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CA 2562770 C 2008/09/16

(11)(21) 2 562 770

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 2006/10/06

(41) Mise à la disp. pub./Open to Public Insp.: 2008/04/06

(45) Date de délivrance/Issue Date: 2008/09/16

(51) Cl.Int./Int.Cl. *E21B 33/03* (2006.01)

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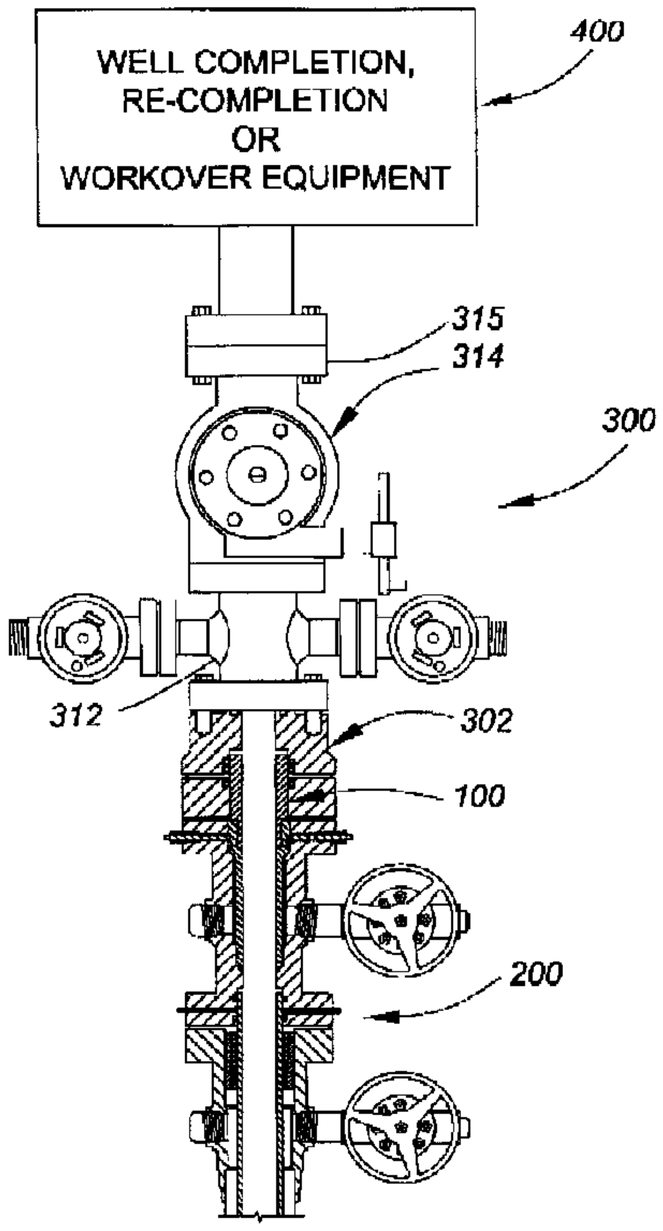
(54) Titre : MANDRIN DE FRACTURE RECUPERABLE ET BLOC OBTURATEUR D'ERUPTION POUR FACILITER LA COMPLETION, LA REMISE EN PRODUCTION OU LE RECONDITIONNEMENT DE PUITS ET METHODE D'UTILISATION

(54) Title: RETRIEVABLE FRAC MANDREL AND WELL CONTROL STACK TO FACILITATE WELL COMPLETION, RE-COMPLETION OR WORKOVER AND METHOD OF USE



(57) Abrégé/Abstract:
A retrievable frac mandrel and a well control stack are used to efficiently accomplish well completion, re-completion or workover. The retrievable frac mandrel is inserted in a tubing head spool of a well to be completed, re-completed or re-worked. The well control stack is mounted to a top of the tubing head spool and seals off against a top of the retrievable frac mandrel. Once well completion, re-completion or workover is completed, the frac mandrel can be retrieved from the tubing head spool without killing or plugging the well.

ABSTRACT OF THE DISCLOSURE

A retrievable frac mandrel and a well control stack are used to efficiently accomplish well completion, re-completion or workover. The retrievable frac mandrel is inserted in a tubing head spool of a well to be completed, re-completed or re-worked. The well control stack is mounted to a top of the tubing head spool and seals off against a top of the retrievable frac mandrel. Once well completion, re-completion or workover is completed, the frac mandrel can be retrieved from the tubing head spool without killing or plugging the well.

RETRIEVABLE FRAC MANDREL AND WELL CONTROL STACK TO FACILITATE WELL COMPLETION, RE-COMPLETION OR WORKOVER AND METHOD OF USE

FIELD OF THE INVENTION

This invention relates in general to hydrocarbon well completion, re-completion or workover and, in particular, to a retrievable frac mandrel and a well control stack, and a method of using the frac mandrel and the well control stack to facilitate well completion, re-completion or workover.

BACKGROUND OF THE INVENTION

It is well understood that attempts to maintain viable hydrocarbon supplies have necessitated the exploitation of more marginal hydrocarbon production zones. It is also well known that exploiting marginal hydrocarbon production zones requires the use of sophisticated well drilling techniques, such as horizontal drilling and multi-stage well completions. It is further known that marginal production zones generally require stimulation in order to be viable producers of hydrocarbons. As understood by those skilled in the art, the stimulation of hydrocarbon production zones generally requires pumping high-pressure fluids into the zones. In order to accomplish this, pressure-sensitive wellhead equipment must be protected during the stimulation process.

Many wellhead isolation tools have been developed to protect sensitive wellhead equipment while high pressure stimulation fluids are pumped into subterranean formations. A high-pressure mandrel of the wellhead isolation tool, commonly referred to as a "frac mandrel" provides the pressure isolation through the wellhead. Some wellhead isolation tools also provide full-bore access to a casing of the well in order to permit downhole operations such as logging, perforating and plugging to be performed through the tools. However, prior art wellhead isolation tools have known disadvantages. For example, they are expensive to use due to labor costs associated with delivering and operating them; they cannot be removed from a live well; or they are known to "get stuck" in the wellhead making them difficult or impossible to remove without killing or plugging a casing of the well.

There therefore exists a need for a retrievable frac mandrel with a well control stack that can be left on a wellhead throughout a well completion, re-completion or workover, and that can be removed from the wellhead without killing the well or plugging the casing.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a retrievable frac mandrel with a well control stack that can be left on a wellhead throughout a well completion, re-completion or workover, and that can be removed from the wellhead without killing the well or plugging the casing.

The invention therefore provides a retrievable frac mandrel and well control stack for facilitating completion, re-completion or workover of a cased well having a wellhead with a tubing head spool, comprising: a frac mandrel having a top end and a bottom end, the bottom end being contoured to be received in the tubing head spool and to provide a high-pressure fluid seal with a seal bore located above a bit guide of the tubing head spool; a well control adapter that mounts to a top flange of the tubing head spool, the well control adapter including an axial seal bore that receives the top end of the frac mandrel to provide a high-pressure fluid seal around a periphery of the top end, and an axial passage that has a diameter smaller than an outer diameter of the top end of the frac mandrel but at least as large as an internal diameter of the frac mandrel; and flow control equipment mounted to a top flange of the well control adapter.

The invention further provides a method of performing a completion, re-completion or workover of a cased well having a wellhead with a tubing head spool, comprising: inserting a bottom end of a frac mandrel into the tubing head spool and locking the frac mandrel in the tubing head spool; mounting a well control stack to a top flange of the tubing head spool, the well control stack including a well control adapter with an axial seal bore that receives the top end of the frac mandrel to provide a high-pressure fluid seal around a periphery of the top end, and an axial passage that has a diameter smaller than an outer diameter of the top end of the frac mandrel but at least as large as an internal diameter of the frac mandrel; mounting well completion, re-completion or workover equipment to a top of

the well control stack; and performing a well completion, re-completion or workover operation using the equipment.

The invention yet further provides a retrievable frac mandrel for facilitating well completion, re-completion or workover of a cased well equipped with a wellhead with a tubing head spool, comprising: a bottom end contoured to be received in a central passage of the tubing head spool, the bottom end including a plurality of O-ring grooves with high pressure O-rings that seal off against a seal bore above a bit guide of the tubing head spool, and an annular groove engaged by lockdown screws of the tubing head spool to lock the frac mandrel in the tubing head spool; and a top end threadedly connected to the bottom end, the top end extending above a top of the tubing head spool.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus generally described the nature of the invention, reference will now be made to the accompanying drawings, in which:

FIG. 1 is a schematic diagram of one embodiment of a retrievable frac mandrel in accordance with the invention suspended over a prior art wellhead;

FIG. 2 is a schematic diagram of the frac mandrel shown in FIG. 1 mounted to the prior art wellhead;

FIG. 3 is a schematic diagram of another embodiment of a frac mandrel in accordance with the invention mounted to the prior art wellhead;

FIG. 4 is a schematic diagram of yet another embodiment of a frac mandrel in accordance with the invention mounted to the prior art wellhead;

FIG. 5 is a schematic diagram of a well control stack in accordance the invention suspended over the wellhead shown in FIG. 2;

FIG. 6 is a schematic diagram of the well control stack shown in FIG. 4 mounted to the wellhead, with well completion, re-completion or workover equipment mounted to the well control stack;

FIG. 7 is a schematic diagram of a frac head being mounted to the well control stack shown in FIG. 6;

FIG. 8 is a schematic diagram of the frac head shown in FIG. 7 mounted to the well control stack;

FIG. 9 is a schematic diagram of a back pressure plug tool mounted to the well control stack for setting a back pressure plug in the frac mandrel, to permit the well control stack to be removed from the wellhead;

FIG. 10 is a schematic diagram of the back pressure plug tool mounted to the well control stack for setting a hydraulic shear-off tubing plug in the frac mandrel shown in FIG. 3, to permit the well control stack to be removed from the wellhead;

FIG. 11 is a schematic diagram of the back pressure plug tool mounted to the well control stack for setting a through-tubing plug in the frac mandrel shown in FIG. 4, to permit the well control stack to be removed from the wellhead;

FIG. 12 is a schematic diagram of the frac mandrel shown in FIG. 9 with the back pressure plug in a set condition;

FIG. 13 is a schematic diagram of the frac mandrel and the well control stack shown in FIG. 12 with a back pressure plug setting tool disengaged from the back pressure plug;

FIG. 14 is a schematic diagram of the well control stack with the backpressure plug setting tool removed and a lifting sub connected to a top of the well control stack;

FIG. 15 is a schematic diagram of the well control stack removed from the wellhead shown in FIG. 2;

FIG. 16 is a schematic diagram of a master valve with a lubricator tube being hoisted onto the wellhead in order to remove the frac mandrel from the wellhead;

FIG. 17 is a schematic diagram of the master valve and the lubricator tube mounted to a top of the wellhead;

FIG. 18 is a schematic diagram of the back pressure plug setting tool mounted to a top of the lubricator tube shown in FIG. 17;

FIG. 19 is a schematic diagram of the back pressure plug setting tool connected to the back pressure plug in order to retrieve the frac mandrel from the wellhead;

FIG. 20 is a schematic diagram of the frac mandrel drawn into the lubricator tube; and

FIG. 21 is a schematic diagram of the master valve in a closed condition with the wellhead ready to be equipped for production.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention provides a retrievable frac mandrel and a well control stack that are used for well completions, re-completions or workovers. The frac mandrel is received in a tubing head spool of a wellhead and locked in place using lockdown screws for securing a tubing hanger in the tubing head spool. A top of the frac mandrel projects above a top flange of the tubing head spool. The well control stack includes a well control adapter having a central passage that receives a top of the frac mandrel and provides a high-pressure fluid seal around it. A cross-flow tee is mounted to a top of the well control adapter, and a flow control device, such as a high-pressure valve or a blowout preventer is mounted to a top of the cross-flow tee. The frac mandrel and the well control stack permit full-bore access to a casing of the well, and enable any downhole operation to be performed. After a well is completed, re-completed or re-worked, the frac mandrel is plugged, the well control stack is removed and the frac mandrel is retrieved from the wellhead to permit the wellhead to be equipped for production.

FIG. 1 is a schematic cross-sectional diagram of a frac mandrel 100 in accordance with the invention suspended over a prior art wellhead 200. The frac mandrel 100 has a top end 102 and a bottom end 104. In one embodiment, the frac mandrel 100 is a two-piece mandrel having the top end 102 and the bottom end 104 threadedly connected by threads

106, as will be explained below in more detail with reference to FIG. 2.

The prior art wellhead 200 with a tubing head spool 206 that includes a flanged surface casing spool 202 connected to a surface casing 204. Mounted to a top of the surface casing spool 202 is the tubing head spool 206. A production casing 208 is supported by casing slips 210. A top end of the production casing 208 is sealed by high-pressure seals 212 that have been up-graded to 10,000 psi. A side valve 214 controls fluid flow from an annulus of the surface casing 204. A side valve 216 controls fluid flow from the production casing 208. A bit guide 218 terminates a seal bore 220 in a bottom of the tubing head spool. A secondary seal bore 222 is located beneath lock down screws 224 that are used to lock a tubing hanger in the tubing head spool.

FIG. 2 is a cross-sectional diagram of the frac mandrel 100 shown in FIG. 1 locked down in the prior art wellhead 200. The bottom end of 104 of the frac mandrel 100 is contoured to mate with the seal bore 214 and the bit guide 216. A bevel 108 on the bottom end 104 matches a bevel angle of the bit guide 216. An O-ring groove 110 receives a high-pressure O-ring 112 to inhibit the migration of well stimulation fluids between the bit guide 216 and the bevel 108 on the bottom end 104. The O-ring groove 110 and the O-ring 112 are optional. At least two O-rings provide a high-pressure fluid seal between the seal bore 214 and the bottom end 104 of the frac mandrel 100. In this embodiment, four O-ring grooves 114a-114d receive O-rings 116a-116d to provide the high-pressure seal. A further high-pressure seal is provided against the

secondary seal bore 222 by an O-ring groove 118 that receives an O-ring 120. The frac mandrel 100 is locked in the wellhead 200, by the lock down screws 224, which engage a V-shaped annular groove 121 in the bottom end 104.

