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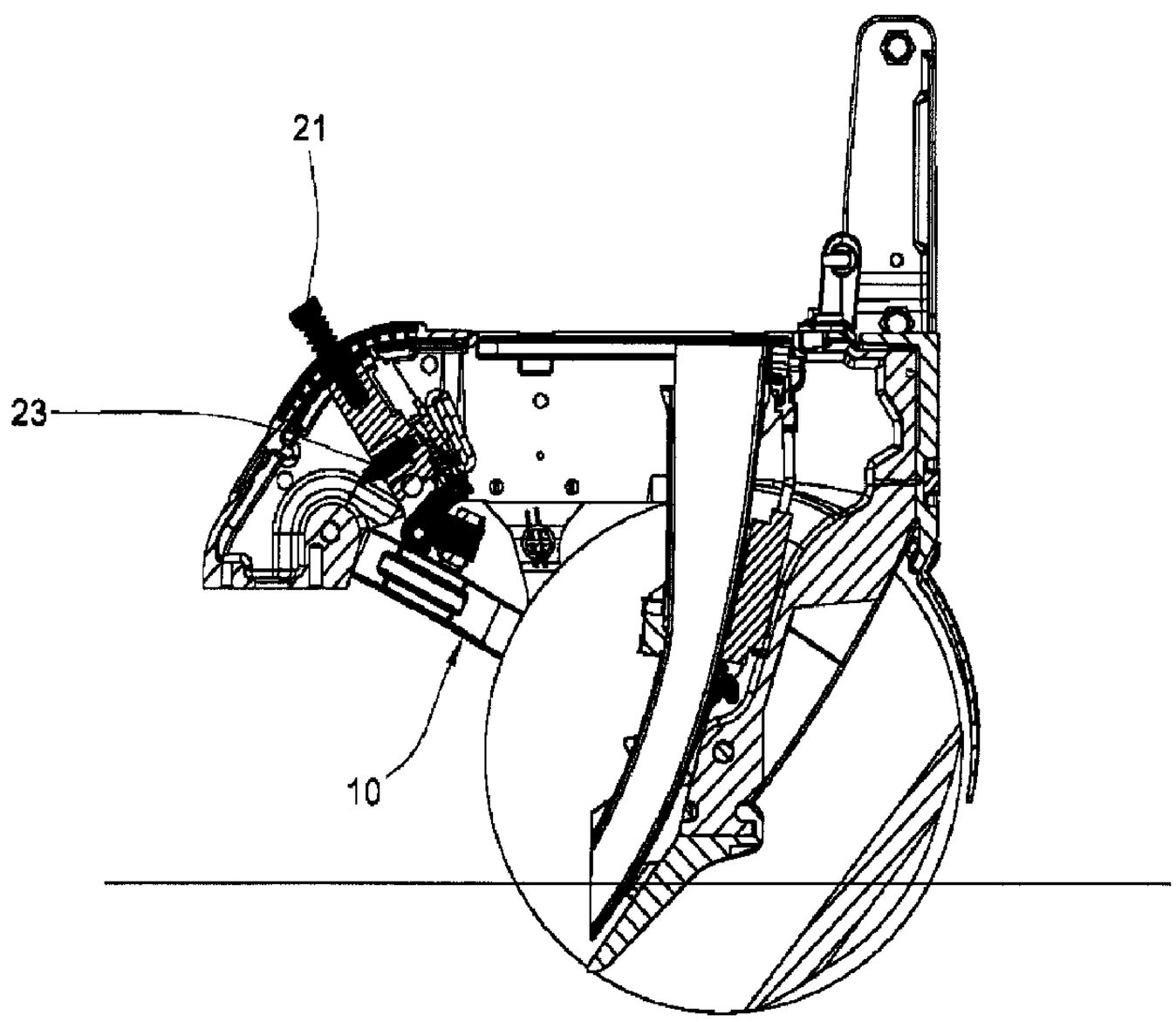
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(71) Demandeurs/Applicants:
DAWN EQUIPMENT COMPANY, US;
BASSETT, JOSEPH D., US

(72) Inventeur/Inventor:
BASSETT, JOSEPH D., US

(74) Agent: BRION RAFFOUL

(54) Titre : SYSTEME DE PLANTATION AGRICOLE DOTE D'UN CONTROLE AUTOMATIQUE DE PROFONDEUR
(54) Title: AGRICULTURAL PLANTING SYSTEM WITH AUTOMATIC DEPTH CONTROL



(57) Abrégé/Abstract:
A control system for controlling the down pressure applied to a soil-engaging component of an agricultural implement includes a down pressure actuator coupled to the soil-engaging component, and an energy storage device and a piston-containing cylinder are coupled to each other by a system containing pressurized fluid. A check valve is coupled between the energy storage device and the down pressure actuator to control the flow of the pressurized fluid from the energy storage device to the cylinder. A controllable relief valve and variable orifice are coupled between the down pressure actuator and the energy storage device to control the flow of the pressurized fluid from the cylinder to the energy storage device. A controller supplies control signals to the relief valve and variable orifice to control the flow of the pressurized fluid from the cylinder to the energy storage device based on the pressure of the pressurized fluid.

ABSTRACT

A control system for controlling the down pressure applied to a soil-engaging component of an agricultural implement includes a down pressure actuator coupled to the soil-engaging component, and an energy storage device and a piston-containing cylinder are coupled to each other by a system containing pressurized fluid. A check valve is coupled between the energy storage device and the down pressure actuator to control the flow of the pressurized fluid from the energy storage device to the cylinder. A controllable relief valve and variable orifice are coupled between the down pressure actuator and the energy storage device to control the flow of the pressurized fluid from the cylinder to the energy storage device. A controller supplies control signals to the relief valve and variable orifice to control the flow of the pressurized fluid from the cylinder to the energy storage device based on the pressure of the pressurized fluid.

AGRICULTURAL PLANTING SYSTEM WITH AUTOMATIC DEPTH CONTROL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Patent Application No. 15/856,875, filed December 28, 2017; U.S. Patent Application No. 15/637,692, filed June 29, 2017; and U.S. Provisional Patent Application No. 62/648,183, filed March 26, 2018, each of which are hereby incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

This invention relates generally to agricultural planters and, more particularly, to gauge wheel load sensors and down pressure control systems for agricultural planters.

BRIEF SUMMARY

In accordance with one embodiment, a control system for controlling the down pressure applied to a soil-engaging component of an agricultural implement includes a source of pressurized fluid, a down pressure actuator coupled to the soil-engaging component and to the source of pressurized fluid, an energy storage device and a piston-containing cylinder coupled to each other by a system containing pressurized fluid, a check valve coupled between the energy storage device and the down pressure actuator to control the flow of the pressurized fluid from the energy storage device to the cylinder, a controllable relief valve and a controllable variable orifice coupled between the down pressure actuator and the energy storage device to control the flow of the pressurized fluid from the cylinder to the energy storage device, a pressure sensor coupled to the pressurized fluid and producing an output signal corresponding to the pressure of the pressurized fluid, and a controller coupled to the pressure sensor to receive the output signal and configured to supply control signals to the controllable relief valve and the controllable variable orifice to control the flow of the pressurized fluid from the cylinder to the energy storage device based on the pressure of the pressurized fluid. The energy storage device is preferably an accumulator.

In one implementation, the controller supplies a control signal to the relief valve to open the relief valve in response to a predetermined change in the pressure of the pressurized fluid and also supplies a control signal to the variable orifice to control the size of the orifice when the relief valve is open, to control the rate of flow of pressurized fluid from the energy storage device to the cylinder.

In accordance with another embodiment, a control system for controlling the depth of an opener device in an agricultural planter comprises a gauge wheel on a pivotably mounted support arm, a mechanical element coupled to the support arm to move in response to changes in the angle of the support arm, a sensor adapted to measure changes in the relative elevations of the opener device and the gauge wheel to produce an output signal representing the current relative elevations of the opener device and the gauge wheel, and a control device receiving the output signal from the sensor and producing a second output signal for maintaining the opener device at a selected elevation relative to the gauge wheel.

Another implementation includes a moisture sensor producing a signal representing the moisture content of the soil being planted, and the control device is responsive to the moisture-representing signal for producing an output signal representing the desired depth of the opening device.

The sensor may translate the upward force from a pivoting gauge wheel support arm into a fluid pressure in a fluid chamber, and a pressure transducer may be coupled to the fluid chamber and produce an output signal that changes in proportion to changes in the fluid pressure in the fluid chamber. The control device may receive the output signal and use that output signal to produce a second output signal for maintaining said opener device at a selected elevation relative to said gauge wheel.

In yet another implementation, the control device supplies a control signal to a relief valve to open the relief valve in response to a predetermined change in the pressure of the pressurized fluid and also supplies a control signal to a variable orifice to control the size of the orifice when the relief valve is open, to control the rate of flow of pressurized fluid to the fluid chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical longitudinal section through a portion of an agricultural planter that includes a gauge wheel and an opener device.

FIG. 2 is an enlargement of the left side of FIG. 1.

FIG. 3 is a bottom perspective of the control portion of the equipment shown in FIG. 1.

FIG. 4 is an enlarged side elevation of the equipment shown in FIG. 3.

FIG. 5 is an enlarged top plan view of the equipment shown in FIG. 3.

FIG. 6 is an enlarged vertical longitudinal section through the equipment shown in FIG. 3.

FIG. 7 is a schematic diagram of a hydraulic control system for controlling the hydraulic system using a gauge wheel load sensor.

FIG. 8 is a schematic diagram of a modified hydraulic control system for controlling the hydraulic system using a gauge wheel load sensor.

FIG. 9 is a waveform diagram illustrating different modes of operation provided by the hydraulic control systems of FIGs. 7 and 8.

FIG. 10 is a plan view of a gauge wheel transducer system for an agricultural planter that includes a gauge wheel and an opener device.

FIG. 11 is a side elevation of the transducer system shown in FIG.10.

FIG. 12 is a sectional view taken along line A--A in FIG. 10.

FIG. 13 is a side elevation, partially in section, of the transducer system of FIGs. 10-12 mounted on a gauge wheel and its supporting structure.

FIG. 14 is a perspective view of portions of the devices shown in FIG. 13.

FIG. 15 is a plan view similar to FIG. 10 but with portions removed to show the equalizer arm.

FIG. 16 is a plan view of a modified transducer system.

FIG. 17 is a longitudinal section taken along line 17--17 in FIG. 16.

FIG. 18A is a side elevation of a modified sensing system for detecting the pressure exerted on a pair of gauge wheels.

FIG. 18B is an end elevation of the system shown in FIG. 18A.

FIG. 19 is a schematic diagram of a hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 20 is a schematic diagram of a first modified hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 21 is a schematic diagram of a second modified hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 22 is a schematic diagram of a third modified hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 23 is a schematic diagram of a fourth modified hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 24 is a flow chart of an exemplary algorithm executed by the controller in the system of FIG. 23.

FIG. 25 is a schematic diagram of a fifth modified hydraulic and electrical control system for controlling a down pressure actuator.

FIG. 26 is sectional elevation of a modified embodiment of an automatic depth control system.

FIG. 27 is a reduced version of the control system of FIG. 26 positioned adjacent a gauge wheel and its support arm.

FIG. 28 is a perspective view of the gauge wheel and control system shown in FIG. 27

FIG. 29 is an enlarged top plan view of the gauge wheel and control system shown in FIG.28.

FIG. 30 is a side elevation of the control system shown in FIG. 26.

FIG. 31 is an enlarged section taken along line 31-31 in FIG. 30.

FIG. 32 is an enlarged section taken along line 32-32 in FIG. 30.

FIG. 33 is an enlarged view of the slider/depth adjuster in the control system of FIG. 30, with the slider/depth adjuster in two different positions.

FIG. 34 is a flow chart of an algorithm for use in the control system of FIGs. 26-33.

DETAILED DESCRIPTION

An agricultural planter typically includes a number of individual row units, each of which includes its own row cleaner device, row opener device and row closing device. The down pressure is typically controlled separately for each row unit or each of several groups of row units, and is preferably controlled separately for one or more of the individual devices in each row unit, as described in more detail in pending U.S. application Serial No. 14/146,822 filed January 3, 2014, which is incorporated by reference herein in its entirety.

FIGs. 1-6 illustrate an improved gauge wheel load sensor that takes the upward force from a pivoting planter gauge wheel support, such as the pivoting support arms 10 in the row unit equipment shown in FIGs. 1 and 2, and translates that force into a fluid pressure in a fluid chamber 11. The gauge wheel support arms push against an equalizer support 12, which is connected to a slider 13 that slides along an arcuate guide 14. Movement of the slider along the guide 14 moves one end of a connector arm 15 that is attached at its other end to a rocker arm 16 mounted for pivoting movement abound a stationary pivot pin 17. The lower end of the rocker arm 16 engages a ram 18 in a hydraulic cylinder 19 that is filled with a pressurized hydraulic fluid.

Depth adjustment is accomplished in the conventional sense by pivoting the assembly around a pivot 20, and locking a handle 21 into the desired position with a mechanism 22. With this design it is preferred that that there is no air trapped in the fluid chamber 11. For this reason the mechanism includes a bleed valve 23. The process for removal of air is to extend the ram to the maximum extent with calibration/travel limiter plates 24 (FIG. 4) removed. The system is then filled completely with fluid with the bleed valve 23 closed. Then the bleed valve 23 is opened, and the rocker arm 14 is pushed against the ram 16 to move the ram to the exact place where the calibration/travel limit plates 24 allow a calibration plate retaining screw 25 to fit into a hole. This ensures that each assembly is set the same so all the row units of the planter are at the same depth. At this point the bleed valve 23 is closed. With all air removed, the mechanical/fluid system will act as a rigid member against forces in compression. The travel limiter plate 24 keeps a cam pivot weldment from falling down when the planter is lifted off the ground.

Standard industry practice is to use a strain gauge to directly measure the planter gauge wheel load. The design shown in FIGs. 1-6 is an improvement over the state of the art because it allows the sensor to measure only the down force on the gauge wheels. In typical designs using strain gauge type sensors, the mechanical linkage that allows the gauge wheels to oscillate causes the measured wheel force to have substantial noise due to changes in the force being applied. For this reason it can be difficult to determine which parts of the signal correspond to actual changes in down force on the gauge wheels, versus signal changes that are due to movement of components of the gauge wheel support mechanism. The reason for this is that strain gauge sensors will only measure the force that is being applied in a single plane. Because of the linkage and pivot assembly that is used on typical planters, the force being applied to the strain gauge type designs can change based on the depth setting or whether the planter gauge wheels are oscillating over terrain. In this way they will tend to falsely register changes in gauge wheel down force and make it difficult to have a closed loop down pressure response remain consistent.

The fluid seal of the pressure sensor described here creates friction in the system which has the effect of damping out high frequency noise. Agricultural fields have very small scale variations in the surface which cause noise to be produced in the typical down force sensor apparatus. By using fluid pressure this invention decouples the sensor from the mechanical linkage and allows the true gauge wheel force to be more accurately measured. Lowering the amount of systematic noise in the gauge wheel load output sensor makes it easier to produce

an automatic control system that accurately responds to true changes in the hardness of the soil, as opposed to perceived changes in soil hardness due to noise induced on the sensor.

FIG. 7 is a schematic diagram of a hydraulic control system for any or all of the hydraulic actuators in a down pressure control system. The hydraulic cylinder 2600 is supplied with pressurized hydraulic fluid from a source 2601 via a first controllable two-position control valve 2602, a restriction 2603 and a check valve 2604. The pressurized hydraulic fluid supplied to the cylinder 2600 can be returned from the cylinder to a sump 2605 via a second controllable two-position control valve 2606, a restriction 2607 and a check valve 2608. Both the control valves 2602 and 2606 are normally closed, but can be opened by energizing respective actuators 2609 and 2610, such as solenoids. Electrical signals for energizing the actuators 2609 and 2610 are supplied to the respective actuators via lines 2611 and 2612 from a controller 2613, which in turn may be controlled by a central processor 2614. The controller 2613 receives input signals from a plurality of sensors, which in the example of FIG. 7 includes a pressure transducer 2615 coupled to the hydraulic cylinder 2600 via line 2616, and a ground hardness sensor 2617. An accumulator 2618 is also coupled to the hydraulic cylinder 2600, and a relief valve 2619 connects the hydraulic cylinder 2600 to the sump 2605 in response to an increase in the pressure in the cylinder 2600 above a predetermined level.

To reduce the energy required from the limited energy source(s) available from the tractor or other propulsion device used to transport the row units over an agricultural field, the control valves 2602 and 2606 are preferably controlled with a pulse width modulation (PWM) control system implemented in the controller 2613. The PWM control system supplies short-duration (e.g., in the range of 50 milliseconds to 2 seconds with orifice sizes in the range of 0.020 to .2 inch) pulses to the actuators 2609 and 2610 of the respective control valves 2602 and 2606 to open the respective valves for short intervals corresponding to the widths of the PWM pulses. This significantly reduces the energy required to increase or decrease the pressure in the hydraulic cylinder 2600. The pressure on the exit side of the control valve is determined by the widths of the individual pulses and the number of pulses supplied to the control valves 2602 and 2606. Thus, the pressure applied to the hydraulic cylinder 2622 may be controlled by separately adjusting the two control valves 2602 and 2606 by changing the width and/or the frequency of the electrical pulses supplied to the respective actuators 2609 and 2610, by the controller 2613. This avoids the need for a constant supply current, which is a significant advantage when the only available power

source is located on the tractor or other vehicle that propels the soil-engaging implement(s) across a field.

The hydraulic control system of FIG. 7 may be used to control multiple hydraulic cylinders on a single row unit or a group of row units, or may be replicated for each individual hydraulic cylinder on a row unit having multiple hydraulic cylinders. For example, in the system described above having a ground hardness sensor located out in front of the clearing wheels, it is desirable to have each hydraulic cylinder on any given row unit separately controlled so that the down pressure on each tool can be adjusted according to the location of that tool in the direction of travel. Thus, when the ground hardness sensor detects a region where the soil is softer because it is wet, the down pressure on each tool is preferably adjusted to accommodate the softer soil only during the time interval when that particular tool is traversing the wet area, and this time interval is different for each tool when the tools are spaced from each other in the direction of travel. In the case of a group of row units having multiple hydraulic cylinders on each row unit, the same hydraulic control system may control a group of valves having common functions on all the row units in a group.

FIG. 8 is a schematic diagram of a modified hydraulic control system that uses a single three-position control valve 2620 in place of the two two-position control valves and the two check valves used in the system of FIG. 7. The centered position of the valve 2620 is the closed position, which is the normal position of this valve. The valve 2620 has two actuators 2620a and 2620b, one of which moves the valve to a first open position that connects a source 2621 of pressurized hydraulic fluid to a hydraulic cylinder 2622 via restriction 2620c, and the other of which moves the valve to a second open position that connects the hydraulic cylinder 2622 to a sump 2623. Electrical signals for energizing the actuators 2620a and 2620b are supplied to the respective actuators via lines 2624 and 2625 from a controller 2626, which in turn may be controlled by a central processor 2627. The controller 2626 receives input signals from a pressure transducer 2628 coupled to the hydraulic cylinder 2622 via line 2629, and from an auxiliary sensor 2630, such as a ground hardness sensor. An accumulator 2631 is coupled to the hydraulic cylinder 2622, and a relief valve 2632 connects the hydraulic cylinder 2622 to the sump 2623 in response to an increase in the pressure in the cylinder 2622 above a predetermined level.

As depicted in FIG. 9, a PWM control system supplies short-duration pulses P to the actuators 2620a and 2620b of the control valve 2620 to move the valve to either of its two open positions for short intervals corresponding to the widths of the PWM pulses. This

significantly reduces the energy required to increase or decrease the pressure in the hydraulic cylinder 2622. In FIG. 9, pulses P1-P3, having a voltage level V1, are supplied to the actuator 2620b when it is desired to increase the hydraulic pressure supplied to the hydraulic cylinder 2622. The first pulse P1 has a width T1 which is shorter than the width of pulses P2 and P3, so that the pressure increase is smaller than the increase that would be produced if P1 had the same width as pulses P2 and P3. Pulses P4-P6, which have a voltage level V2, are supplied to the actuator 2620a when it is desired to decrease the hydraulic pressure supplied to the hydraulic cylinder 2622. The first pulse P4 has a width that is shorter than the width T2 of pulses P2 and P3, so that the pressure decrease is smaller than the decrease that would be produced if P4 had the same width as pulses P5 and P6. When no pulses are supplied to either of the two actuators 2620a and 2620b, as in the "no change" interval in FIG. 9, the hydraulic pressure remains substantially constant in the hydraulic cylinder 2622.

