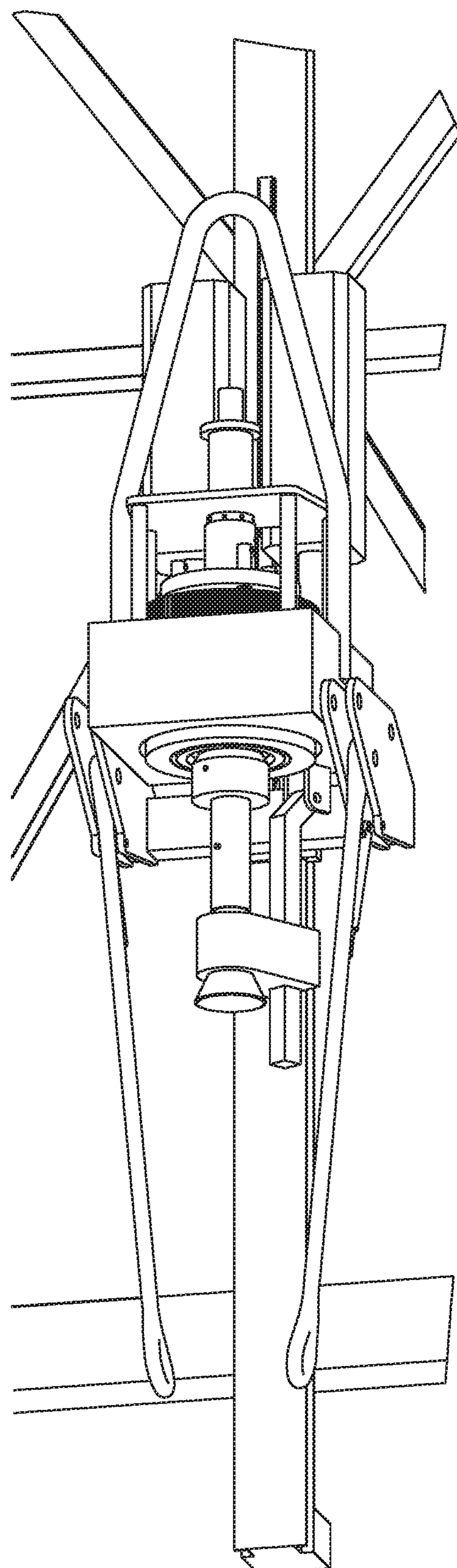
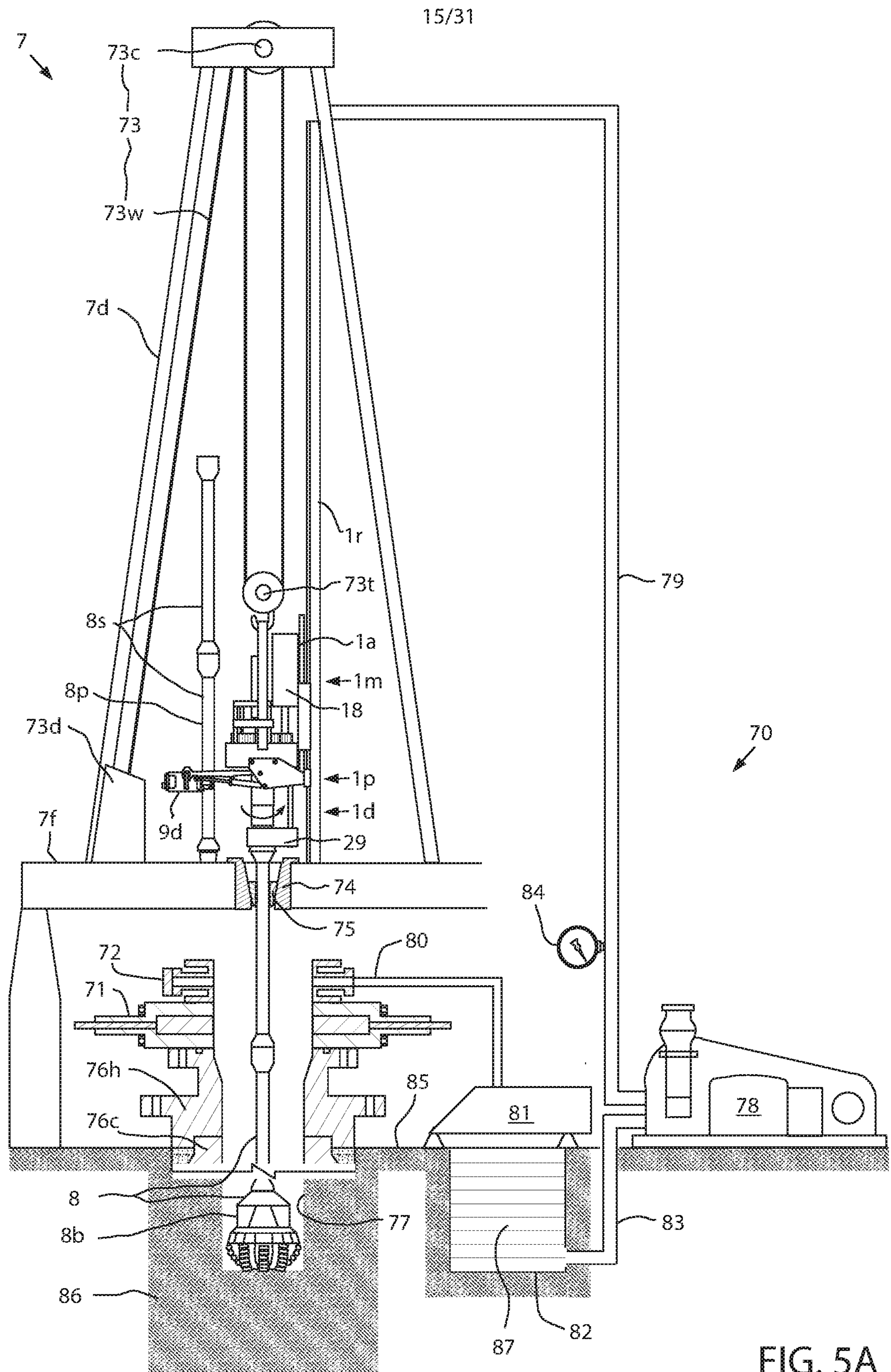