As explained above, the top end 102 is releasably connected to the bottom end 104 by threads 106, which include a box thread in the bottom end 104 and a mating pin thread on the top end 102. O-ring grooves 122a, 122b receive O-rings 124a, 124b for providing a fluid seal to prevent the migration of stimulation fluids into the threads 106. A backup seal is provided by a metal ring gasket 128 received in complementary metal ring gasket grooves 126a, 126b. The metal ring gasket 128 is a ring gasket of the type described in Applicant's United States patent application published on April 21, 2005 under publication number 2005/0082829 A1, the specification of which is incorporated herein by reference. Back pressure threads 130 support a back pressure plug for sealing a central passage of the frac mandrel 100, as will be explained below with reference to FIG. 9. The two-piece frac mandrel 100 permits the top end 102 to be replaced if the back pressure threads 130 are damaged or "washed out".

FIG. 3 is a cross-sectional schematic diagram of another embodiment of the frac mandrel in accordance with the invention, generally indicated by number reference 100b. The frac mandrel 100b is identical to the frac mandrel 100 described above with reference to FIG. 2, with the exception that the back pressure threads 130 are replaced by an annular groove 132 machined in the internal passage through the top end 102b. The annular groove 132 provides a profile that may be gripped by a hydraulic

shear-off tubing plug, as will be explained below with reference to FIG. 10.

FIG. 4 is a cross-sectional schematic diagram of yet another embodiment of the frac mandrel in accordance with the invention, generally indicated by reference number 100c. The frac mandrel 100c is identical to the frac mandrel 100 described above with reference to FIG. 2 with the exception that the top end of 102c has a smooth internal passage 134 that may be gripped using a through-tubing plug, as will be explained below with reference to FIG. 11.

FIG. 5 is a schematic diagram of the frac mandrel 100 and the prior art wellhead 200 shown in FIG. 2, with a well control stack 300 suspended over a top of the frac mandrel 100. The well control stack 300 includes a well control adapter 302 having an axial seal bore 303 that receives the top end 102 of the frac mandrel 100. O-ring grooves 304a-304c receive O-rings 306a-306c, which provide a high-pressure fluid seal around a periphery of the top end 102 of the frac mandrel 100. Test port plugs 308 seal test bores 309 used to test an integrity of the high-pressure seals. An axial passage 310 in a top end of the well control adapter 302 has a diameter smaller than an outer diameter of the top end of the frac mandrel 100, but at least as large as an internal diameter of the central passage of the frac mandrel 100 and the production casing 208.

The well control stack 300 further includes flow control equipment, such as a cross-flow tee 312 used for pressure balancing and flow-back, and a pressure control

spool, such as a high-pressure valve 314 or a blowout preventer (not shown).

FIG. 6 is a schematic diagram of the well control stack 300 mounted to a top of the prior art wellhead 200. Once the well control stack 300 has been mounted to the prior art wellhead 200, well completion, re-completion or workover equipment 400 can be mounted to a top of the high-pressure valve 314. The well completion, re-completion or workover equipment 400 may include any one or more of the following: a lubricator tube; a coil tubing injector; a wireline grease injector; a blowout preventer; a coil tubing blowout preventer; a wire line blowout preventer; a frac head; or any other tool required for well completion, re-completion or workover.

FIG. 7 shows a frac head 318 supported by lifting sub 322 suspended over the well control stack 300. A threaded union adapter 316 is connected to a top of the high-pressure valve 314 and used to mount to the frac head 318 to the well control stack 300.

FIG. 8 shows the frac head 318 after stimulation fluids have been pumped into the production casing 208, flowed back out of the wellbore and high pressure lines have been disconnected from the frac head 318. A lock down nut 320 secures the frac head 318 to the threaded union adapter 316. In this embodiment, the lock down nut 320 is a hammer nut well known in the art. The lock down nut 320 is released to remove the frac head 318 from the well control stack 300. As is well known in the art, stimulation of the well is generally a last step in any well completion, re-completion or workover. Consequently, after the stimulation fluids have been flowed back out of

the well and the frac head 318 is removed, the well is ready to be equipped for production. However, in order to equip the well for production the well control stack 300 and the frac mandrel 100 must be removed from the wellhead 200.

Consequently, after the frac head 318 is removed from the well control stack 300 a prior art back pressure plug setting tool 330 schematically shown in FIG. 9 is mounted to the threaded union adapter 316 using a hammer nut 332. The back pressure plug setting tool 330 includes a hydraulic injector cylinder 336 supported by plurality of stay rods 334. A cylinder rod 338 of the injector cylinder 336 is connected to a back pressure setting tool adapter 356, which in turn connects to a back pressure plug 340. The cylinder rod 338 reciprocates through a stuffing box 341, which provides a high-pressure fluid seal around the cylinder rod 338. After the back pressure plug setting tool 330 is mounted to the well control stack 300, fluid pressure is balanced across the high-pressure valve 314 using a high-pressure line 350 connected to a pressure balance port 352 of the back pressure plug setting tool 330 in a manner well known in the art. The high-pressure valve 314 is then opened, and the back pressure plug 340 is stroked through the high-pressure valve as shown in FIG. 9.

FIG. 10 is a schematic diagram of the back pressure plug setting tool 330 being used to set a hydraulic shear-off tubing plug 360. The hydraulic shear-off tubing plug 360 is used to plug the internal passage through the frac mandrel 100b shown in FIG. 3. The hydraulic shear-off tubing plug 360 engages the annular groove the 132 in the internal passage through the frac mandrel 100b.

FIG. 11 is a schematic diagram of the back pressure plug setting tool 330 being used to set a through-tubing plug 370 in the frac mandrel 100c. The through-tubing plug 360 is used to plug the internal passage 134 through the frac mandrel 100c shown in FIG. 4. The through-tubing plug 360 is, for example, a PosiSet® through-tubing plug manufactured by Schlumberger Corporation.

FIG. 12 is a schematic diagram of the back pressure plug 340 after it has been stroked through the well control stack 300 and secured by the back pressure threads 130. As is well understood in the art, the back pressure threads 130 are right-handed threads, whereas the back pressure plug tool adapter 356 engages the back pressure plug 340 with a left-handed thread. Consequently, once the back pressure plug 340 is firmly engaged with the back pressure plug threads 130, the back pressure plug tool adapter 356 can be further rotated to release it from the back pressure plug 340 as shown in FIG. 13. The back pressure plug setting tool 330 is then removed from the well control stack 300 by releasing the hammer nut 322 after the back pressure plug tool adapter 356 is stroked up through the high-pressure valve 314, a fluid path through the well control stack 300 is closed by closing the high-pressure valve 314, and pressure is bled off through the pressure balance port 352.

As shown in FIG. 14, the lifting sub 322 is then connected to the threaded union adapter 316 and the well control stack 300 is removed from the wellhead 200 after studs 360 are removed. FIG. 15 shows the well control stack 300 being hoisted away from the wellhead 200 using the lifting sub 322.

FIG. 16 shows the lifting sub 322 been used to mount a master valve a 370 and a lubricator tube 380 to the wellhead 200 after the well control stack 300 has been removed as shown in FIG. 15.

The wellhead 200 with the master valve 370 and lubricator tube 380 mounted thereto is shown in FIG. 17. The back pressure plug setting tool 330 is then mounted to a top of the lubricator tube 380 using the hammer nut 332, and the back pressure plug tool adapter 356 is stroked through the lubricator tube 380 and the master valve 370 and connected to the back pressure plug 304 as shown in FIG. 19.

Well pressure is then balanced across the frac mandrel 100 using a high-pressure line connected between the side port 201 and the pressure balance port 352, as shown in FIG. 19. The hydraulic cylinder 336 of the back pressure plug setting tool 330 is then operated to pull the frac mandrel 100 up into the lubricator tube 380 as shown in FIG. 20. Once the frac mandrel 100 is drawn up into lubricator tube 380, the master valve 370 is closed to control the well, the high-pressure line 350 is disconnected and pressure is bled off through the pressure balance port 352 to permit the lubricator tube 380 to be disconnected from the master valve 370. The lubricator tube 380 and the back pressure plug setting tool 330 are then removed from the master valve 370 and the well is ready to be prepared for production. Depending on the type of the hydrocarbon formation(s) with which the well communicates, a production tubing may be run into the well and suspended in the well using a tubing hanger (not shown) supported by the tubing head spool 206. Alternatively, a

production tree may be connected directly to a top of the master valve 370 and a gate 372 of the master valve 370 opened using a valve control wheel 374, shown in FIG. 21.

As will be understood by those skilled in the art, the frac mandrels 100, 100b or 100c, in combination with the well control stack 300, provide a versatile and inexpensive system for well completion, re-completion or workover. The frac mandrel 100, 100b or 100c and the well control stack 300 can be installed and left on a wellhead for as long as required to perform a completion, re-completion or workover of the well. Operation scheduling therefore becomes less critical, delays are less costly and labor costs are reduced.

As will be further understood by those skilled in the art, the frac mandrel and well control stack in accordance with the invention enables full control of the well, while permitting equipment required for well completion, re-completion or workover to be readily and safely mounted to, or removed from, the wellhead. Since the frac mandrel and well control stack in accordance with the invention provides full-bore access to the production casing of the well, there is no restriction on the size or type of downhole tool that can be used during well completion, re-completion or workover operations.

While various alternative constructions of the frac mandrel of the system in accordance with the invention have been described, it should be understood that the embodiments described above are exemplary only.

The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.

EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVELEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A retrievable frac mandrel and well control stack for facilitating completion, re-completion or workover of a cased well having a wellhead with a tubing head spool, comprising:

a frac mandrel having a top end and a bottom end, the bottom end being contoured to be received in the tubing head spool and to provide a high-pressure fluid seal with a seal bore located above a bit guide of the tubing head spool;

a well control adapter that mounts to a top flange of the tubing head spool, the well control adapter including an axial seal bore that receives the top end of the frac mandrel to provide a high-pressure fluid seal around a periphery of the top end, and an axial passage that has a diameter smaller than an outer diameter of the top end of the frac mandrel but at least as large as an internal diameter of the frac mandrel; and

flow control equipment mounted to a top flange of the well control adapter.

2. The retrievable frac mandrel and well control stack as claimed in claim 1 wherein the high-pressure fluid seal with the seal bore located above the bit guide of the tubing head spool comprises a plurality of O-ring grooves in a periphery of the bottom end of the frac mandrel, each of the O-ring grooves receiving a high-pressure O-ring that seals against the seal bore.

3. The retrievable frac mandrel and well control stack as claimed in claims 1 or 2 wherein the bottom end of the frac mandrel further comprises a bevel that matches a bevel angle of the bit guide, and the bevel includes an O-ring groove that receives an O-ring which seals against the bit guide.

4. The retrievable frac mandrel and well control stack as claimed in any one of claims 1-3 wherein the bottom end of the frac mandrel further comprises an annular groove engaged by lockdown screws for securing a tubing hanger in the tubing head spool, the lockdown screws locking the frac mandrel in the tubing head spool.

5. The retrievable frac mandrel and well control stack as claimed in claim 4 wherein the bottom end of the frac mandrel further comprises an O-ring groove located below the annular groove, and an O-ring received in the O-ring groove that seals against a secondary seal bore in the tubing head spool.

6. The retrievable frac mandrel and well control stack as claimed in any one of claims 1-5 wherein the axial seal bore comprises O-ring grooves that receive O-rings to provide the high-pressure fluid seal around the periphery of the top end of the frac mandrel

7. The retrievable frac mandrel and well control stack as claimed in any one of claims 1-6 wherein the top end and the bottom end of the frac mandrel comprise separate pieces that are interconnected by a threaded

connection and O-ring seals provide a fluid seal between the separate pieces.

8. The retrievable frac mandrel and well control stack as claimed in any one of claims 1-7 wherein the flow control equipment comprises a cross-flow tee and a high pressure valve.

9. The retrievable frac mandrel and well control stack as claimed in claim 1 wherein the frac mandrel further comprises one of: backpressure plug threads for the connection of a backpressure plug to provide a high-pressure seal in a central passage through the frac mandrel; an annular groove engaged by a hydraulic shear-off tubing plug to provide the high-pressure seal in the central passage through the frac mandrel; and a smooth internal passage that is gripped by a through-tubing plug to provide the high-pressure seal in the central passage through the frac mandrel.

10. A method of performing a completion, re-completion or workover of a cased well having a wellhead with a tubing head spool, comprising:

inserting a bottom end of a frac mandrel into the tubing head spool and locking the frac mandrel in the tubing head spool;

mounting a well control stack to a top flange of the tubing head spool, the well control stack including a well control adapter with an axial seal bore that receives the top end of the frac mandrel to provide a high-pressure fluid seal

around a periphery of the top end, and an axial passage that has a diameter smaller than an outer diameter of the top end of the frac mandrel but at least as large as an internal diameter of the frac mandrel;

mounting well completion, re-completion or workover equipment to a top of the well control stack; and

performing a well completion, re-completion or workover operation using the equipment.

11. The method as claimed in claim 10 further comprising:

closing a fluid path through the well control stack;

removing the well completion, re-completion or workover equipment from the top of the well control stack;

mounting a frac head to the well control stack;

opening the fluid path through the well control stack; and

pumping high-pressure well stimulation fluids through the well control stack and the frac mandrel into the cased well.