FIGs. 10-15 illustrate a modified gauge wheel load sensor that includes an integrated accumulator 122. The purpose of the accumulator 122 is to damp pressure spikes in the sensor when the planter is operating at low gauge wheel loads. When the forces that the gauge wheel support arms 110 are exerting on the hydraulic ram 117 are near zero, it is more common for the surface of the soil or plant residue to create pressure spikes that are large in relation to the desired system sensor pressure. These pressure spikes produce corresponding changes in the vertical position (elevation) of the gauge wheels. As the target gauge wheel down force increases, and consequently the pressure in the fluid chamber 111 and the transducer output voltage from sensor 118, the small spikes of pressure due to variations in the soil surface or plant residue decrease proportionally.

In the present system, rather than have a perfectly rigid fluid coupling between the ram 117 and the pressure transducer 118, as load increases on the ram 117, the fluid first pushes against a piston 125 of the accumulator 122 that is threaded into a side cavity 123 in the same housing that forms the main cavity for the ram 117. The increased pressure compresses an accumulator spring 126 until the piston 125 rests fully against a shoulder on the interior wall of the accumulator housing 127, thus limiting the retracting movement of the accumulator piston 125. At this point, the system becomes perfectly rigid. The amount of motion permitted for the accumulator piston 125 must be very small so that it does not allow the depth of the gauge wheel setting to fluctuate substantially. The piston accumulator (or other energy storage device) allows the amount of high frequency noise in the system to be reduced at low gauge-wheel loads. Ideally an automatic down pressure control system for an

agricultural planter should maintain a down pressure that is as low as possible to avoid over compaction of soil around the area of the seed, which can inhibit plant growth. However, the performance of most systems degrades as the gauge wheel load becomes close to zero, because the amount of latent noise produced from variation in the field surface is large in relation to the desired gauge wheel load.

Planter row units typically have a gauge wheel equalizer arm 130 that is a a single unitary piece. It has been observed that the friction between the equalizer arm 130 and the gauge wheel support arms 110, as the gauge wheel 115 oscillates up and down, can generate a substantial amount of noise in the sensor. At different adjustment positions, the edges of the equalizer arm 130 contact the support arms 10 at different orientations and can bite into the surface and prevent forces from being smoothly transferred as they increase and decrease. When the equalizer arm 130 is a single unitary piece, there is necessarily a high amount of friction that manifests itself as signal noise in the sensor. This signal noise makes it difficult to control the down pressure system, especially at low levels of gauge wheel load.

To alleviate this situation, the equalizer arm 130 illustrated in FIG. 16 has a pair of contact rollers 131 and 132 are mounted on opposite ends of the equalizer arm. These rollers 131 and 132 become the interface between the equalizer arm and the support arms 110, allowing forces to be smoothly transferred between the support arms 110 and the equalizer arm 130. The roller system allows the gauge wheel support arms 110 to oscillate relative to each other without producing any sliding friction between the support arms 110 and the equalizer arm 130. This significantly reduces the friction that manifests itself as signal noise in the sensor output, which makes it difficult to control the down pressure control system, especially at low levels of gauge wheel load.

FIG. 17 is a longitudinal section through the device of FIG. 16, with the addition of a rocker arm 150 that engages a ram 151 that controls the fluid pressure within a cylinder 152. A fluid chamber 153 1adjacent the inner end of the ram 151 opens into a lateral cavity that contains a pressure transducer 154 that produces an electrical output signal representing the magnitude of the fluid pressure in the fluid chamber 153. The opposite end of the cylinder 152 includes an accumulator 155 similar to the accumulator 125 included in the device of FIG. 9 described above. Between the fluid chamber 153 and the accumulator 155, a pair of valves 156 and 157 are provided in parallel passages158 and 159 extending between the chamber 153 and the accumulator 155. The valve 156 is a relief valve that allows the pressurized fluid to flow from the chamber 153 to the accumulator 155 when the ram 151

advances farther into the chamber 153. The valve 157 is a check valve that allows pressurized fluid to flow from the accumulator 155 to the chamber 153 when the ram 151 moves outwardly to enlarge the chamber 153. The valves 156 and 157 provide overload protection (e.g., when one of the gauge wheels hits a rock) and to ensure that the gauge wheels retain their elevation setting.

FIGs. 18A and 18B illustrate a modified sensor arrangement for a pair of gauge wheels 160 and 161 rolling on opposite sides of a furrow 162. The two gauge wheels are independently mounted on support arms 163 and 164 connected to respective rams 165 and 166 that control the fluid pressure in a pair of cylinders 167 and 168. A hydraulic hose 169 connects the fluid chambers of the respective cylinders 167 and 168 to each other and to a common pressure transducer 170, which produces an electrical output signal corresponding to the fluid pressure in the hose 169. The output signal is supplied to an electrical controller that uses that signal to control the down forces applied to the two gauge wheels 160 and 161. It will be noted that the two gauge wheels can move up and down independently of each other, so the fluid pressure sensed by the transducer 170 will be changed by vertical movement of either or both of the gauge wheels 160 and 161.

FIGs. 19-22 illustrate electrical/hydraulic control systems that can be used to control a down-pressure actuator 180 in response to the electrical signal provided to a controller 181 by a pressure transducer 182. In each system the transducer 182 produces an output signal that changes in proportion to changes in the fluid pressure in a cylinder 183 as the position of a ram 184 changes inside the cylinder 183. In FIG. 19, the pressurized fluid chamber in the cylinder 183 is coupled to an accumulator 185 by a relief valve 186 to allow pressurized fluid to flow to the accumulator, and by a check valve 187 to allow return flow of pressurized fluid from the accumulator to the cylinder 183. In FIG. 20, the accumulator 185 is replaced with a pressurized fluid source 188 connected to the check valve 187, and a sump 189 connected to the relief valve 186. In FIG. 21, the accumulator 185 is connected directly to the pressurized fluid chamber in the cylinder 183, without any intervening valves. In the system of FIG. 22, there is no accumulator, and the pressure sensor 182 is connected directly to the pressurized fluid chamber in the cylinder 183.

FIG. 23 illustrates a modified electrical/hydraulic control system for controlling a down-pressure actuator 200 in response to an electrical signal provided to a controller 201 by a pressure transducer 202. The transducer 202 produces an output signal that changes in proportion to changes in the fluid pressure in a cylinder 203 as the position of a ram 204

changes inside the cylinder 203. Thus the ram 204 functions as a gauge wheel sensor. The pressurized fluid chamber in the cylinder 203 is coupled to an accumulator 205 by a controllable valve 206 to allow pressurized fluid to flow to the accumulator 205 through a controllable variable orifice 207, and by a check valve 208 to allow return flow of pressurized fluid from the accumulator 205 to the cylinder 203.

When the force applied to the piston 204, e.g., by the rocker arm 14, increases when the ground-engaging implement encounters harder ground or strikes a rock, the piston 204 is moved to the left. This causes a portion of the pressurized fluid to flow through the variable orifice 207 and the relief valve 206 to the accumulator 205. Both the variable orifice 207 and the relief valve 206 are controlled by electrical control signals from the controller 201, which receives the output signal from the pressure sensor 202.

The variable orifice 207 acts as an adjustable and controllable damper affecting the stiffness of, for example, a planter gauge wheel suspension. Also, the electro-proportional relief valve 206 allows the stiffness of, for example, a planter row unit ride to be changed dynamically. For example, the controller 201 can be programmed to allow a stiffer setting or higher relief pressure in smooth fields. In rougher fields, the relief pressure can be reduced to allow more travel of the gauge wheels relative to the opener disks. This results in less bouncing of the row unit. The amount of variation in the pressure sensor output signal reflects variations in the roughness of the field. The controller can use this variation or smoothness of the pressure signal over time to control the relief pressure in real time.

When the force applied to the piston is reduced, the fluid pressure within the cylinder 203 is reduced, and the accumulator causes a portion of the fluid to flow back into the cylinder 203 via the check valve 208. The reduced pressure is sensed by the pressure sensor 202, which produces a corresponding change in the sensor output signal supplied to the controller 201.

The controller 201 is programmed with an algorithm represented by the flow chart in FIG. 24. The first step 250 selects a predetermined system "mapping" of variables such as the diameter of the variable orifice 207 and relief pressure in the cylinder 203. Other variables such as the down pressure control system set point can be included in the mapping. The mapping is based on tillage and soil conditions that lead to typical characteristics in the sensor data. After the mapping of the selected variables, a field operation such as planting, fertilizing or tillage, is started at step 251, and at step 252 the pressure transducer 202 supplies the controller 201 with a signal that varies with the fluid pressure in the cylinder

203, which corresponds to changes in the gauge wheel load. The controller 201 computes a running average value of the gauge wheel load for a selected time period at step 253, and at step 254 supplies a control signal to the down-pressure actuator 200 to control the down pressure in a closed loop.

In parallel with the closed loop control of the down-pressure actuator 200, the controller also adjusts the values of the mapped variables in steps 255-259. Step 255 performs a statistical analysis of the gauge wheel sensor values to determine the signal-to-noise ratio ("SNR"), of the level of the desired signal to the level of background noise in the gauge wheel down pressure signal. The SNR can be determined by any of the known standard procedures, such as determining the ratio of the arithmetic mean to the standard deviation. The controller then determines whether the current SNR is above or below a preselectd value, at steps 256 and 257. If the SNR is determined to be above the preselected value at step 256, step 258 adjusts the mapped values to reduce the target set point and the orifice diameter and to increase the relief pressure. If the SNR is below the preselected value at step 257, step 259 adjusts the mapped values to increase the target set point and the orifice diameter and to decrease the relief pressure.

FIG. 25 illustrates a modified control system in which the relief valve 206 is replaced with a controllable 3-way valve 306, and a sump 309 and a pressure supply pump 310 are connected to the valve 306. This control system also includes a position sensor 312, such as an inductive sensor or a linear encoder, which supplies the controller 301 with a signal representing the position of the piston 304 within the cylinder 303. The signal from the position sensor 302 enables the controller 301 to identify in real time the depth of the opener relative to the gauge wheel.

When the 3-way valve 306 is in its center position, as shown in FIG. 25, the cylinder 303 is disconnected from both the sump 309 and the pump 310, and thus the cylinder 303 is coupled to the accumulator 305 via the variable orifice 307. This is the normal operating position of the valve 306. When the controller 301 produces a signal that moves the valve 306 to the right, the valve connects the cylinder 303 to the pressure supply pump 310 to increase the fluid pressure in the cylinder 303 to a desired level. When the controller 301 produces a signal that moves the valve 306 to the left, the valve connects the cylinder 303 to the sump 309 to relieve excessive pressure in the cylinder 303.

The system in FIG. 25 allows active control of the depth of the ground-engaging element by using the pressure control valve 306 to change the pressure in the cylinder 303.

Because the piston 304 is connected to the gauge wheel arms via the rocker, the gauge wheels move relative to the opener disks as the piston 304 moves in and out.

When planting an agricultural field with seeds, it is important to control the planting depth in real time as the planting machine traverses the field, because it is critical that the seeds all be planted into moisture so that each seed emerges from the soil at the same time. The depth of the seed can be changed based on some type of moisture sensor system, or even based on a satellite or drone system that is able to detect changes in the soil chemistry that would make it desirable to change the depth of the planted seed in different areas of the field.

FIG. 26 illustrates a modified system that enables the operator to select a desired planting depth setting, and then automatically maintains the actual planting depth within a selected range above and below the selected depth. In this system, a fluid chamber 408 includes a fluid port 420 (see FIGs. 30 and 31) that is connected to one or more valves to allow hydraulic fluid to be added to or removed from the chamber 408 to change the angle of the opener disc relative to the gauge wheel. A distance sensor 411 produces an output signal representing the position of the opener disc support arm along the arcuate guide, which changes as the angle between the two support arm changes with changes in the depth of the opener disc relative to the elevation of the gauge wheel (the soil surface). The output signal from the distance sensor 411 will be referred to as the "seed depth" signal because the depth of the opener disc determines the depth of the furrow in which the seed is planted.

In one embodiment that provides both environmental protection and low cost, a pair of valves are controlled to open and close to extend or retract the ram of a hydraulic cylinder to move a slider/depth adjuster to the desired position. If the position of the slider/depth adjuster falls out of tolerance, the system automatically opens and closes the valve to maintain the correct setting. Each row unit may be provided with its own valves and associated control system. This design may use a small hydraulic ram 406 to perform what would typically be a manual depth adjustment. The ram 406 pushes on a rocker arm 404, which is connected to a link arm 410, which is connected to a slider piece 412. The slider piece 412 is connected to the planter row unit depth adjustment handle and is free to move throughout the same adjustment range that the handle could be moved manually to effect a depth adjustment.

The pressure inside the chamber 408 is equivalent to the force on the gauge wheels. Thus, a single device can provide both depth adjustment and gauge wheel force measurement, without the need for the typical strain gauge. The system allows fluid pressure

to be used both to change the depth that the seed is planted in the ground and how hard the planter gauge wheels are pushing on the ground in a single device.

In the illustrative system, the fluid port 420 in the fluid chamber 408 is connected to one or more valves to allow hydraulic fluid to be added to or removed from the chamber 408 to change the angle of the opener disc relative to the gauge wheel for any given soil condition.

The distance sensor 411 produces an output signal corresponding to the position of the piston within the hydraulic cylinder, which changes when the depth of the opening disc changes relative to the elevation of the gauge wheel. For example, if the soil engaged by the opening disc becomes harder, the depth of the opening disc becomes smaller unless the down pressure applied to the opening disc is increased. Conversely, if the soil engaged by the opening disc becomes softer, the depth of the opening disc becomes greater unless the down pressure applied to the opening disc is decreased. Thus, the position signal from the hydraulic cylinder actually represents the depth of the opening disc.

The small hydraulic ram 406 performs what would typically be a manual depth adjustment. The ram 406 pushes on a rocker arm 404, which is connected to a link arm 410, which is connected to a slider/depth adjuster 412. The slider/depth adjuster 412 is free to move through the same adjustment range that the conventional depth adjustment handle could be moved manually to effect a depth adjustment.

The inductive distance sensor 411 that moves closer or farther away from a metal cam target 424 as the slider/depth adjuster 412 is moved throughout its adjustment range. The distance sensor 411 produces an output signal that is sent to an electronic controller that compares the signal from the distance sensor 411 with a desired depth value entered by the operator of the planter, as described in more detail below. A variety of linear or angular position sensors could be used in place of the illustrated distance sensor, which is preferred for its environmental protection and low cost.

As a controller compares the actual depth with the desired depth, it produces an output signal that controls a pair of valves that can be opened and closed to adjust the pressure in the hydraulic cylinder that receives the ram 406. Changing this pressure extends or retracts the ram 406 to move the slider/depth adjuster 412 to the desired position. Thus, if the position of the ram 406 falls out of tolerance, the system will automatically open and close the valves to maintain the correct setting.

Also provided is a pressure sensor 415 that measures the pressure inside a hydraulic cylinder 408 that receives the ram 406. It can be seen that the force exerted on the ground by the gauge wheels is transmitted from the tires to the gauge wheel arms 407, both of which pivot and are supported by the pivoting equalizer 400. This equalizer 400 is connected to the slider/depth adjuster 412, which is connected to the link arm 410, which is connected to the rocker arm 404, which in turn contacts the ram 406, which in turn compresses the fluid in the cylinder 406, which is measured by a pressure sensor 415. Thus, the pressure inside the cylinder 406 is equivalent to the force on the gauge wheels. In this way, a single device accomplishes both depth adjustment and gauge wheel force measurement, and eliminates the need for the typical strain gauge.

When planting an agricultural field with seeds, it is important to control the planting depth in real time as the planting machine traverses the field, because it is critical that the seeds all be planted into moisture so that each seed emerges from the soil at the same time. The depth of the seed can be changed based on some type of moisture sensor system, or even based on a satellite or drone system that is able to detect changes in the soil chemistry that would make it desirable to change the depth of the planted seed in different areas of the field.

An objective of the present invention is to provide a planting system that enables the operator to select a desired planting depth setting, and then automatically maintains the actual planting depth within a selected range above and below the selected depth.

In one embodiment that provides both environmental protection and low cost, a pair of valves are controlled to open and close to extend or retract the ram of a hydraulic cylinder to move a slider/depth adjuster to the desired position. If the position of the slider/depth adjuster falls out of tolerance, the system automatically opens and closes the valve to maintain the correct setting. Each row unit may be provided with its own valves and associated control system.

The pressure inside the cylinder 408 is equivalent to the force on the gauge wheels. Thus, a single device can provide both depth adjustment and gauge wheel force measurement, without the need for the typical strain gauge. The system allows fluid pressure to be used both to change the depth that the seed is planted in the ground and how hard the planter gauge wheels are pushing on the ground in a single device.

In the illustrative system, a fluid port 420 in the fluid chamber 408 is connected to one or more valves to allow hydraulic fluid to be added to or removed from the chamber 408 to change the angle of the opener disc relative to the gauge wheel.

The distance sensor 411 produces an output signal representing the position of the cutting wheel support arm along the arcuate slot. That position changes as the angle between the two support arm changes with changes in the depth of the opener disc relative to the elevation of the gauge wheel (the soil surface). The output signal from the distance sensor 411 will be referred to as the "seed depth" signal because the depth of the opener disc determines the depth of the furrow in which the seed is planted.

The position sensor produces an output signal corresponding to the position of the piston within the hydraulic cylinder, which changes when the depth of the opener disc changes relative to the elevation of the gauge wheel. For example, if the soil engaged by the opening disc becomes harder, the depth of the opening disc becomes smaller unless the down pressure applied to the opening disc is increased. Conversely, if the soil engaged by the opening disc becomes softer, the depth of the opening disc becomes greater unless the down pressure applied to the opening disc is decreased. Thus, the position signal from the hydraulic cylinder actually represents the depth of the opening disc.

The output signal from the position sensor is supplied to the controller, which determines whether any change in that signal falls within predetermined dead bands on opposite sides of the target value. If a change exceeds a dead band, the controller produces a control signal that increases or decreases the down pressure on the opening disc to maintain the depth of the opening disc within a desired range on both sides of the target value.

The target value can be changed automatically as the planter traverses a field having variable soil conditions. For example, a soil moisture sensor cane be used to determine optimum target values in different areas of a field being planted. Another example is to use stored data corresponding to the soil properties at different GPS locations in the field to adjust the target value as the planter traverses those locations.

The gauge wheel support arms 400 push against an equalizer support which is connected to the slider/depth adjuster 412 that slides along an arcuate guide 412. Movement of the slider/depth adjuster 412 along the arcuate guide moves one end of the link arm 410 that is attached at its other end to the rocker arm 408 mounted for pivoting movement abound a stationary pivot pin 405. The lower end of the rocker arm 408 engages the ram 406 in the hydraulic cylinder 408 that is filled with a pressurized hydraulic fluid.

The force on the gauge wheels due to the weight of the row unit and applied down force causes the rocker arm 404 to pivot around the pivot bolt 405 and push against the hydraulic ram 406. This force on the ram 406 controls the pressure on the fluid in the cylinder 408, so

the fluid pressure in the cylinder 408 is proportional to the amount of gauge wheel load. This fluid pressure controls the depth of the opener blade by controlling the angle between the support arms for the gauge wheel and the opener blade.

To adjust the depth of the opener blade, the pressure of the hydraulic fluid in the cylinder 408 can be adjusted by increasing or decreasing the amount of hydraulic fluid in the cylinder. This is accomplished by a pair of valves that can be opened and closed by electrical signals from an electrical controller.

The fluid cylinder 408 includes a fluid port 420 that is connected to one or more valves to allow hydraulic fluid to be added to or removed from the cylinder 408 to change the angle of the opener disc relative to the gauge wheel. The distance sensor 411 produces an output signal representing the position of the opener disc support arm 402 along an arcuate guide, which changes as the angle between the two support arms changes with changes in the depth of the opener disc relative to the elevation of the gauge wheel (the soil surface). The output signal from the distance sensor 411 can be referred to as the "seed depth" signal because the depth of the opener disc determines the depth of the furrow in which the seed is planted.

FIG. 34 is a flow chart of an algorithm for generating signals that control the one or more valves that control the flow of hydraulic fluid in and out of the fluid chamber 408. At step 488, this algorithm calibrates the distance or angle sensor to read the correct seed depth in inches, and step 490 calibrates the pressure sensor 415 to read the gauge wheel force in pounds or kilograms. Step 492 computes the target seed depth and down pressure based on the output of step 491 and external soil property data, furrow hardness sensor data and/or moisture sensor data. Then seed depth dead band values are entered at step 493, and down pressure dead band values are entered at step 494.

Step 500 in this algorithm determines whether the planter row unit is in an operating configuration on the ground, as will be described in detail below. When step 500 produces an affirmative answer, step 501 measures the actual seed depth, and step 502 measures the actual gauge wheel load. Steps 503 and 504 then determine whether the actual seed depth and the actual gauge wheel load are within their respective dead bands and, if the answer is negative in either case, whether the actual value is above or below that dead band.