FIG. 4M



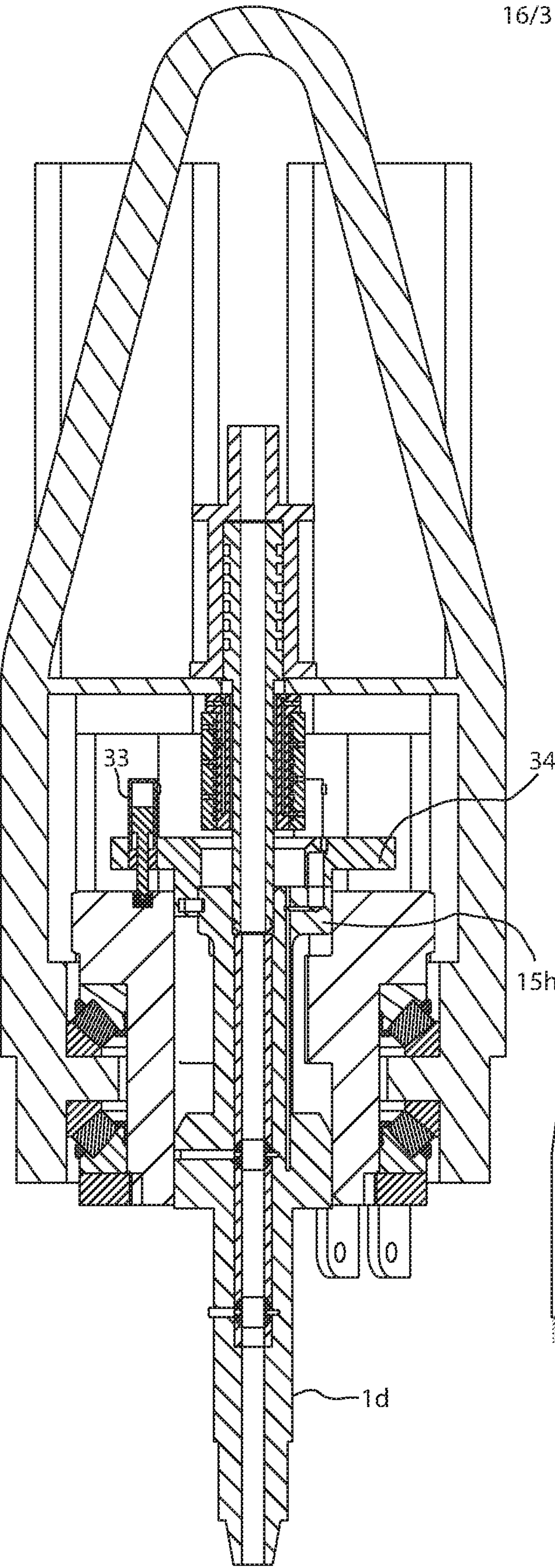


FIG. 5B

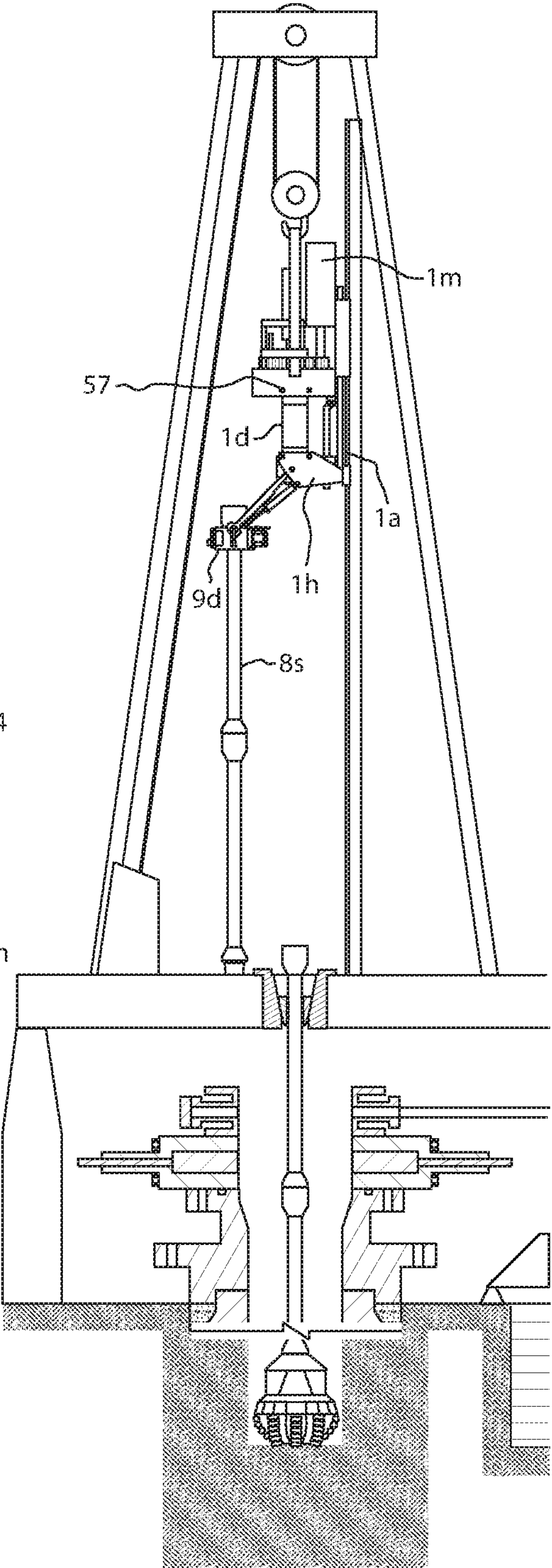


FIG. 5C

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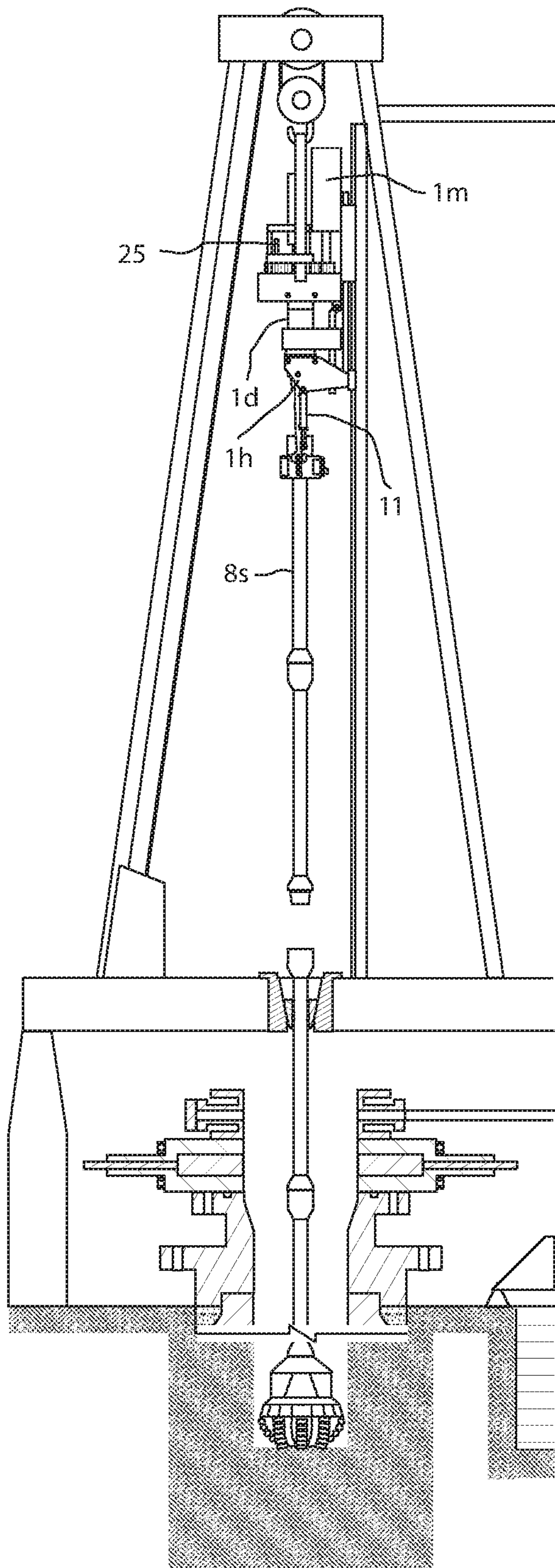


FIG. 5D

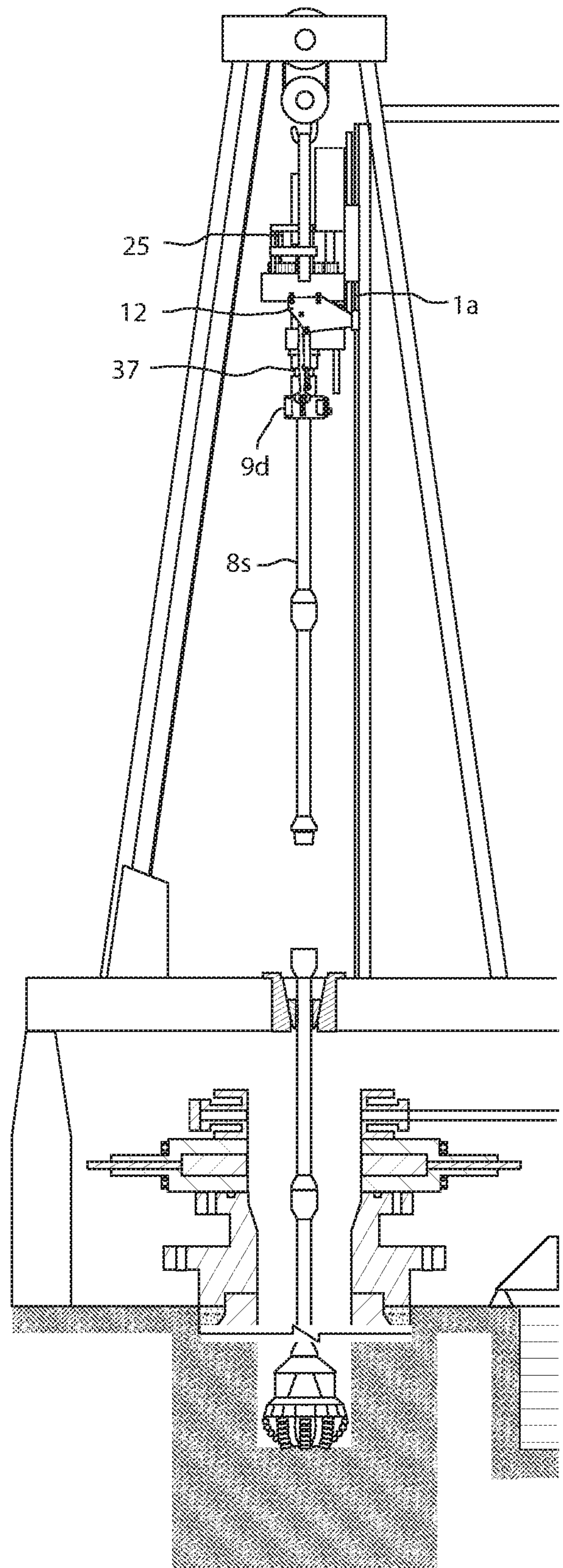


FIG. 5E

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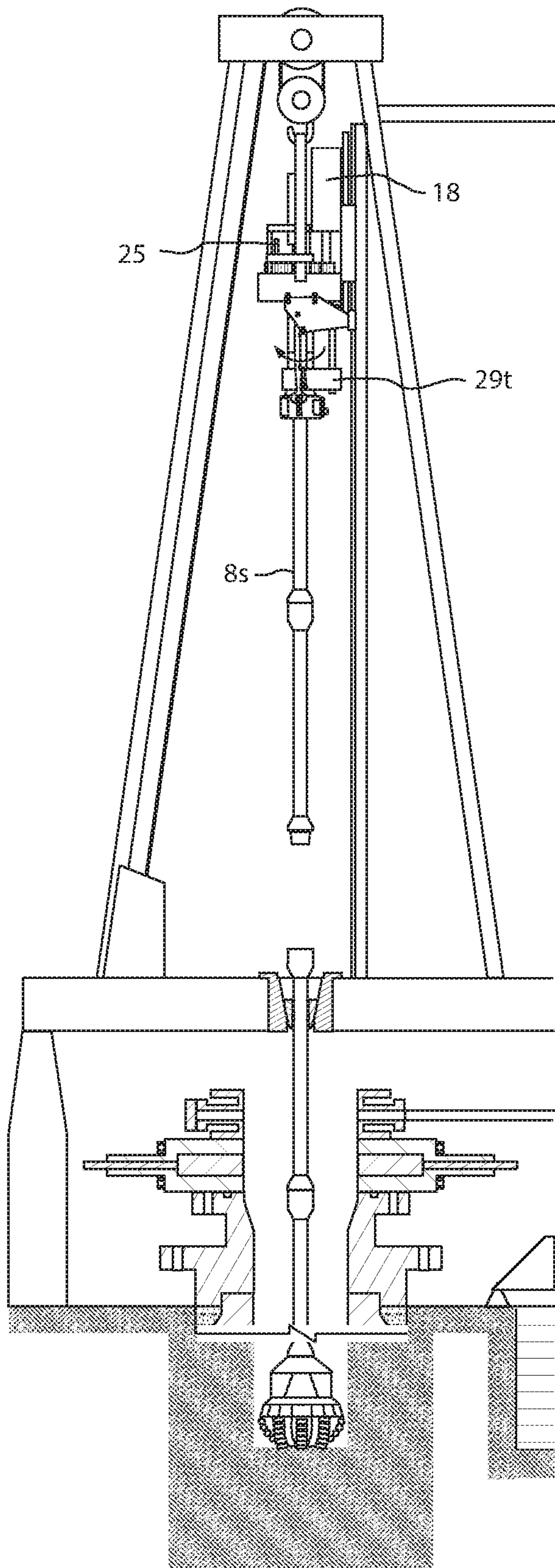