12. The method as claimed in claim 11 further comprising:

flowing back the high-pressure well stimulation fluids;

closing the fluid path through the well control stack;

bleeding off fluid pressure from the well control stack; and

removing the frac head from the well control stack.

13. The method as claimed in claim 12 further comprising;

mounting a backpressure plug insertion tool to a top of the well control stack;

pressure balancing well pressure across the closed fluid path through the well control stack;

opening the fluid path through the well control stack;

stroking a plug through the well control stack using the backpressure plug insertion tool;

inserting the plug into the frac mandrel to provide a high pressure fluid seal in a central passage through the frac mandrel;

releasing fluid pressure from the well control stack;

removing the backpressure plug insertion tool from the well control stack; and

removing the well control stack from the tubing head spool.

14. The method as claimed in claim 13 further comprising:

mounting a lubricator tube and a master valve to a top of the tubing head spool;

mounting the backpressure plug insertion tool to a top of the lubricator tube;

stroking a plug adapter down through the lubricator tube and master valve and connecting the plug adapter to the plug in the frac mandrel;

releasing the frac mandrel from the tubing head spool; and

pulling the frac mandrel up into the lubricator tube.

15. The method as claimed in claim 14 further comprising:

closing the master valve;

releasing fluid pressure from the lubricator tube; and

removing the lubricator tube, the backpressure plug insertion tool and the frac mandrel from the master valve.

16. A retrievable frac mandrel for facilitating well completion, re-completion or workover of a cased well equipped with a wellhead that with a tubing head spool, comprising:

a bottom end contoured to be received in a central passage of the tubing head spool, the bottom end including a plurality of O-ring grooves with high pressure O-rings that seal off against a seal bore above a bit guide of the tubing head spool, and an annular groove engaged by lockdown screws of the tubing head spool to lock the frac mandrel in the tubing head spool; and

a top end threadedly connected to the bottom end, the top end extending above a top of the tubing head spool.

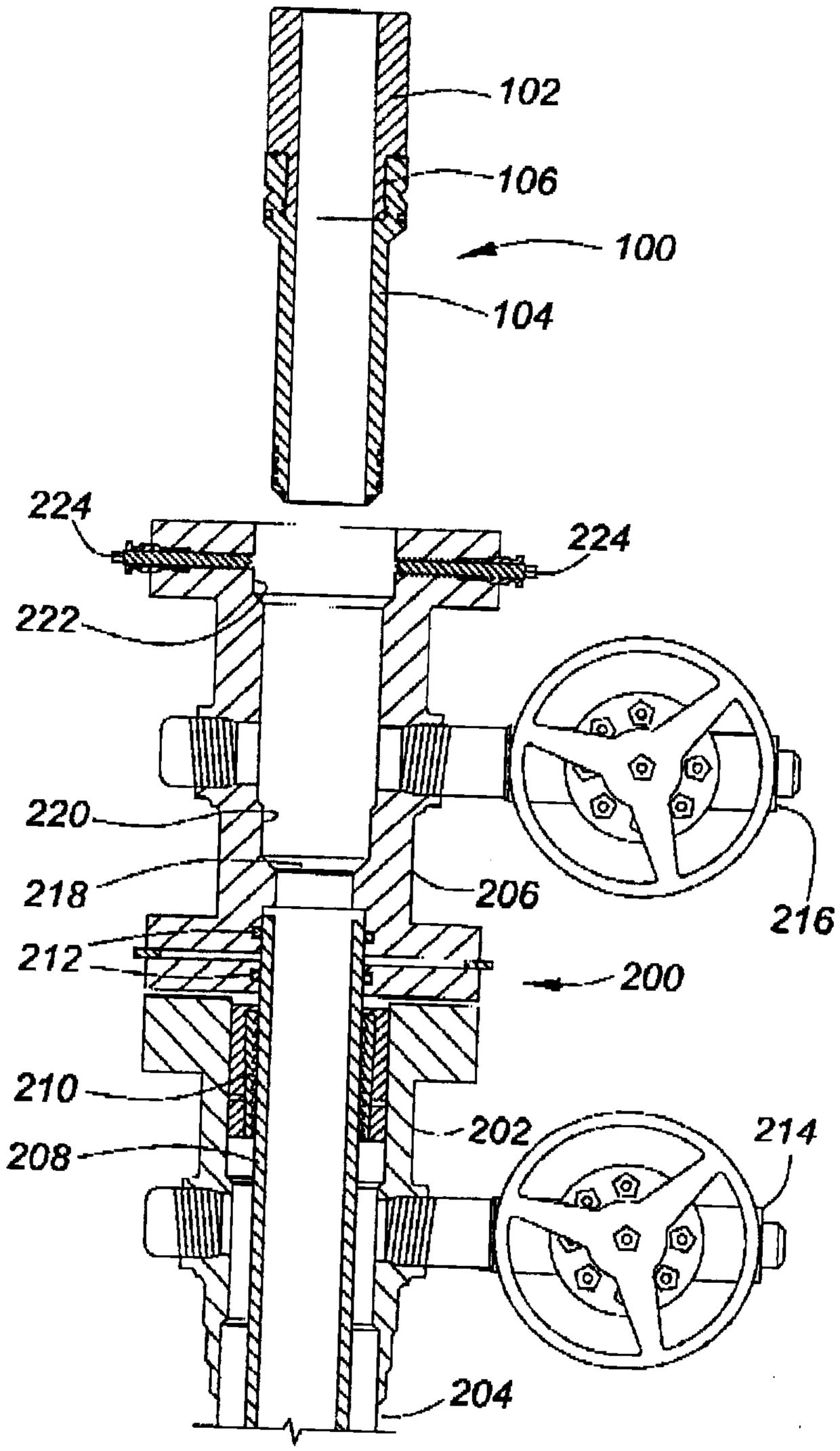
17. The frac mandrel as claimed in claim 16 wherein the top end further comprises an internal passage with backpressure plug threads for receiving a backpressure plug for providing a high-pressure fluid seal for blocking the internal passage, and for providing an attachment point for retrieving the frac

mandrel from the tubing head spool after the well completion, re-completion or workover is completed.

18. The frac mandrel as claimed in claims 16 or 17 wherein the top end further comprises an internal passage with an annular groove engaged by a hydraulic shear-off plug for providing a high-pressure fluid seal for blocking the internal passage, and for providing an attachment point for retrieving the frac mandrel from the tubing head spool after the well completion, re-completion or workover is completed.

19. The frac mandrel as claimed in any one of claims 16-18 further comprising O-ring grooves with high-pressure O-rings located adjacent the threaded connection between the first and second ends to provide a high-pressure fluid seal between the first and second ends.

20. The frac mandrel as claimed in claim 19 wherein the bottom end further comprises a bevel that matches a bevel angle of the bit guide, the bevel including an O-ring groove with a high-pressure O-ring that seals against the bit guide of the tubing head spool.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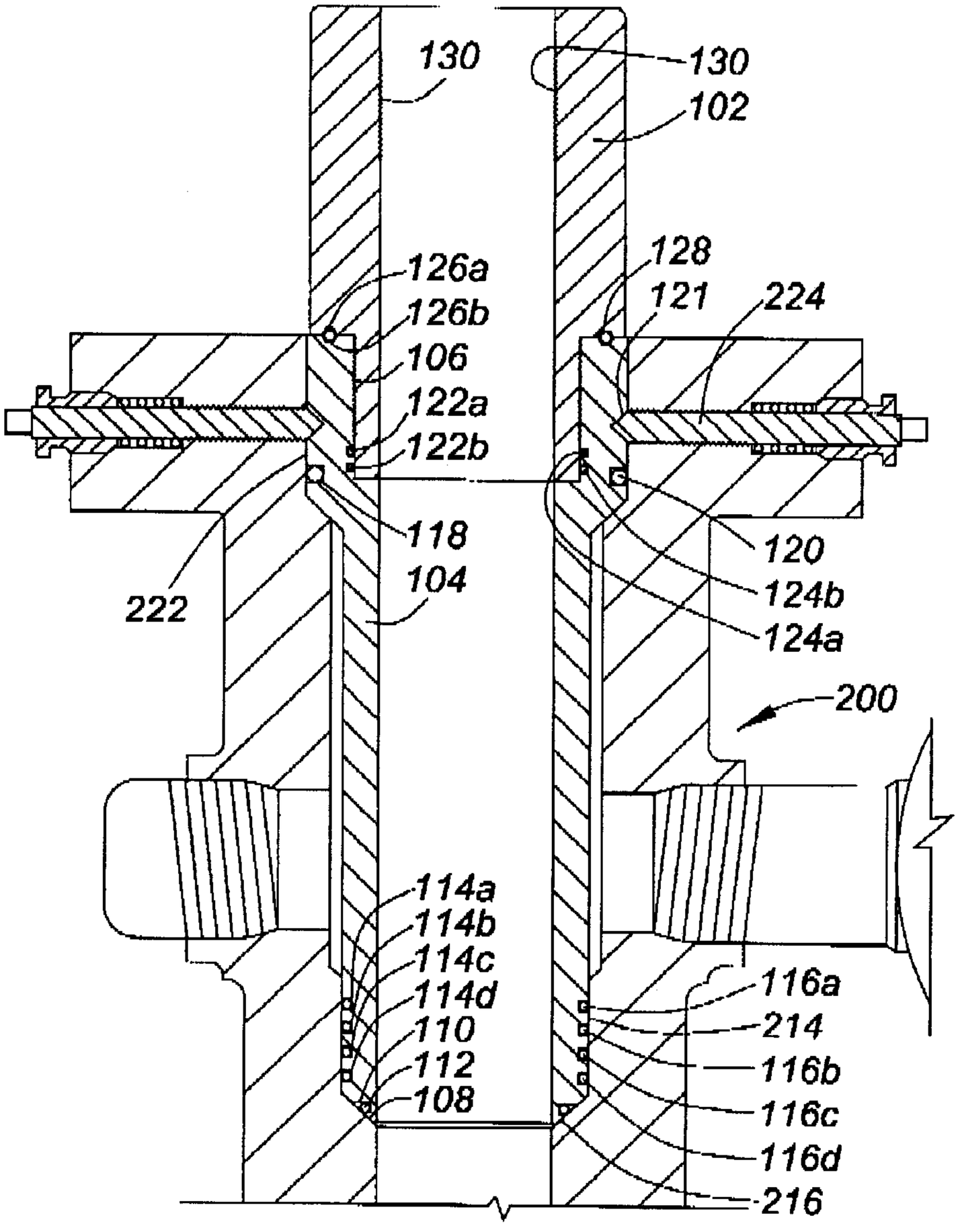
204

FIG. 1


130
130
102
126a
126b
106
122a
122b
128
121
224
118
104
222
120
124b
124a
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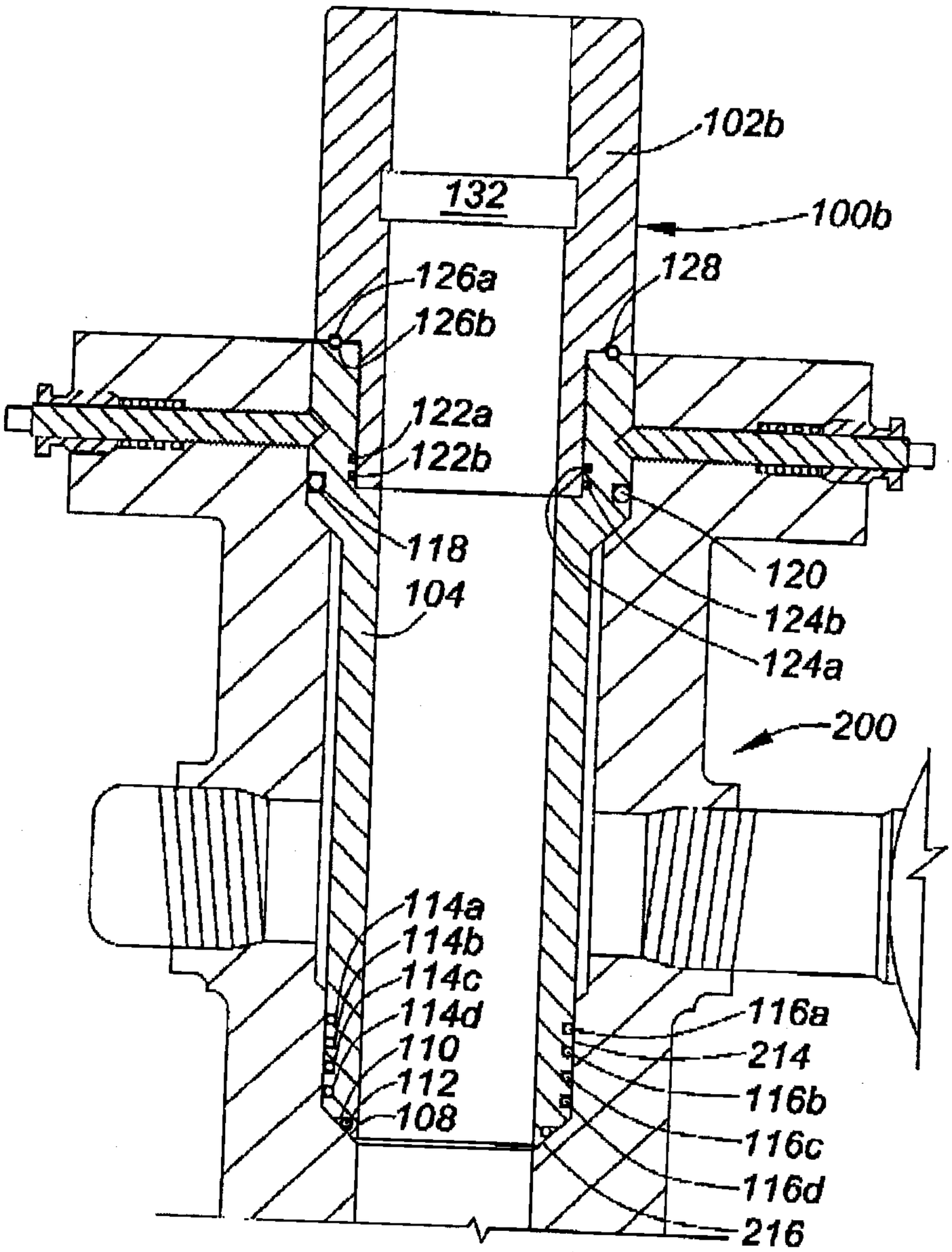
114b
114c
114d
110
112
108
116a
214
116b
116c
116d
216