In the case of the seed depth, if the actual seed depth is within the dead band, the system returns to step 500 to repeat steps 501-504. If the actual seed depth is outside the dead band and is too deep, step 505 opens a valve to supply additional hydraulic fluid to the cylinder 406 for a brief time interval. If the actual seed depth is outside the dead band and

too shallow, step 505 opens a valve to allow hydraulic fluid to flow out of the cylinder 408 for a brief time interval.

In the case of the gauge wheel load, if the actual gauge wheel load is above the dead band, step 505 opens a valve to supply additional hydraulic fluid to the cylinder 408. If the actual gauge wheel load is above the dead band, step 507 decreases the down pressure actuator pressure. If the actual gauge wheel load is below the dead band, step 108 increases the down pressure actuator pressure. If the actual gauge wheel load is within the dead band, the system returns to step 500 to repeat steps 501-504.

When step 500 produces a negative answer, step 509 performs an active air purge process, and step 510 maintains the row unit down pressure at zero for safety.

According to Embodiment A1, a control system is directed to controlling the depth of an opener device in an agricultural planter. The system includes a gauge wheel on a pivotably mounted support arm; a mechanical element coupled to the support arm to move in response to changes in the angle of the support arm; a sensor adapted to measure changes in the relative elevations of the opener device and the gauge wheel to produce an output signal representing the current relative elevations of the opener device and the gauge wheel; and a control device receiving the output signal from the sensor and producing a second output signal for maintaining the opener device at a selected elevation relative to the gauge wheel.

According to Embodiment A2, the control system of Embodiment A1 includes a moisture sensor producing a signal representing the moisture content of the soil being planted, and the controller is responsive to the moisture-representing signal for producing an output signal representing the desired depth of the opening device.

According to Embodiment A3, the control system of Embodiment A1 has the sensor translating the upward force from a pivoting gauge wheel support arm into a fluid pressure in a fluid chamber.

According to Embodiment A4, the control system of Embodiment A3 has the fluid pressure being proportional to the gauge wheel load.

According to Embodiment A5, the control system of Embodiment A3 includes a pressure transducer coupled to the fluid chamber and produces an output signal that changes in proportion to changes in the fluid pressure in the fluid chamber, the control device receiving the output signal and using that output signal to produce the second output signal.

According to Embodiment A6, a method is directed to controlling the depth of an opener device in an agricultural planter having a gauge wheel on a pivotably mounted support

arm, the method comprising: in response to changes in the angle of the support arm, moving a mechanical element coupled to the support arm; producing a first output signal representing the current relative elevations of the opener device and the gauge wheel, in response to changes in the relative elevations of the opener device and the gauge wheel; and in response to the first output signal, producing a second output signal for maintaining the opener device at a selected elevation relative to the gauge wheel.

According to Embodiment A7, the method of Embodiment A6 includes producing a signal representing the moisture content of the soil being planted, and in response to the moisture-representing signal, producing an output signal representing the desired depth of the opening device.

According to Embodiment A8, the method of Embodiment A6 has the upward force from a pivoting gauge wheel support arm being translated into a fluid pressure in a fluid chamber.

According to Embodiment A9, the method of Embodiment A8 has the fluid pressure being proportional to the gauge wheel load.

According to Embodiment A10, the method of Embodiment A8 includes producing an output signal that changes in proportion to changes in the fluid pressure in the fluid chamber, and using that output signal to produce the second output signal.

According to Embodiment B1, a gauge wheel load sensor for an agricultural planter has a row unit that includes a pivotably mounted gauge wheel and a down pressure controller for controlling the down pressure on at least a portion of the row unit, the load sensor comprising: a mechanical element mounted for movement in response to the downward force applied to the row unit; a fluid-containing device containing an element coupled to the mechanical element for changing the fluid pressure in the fluid-containing device in response to the movement of the mechanical element; and a transducer coupled to the fluid-containing device for producing an output signal in response to changes in the fluid pressure.

According to Embodiment B2, the gauge wheel load sensor of Embodiment B1 has the mechanical element being a rocker arm coupled to the gauge wheel so that the pressure on a ram within the cylinder is adjusted in response to vertical movement of the gauge wheel.

According to Embodiment B3, the gauge wheel load sensor of Embodiment B2 has the pressure on the ram increased only in response to a change in the down force on the gauge wheel.

According to Embodiment B4, the gauge wheel load sensor of Embodiment B1 includes an accumulator coupled to the portion of the fluid-containing device where the fluid pressure increases in response to the movement of the of the mechanical element.

According to Embodiment B5, the gauge wheel load sensor of Embodiment B4 has the mechanical element being a ram in a hydraulic cylinder containing pressurized fluid, the ram is coupled to the gauge wheel so that the ram is moved within the cylinder in response to vertical movement of the gauge wheel, and which includes an accumulator coupled to the hydraulic cylinder for receiving a portion of the pressurized fluid.

According to Embodiment B6, the gauge wheel load sensor of Embodiment B5 has the accumulator including a ram in a cavity that receives the pressurized fluid.

According to Embodiment B7, the gauge wheel load sensor of Embodiment B5 has the accumulator damp changes in the pressure of the fluid in response to vibratory movement of the ram.

According to Embodiment B8, a gauge wheel load sensor for an agricultural planter having a row unit that includes a pivotably mounted gauge wheel and a down pressure controller for controlling the down pressure on at least a portion of the row unit, the load sensor comprising: a mechanical element mounted for movement in response to the downward force applied to the row unit; a fluid-containing device containing an element coupled to the mechanical element for changing the fluid pressure in the fluid-containing device in response to the movement of the mechanical element; a transducer coupled to the fluid-containing device for producing an output signal in response to changes in the fluid pressure; and an energy storage device coupled to the fluid-containing device for receiving a limited amount of fluid in response to changes in the fluid pressure to damp pressure spikes in the output signal of the transducer.

According to Embodiment B9, the gauge wheel load sensor of Embodiment B8, the fluid-containing device being a hydraulic cylinder, and the movable element is a piston in the cylinder.

According to Embodiment B10, the gauge wheel load sensor of Embodiment B8, the energy storage device being an accumulator receiving pressurized fluid from the fluid-containing device, the accumulator containing a movable element responsive to the pressure of the fluid received from the fluid-containing device.

According to Embodiment B11, an agricultural planter row unit comprising a pivotably mounted gauge wheel and a down pressure controller for controlling the elevation of the row

unit; a pair of gauge wheel support arms mounted for pivoting movement independently of each other; a gauge wheel equalizer arm extending transversely across the support arms and mounted for pivoting movement about an axis extending in the direction of travel of the row unit; and a pair of contact rollers mounted on opposite ends of the equalizer arm, each of the contact rollers engaging different ones of the support arms for pivoting the equalizer arm in response to the independent vertical movements of the support arms.

According to Embodiment B12, the agricultural planter row unit of Embodiment B11, including a rocker arm coupled to the center of the equalizer arm and mounted for pivoting movement in response to changes in the elevation of the center of the equalizer arm.

According to Embodiment B13, a control system for controlling the down pressure applied to a soil-engaging component of an agricultural implement, the system comprising: a source of pressurized fluid; a down pressure actuator coupled to the soil-engaging component and to the source of pressurized fluid; an energy storage device and a piston-containing cylinder coupled to each other by a system containing pressurized fluid; a check valve coupled between the energy storage device and the down pressure actuator to control the flow of the pressurized fluid from the energy storage device to the cylinder; a controllable relief valve and a controllable variable orifice coupled between the down pressure actuator and the energy storage device to control the flow of the pressurized fluid from the cylinder to the energy storage device; a pressure sensor coupled to the pressurized fluid and producing an output signal corresponding to the pressure of the pressurized fluid; and a controller coupled to the pressure sensor to receive the output signal and configured to supply control signals to the controllable relief valve and the controllable variable orifice to control the flow of the pressurized fluid from the cylinder to the energy storage device based on the pressure of the pressurized fluid.

According to Embodiment B14, the control system of Embodiment B13, in which the energy storage device is an accumulator.

According to Embodiment B15, the control system of Embodiment B13 in which the controller supplies a control signal to the relief valve to open the relief valve in response to a predetermined change in the pressure of the pressurized fluid.

According to Embodiment B16, the control system of Embodiment B13 in which the controller supplies a control signal to the variable orifice to control the size of the orifice when the relief valve is open, to control the rate of flow of pressurized fluid from the energy storage device to the cylinder.

While particular embodiments and applications of the present invention have been illustrated and described, it is to be understood that the invention is not limited to the precise construction and compositions disclosed herein and that various modifications, changes, and variations can be apparent from the foregoing descriptions without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A gauge wheel load sensor for an agricultural planter having a row unit that includes a pivotably mounted gauge wheel and a down pressure controller for controlling the down pressure on at least a portion of the row unit, said load sensor comprising

a mechanical element mounted for movement in response to the downward force applied to the row unit,

a fluid-containing device containing an element coupled to said mechanical element for changing the fluid pressure in said fluid-containing device in response to the movement of said mechanical element, and

a transducer coupled to said fluid-containing device for producing an output signal in response to changes in said fluid pressure.

2. The gauge wheel load sensor of claim 1, in which said mechanical element is a rocker arm coupled to said gauge wheel so that the pressure on a ram within said cylinder is adjusted in response to vertical movement of said gauge wheel.

3. The gauge wheel load sensor of claim 2, in which the pressure on said ram is increased only in response to a change in the down force on said gauge wheel.

4. The gauge wheel load sensor of claim 1, which includes an accumulator coupled to the portion of said fluid-containing device where said fluid pressure increases in response to the movement of said of said mechanical element.

5. The gauge wheel load sensor of claim 4, in which said mechanical element is a ram in a hydraulic cylinder containing pressurized fluid, said ram is coupled to said gauge wheel so that said ram is moved within said cylinder in response to vertical movement of said gauge wheel, and which includes an accumulator coupled to said hydraulic cylinder for receiving a portion of said pressurized fluid.

6. The gauge wheel load sensor of claim 5, in which said accumulator includes a ram in a cavity that receives said pressurized fluid.

7. The gauge wheel load sensor of claim 5, in which said accumulator damps changes in the pressure of said fluid in response to vibratory movement of said ram.

8. A gauge wheel load sensor for an agricultural planter having a row unit that includes a pivotably mounted gauge wheel and a down pressure controller for controlling the down pressure on at least a portion of the row unit, said load sensor comprising

a mechanical element mounted for movement in response to the downward force applied to the row unit,

a fluid-containing device containing an element coupled to said mechanical element for changing the fluid pressure in said fluid-containing device in response to the movement of said mechanical element,

a transducer coupled to said fluid-containing device for producing an output signal in response to changes in said fluid pressure, and

an energy storage device coupled to said fluid-containing device for receiving a limited amount of fluid in response to changes in said fluid pressure to damp pressure spikes in the output signal of said transducer.

9. The gauge wheel load sensor of claim 8, in which said fluid-containing device is a hydraulic cylinder, and said movable element is a piston in said cylinder.

10. The gauge wheel load sensor of claim 8, in which said energy storage device is an accumulator receiving pressurized fluid from said fluid-containing device, said accumulator containing a movable element responsive to the pressure of the fluid received from said fluid-containing device.

11. An agricultural planter row unit comprising

a pivotably mounted gauge wheel and a down pressure controller for controlling the elevation of the row unit,

a pair of gauge wheel support arms mounted for pivoting movement independently of each other,

a gauge wheel equalizer arm extending transversely across said support arms and mounted for pivoting movement about an axis extending in the direction of travel of the row unit, and

a pair of contact rollers mounted on opposite ends of said equalizer arm, each of said contact rollers engaging different ones of said support arms for pivoting said equalizer arm in response to the independent vertical movements of said support arms.

12. The agricultural planter row unit of claim 11, which includes a rocker arm coupled to the center of said equalizer arm and mounted for pivoting movement in response to changes in the elevation of the center of said equalizer arm.

13. A control system for controlling the down pressure applied to a soil-engaging component of an agricultural implement, said system comprising

a source of pressurized fluid,

a down pressure actuator coupled to said soil-engaging component and to said source of pressurized fluid,

an energy storage device and a piston-containing cylinder coupled to each other by a system containing pressurized fluid,

a check valve coupled between said energy storage device and said down pressure actuator to control the flow of said pressurized fluid from said energy storage device to said cylinder,

a controllable relief valve and a controllable variable orifice coupled between said down pressure actuator and said energy storage device to control the flow of said pressurized fluid from said cylinder to said energy storage device,

a pressure sensor coupled to said pressurized fluid and producing an output signal corresponding to the pressure of said pressurized fluid, and

a controller coupled to said pressure sensor to receive said output signal and configured to supply control signals to said controllable relief valve and said controllable variable orifice to control the flow of said pressurized fluid from said cylinder to said energy storage device based on the pressure of said pressurized fluid.

14. .The control system of claim 13, in which said energy storage device is an accumulator.

15. The control system of claim 13, in which said controller supplies a control signal to said relief valve to open said relief valve in response to a predetermined change in the pressure of said pressurized fluid.

16. The control system of claim 13, in which said controller supplies a control signal to said variable orifice to control the size of said orifice when said relief valve is open, to control the rate of flow of pressurized fluid from said energy storage device to said cylinder.

17. A control system for controlling the depth of an opener device in an agricultural planter, said system comprising

a gauge wheel on a pivotably mounted support arm,

a mechanical element coupled to said support arm to move in response to changes in the angle of said support arm,

a sensor adapted to measure changes in the relative elevations of said opener device and said gauge wheel to produce an output signal representing the current relative elevations of said opener device and said gauge wheel, and

a control device receiving said output signal from said sensor and producing a second output signal for maintaining said opener device at a selected elevation relative to said gauge wheel.

18. The control system of claim 17, which includes a moisture sensor producing a signal representing the moisture content of the soil being planted, and said controller is responsive to said moisture-representing signal for producing an output signal representing the desired depth of said opening device.

19. The control system of claim 17, in which said sensor translates the upward force from a pivoting gauge wheel support arm into a fluid pressure in a fluid chamber.

20. The control system of claim 19, in which said fluid pressure is proportional to the gauge wheel load.

21. The control system of claim 19, which includes a pressure transducer coupled to said fluid chamber and producing an output signal that changes in proportion to changes in said fluid pressure in said fluid chamber, said control device receiving said output signal and using that output signal to produce said second output signal.

22. A method of controlling the depth of an opener device in an agricultural planter having a gauge wheel on a pivotably mounted support arm, said method comprising

in response to changes in the angle of said support arm, moving a mechanical element coupled to said support arm

producing a first output signal representing the current relative elevations of said opener device and said gauge wheel, in response to changes in the relative elevations of said opener device and said gauge wheel, and

in response to said first output signal, producing a second output signal for maintaining said opener device at a selected elevation relative to said gauge wheel.

23. The method of claim 22, which includes producing a signal representing the moisture content of the soil being planted, and in response to said moisture-representing signal, producing an output signal representing the desired depth of said opening device.

24. The method of claim 22, in which the upward force from a pivoting gauge wheel support arm is translated into a fluid pressure in a fluid chamber.

25. The method of claim 24, in which said fluid pressure is proportional to the gauge wheel load.

26. The method of claim 24, which includes producing an output signal that changes in proportion to changes in said fluid pressure in said fluid chamber, and using that output signal to produce said second output signal.