FIG. 5F

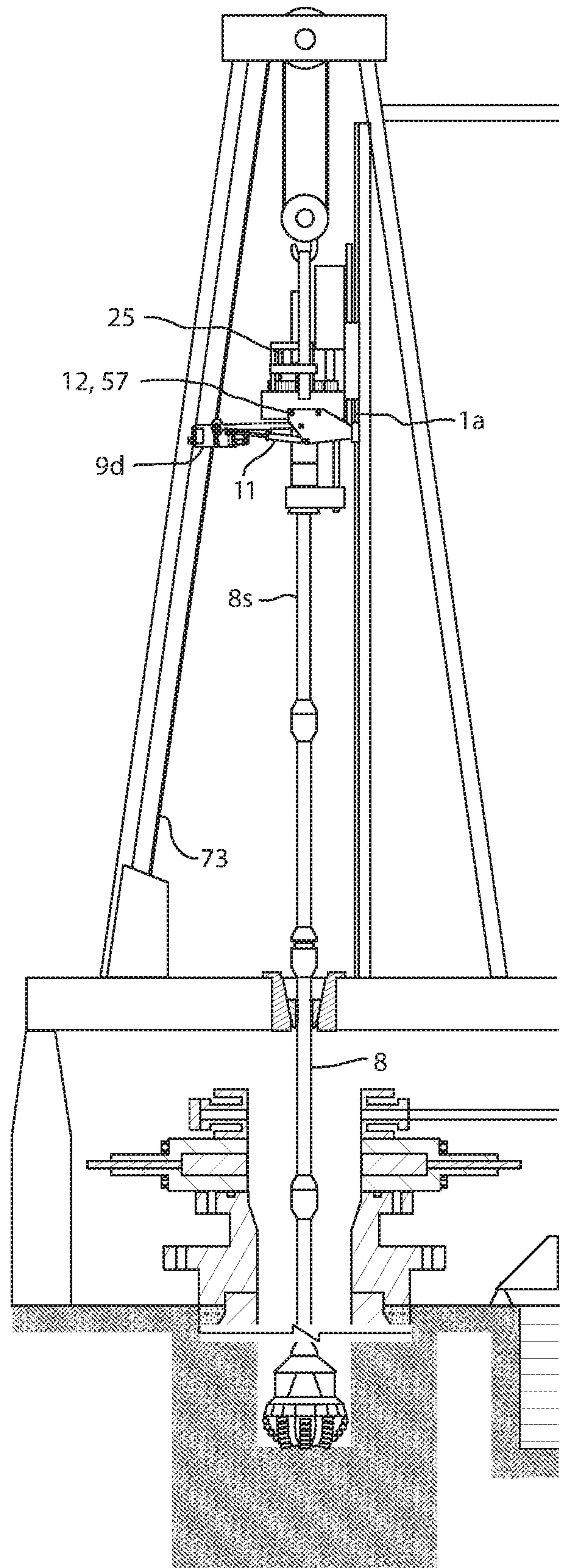


FIG. 5G

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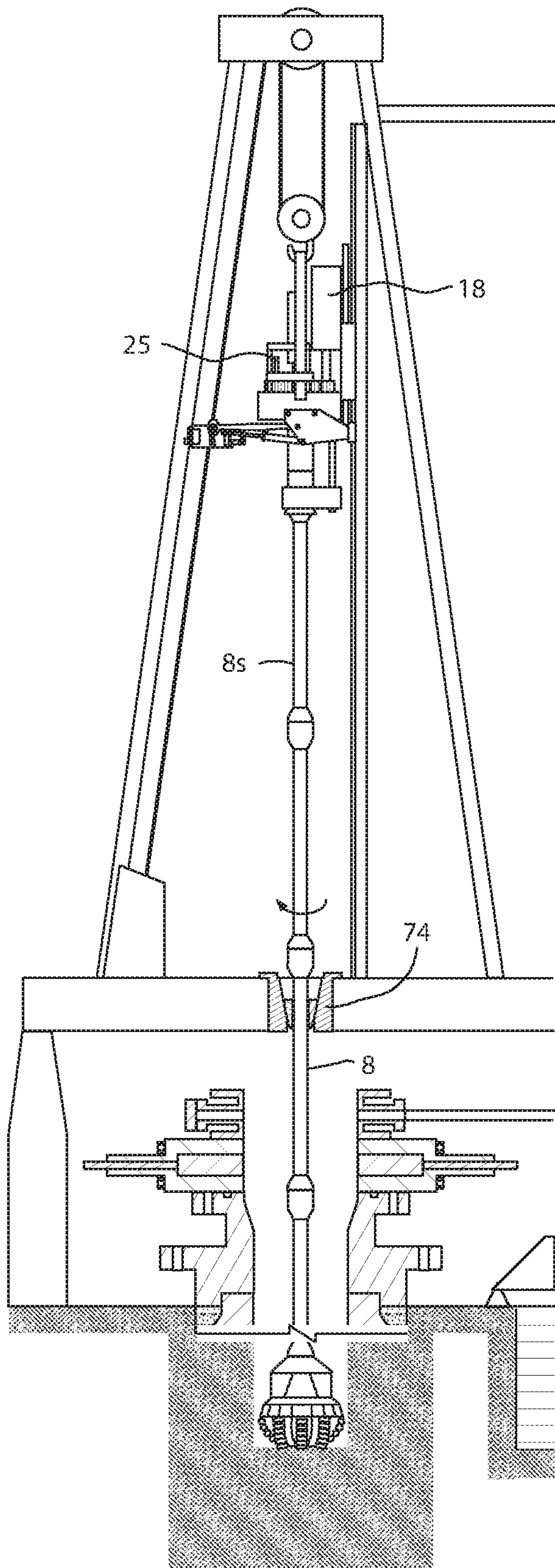


FIG. 5H

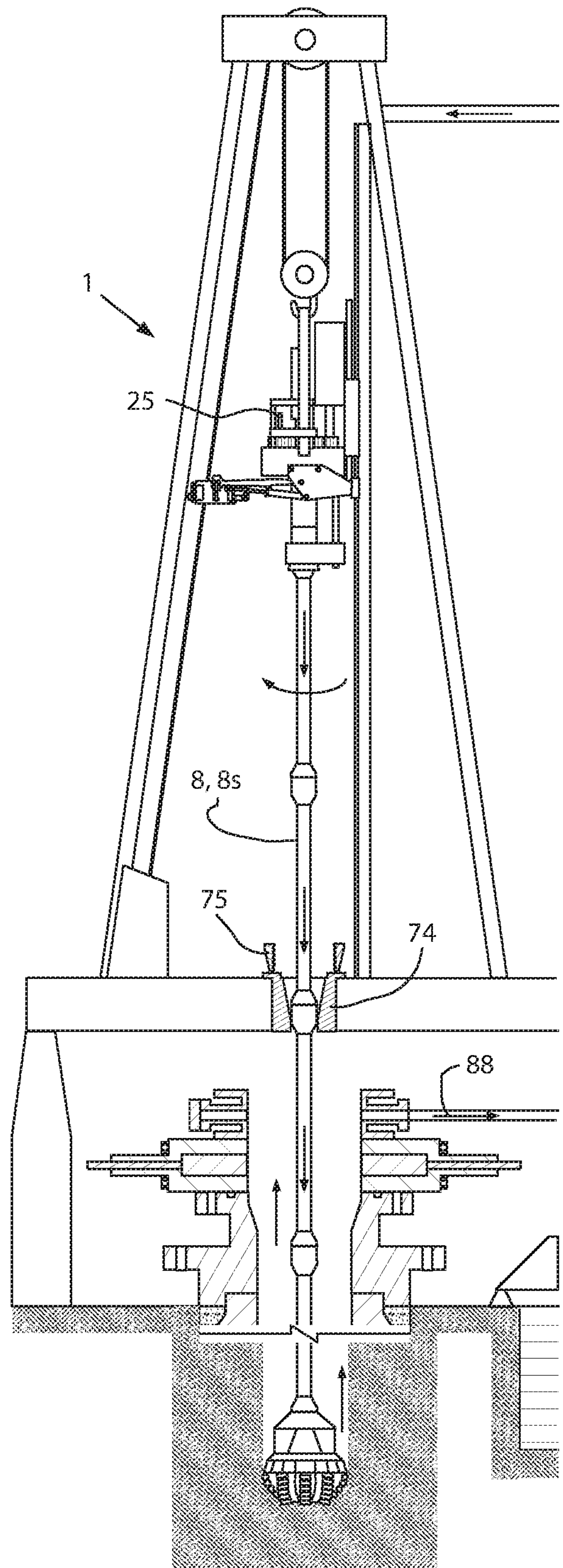
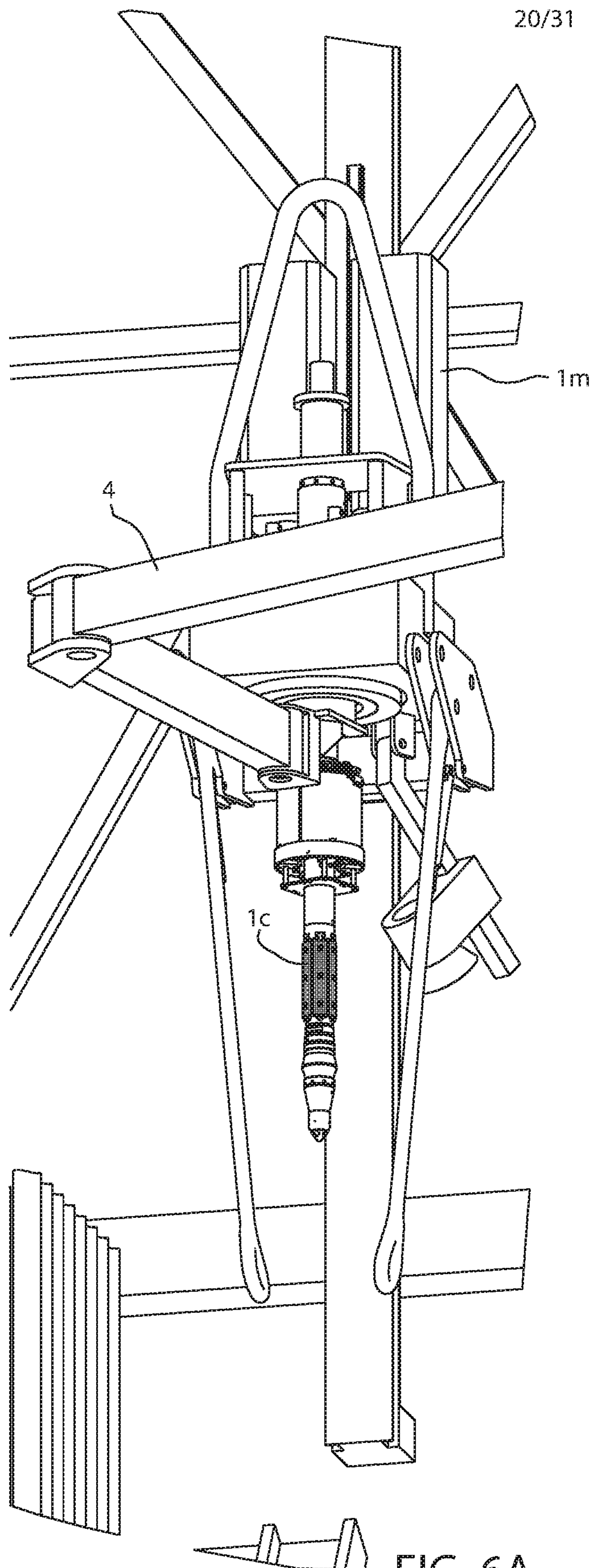