FIG. 2


102b
132
100b
126a
128
126b
122a
122b
118
120
104
124b
124a
200
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114b
114c
114d
110
112
108
116a
214
116b
116c
116d
216

FIG. 3

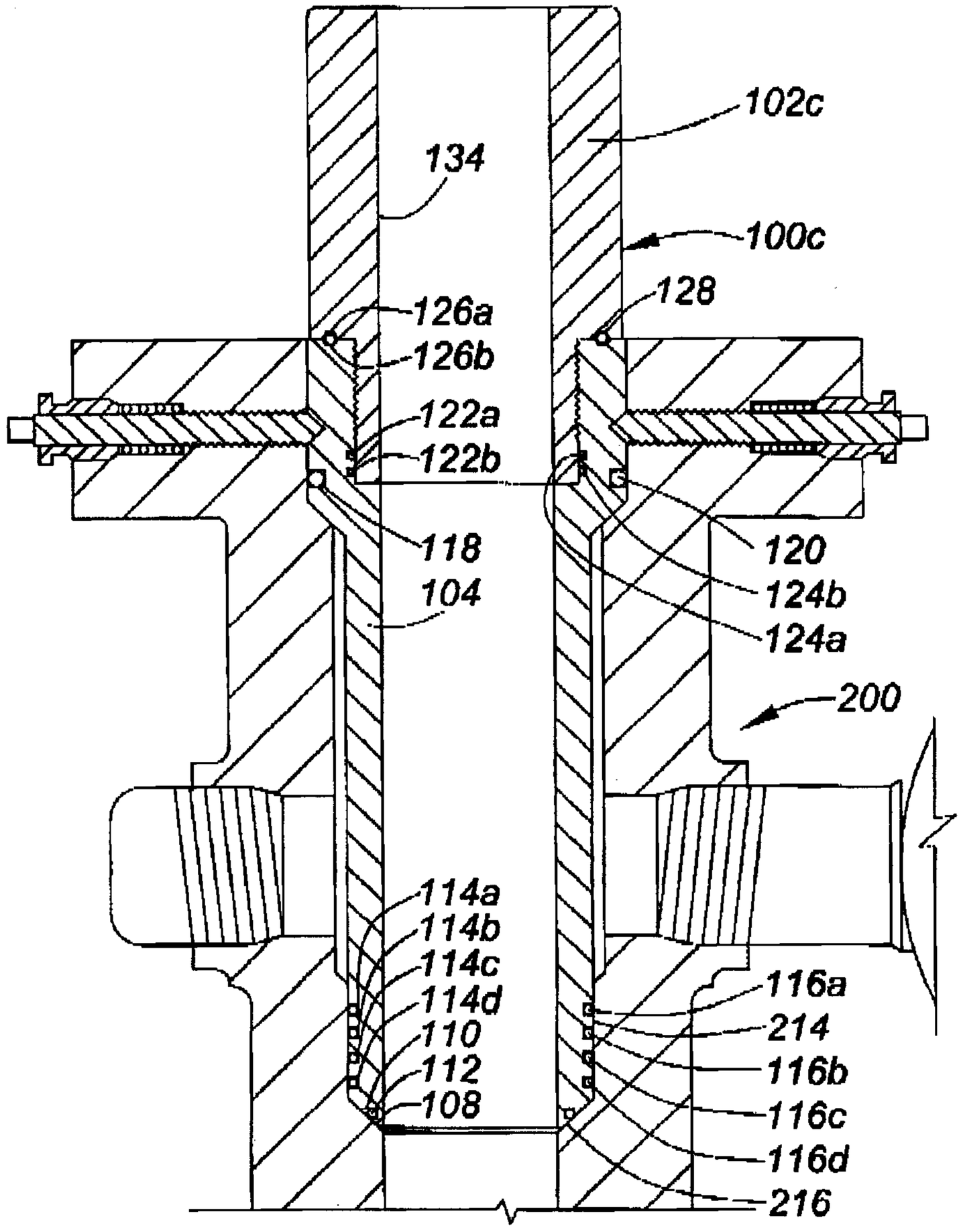
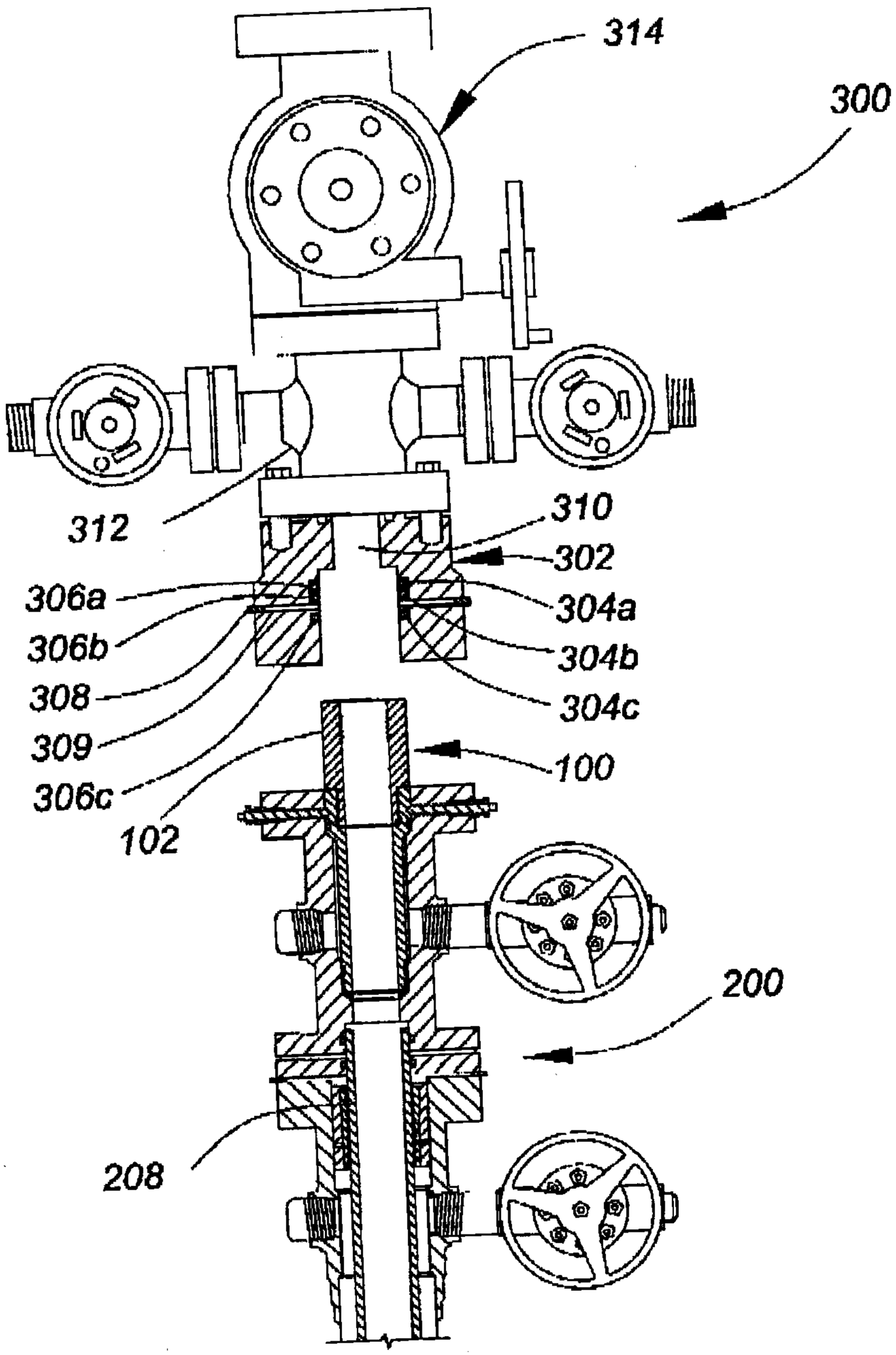

102c
134
100c
128
126a
126b
122a
122b
118
120
104
124b
124a
200
114a
114b
114c
114d
110
112
108
116a
214
116b
116c
116d
216

FIG. 4


314
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302
306a
304a
306b
304b
308
304c
309
100
306c
102
200
208