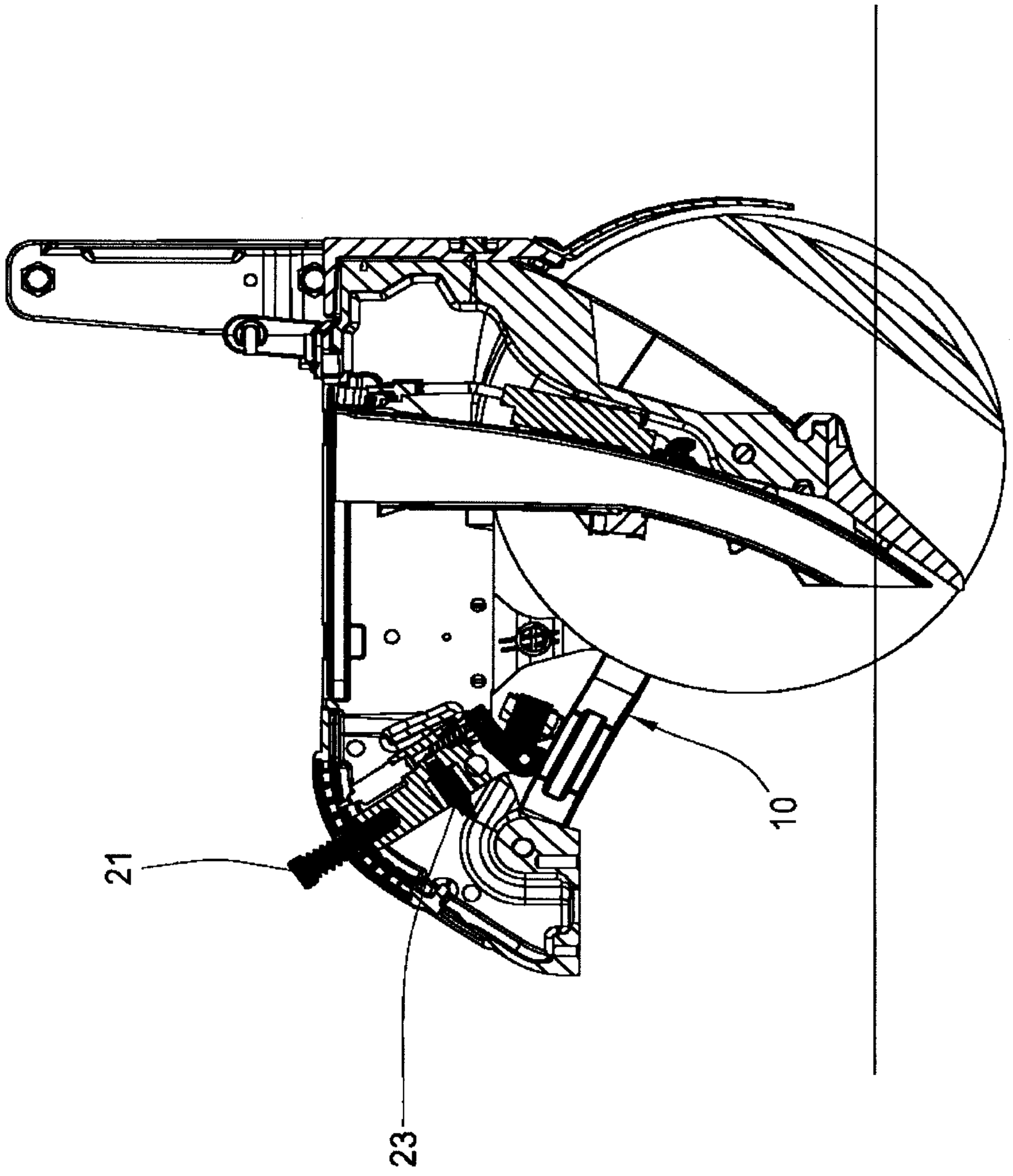


FIG. 1

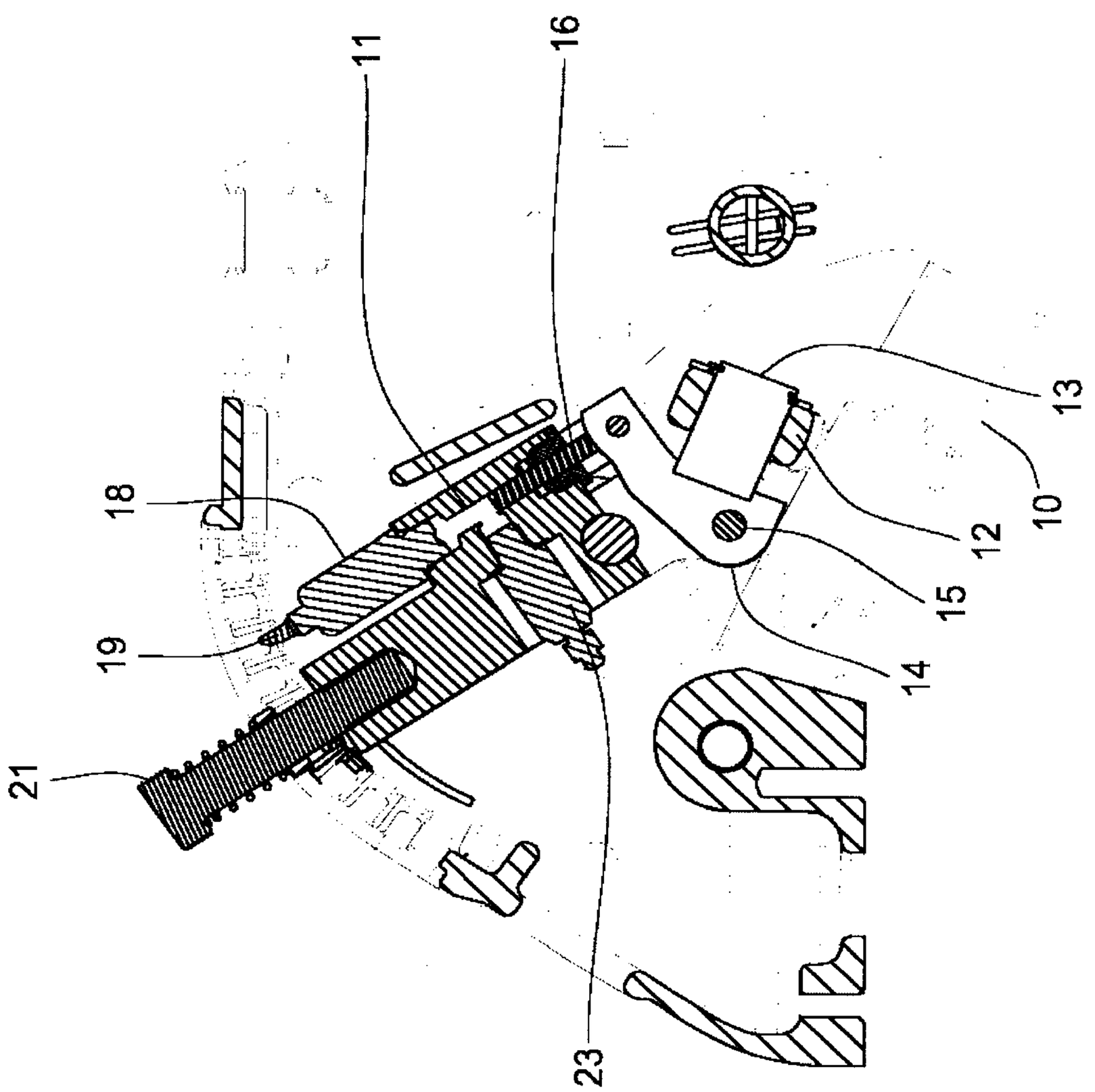


FIG. 2

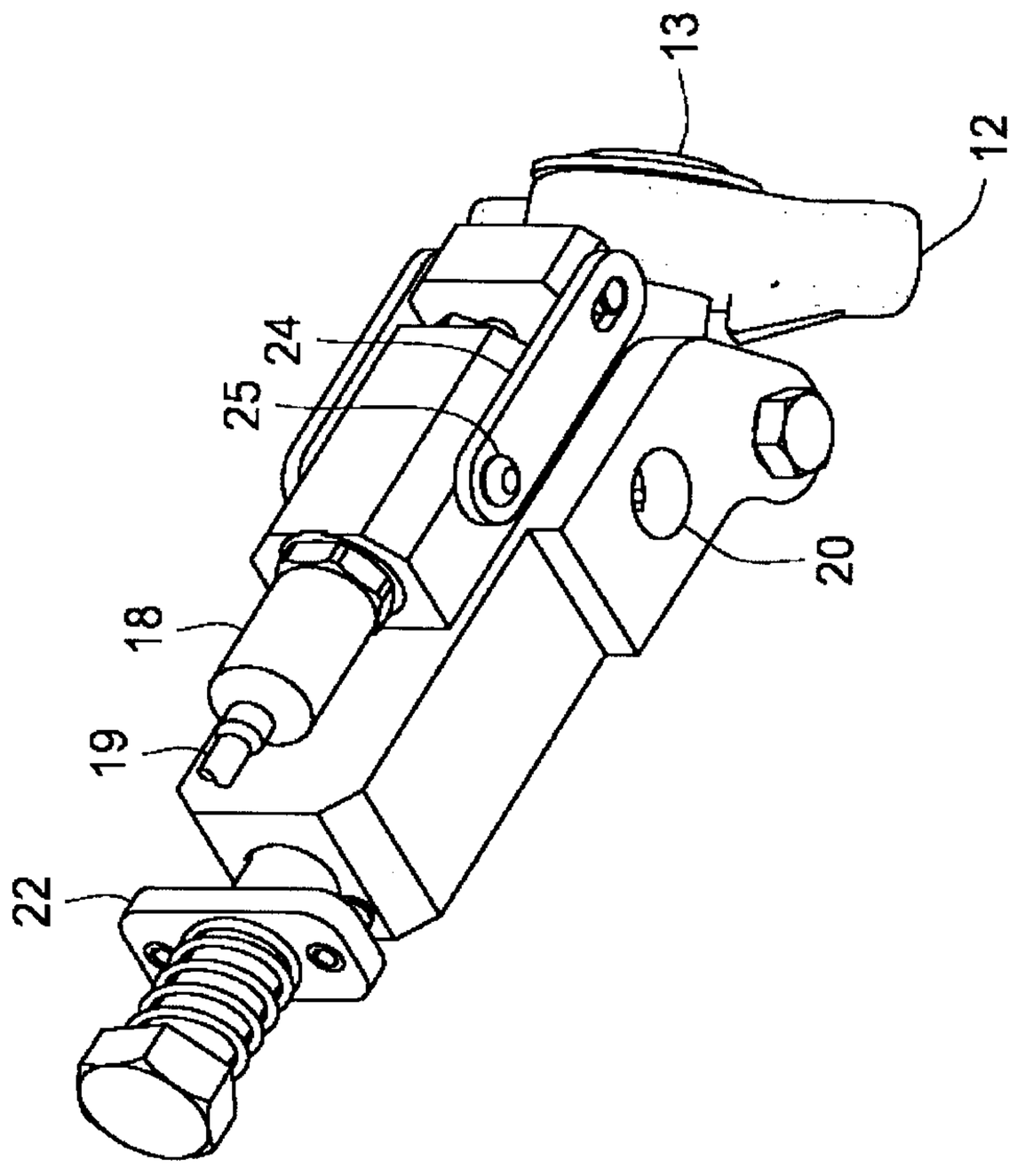


FIG. 3

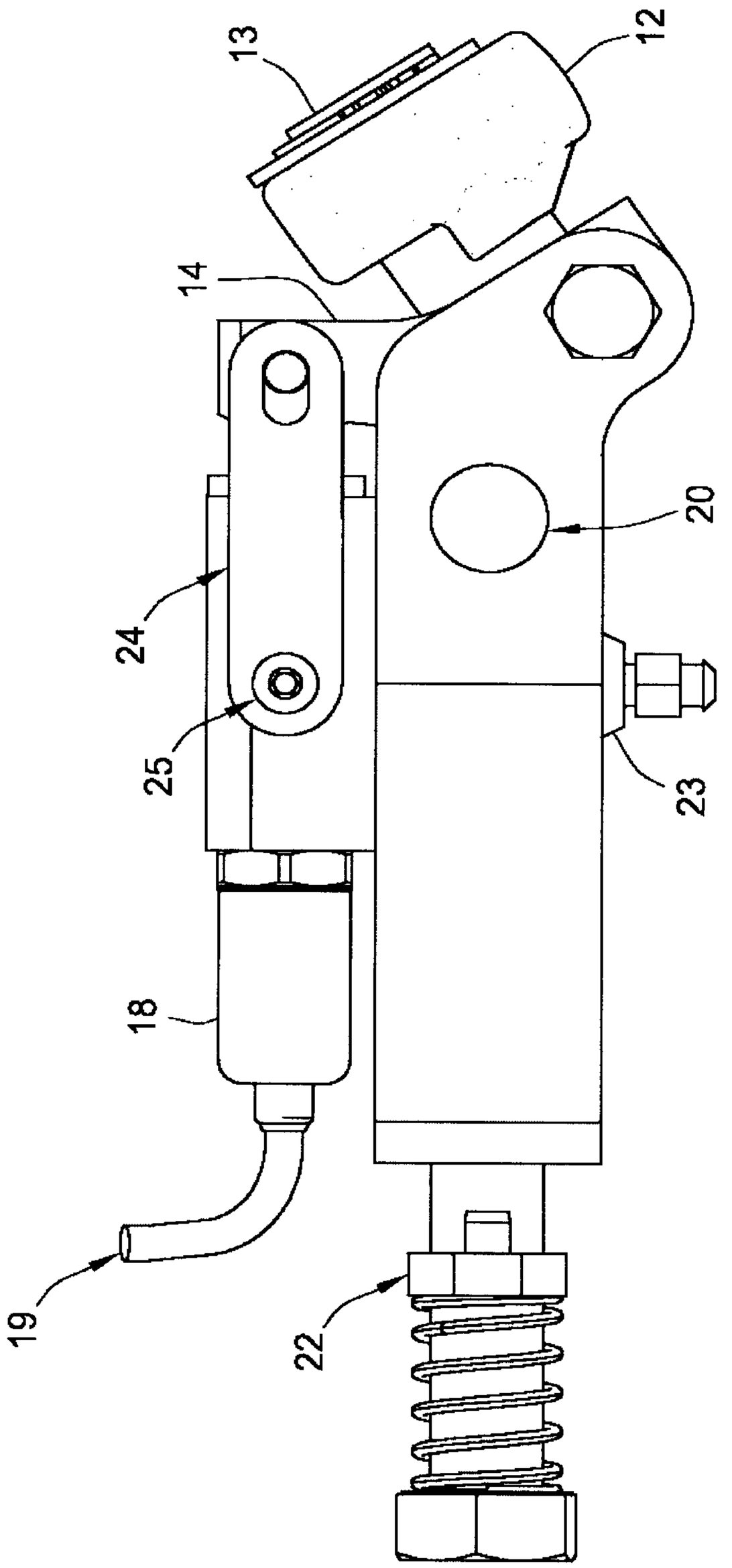


FIG. 4

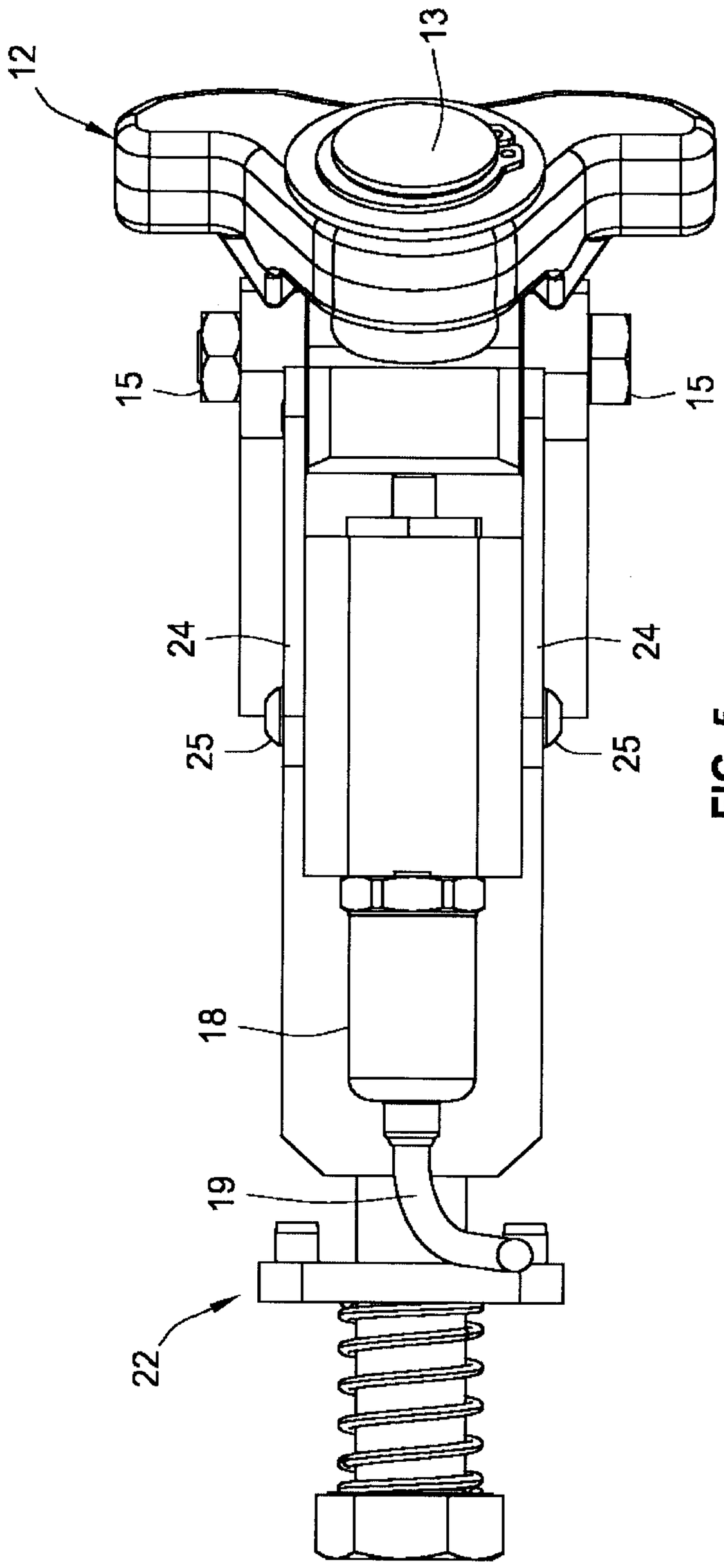


FIG. 5

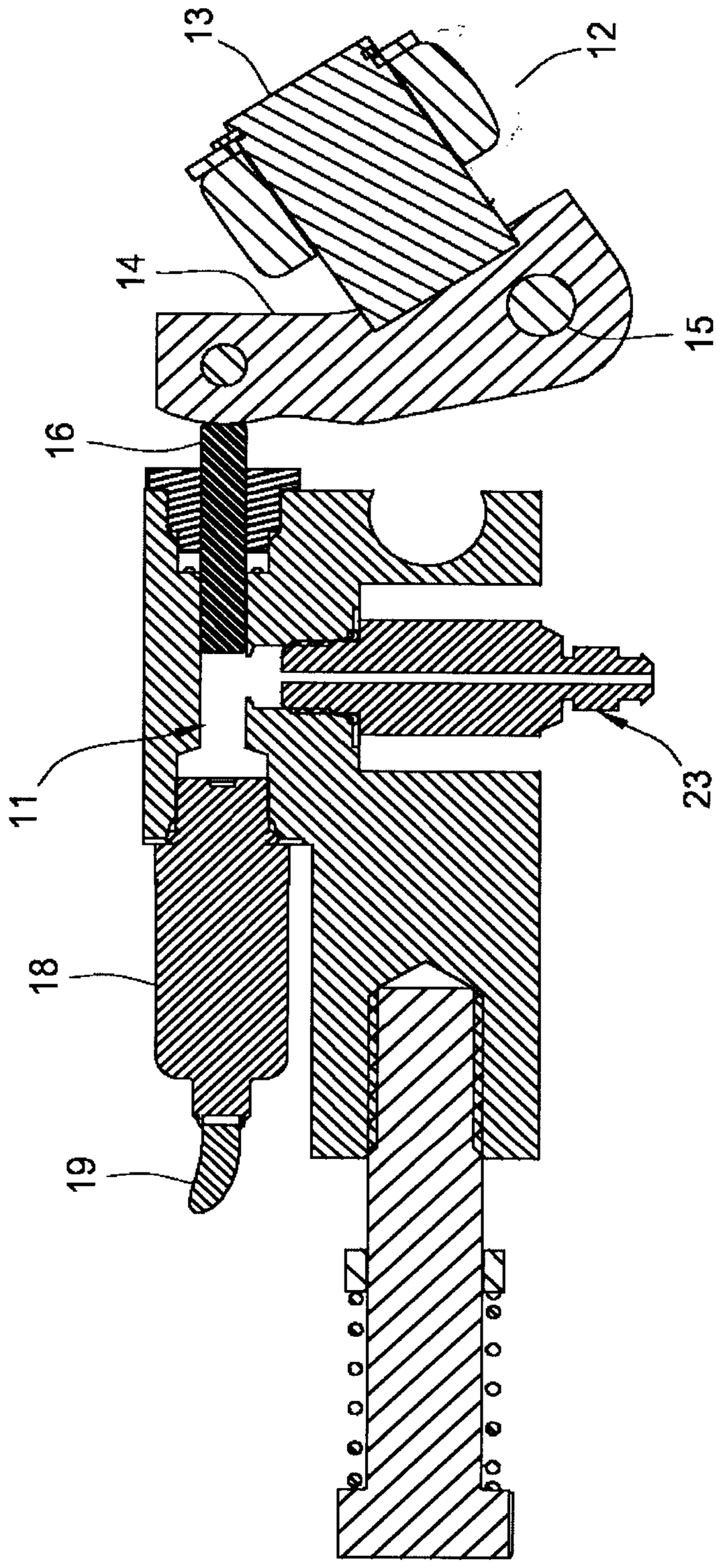


FIG. 6

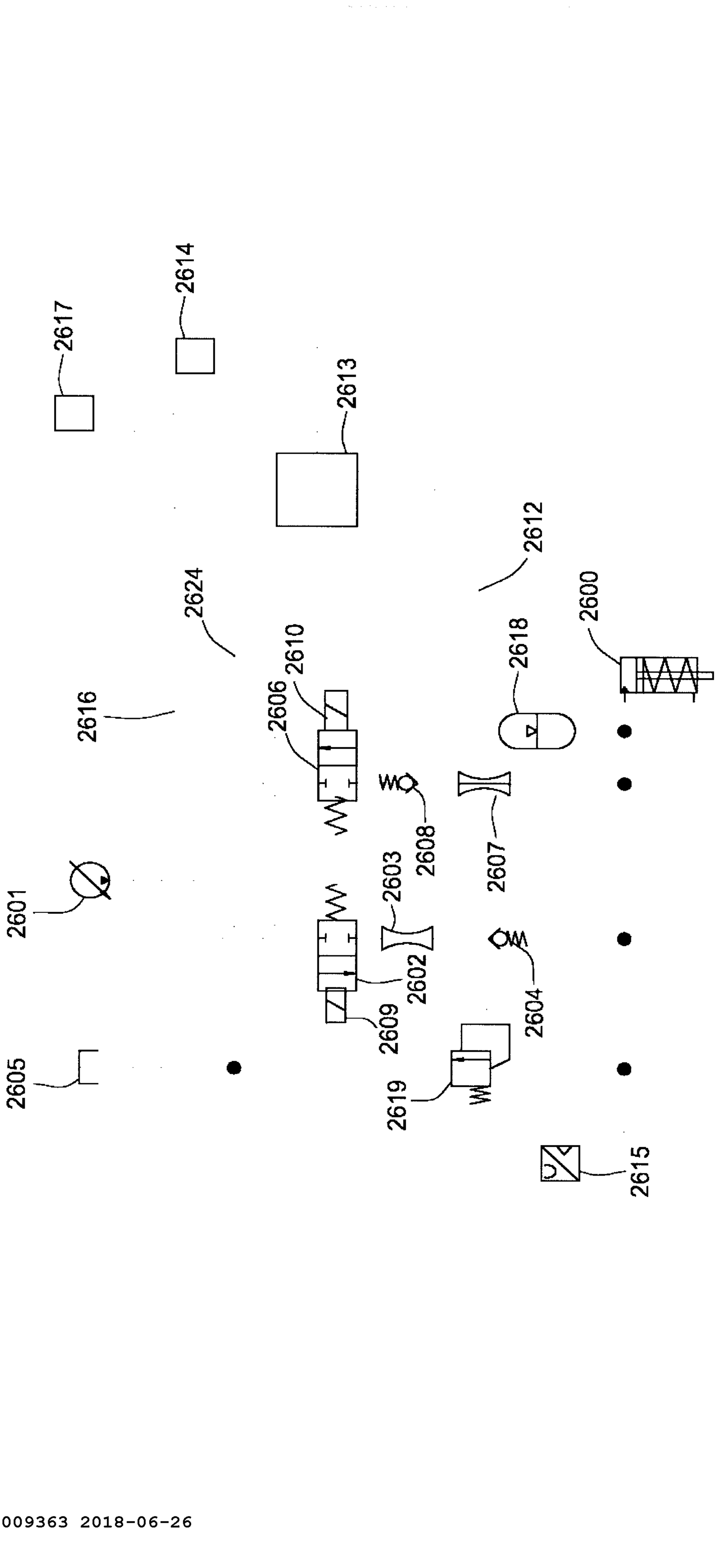

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FIG. 7

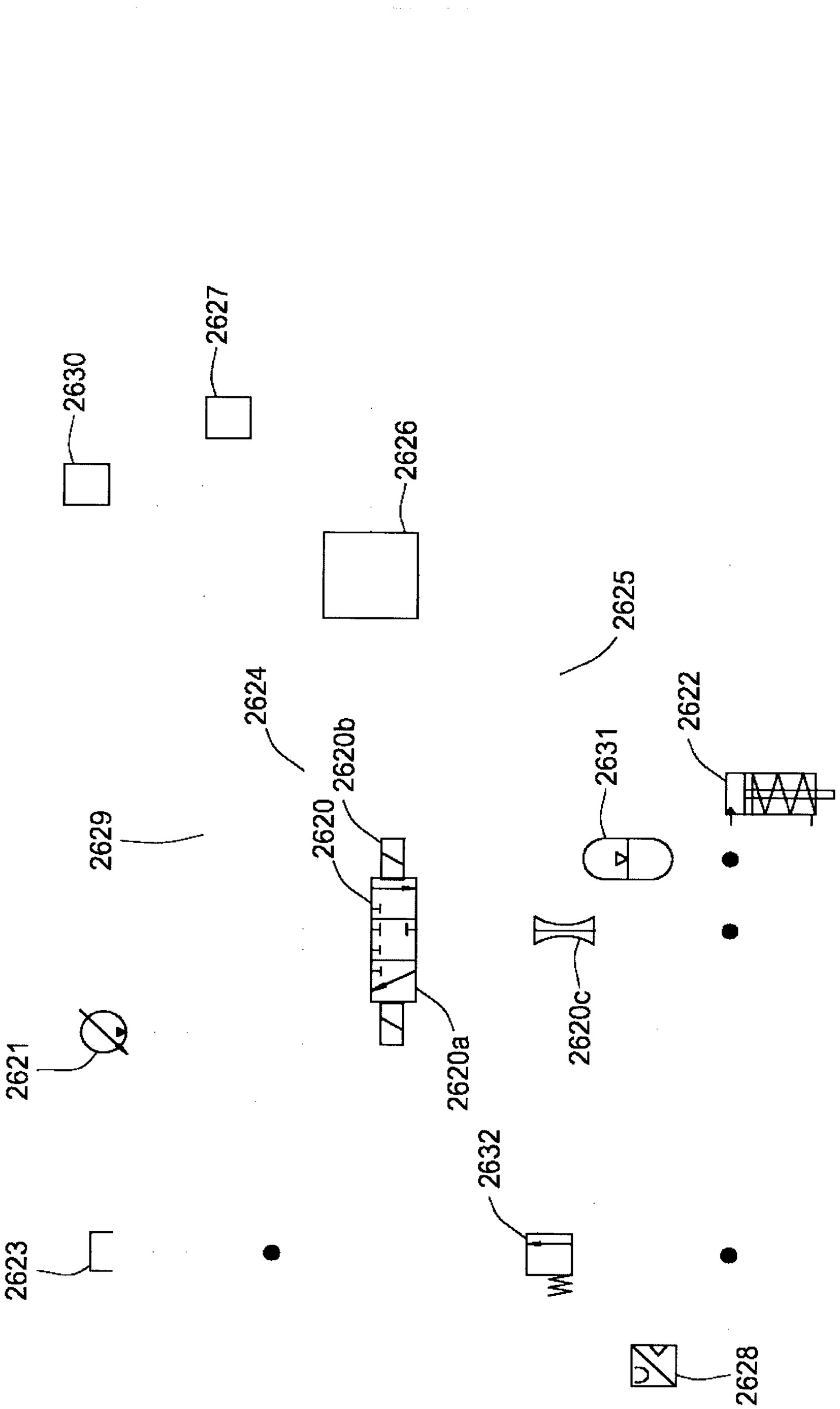

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FIG. 8

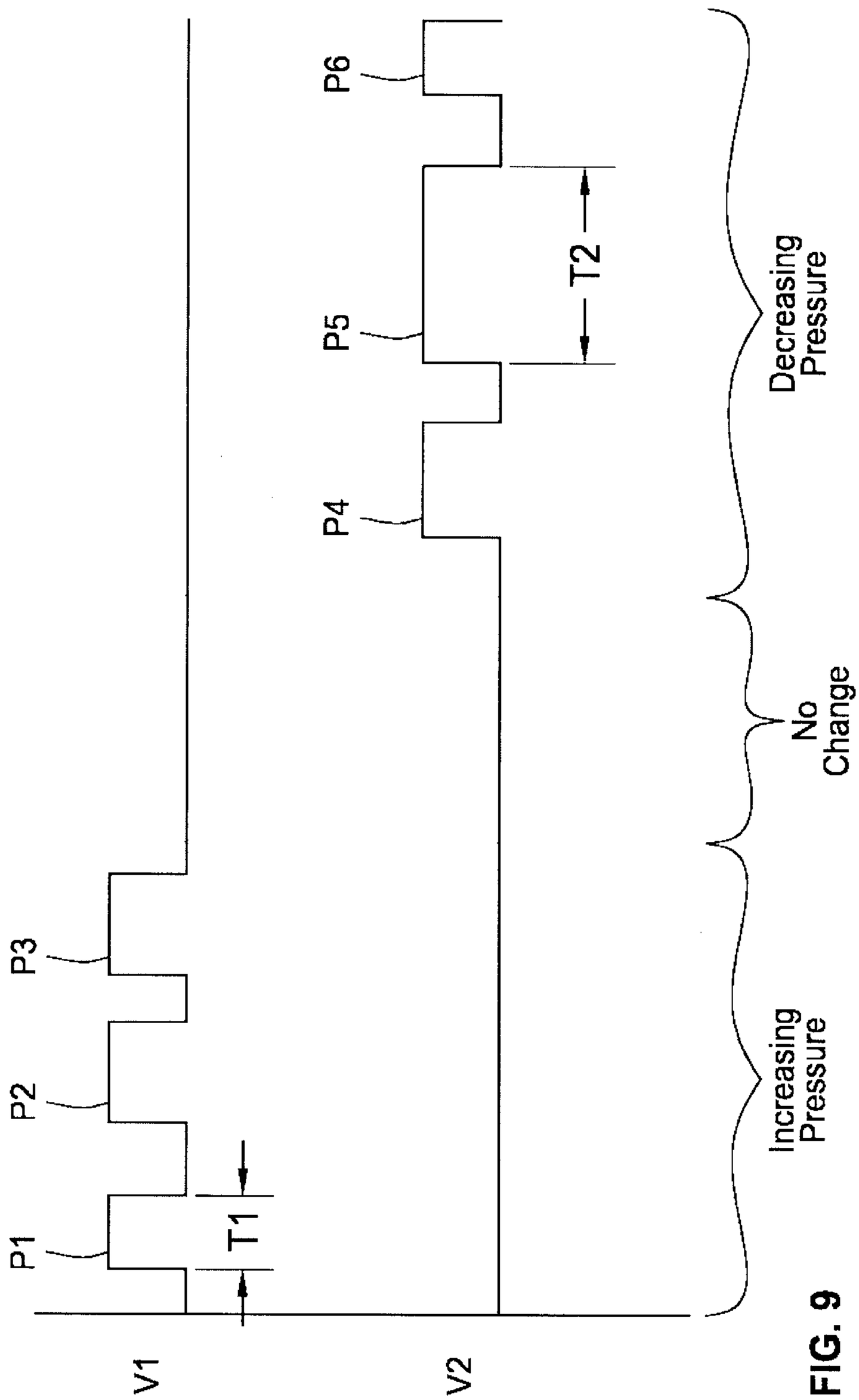

P1
P2
P3
P4
P5
P6
T1
T2
V1
V2
Increasing Pressure
No Change
Decreasing Pressure

FIG. 9

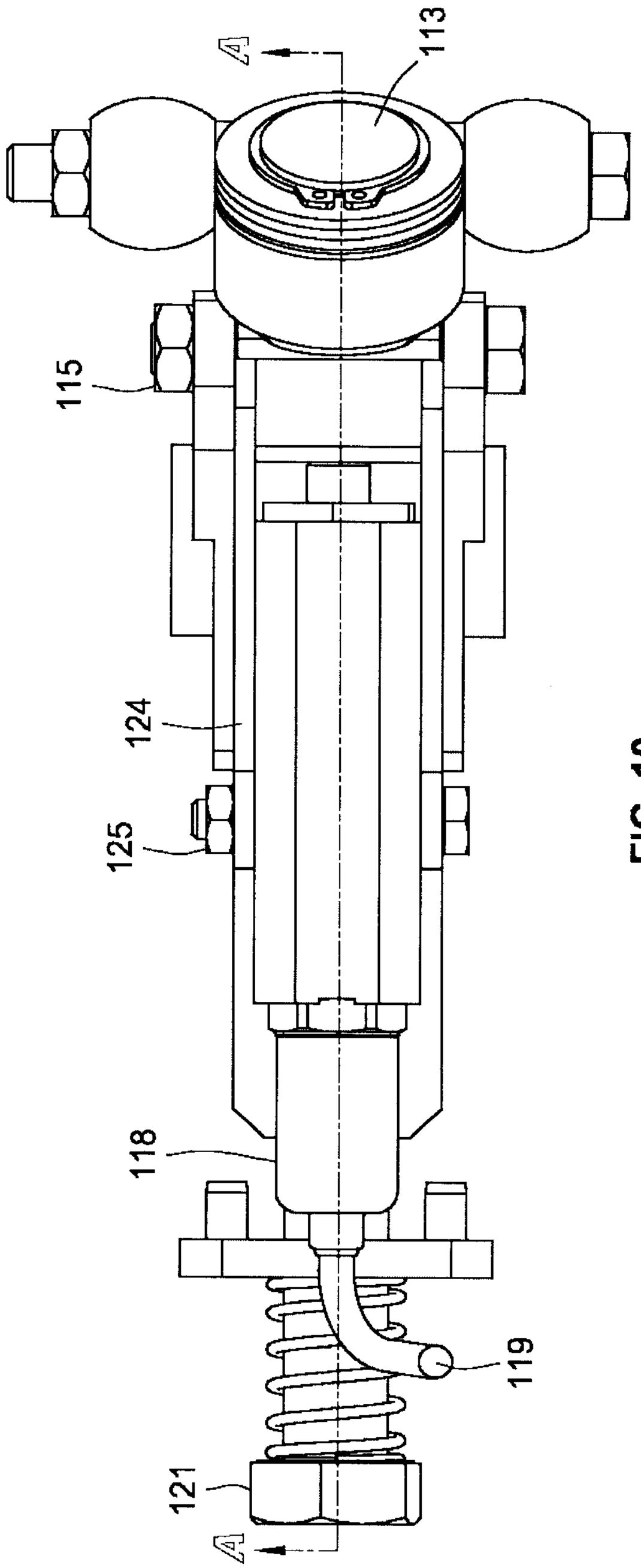