FIG. 5I



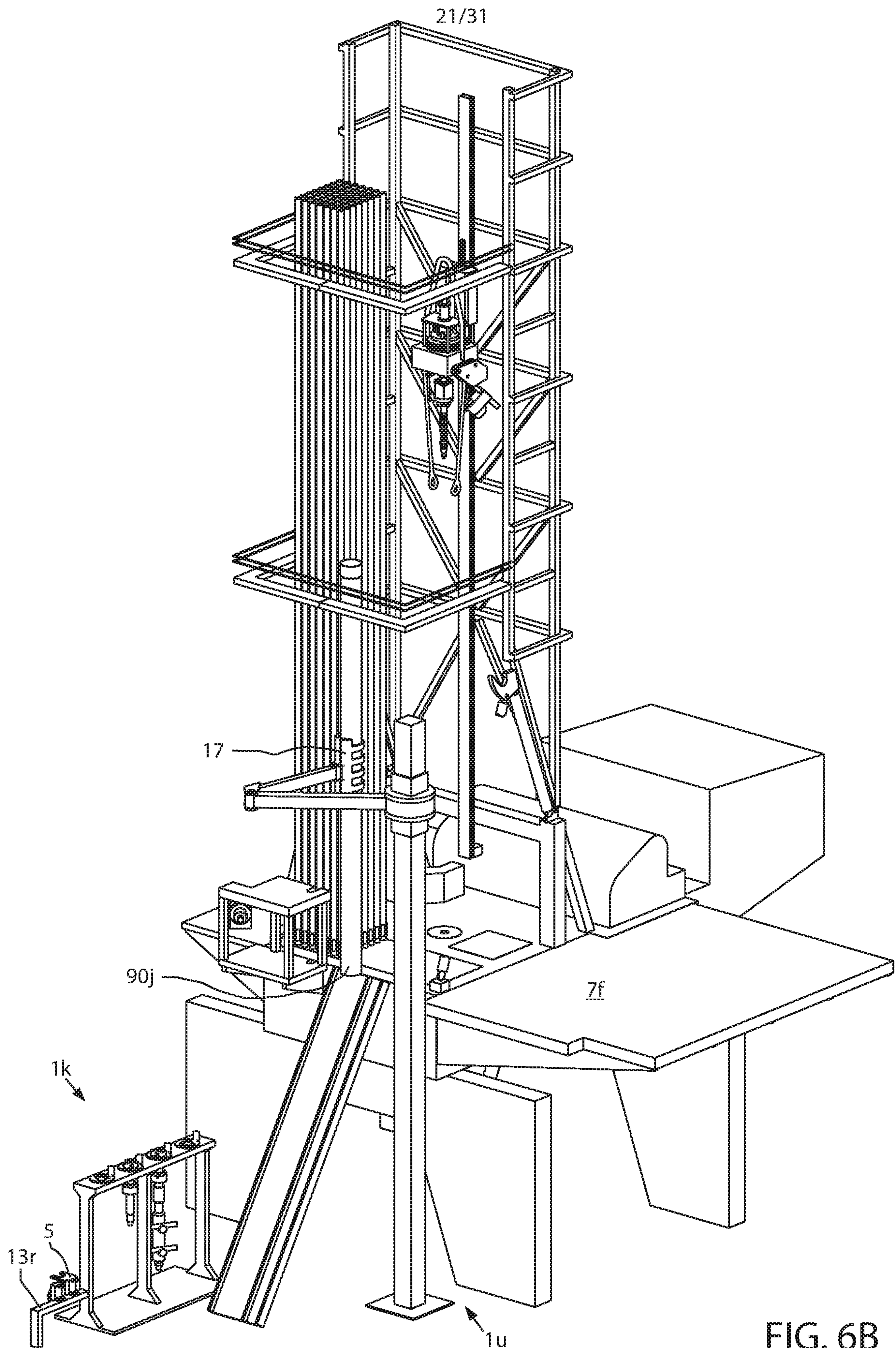


FIG. 6B

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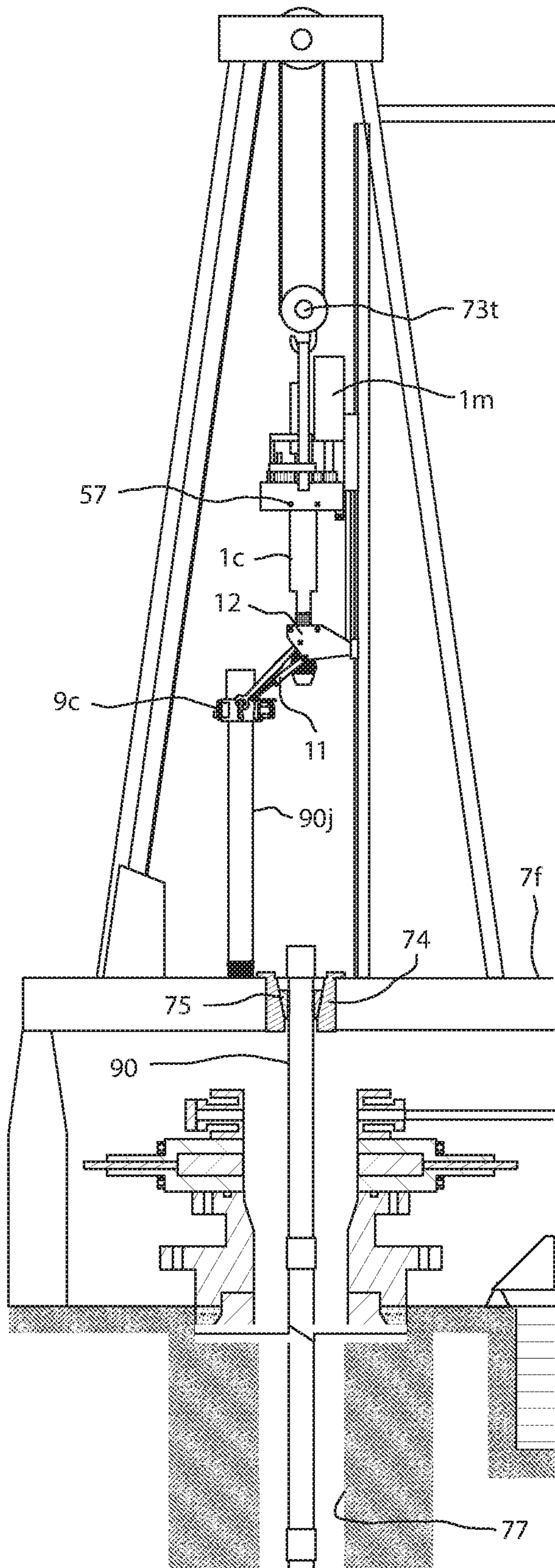


FIG. 6C

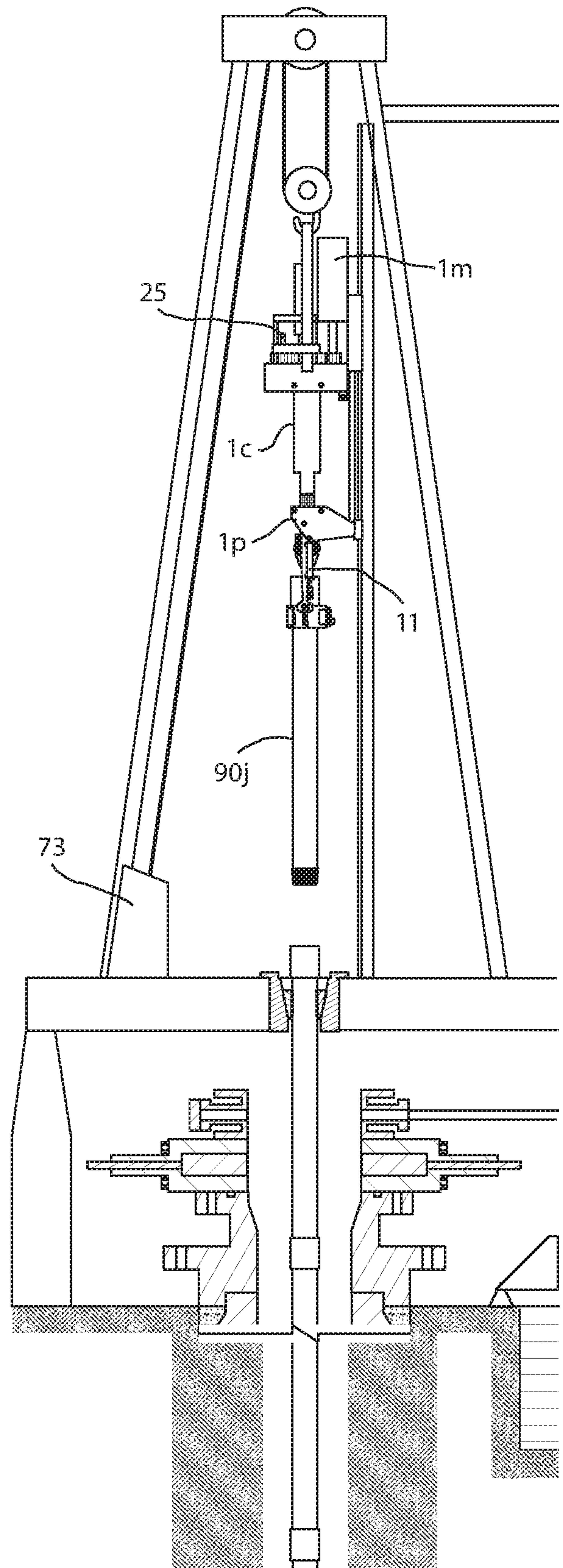


FIG. 6D

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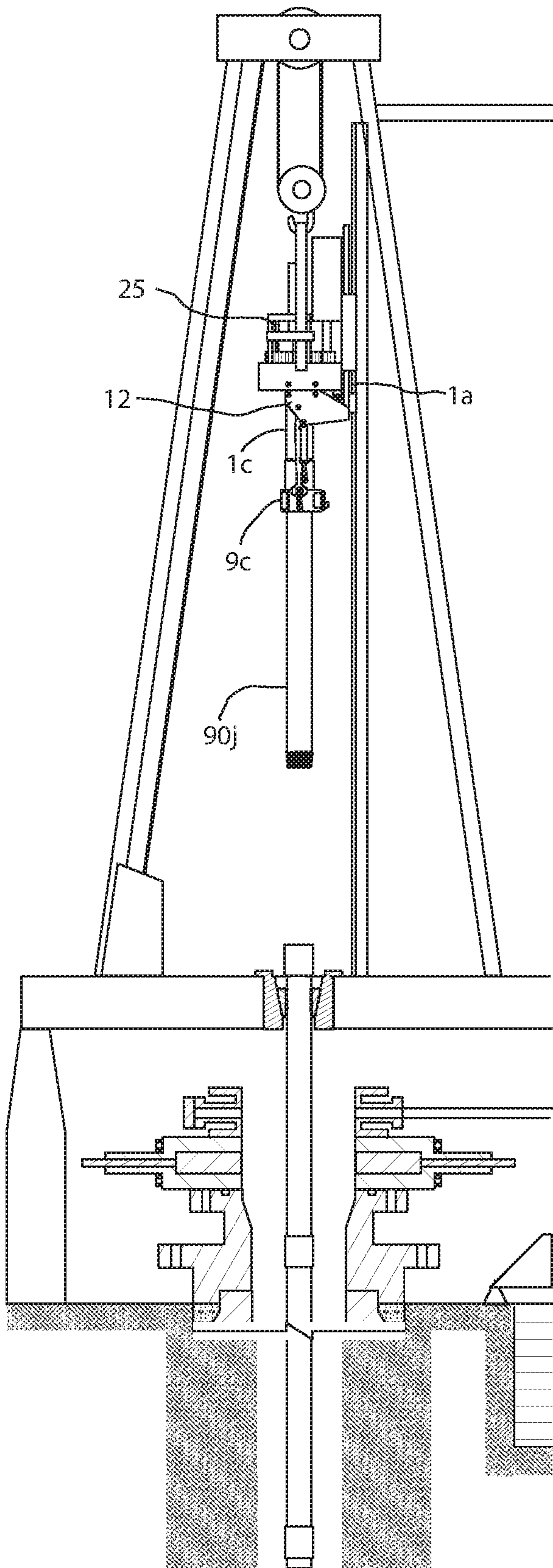