FIG. 5

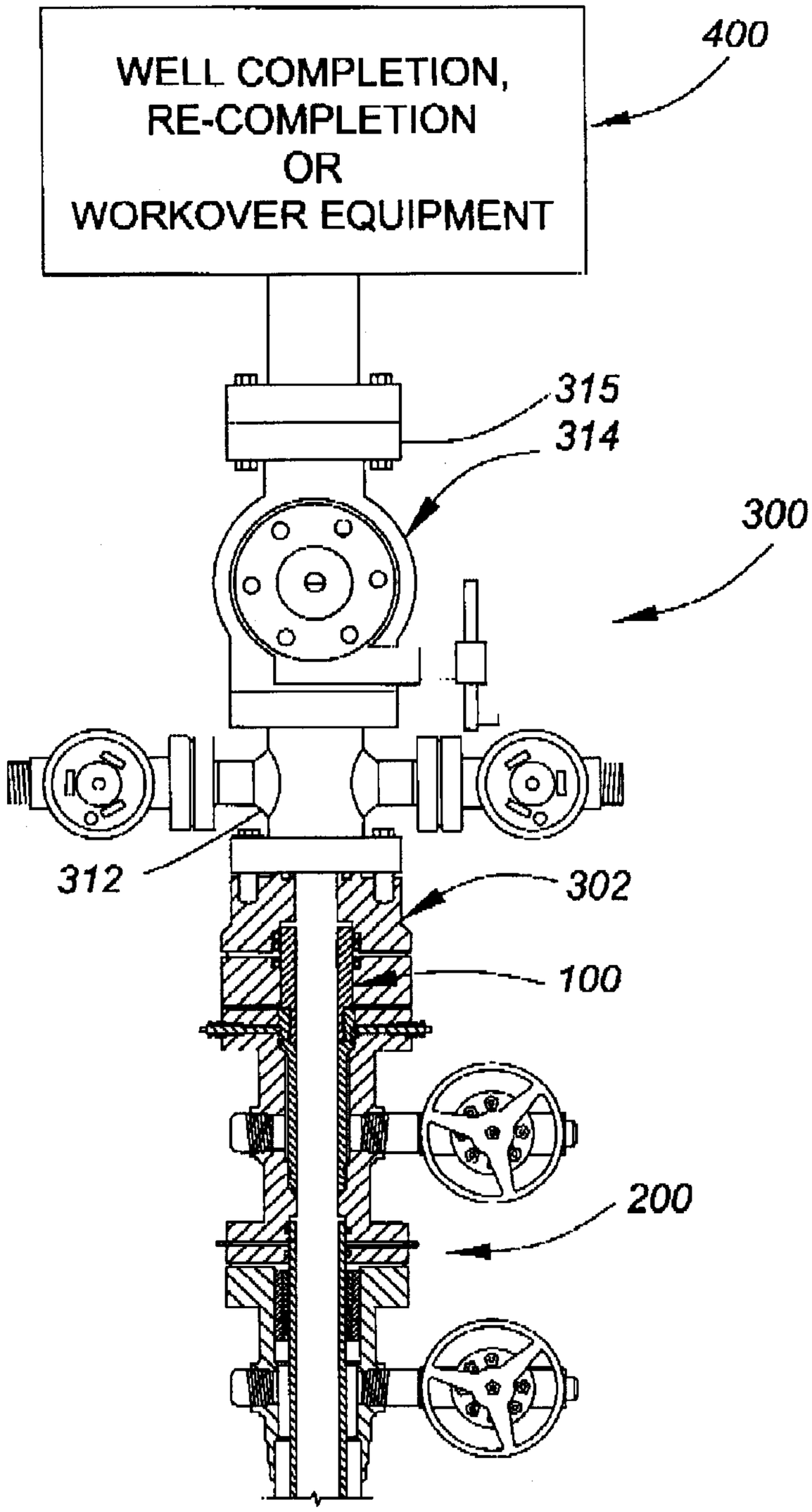

WELL COMPLETION,
RE-COMPLETION
OR
WORKOVER EQUIPMENT
400
315
314
300
312
302
100
200

FIG. 6

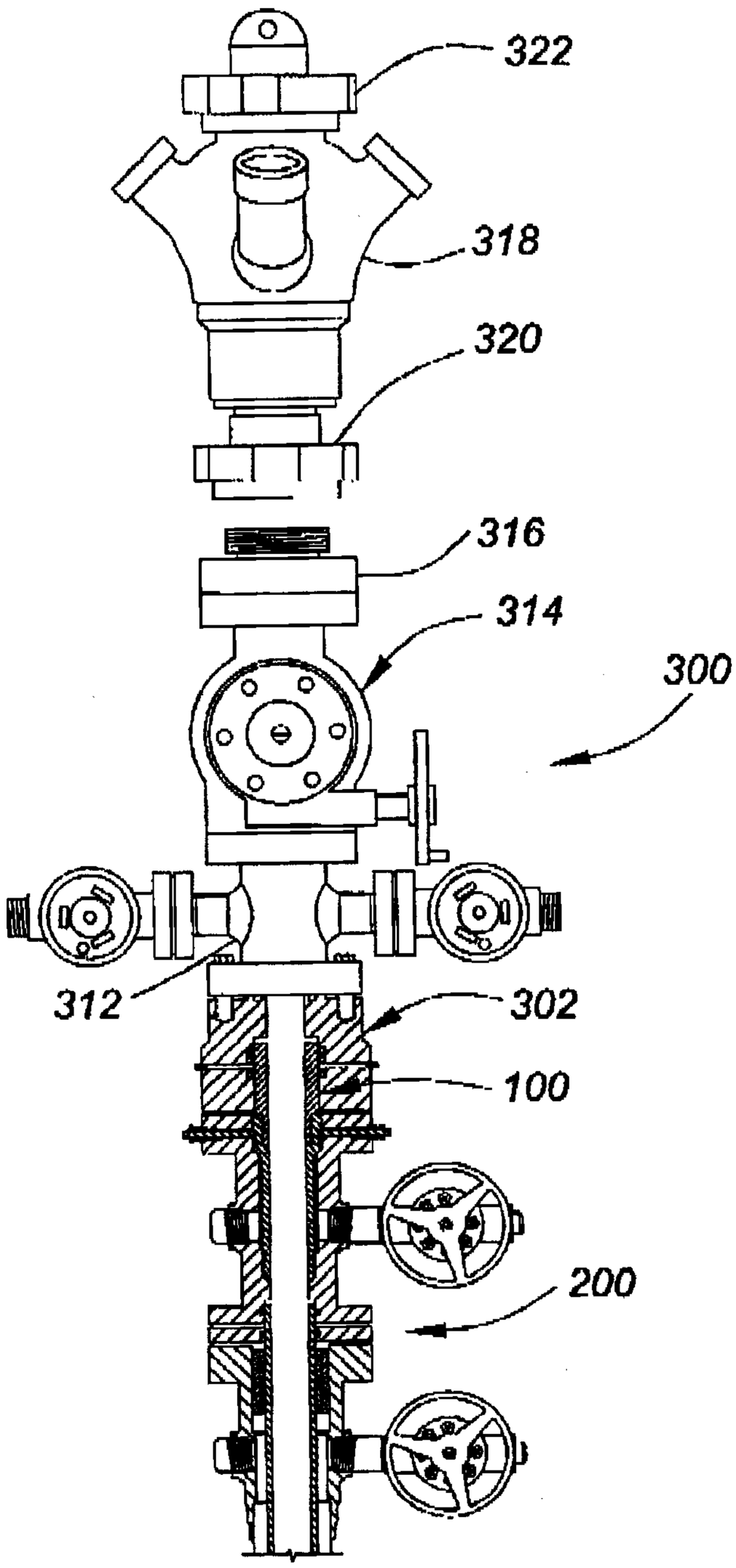


FIG. 7

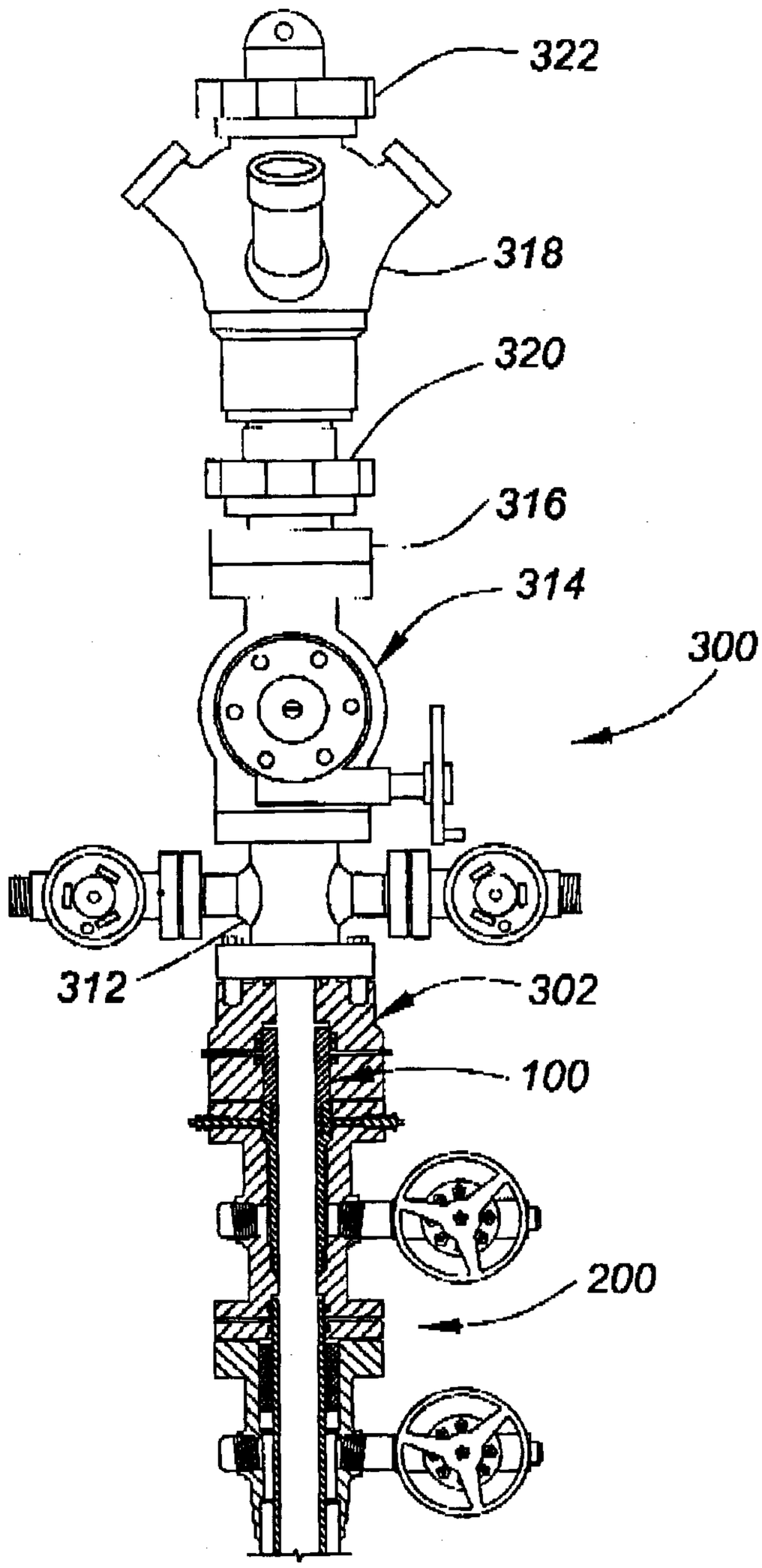
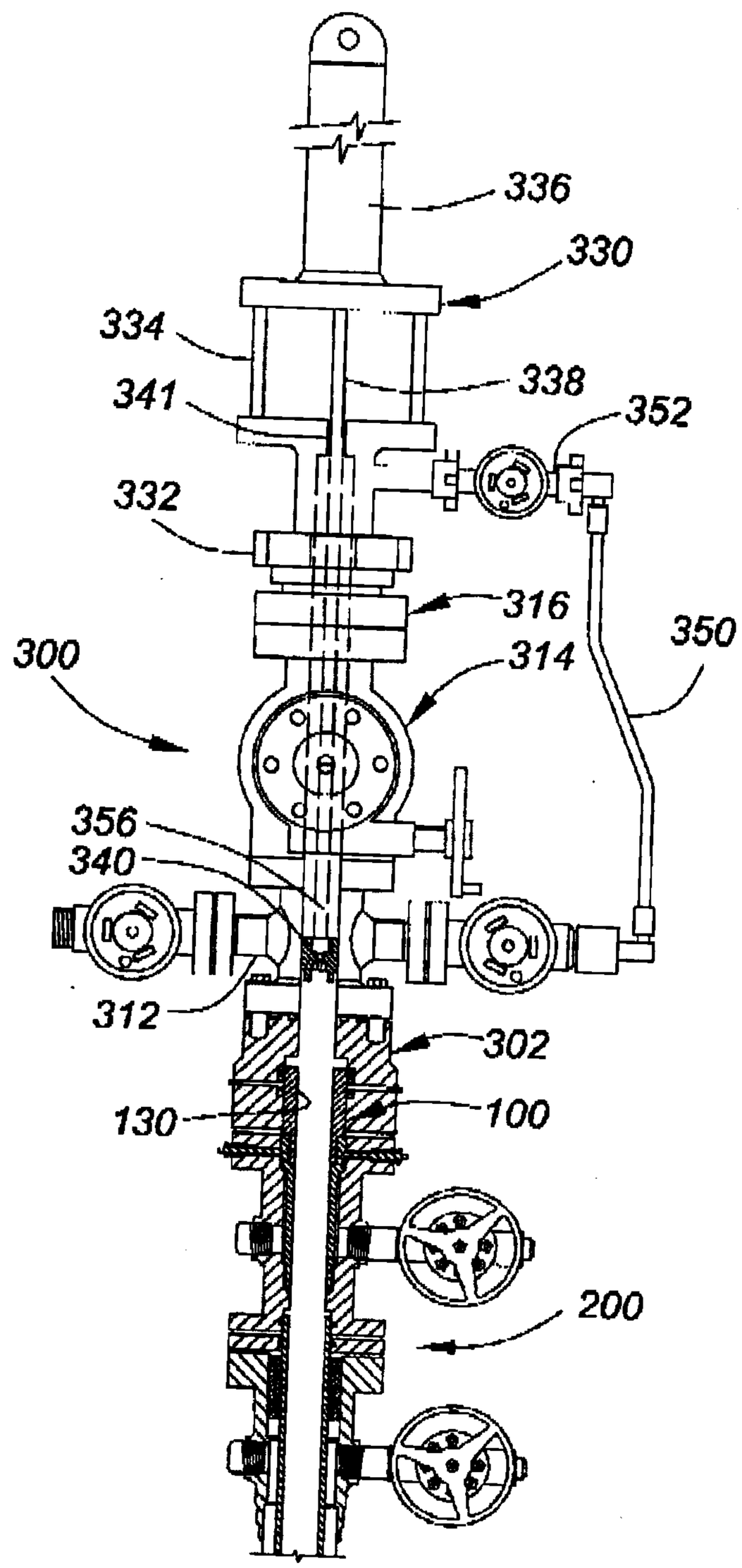


FIG. 8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300
314
356
340
312
302
130
100
200