FIG. 10

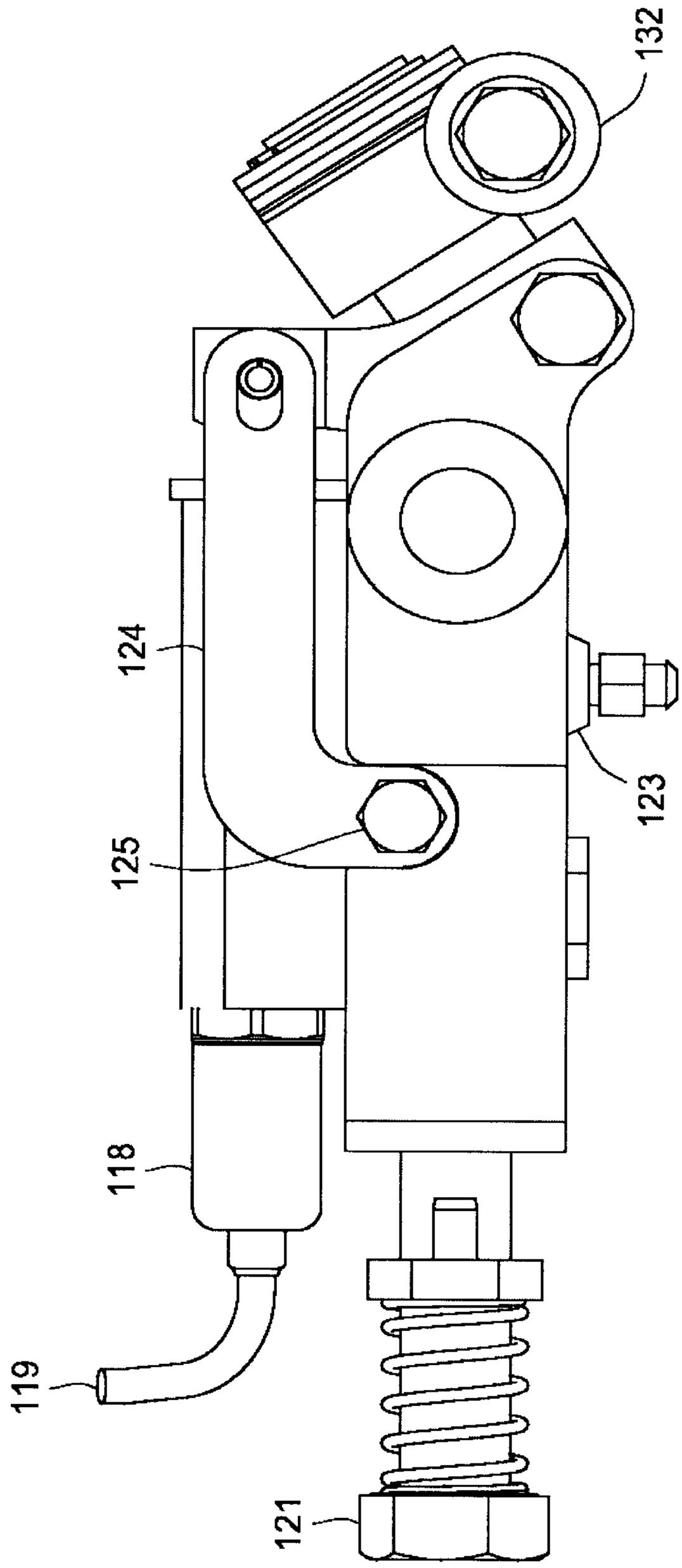


FIG. 11

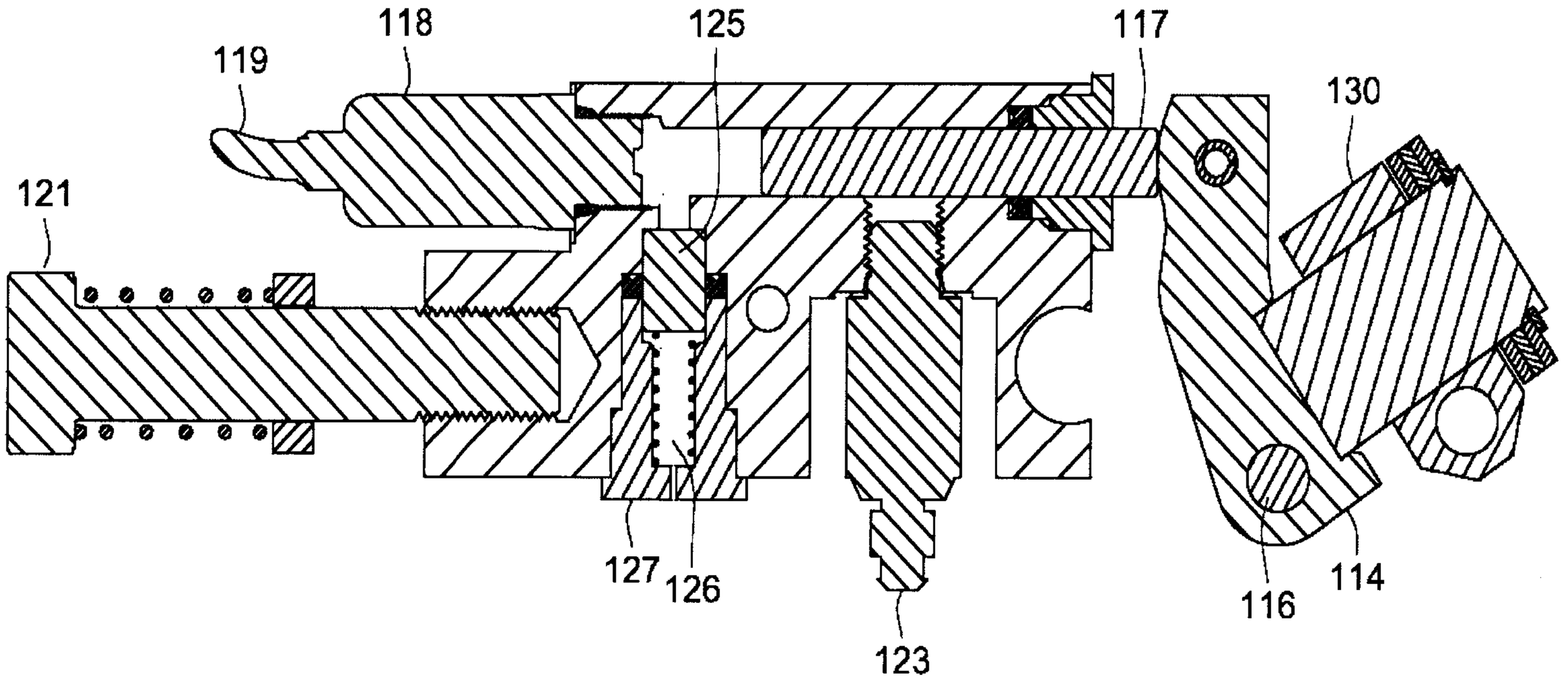


FIG. 12

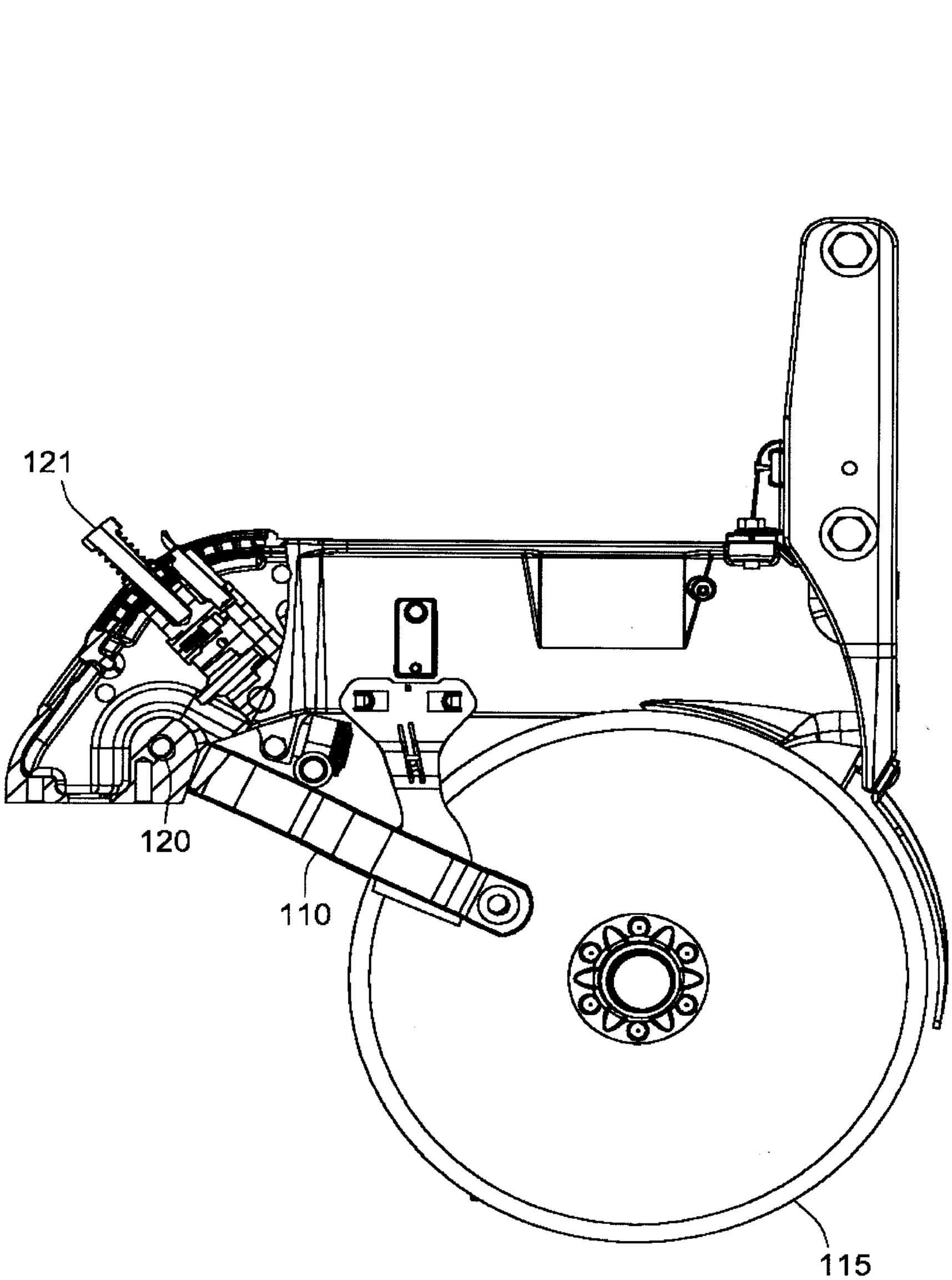


FIG. 13

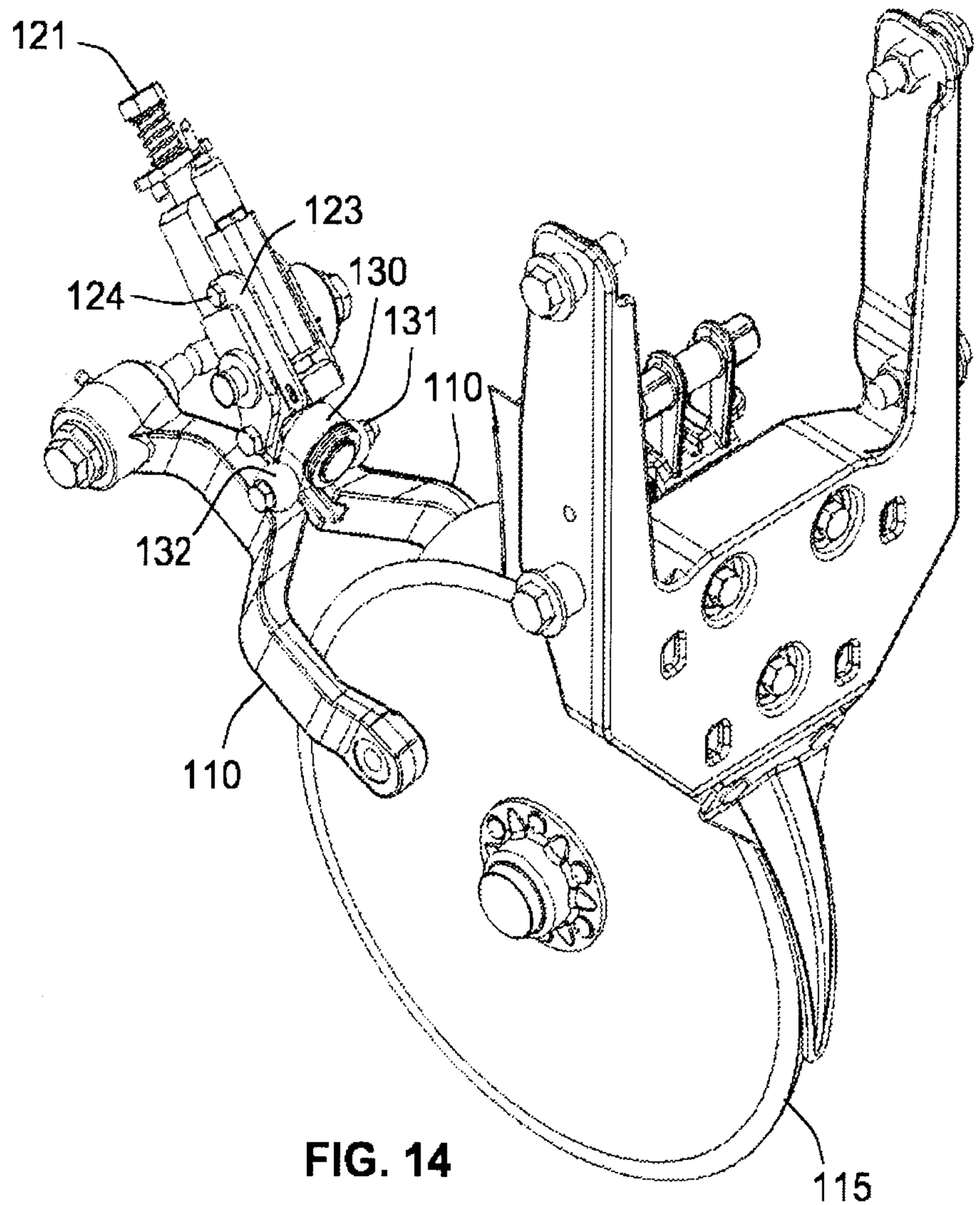


FIG. 14

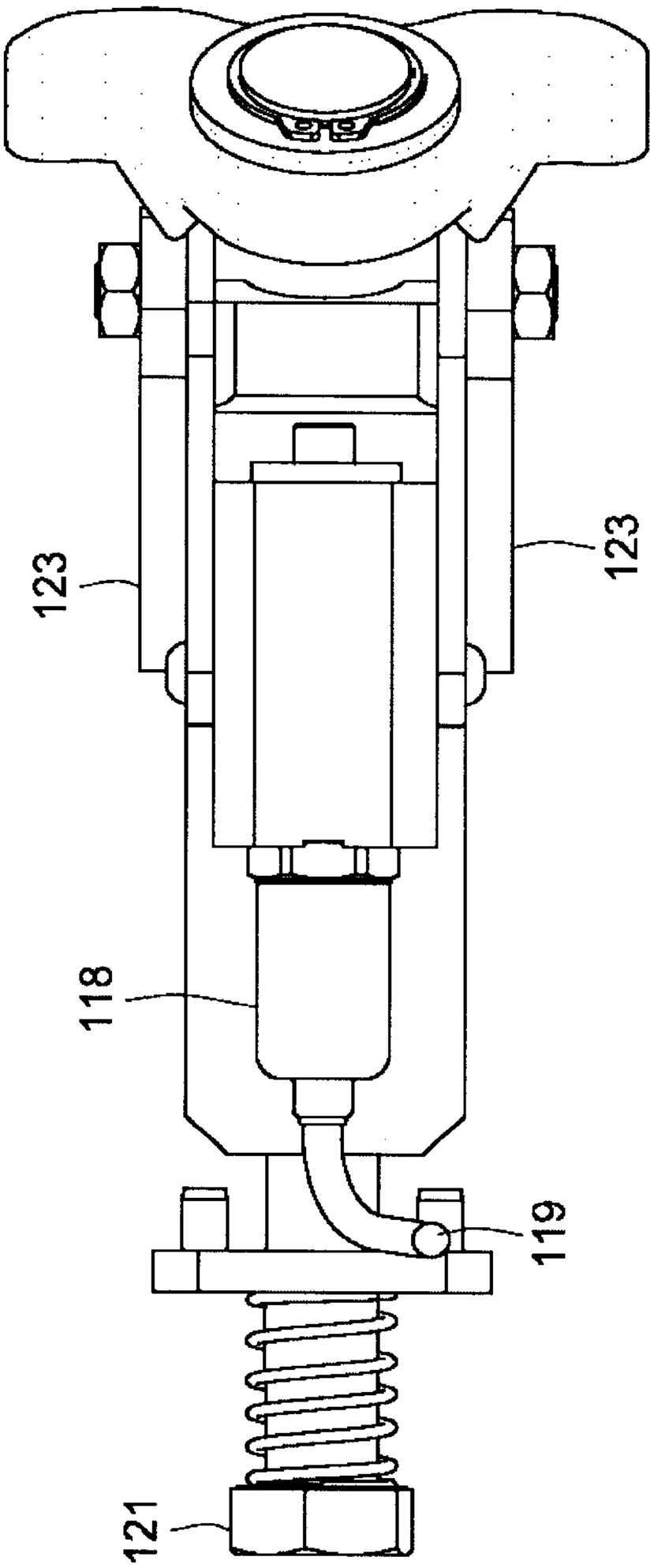


FIG. 15

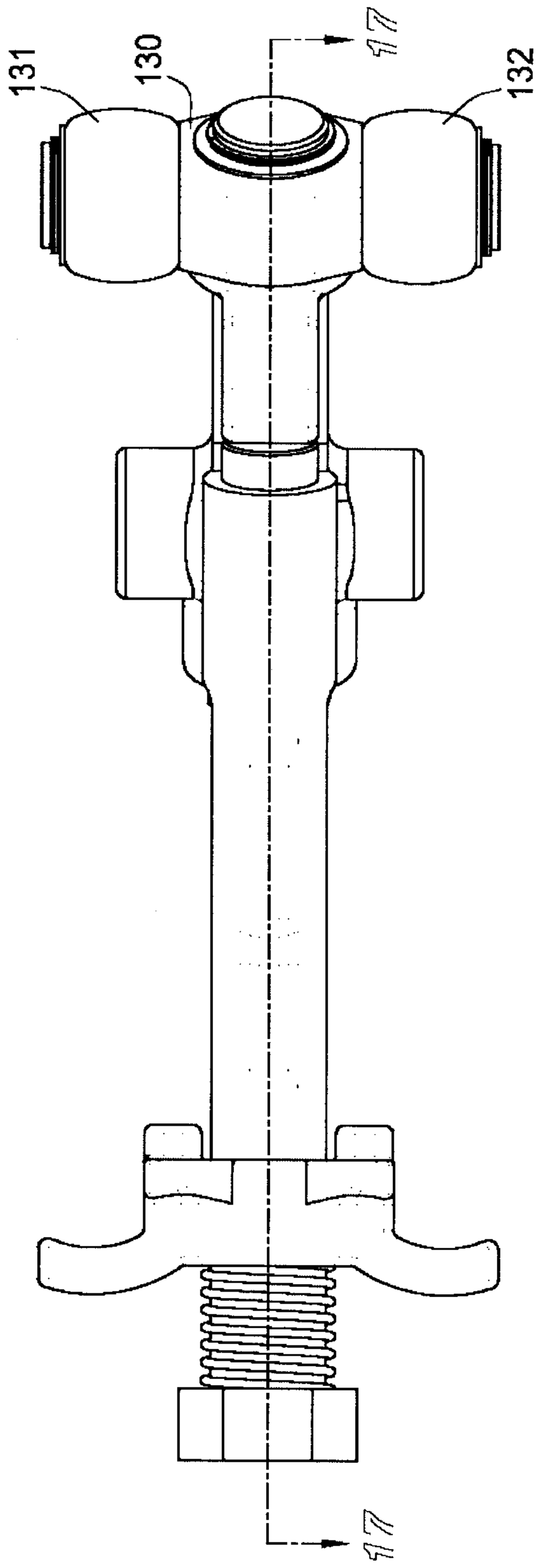


FIG. 16

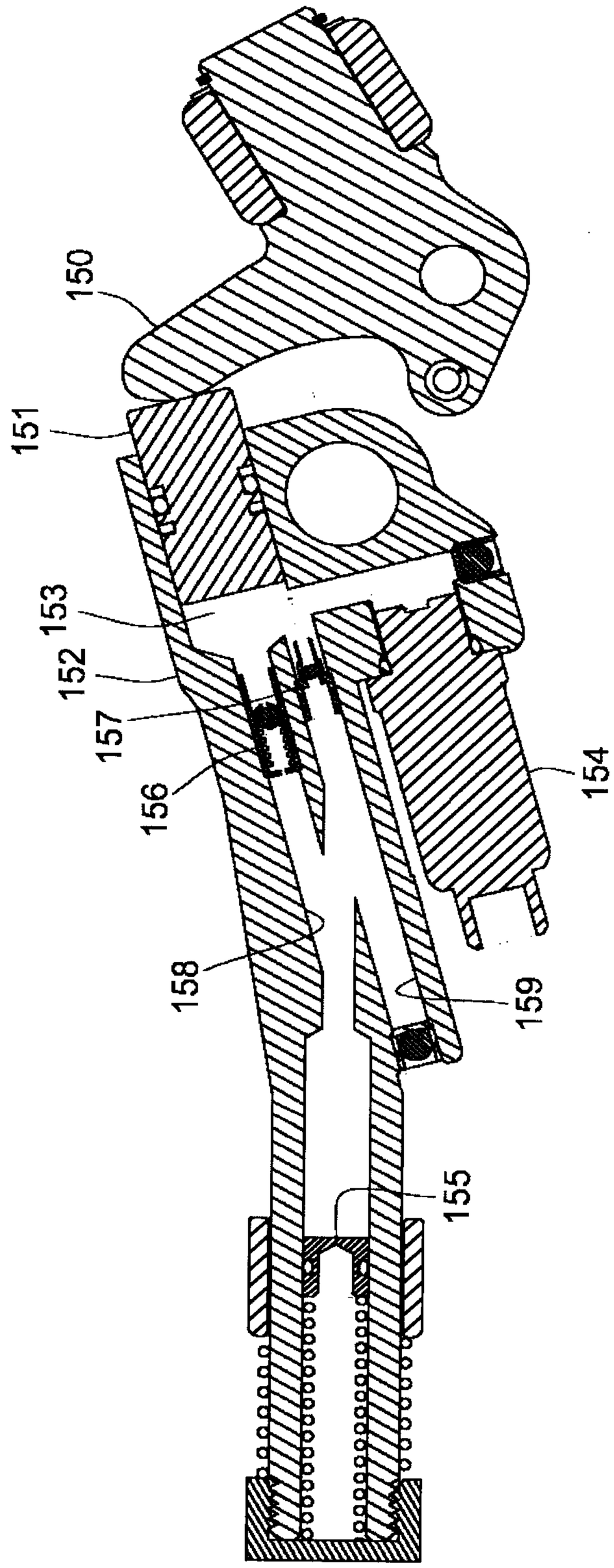


FIG. 17

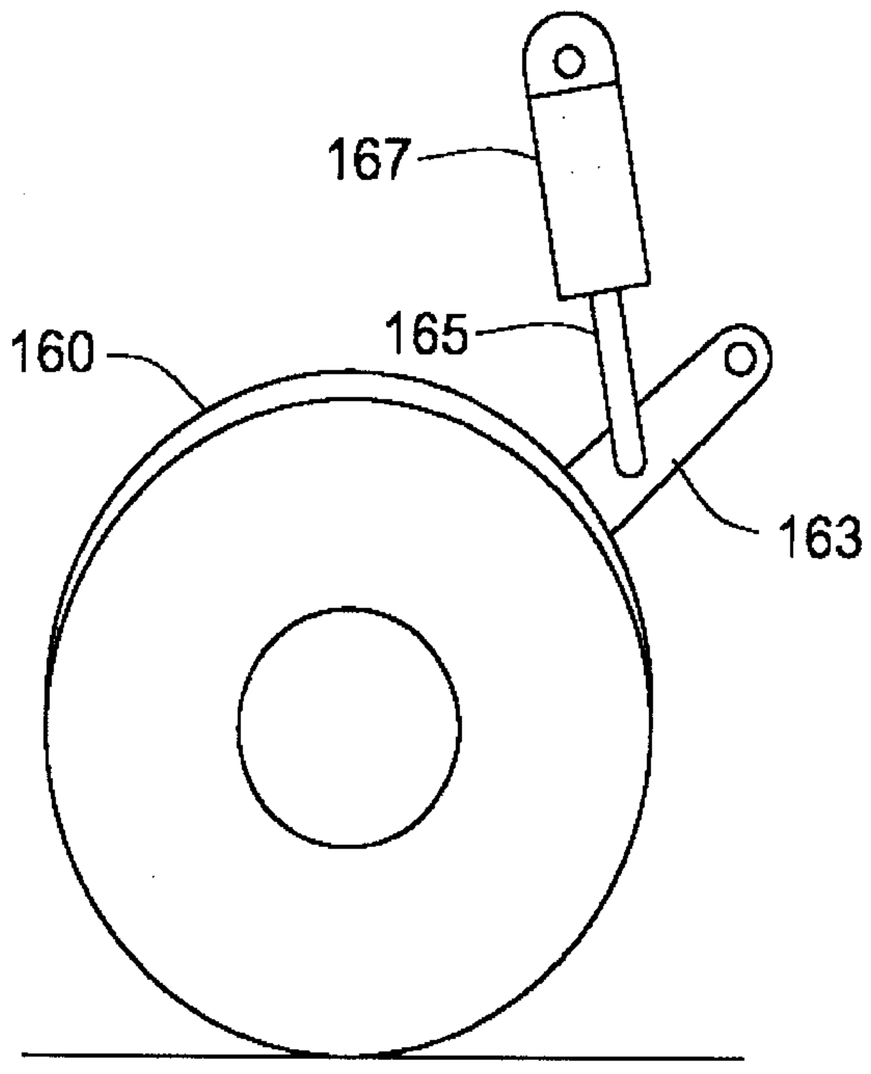


FIG. 18A

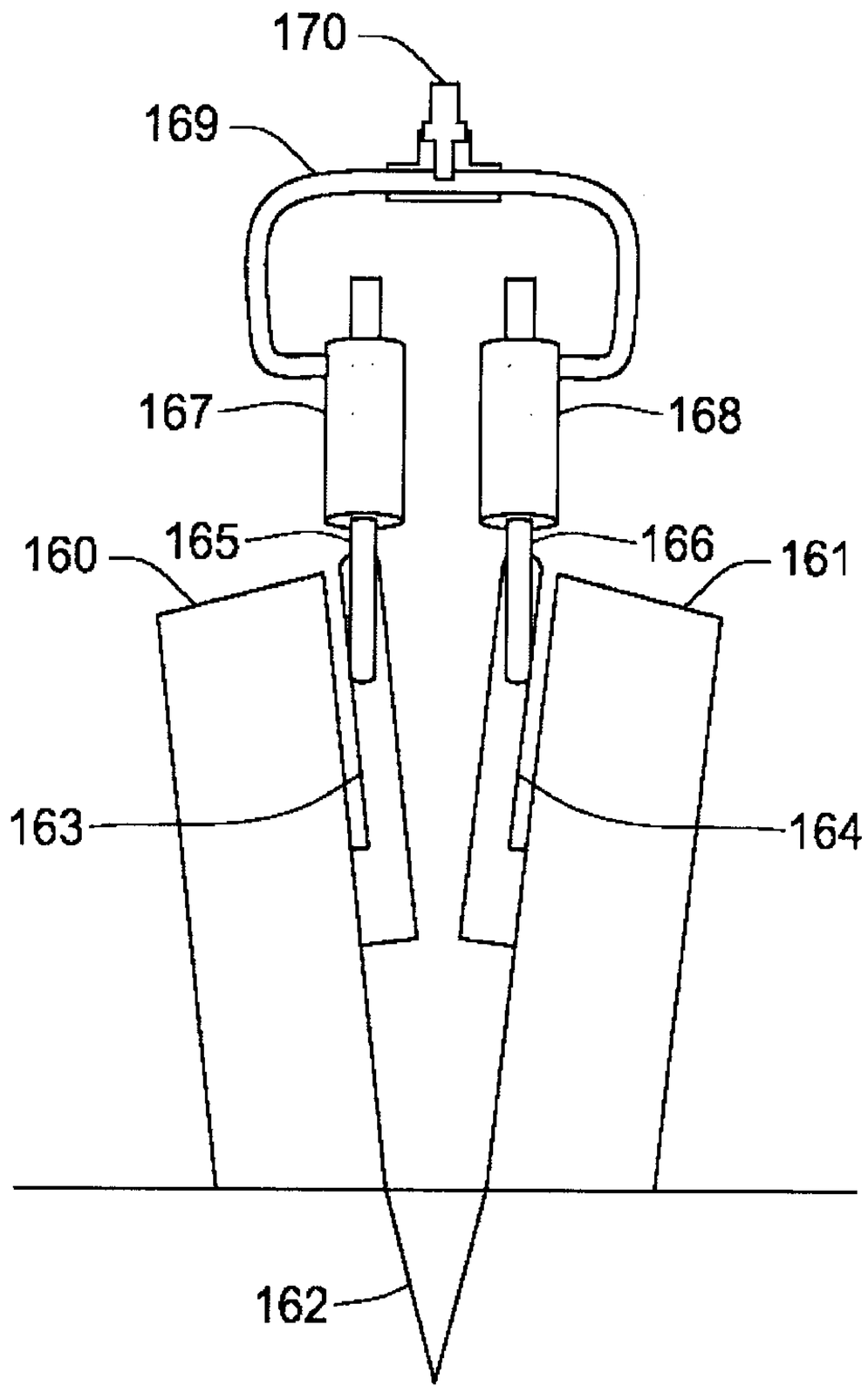


FIG. 18B

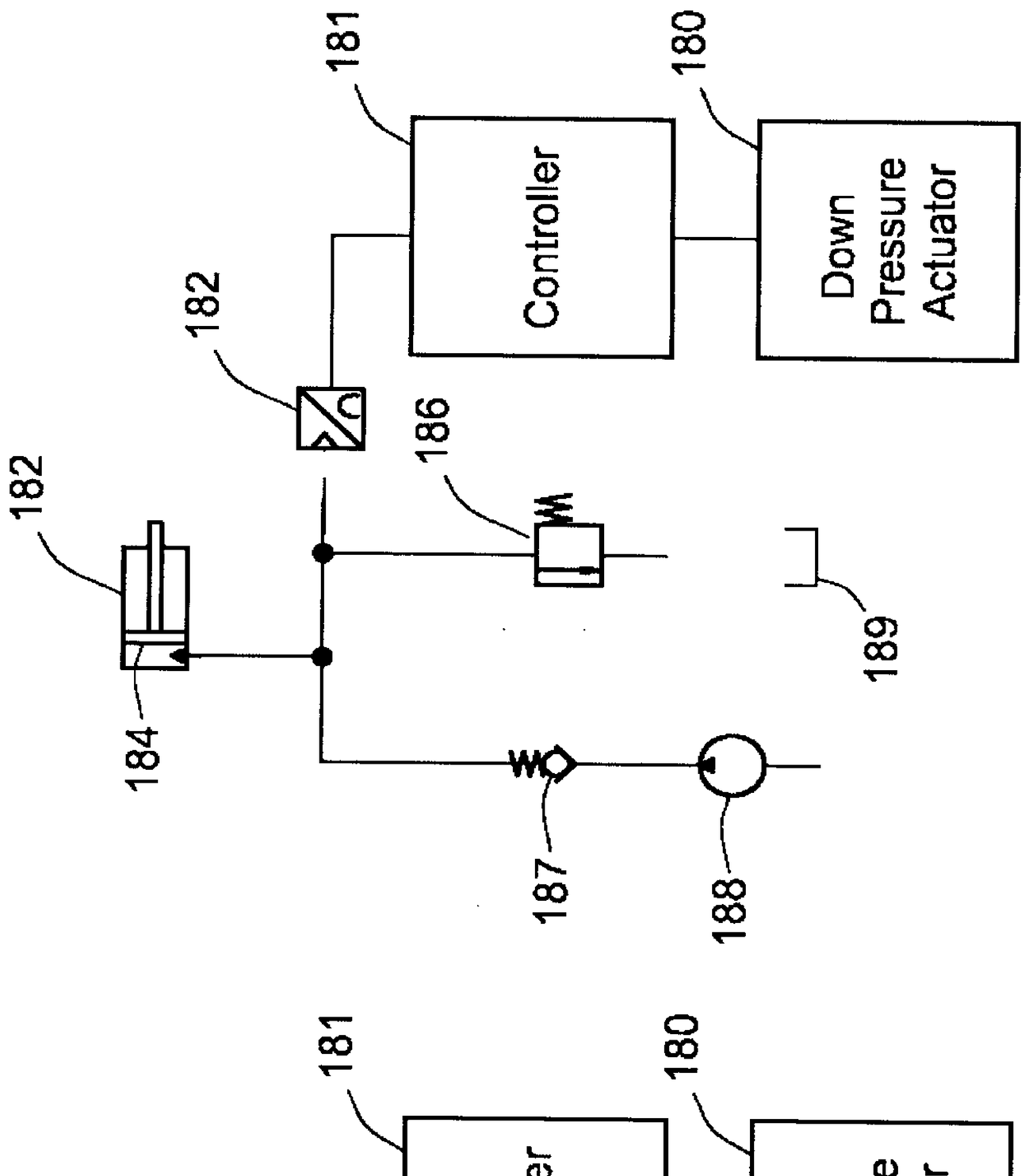

181
180
Controller
Down Pressure Actuator
182
186
182
184
189
187
88

FIG. 20

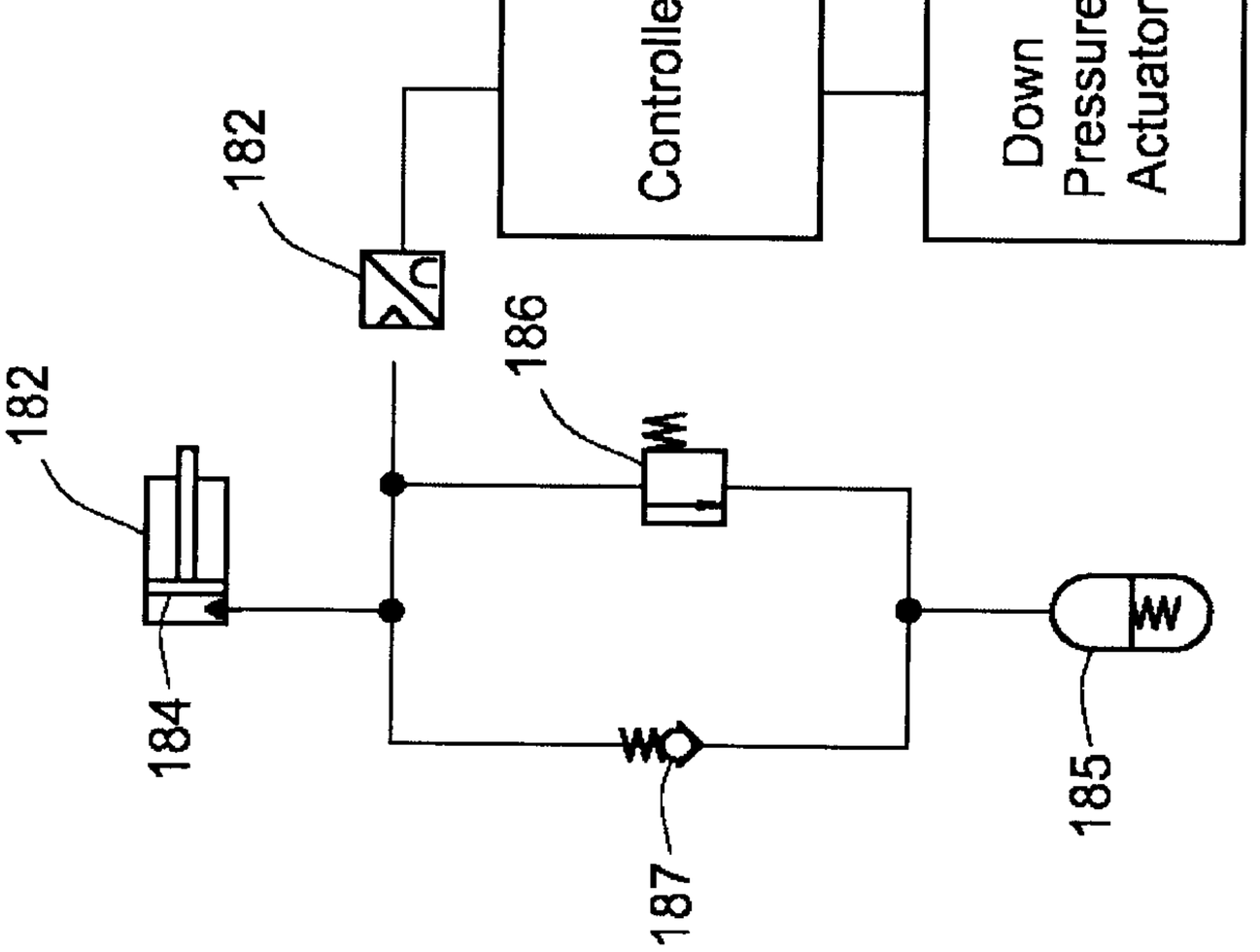

181
180