FIG. 6E

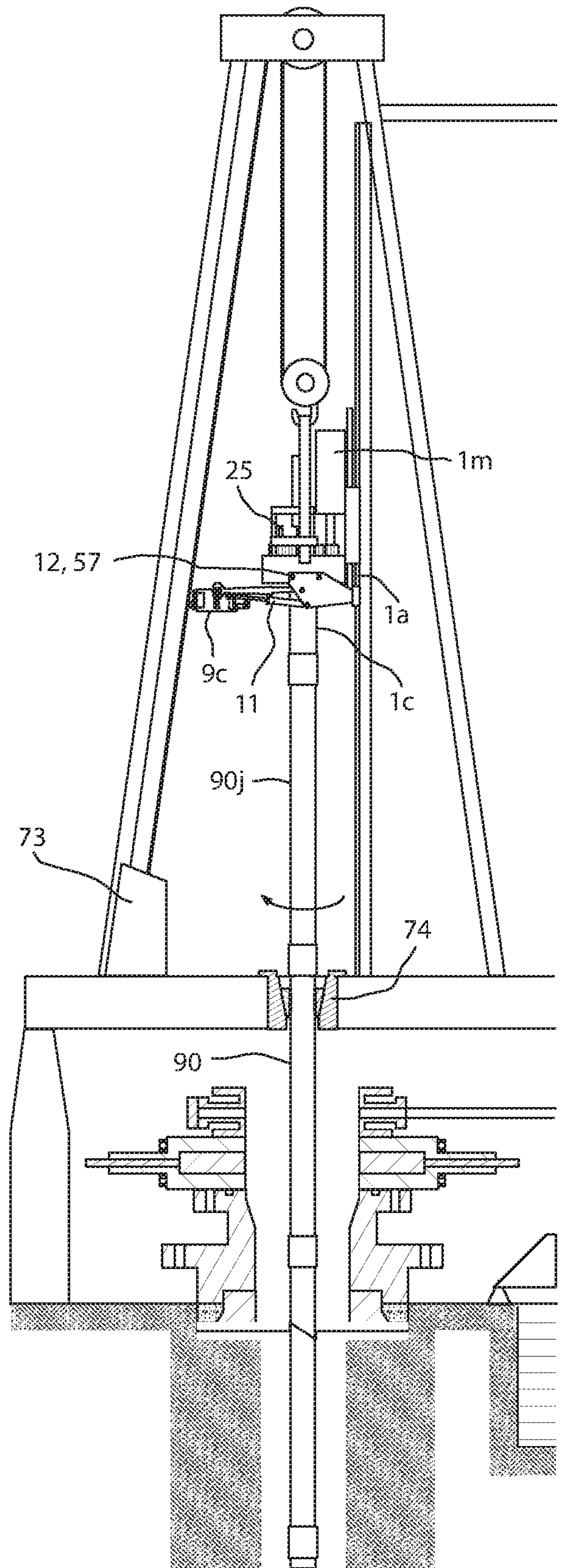


FIG. 6F

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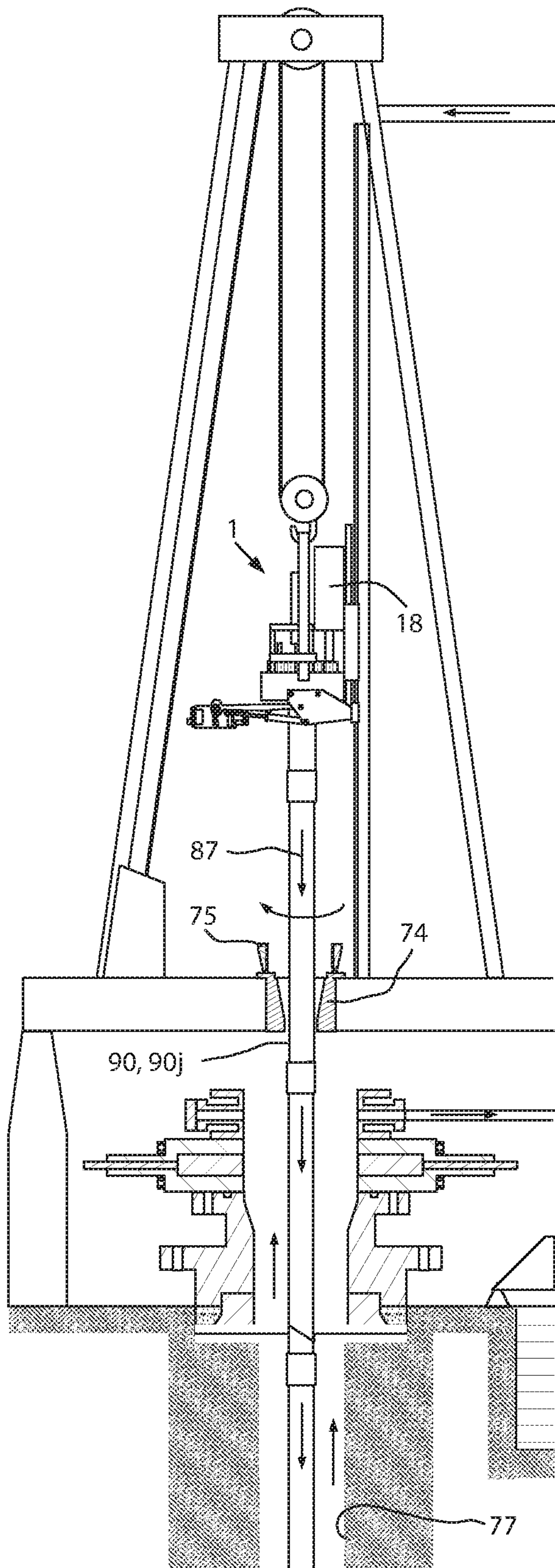


FIG. 6G

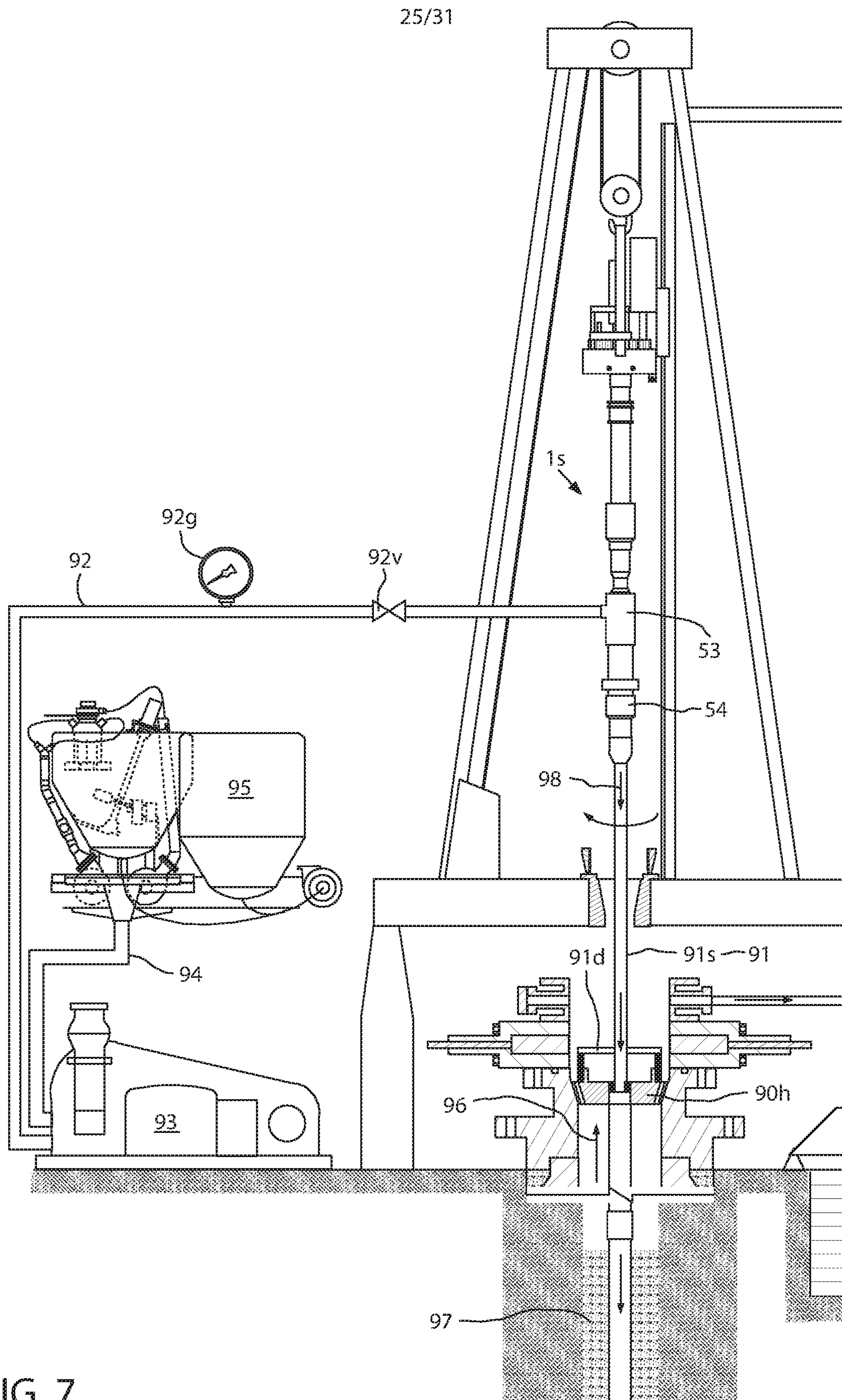


FIG. 7

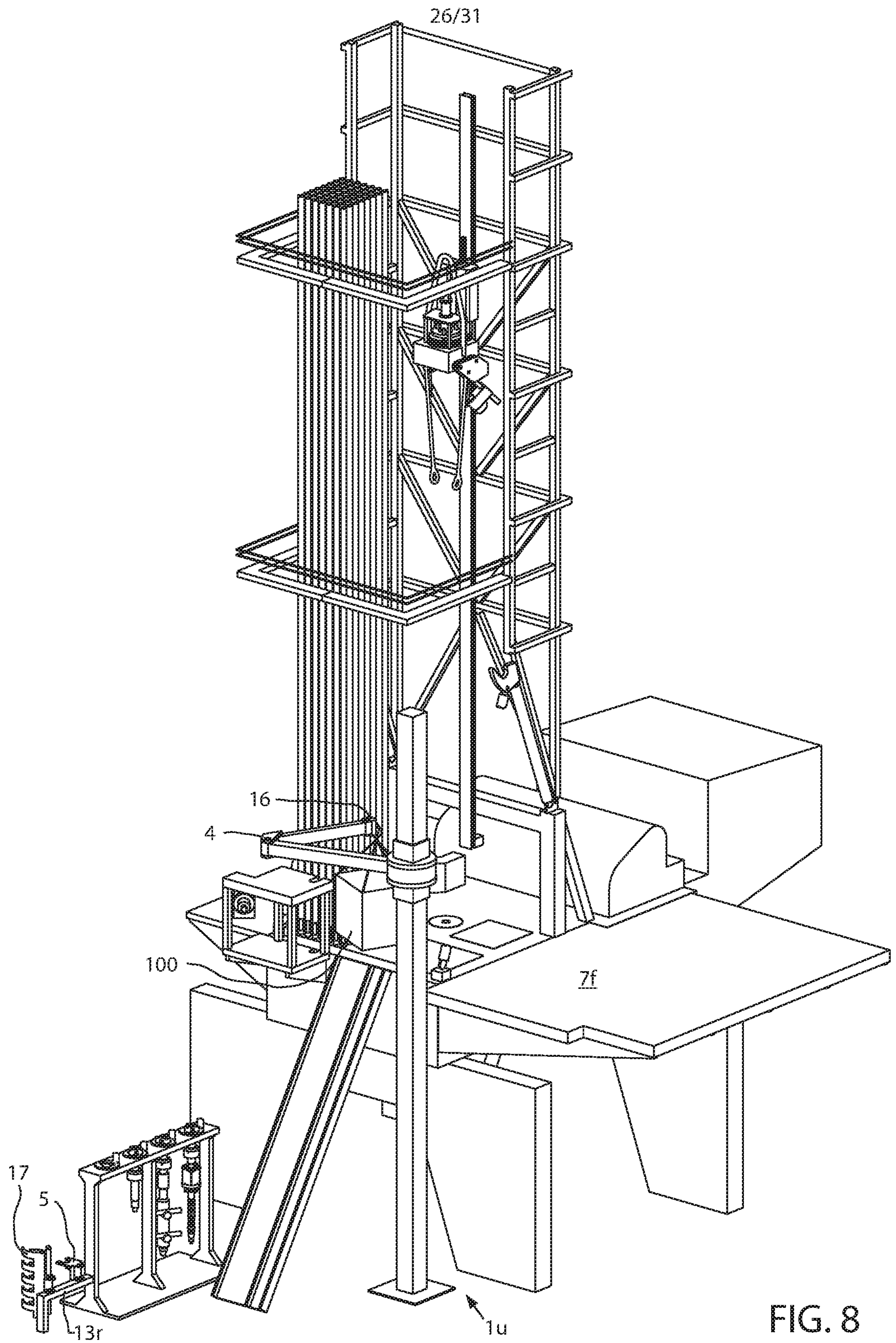
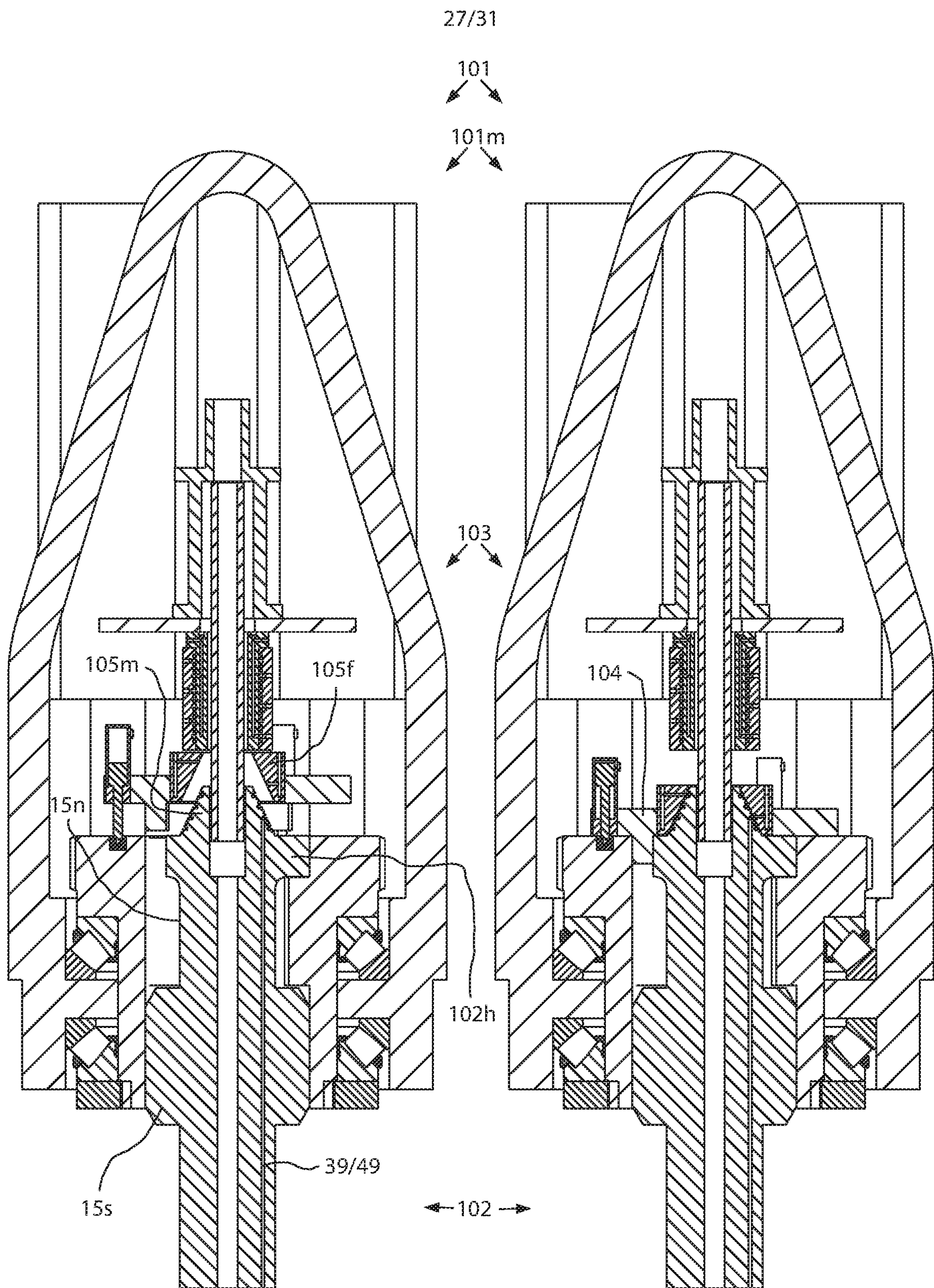