FIG. 9

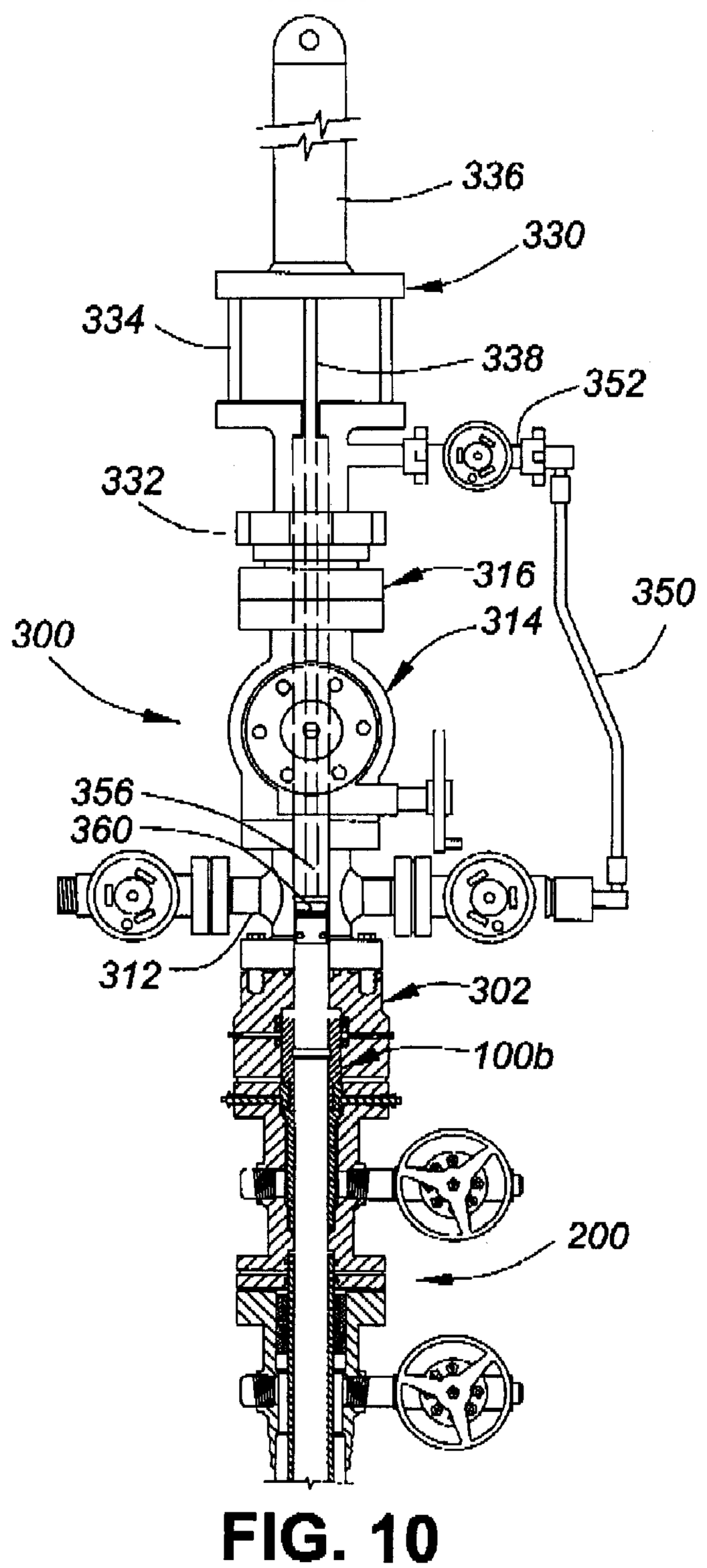
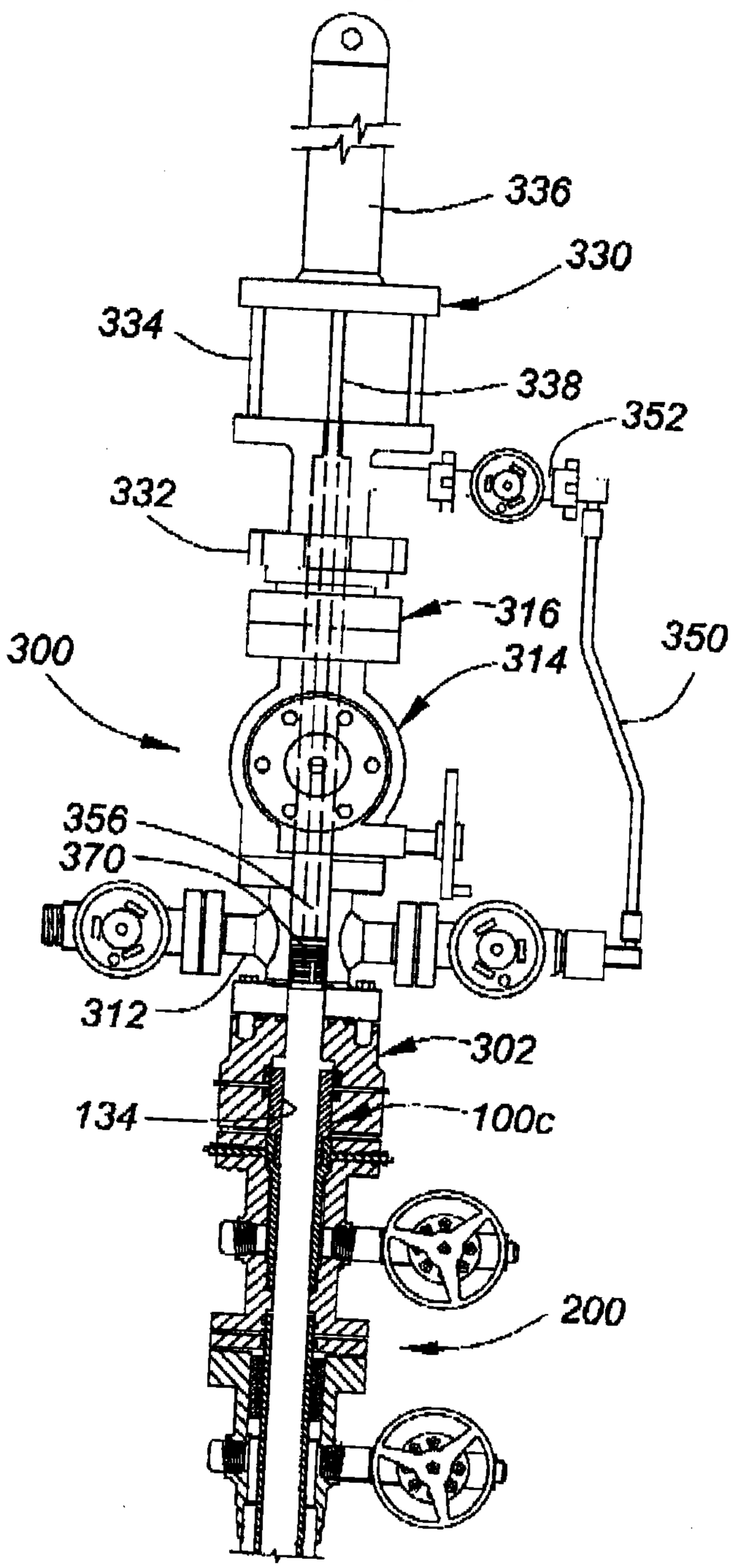


FIG. 10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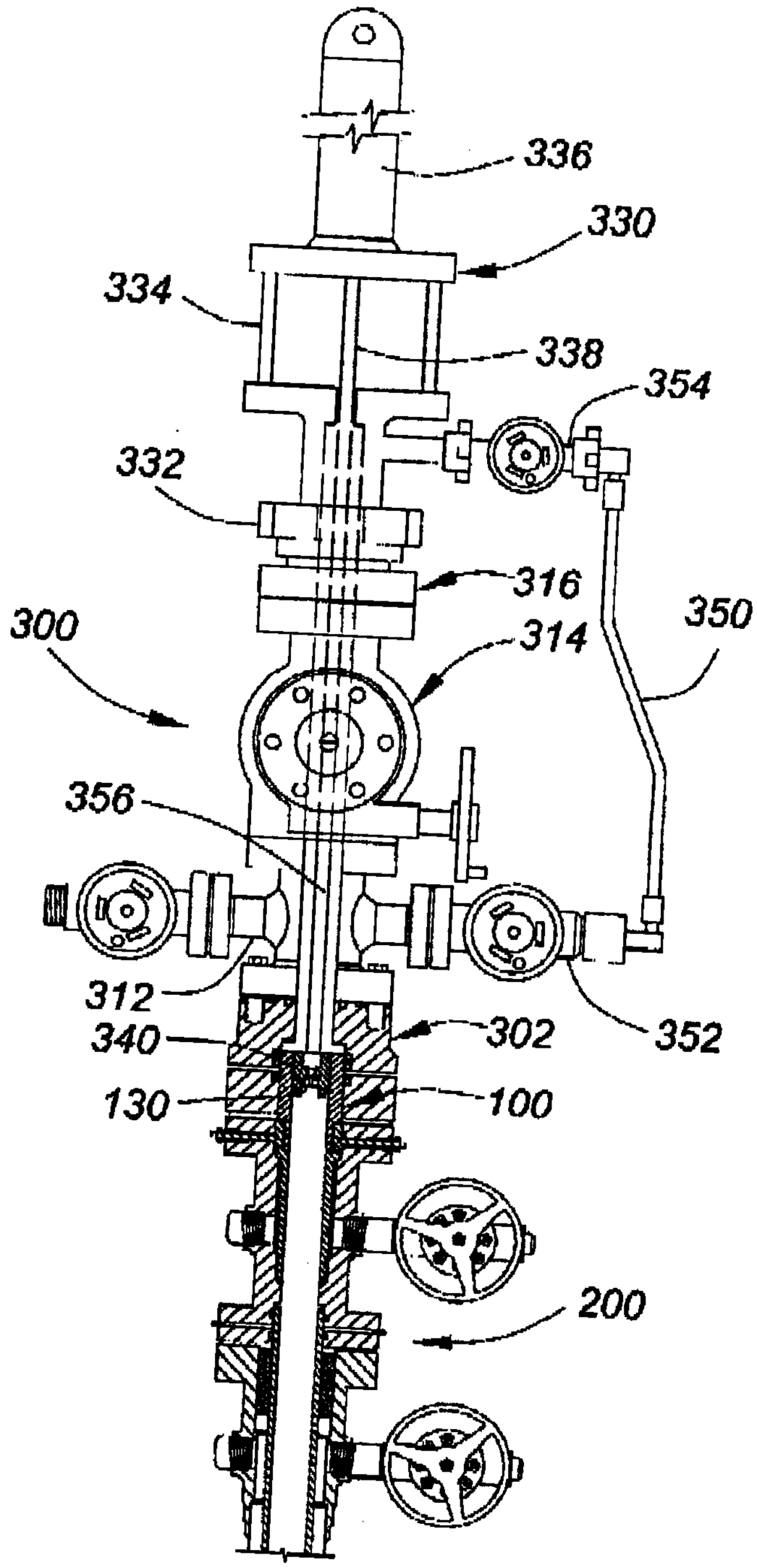
356
370
312
302
134
100c
200

FIG. 11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300
314
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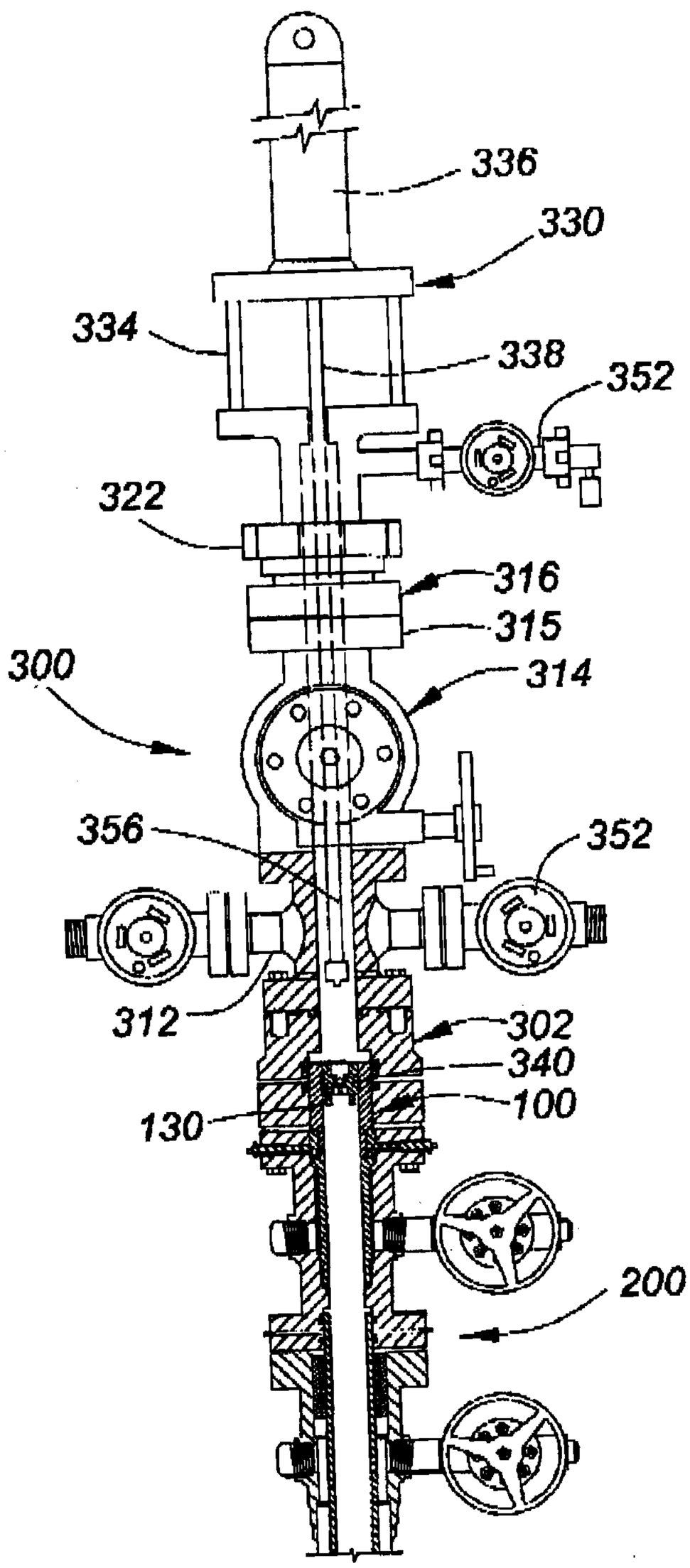
352
130
100
200

FIG. 12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300
314
356
352
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302
340
130
100
200