Controller
Down Pressure Actuator
182
186
182
184
185
187

FIG. 19

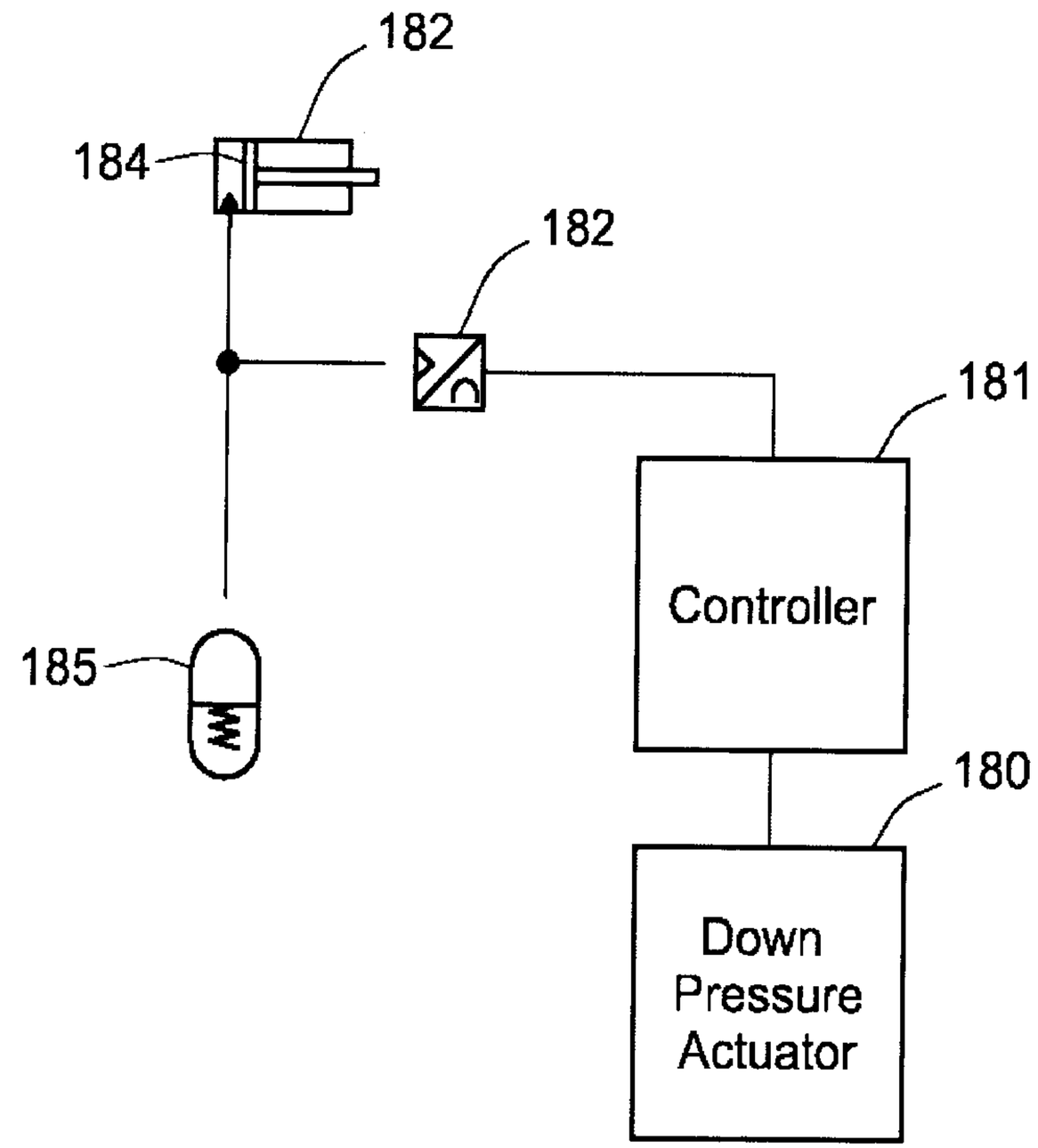

182
184
182
181
Controller
185
180
Down
Pressure
Actuator

FIG. 21

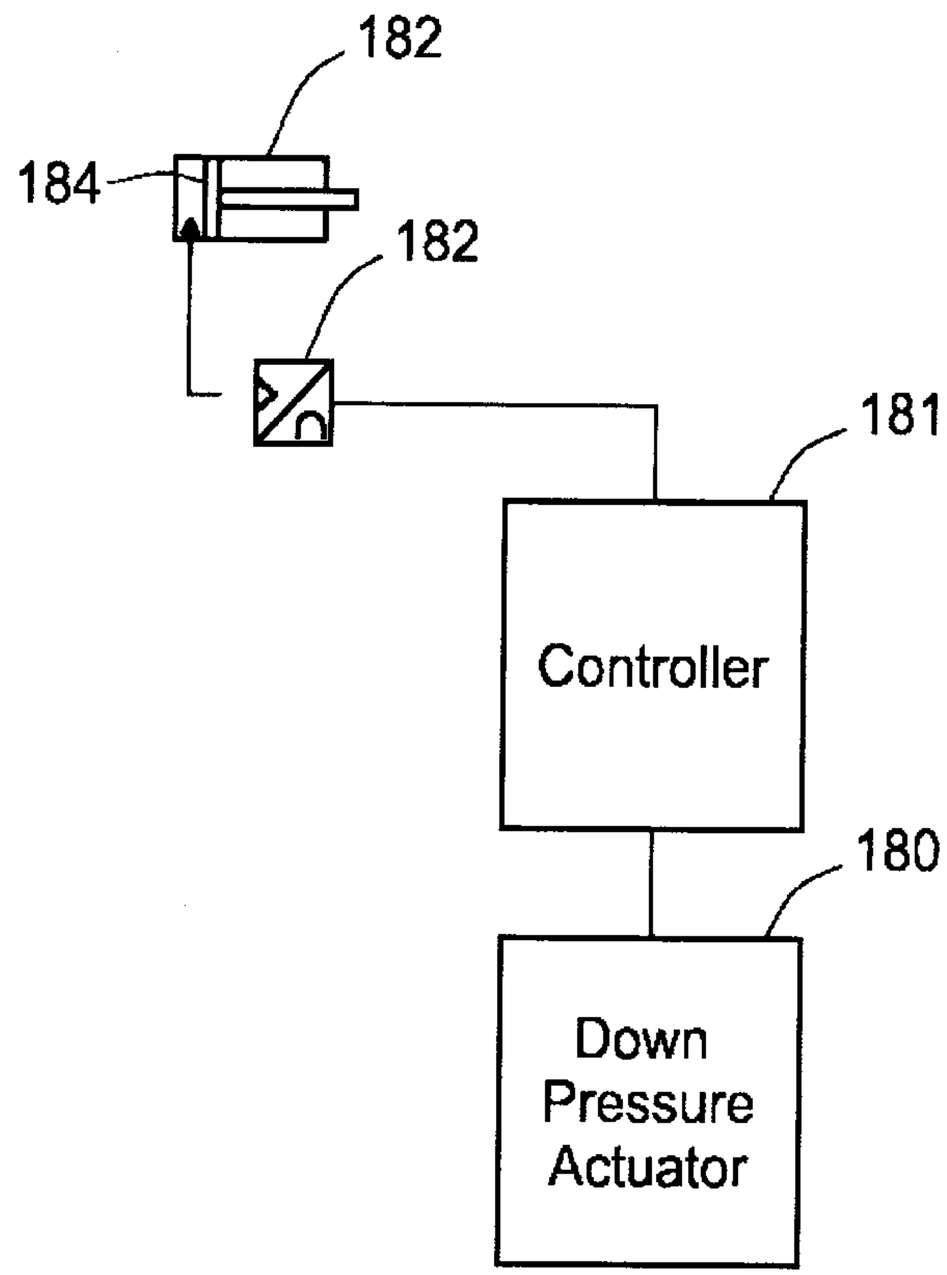

182
184
182
181
Controller
180
Down
Pressure
Actuator

FIG. 22

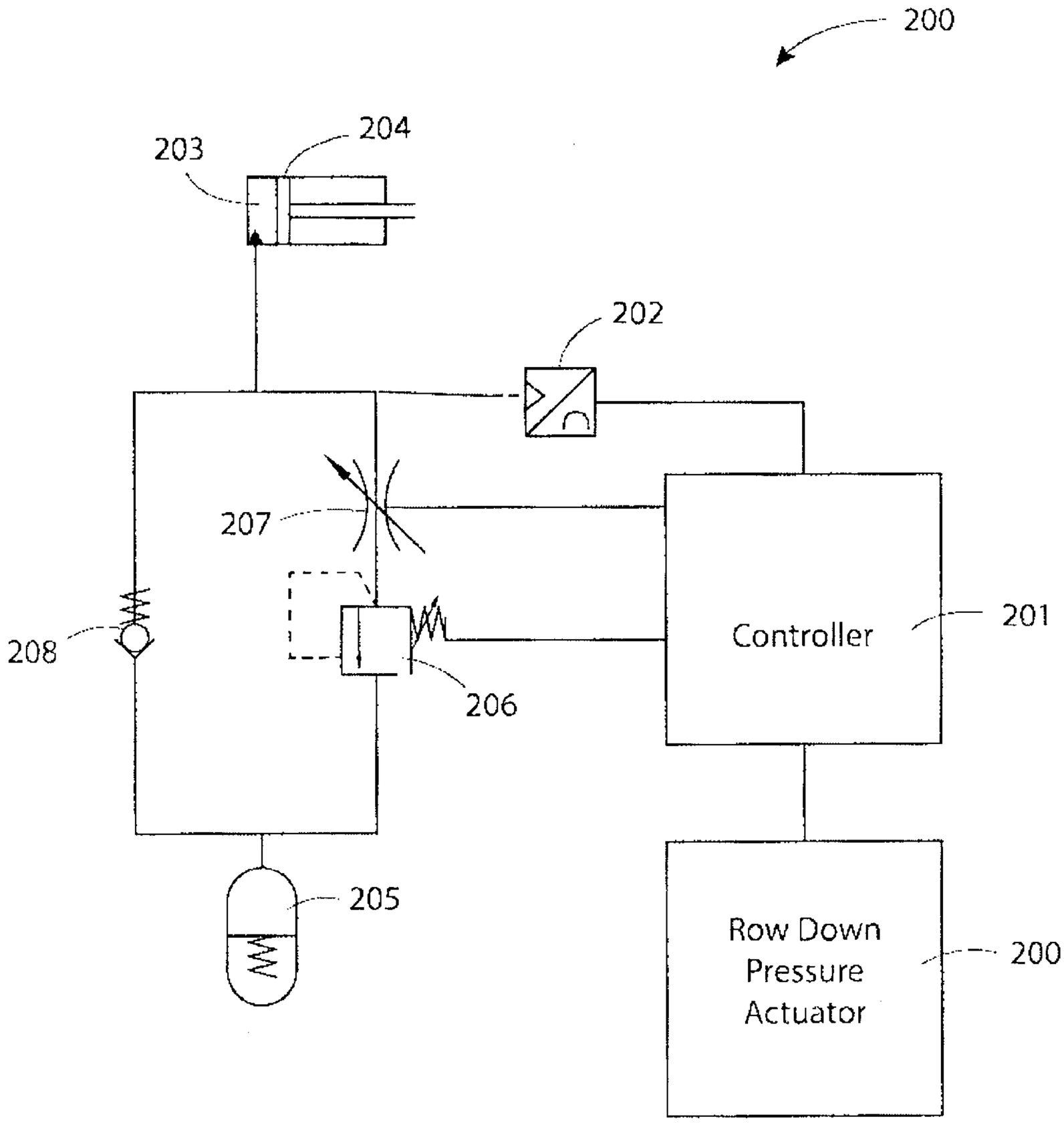

200
203
204
202
207
208
206
Controller
201
205
Row Down
Pressure
Actuator
200

FIG. 23

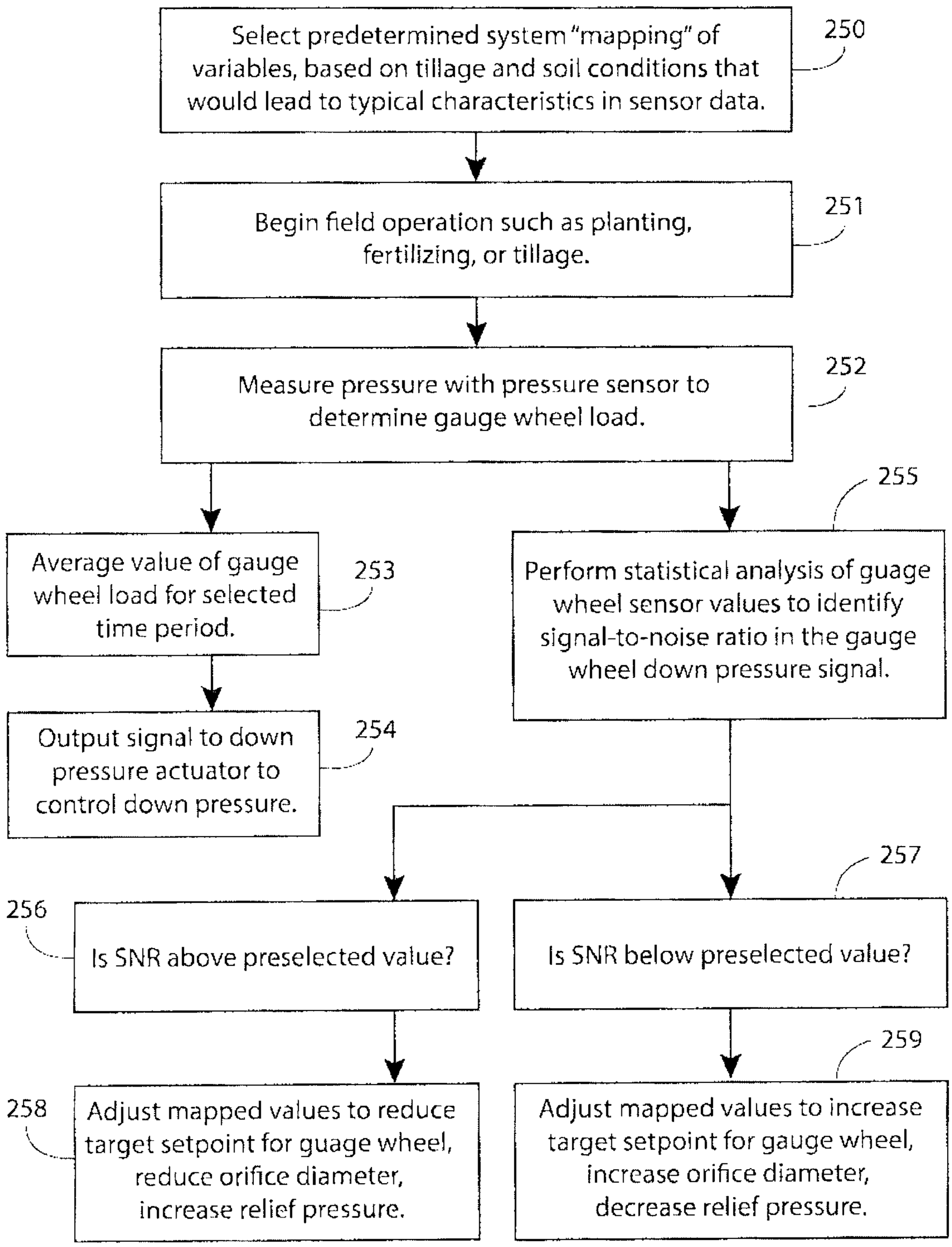

Select predetermined system "mapping" of variables, based on tillage and soil conditions that would lead to typical characteristics in sensor data.
250
Begin field operation such as planting, fertilizing, or tillage.
251
Measure pressure with pressure sensor to determine gauge wheel load.
252
Average value of gauge wheel load for selected time period.
253
Output signal to down pressure actuator to control down pressure.
254
Perform statistical analysis of guage wheel sensor values to identify signal-to-noise ratio in the gauge wheel down pressure signal.
255
256
Is SNR above preselected value?
257
Is SNR below preselected value?
258
Adjust mapped values to reduce target setpoint for guage wheel, reduce orifice diameter, increase relief pressure.
259
Adjust mapped values to increase target setpoint for gauge wheel, increase orifice diameter, decrease relief pressure.