FIG. 8



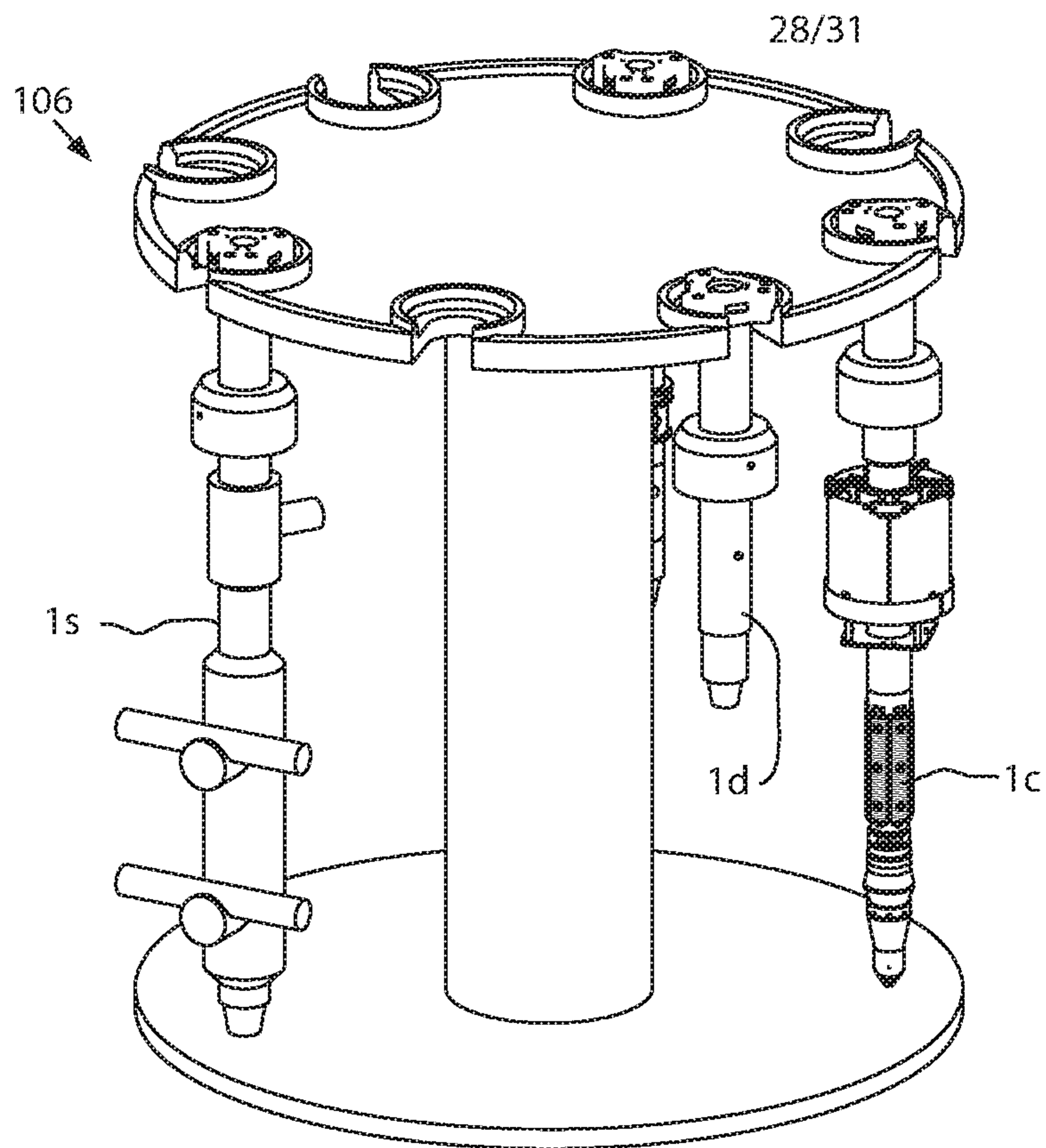


FIG. 10A

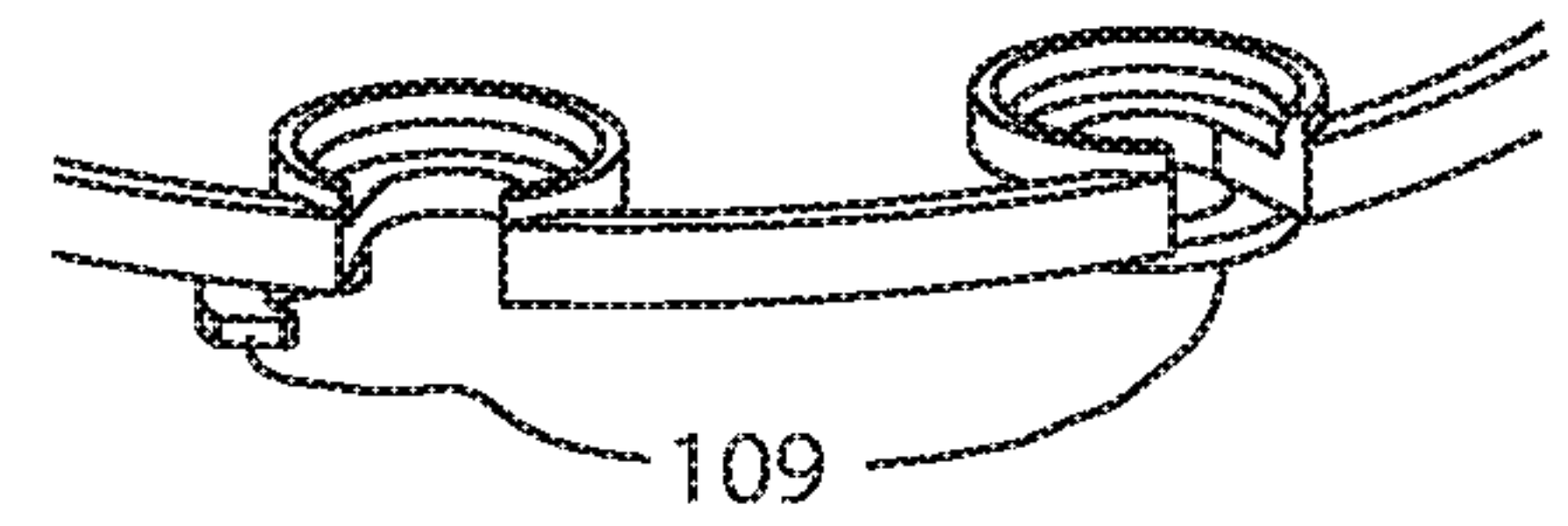


FIG. 10B

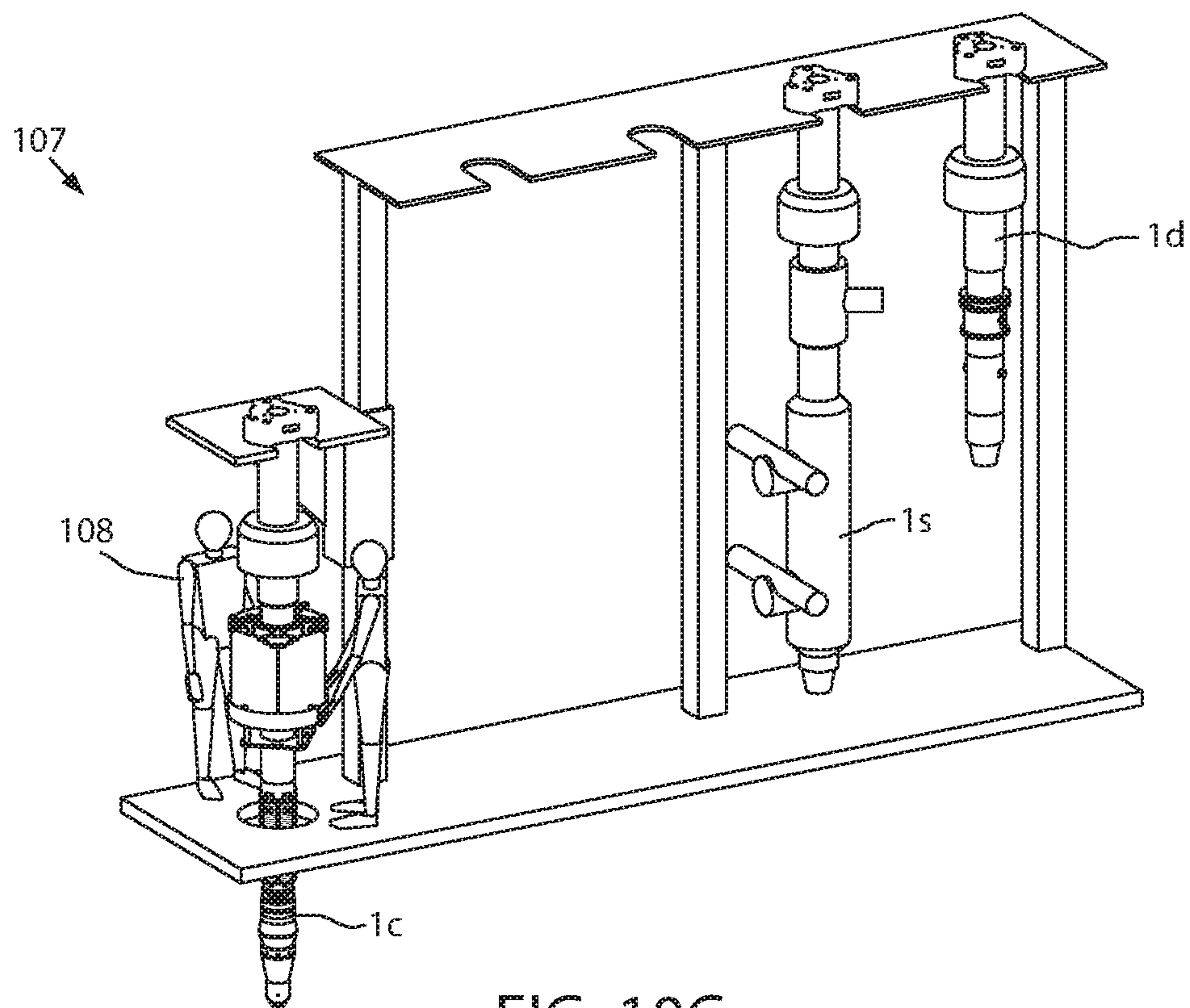


FIG. 10C

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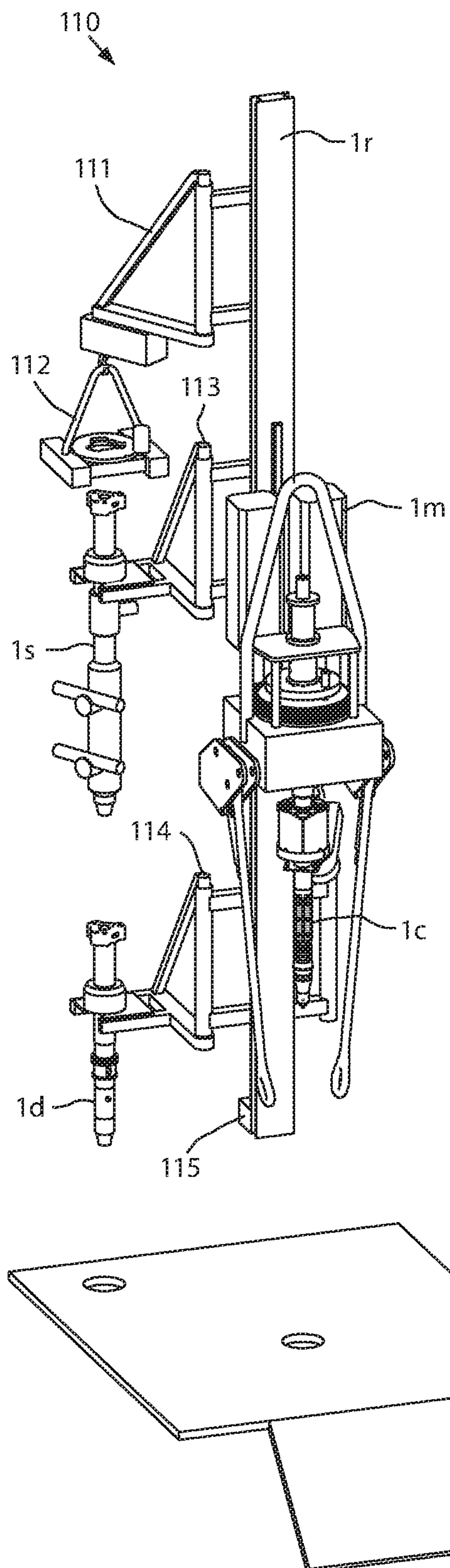