FIG. 13

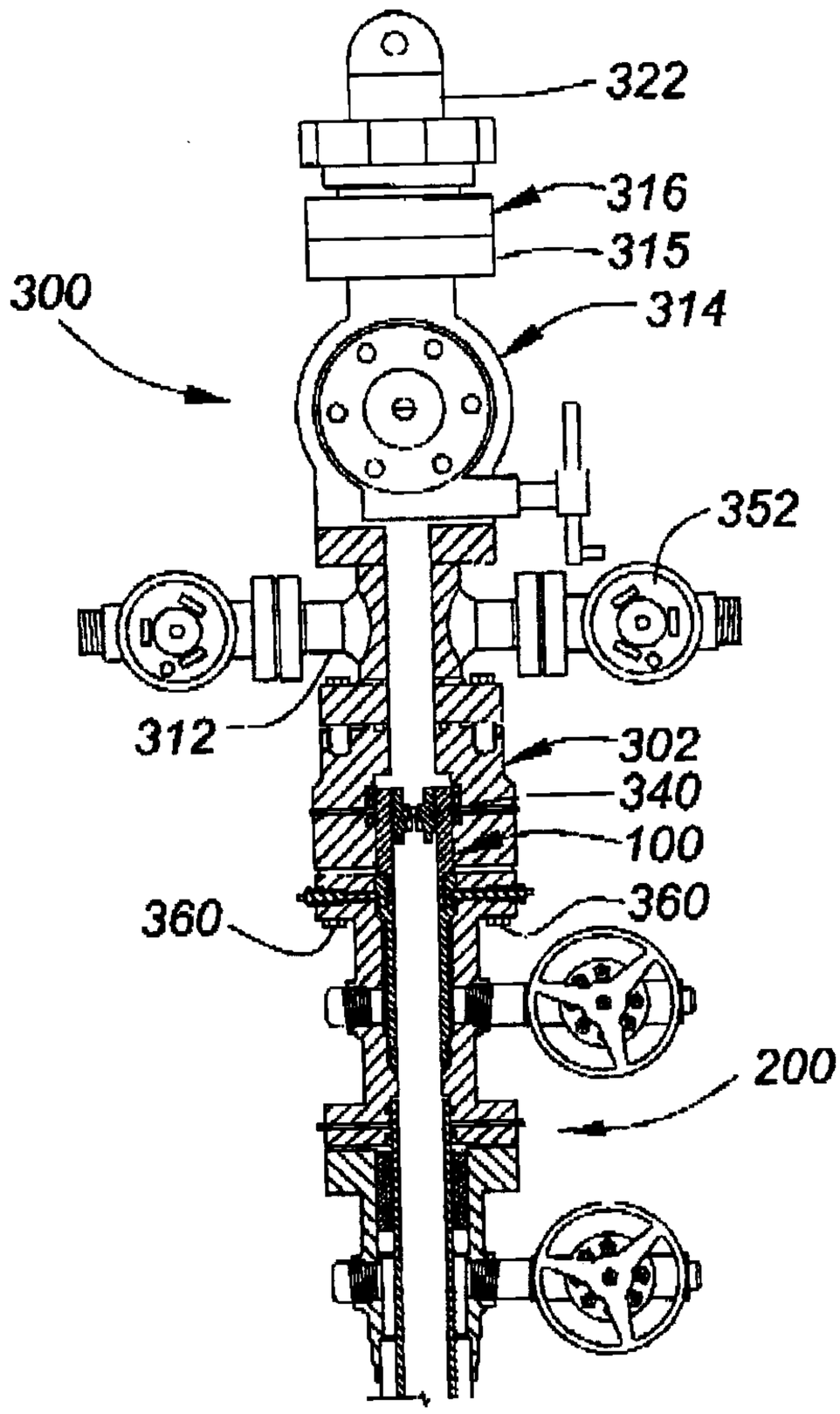


FIG. 14

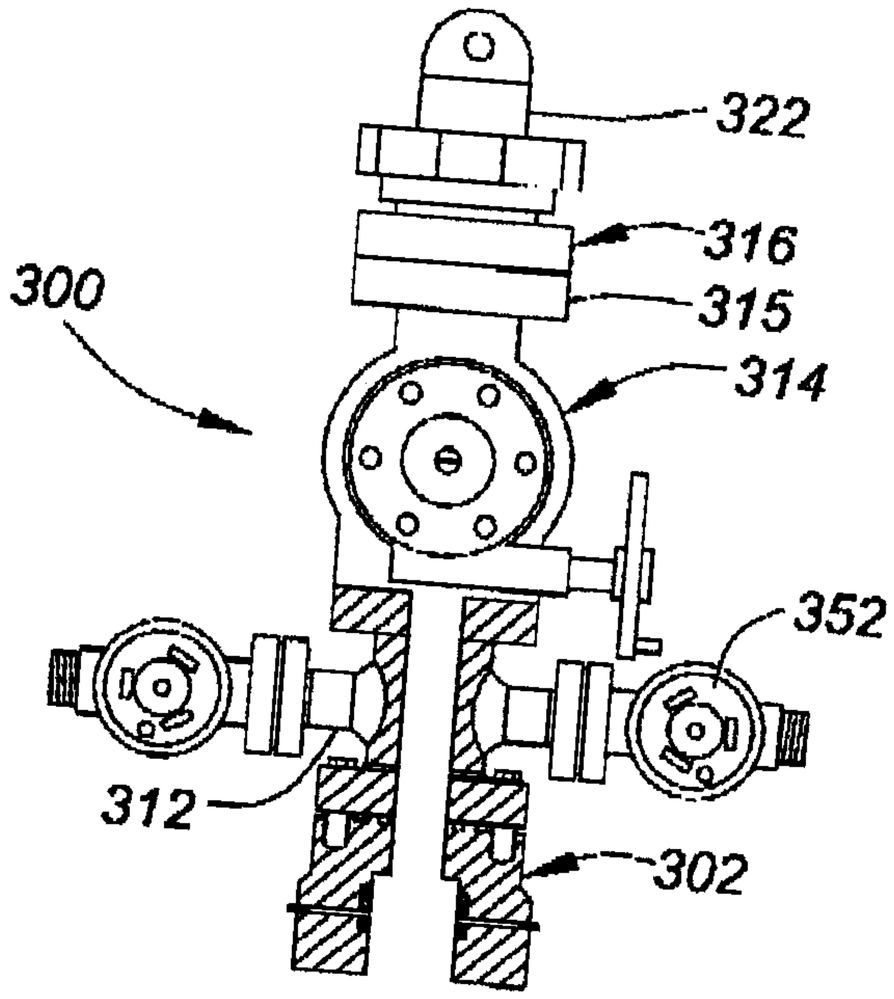


FIG. 15

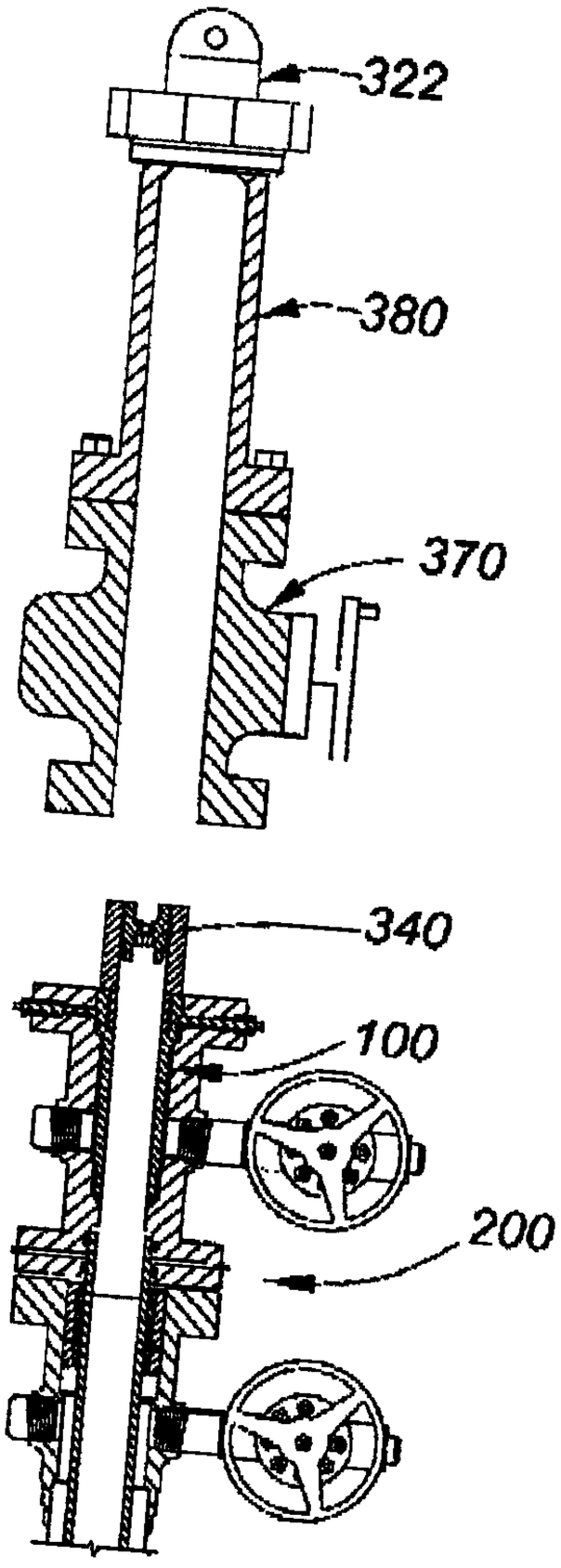


FIG. 16

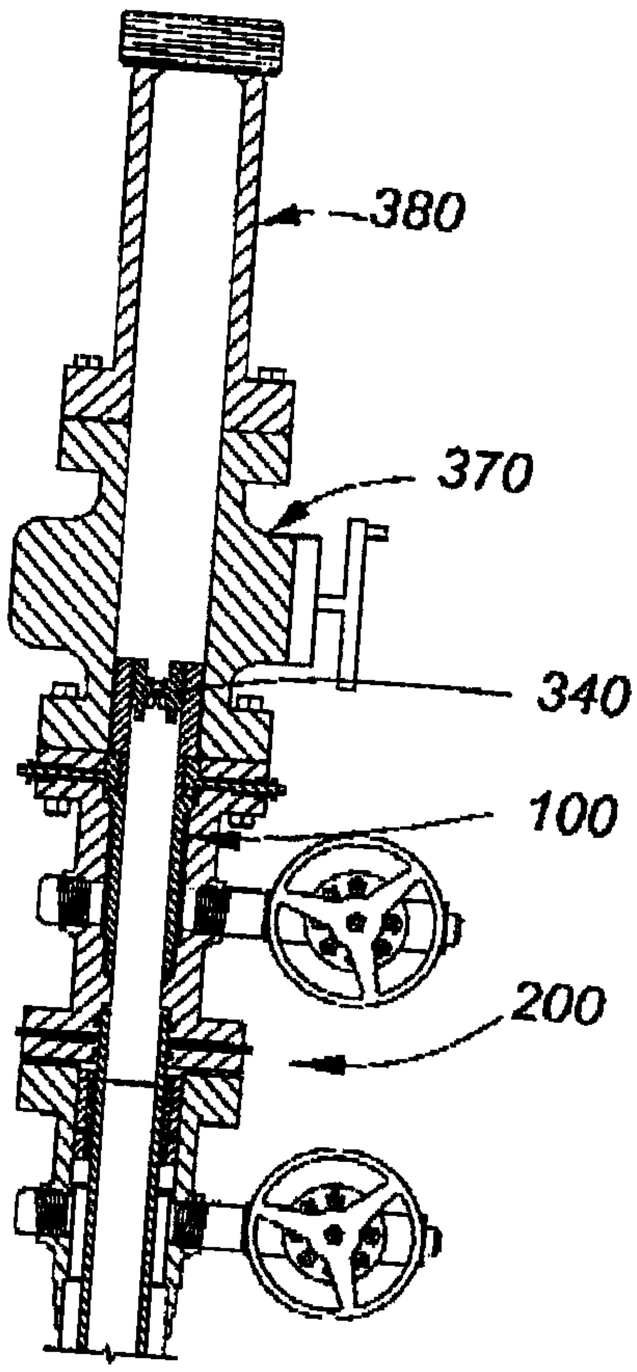


FIG. 17

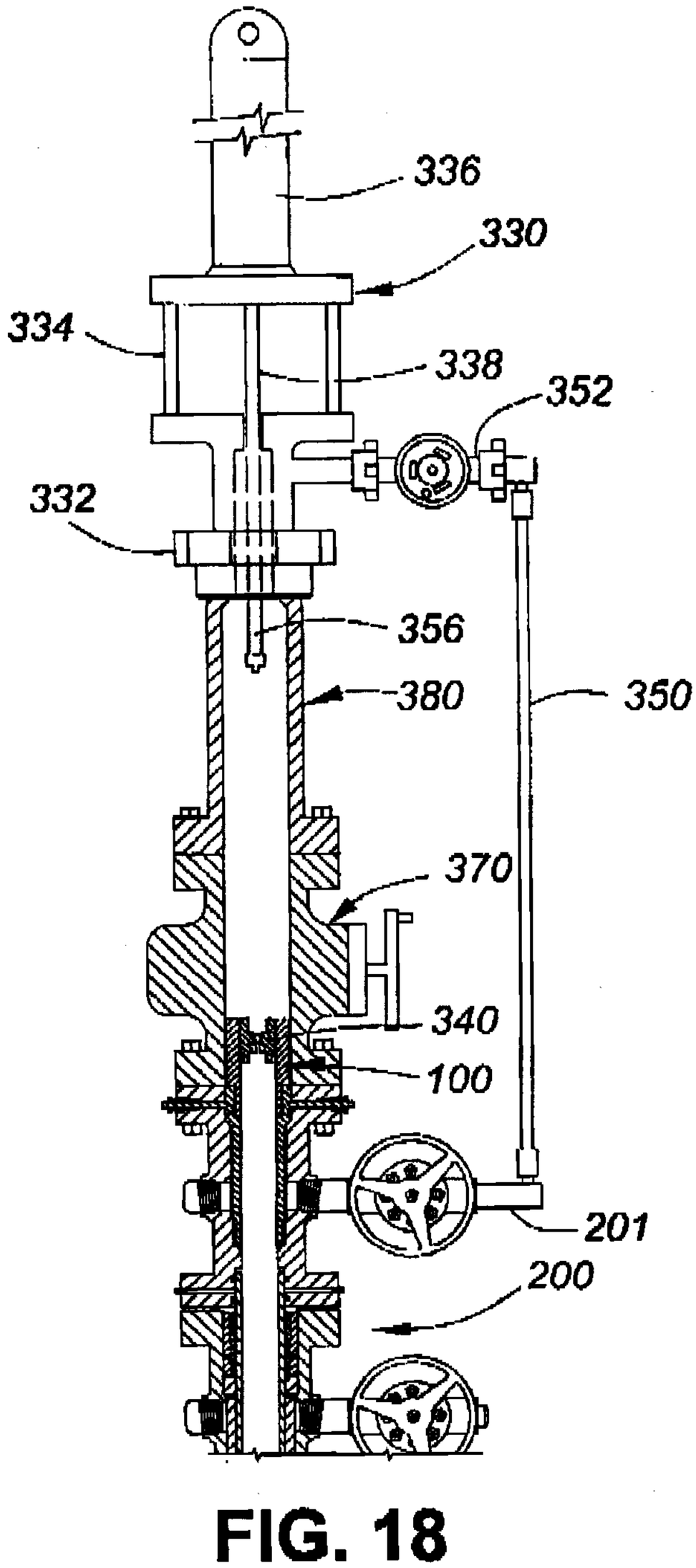


FIG. 18