FIG. 11A

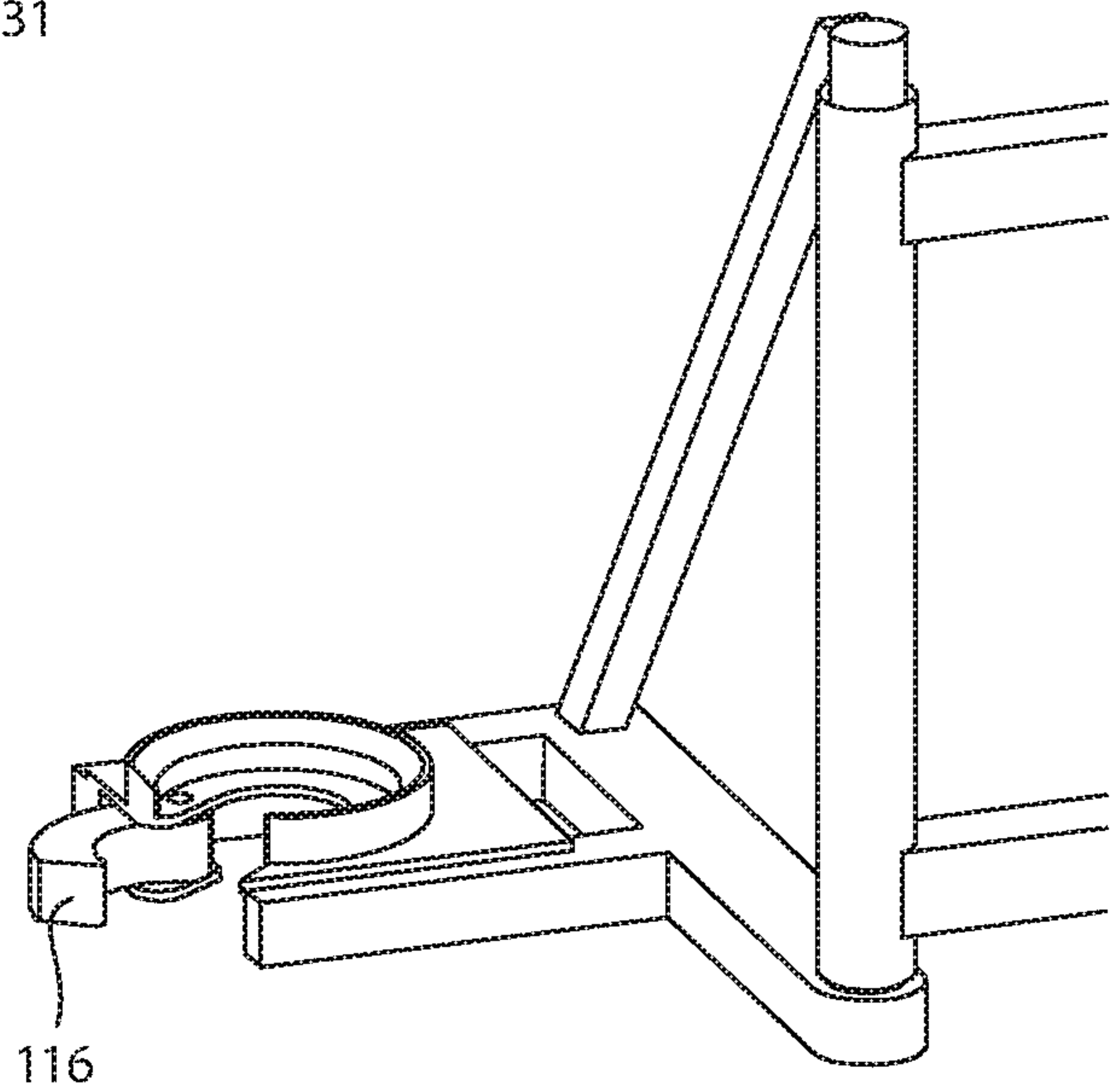


FIG. 11B

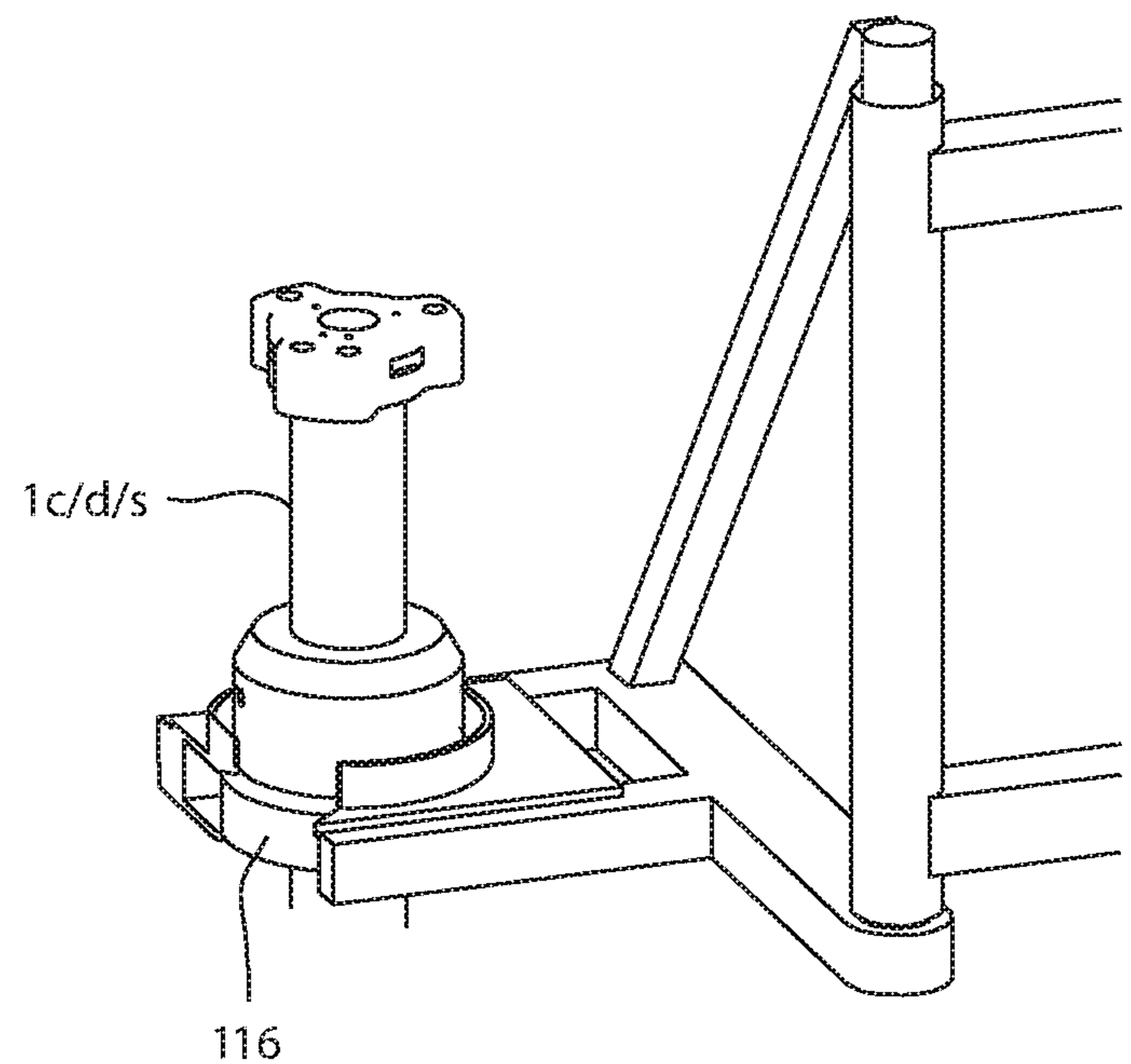


FIG. 11C

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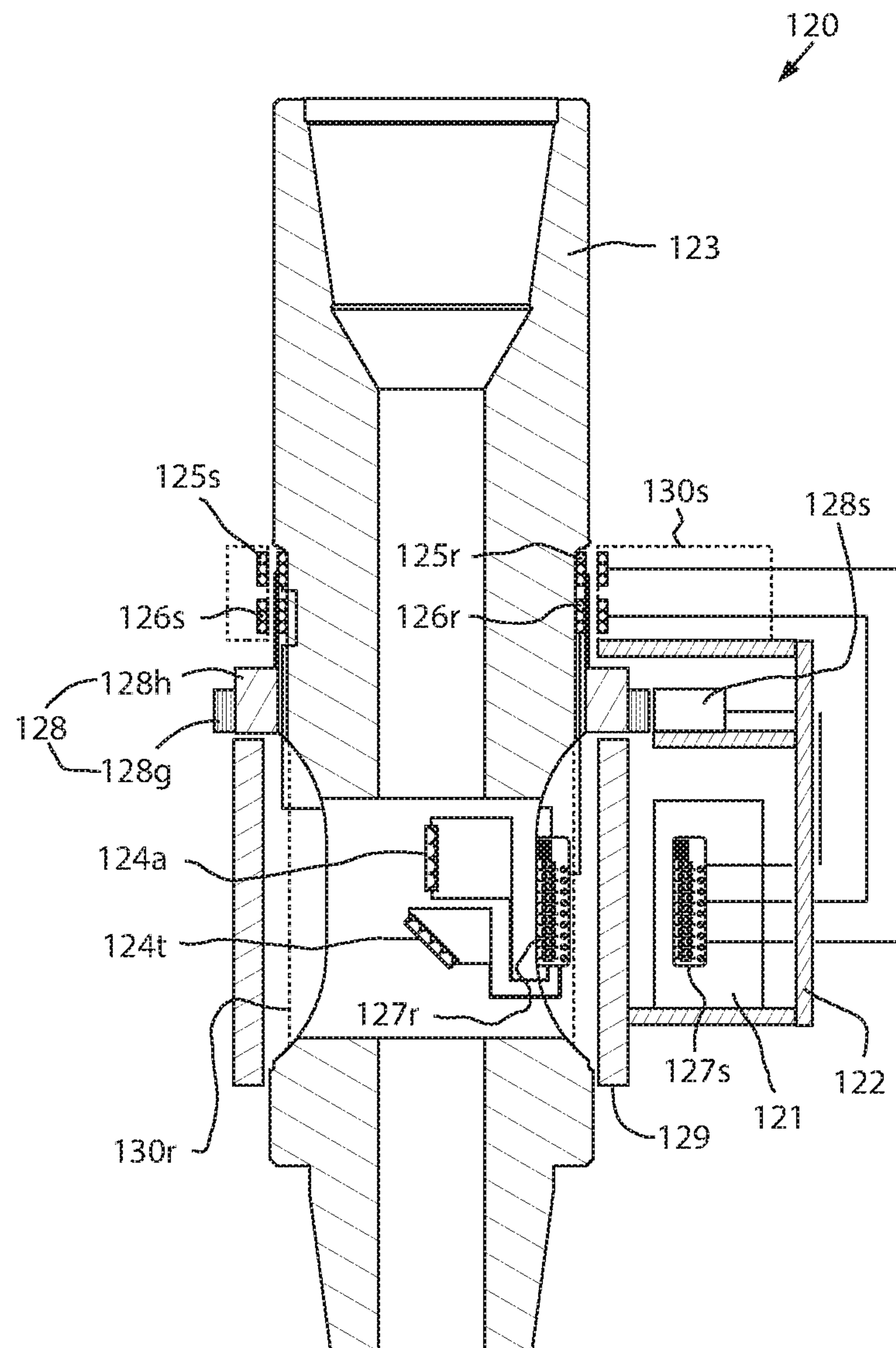