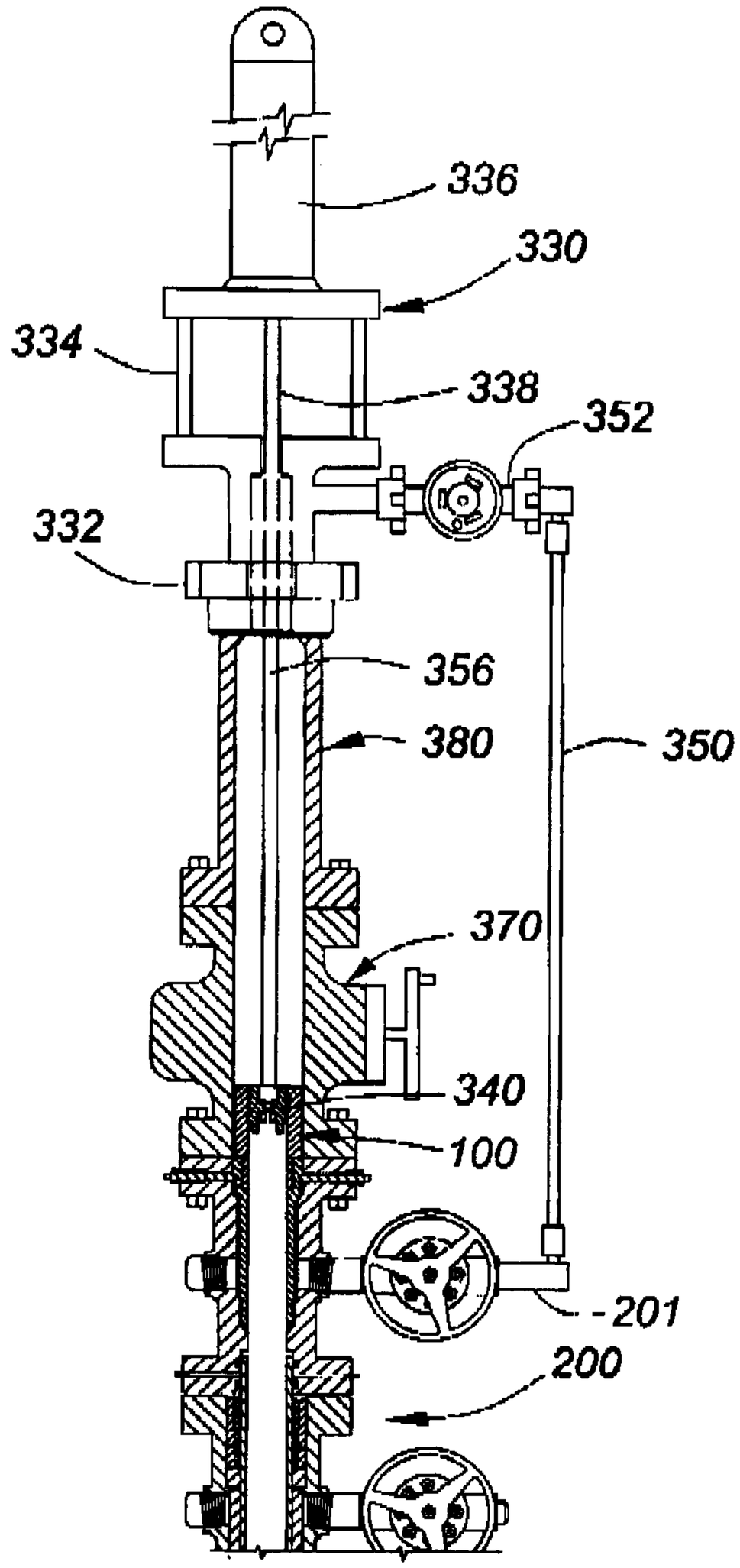


FIG. 19

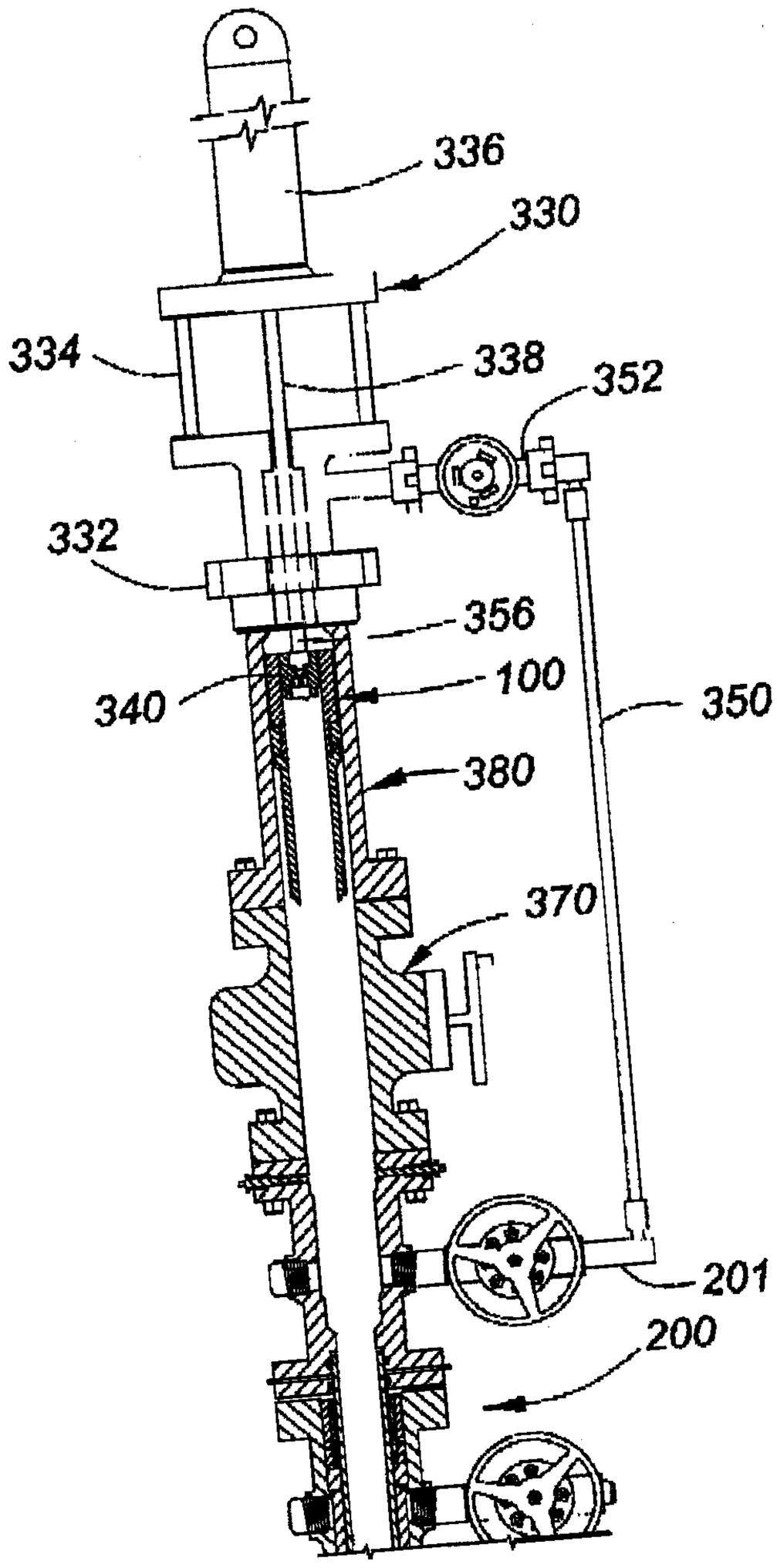


FIG. 20

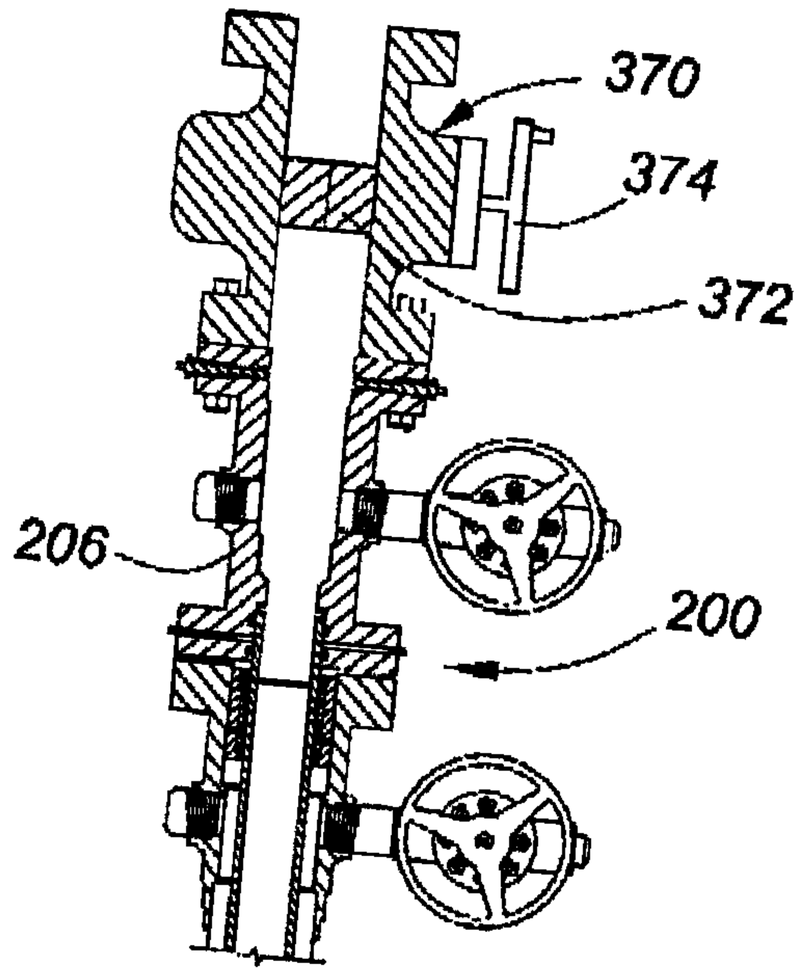
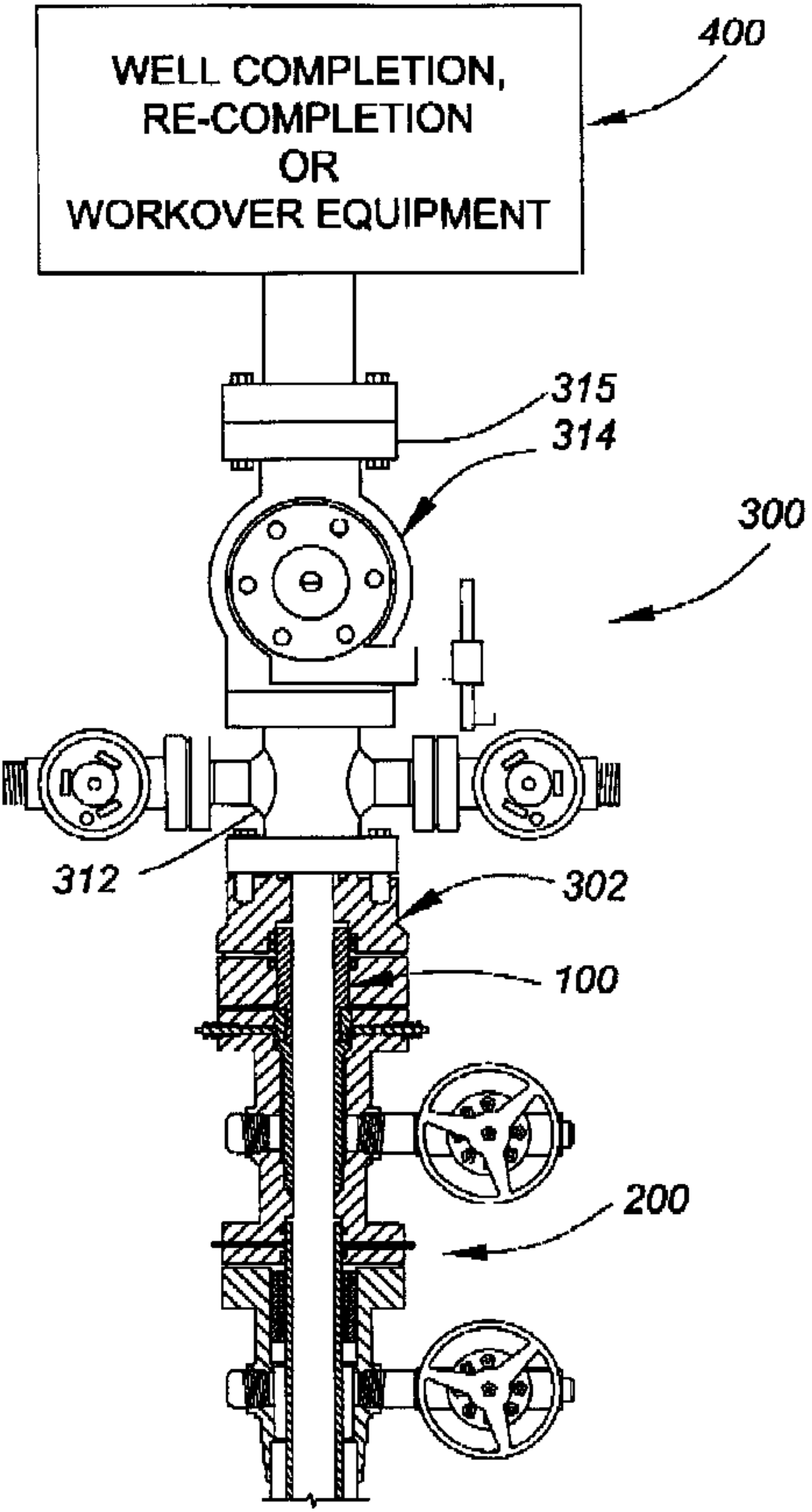


FIG. 21


WELL COMPLETION,
RE-COMPLETION
OR
WORKOVER EQUIPMENT
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