FIG. 12

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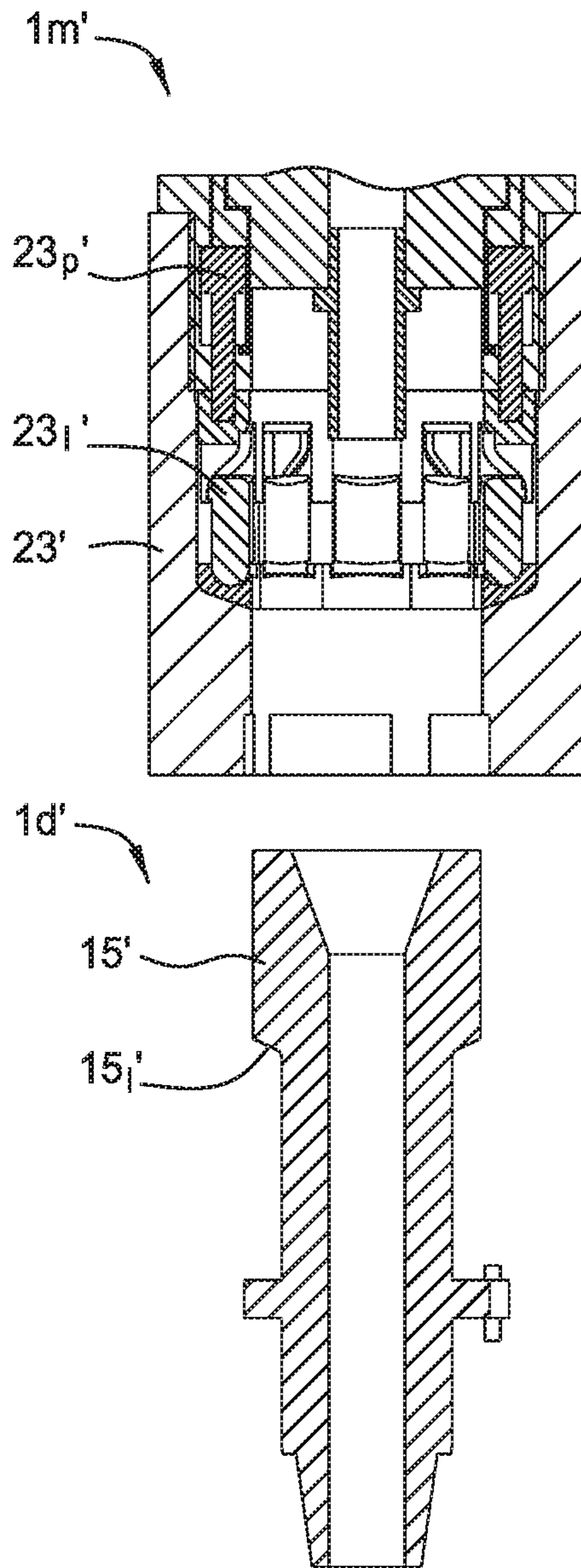


FIG. 13A

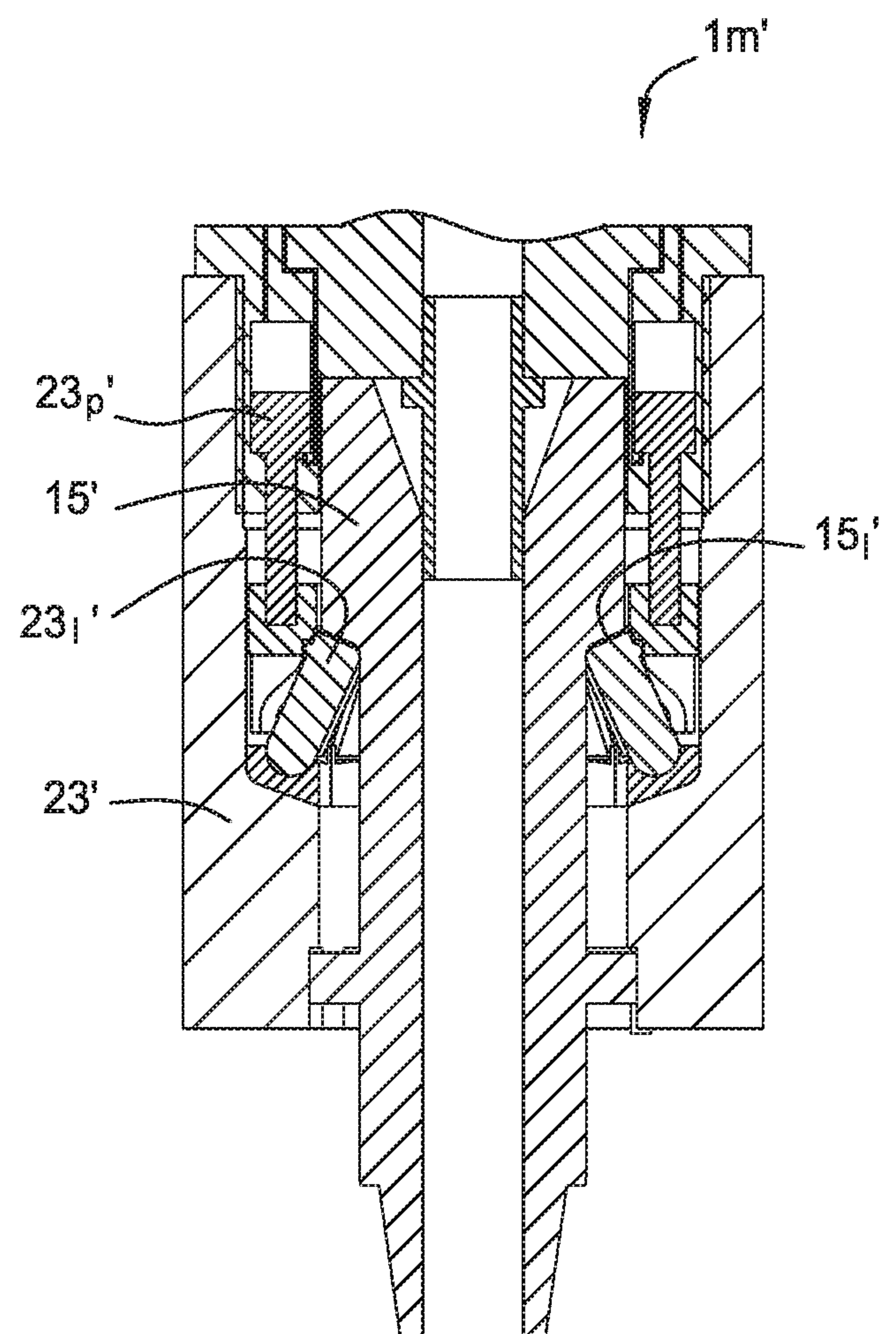


FIG. 13B

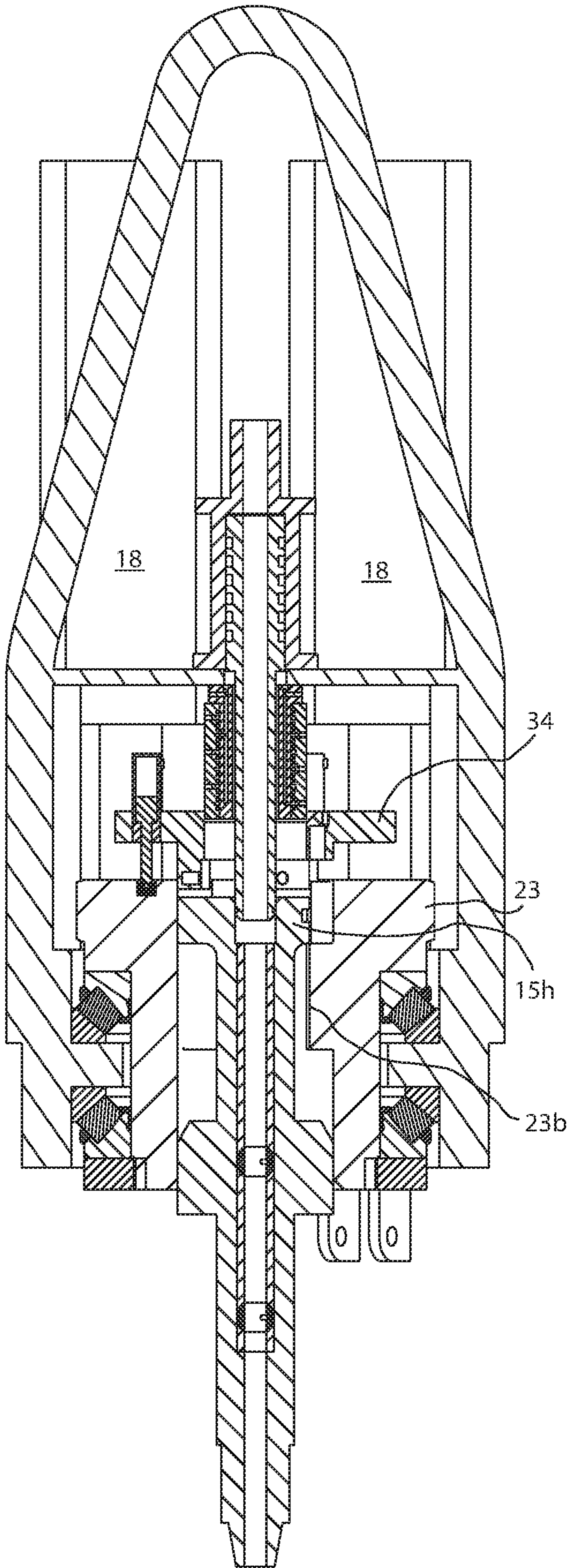


FIG. 4F