FIG. 24

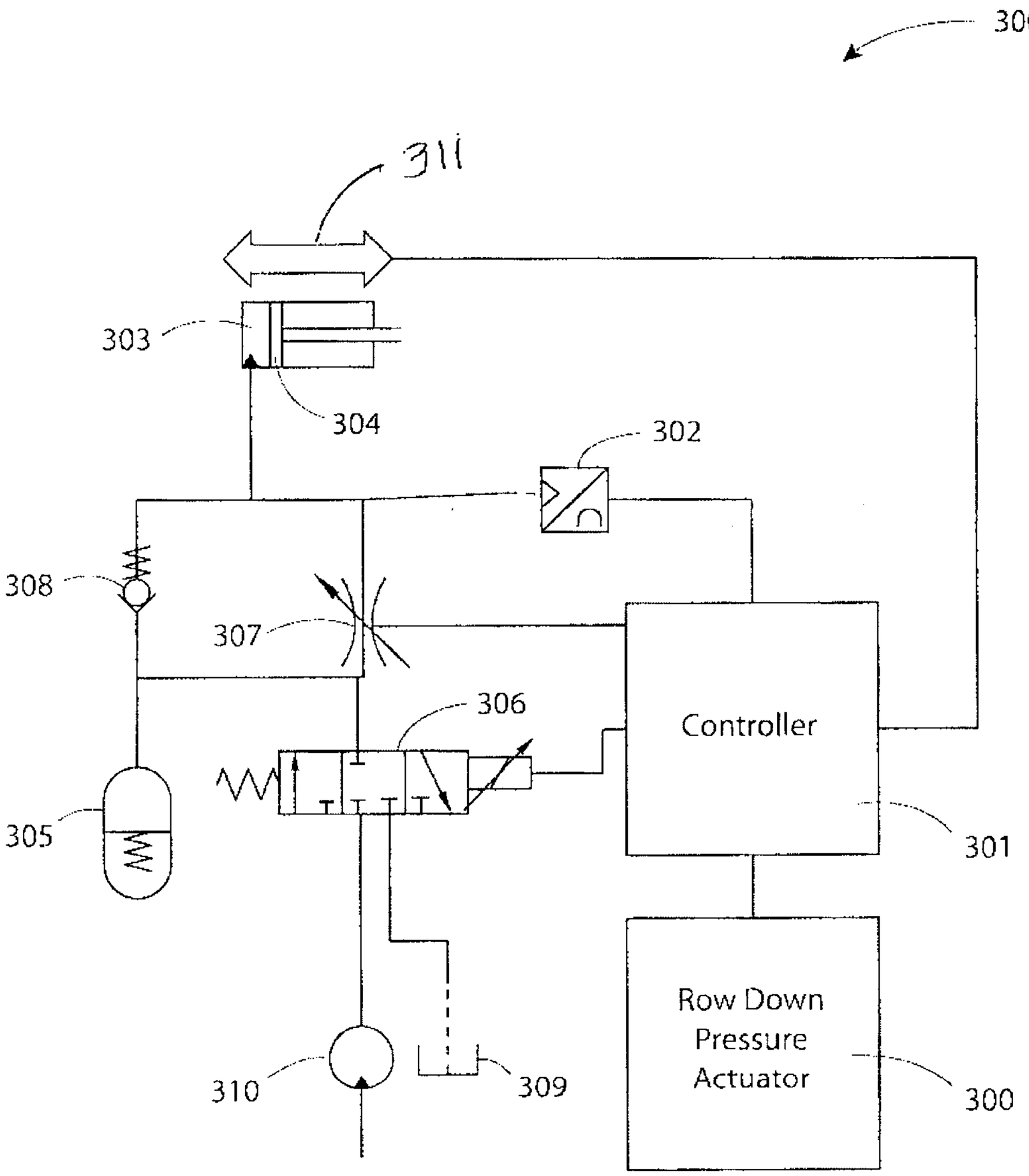

300
311
303
304
302
308
307
306
305
Controller
301
Row Down
Pressure
Actuator
310
309
300

FIG. 25

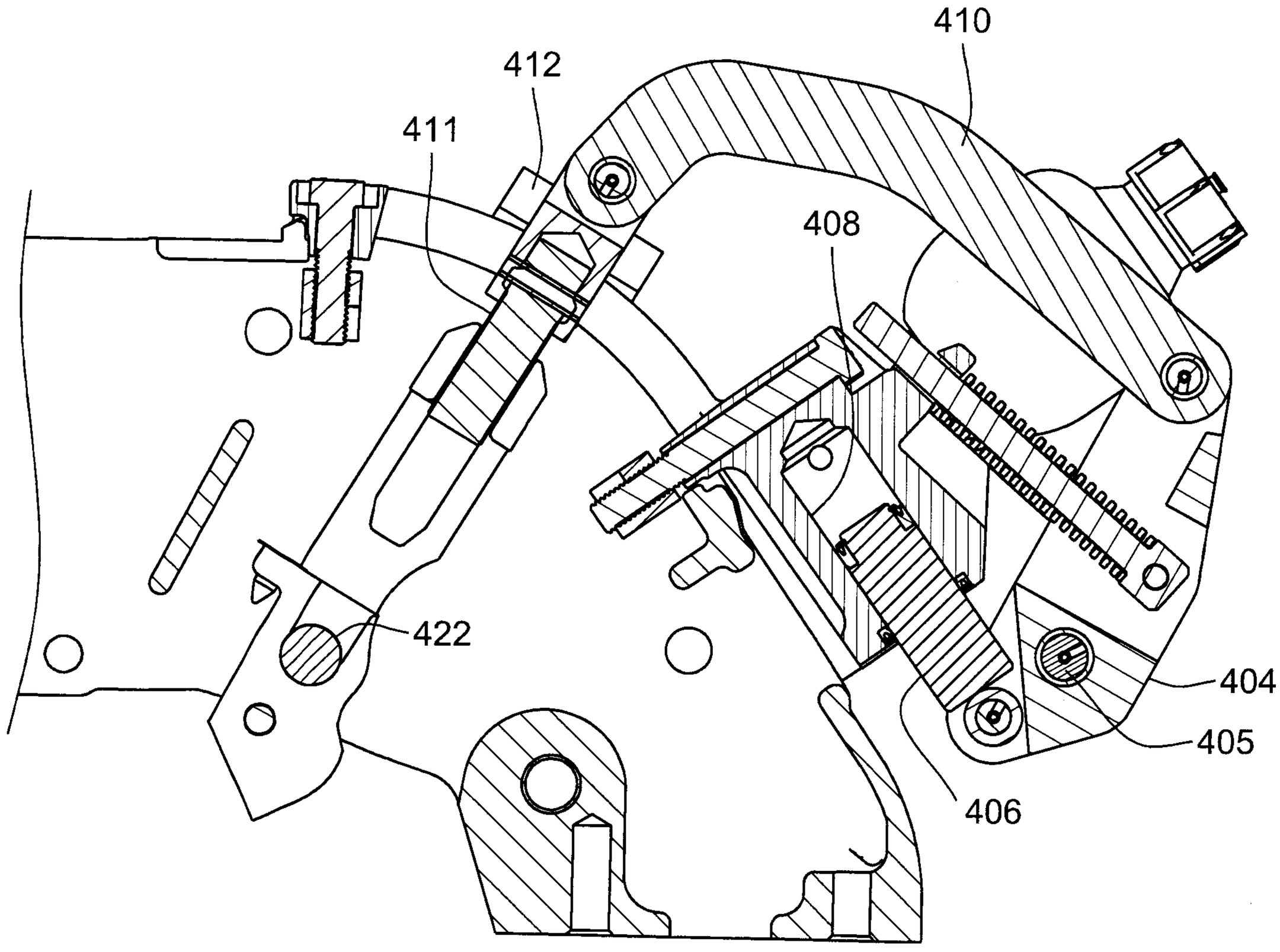


FIG. 26

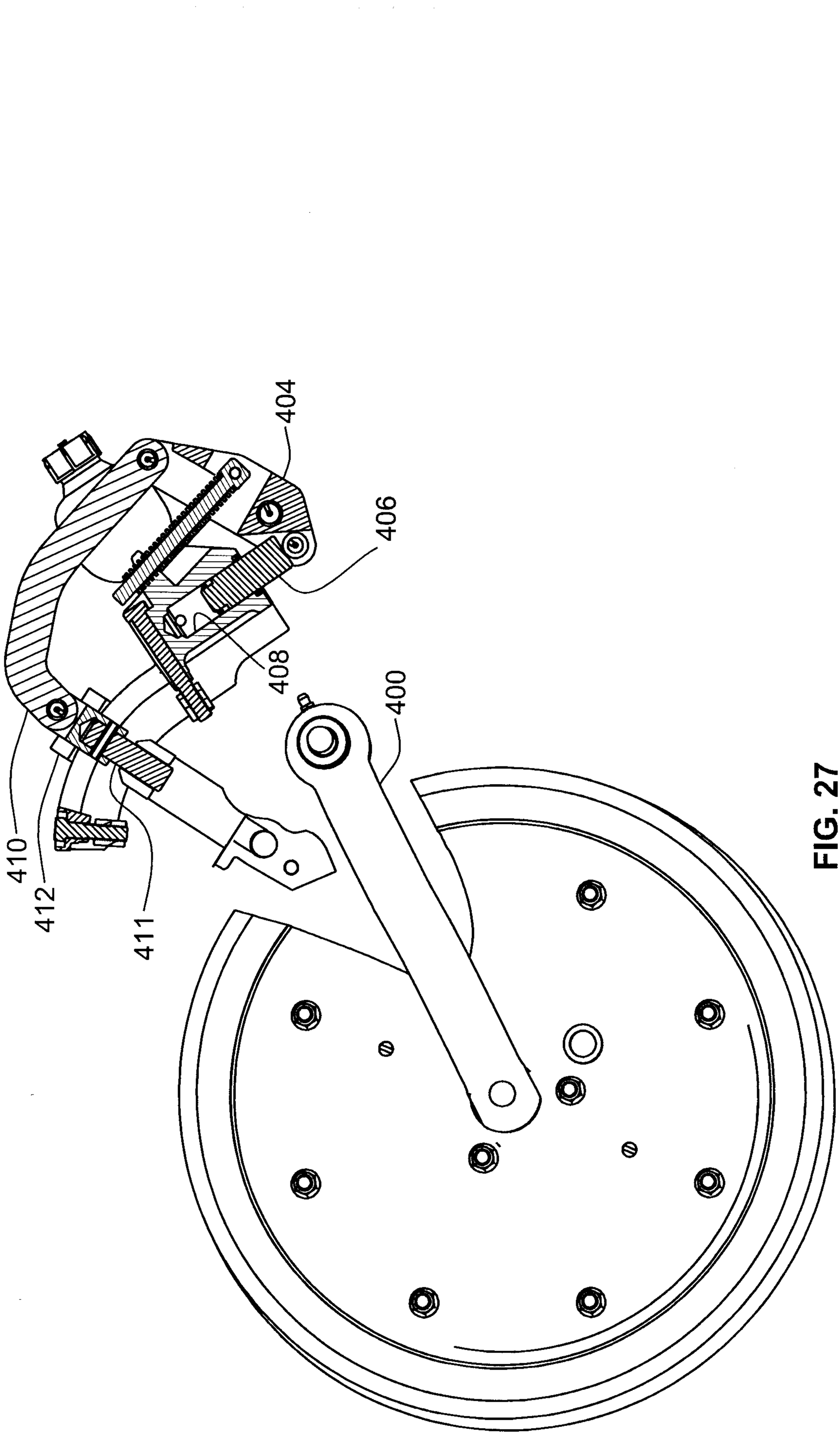


FIG. 27

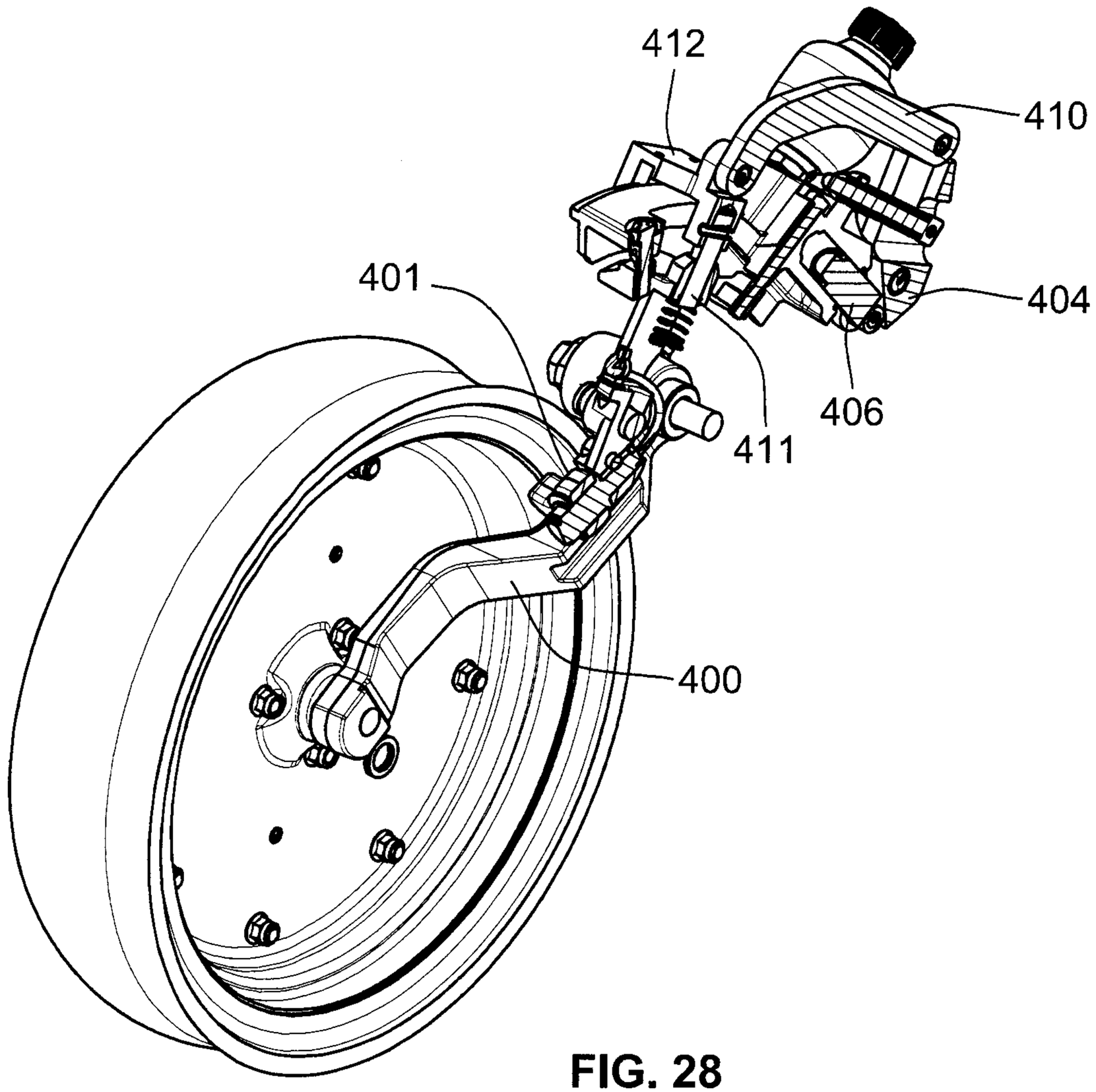


FIG. 28

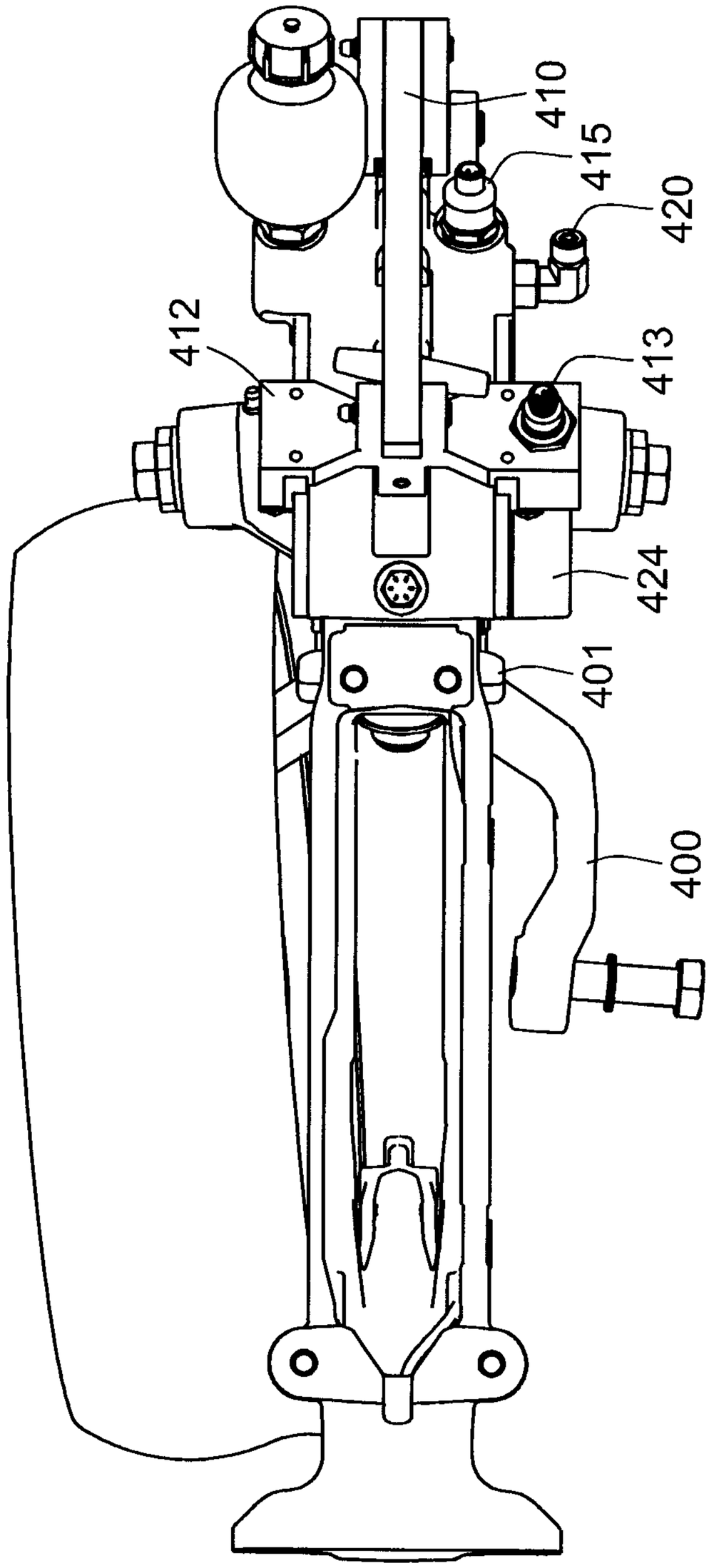


FIG. 29

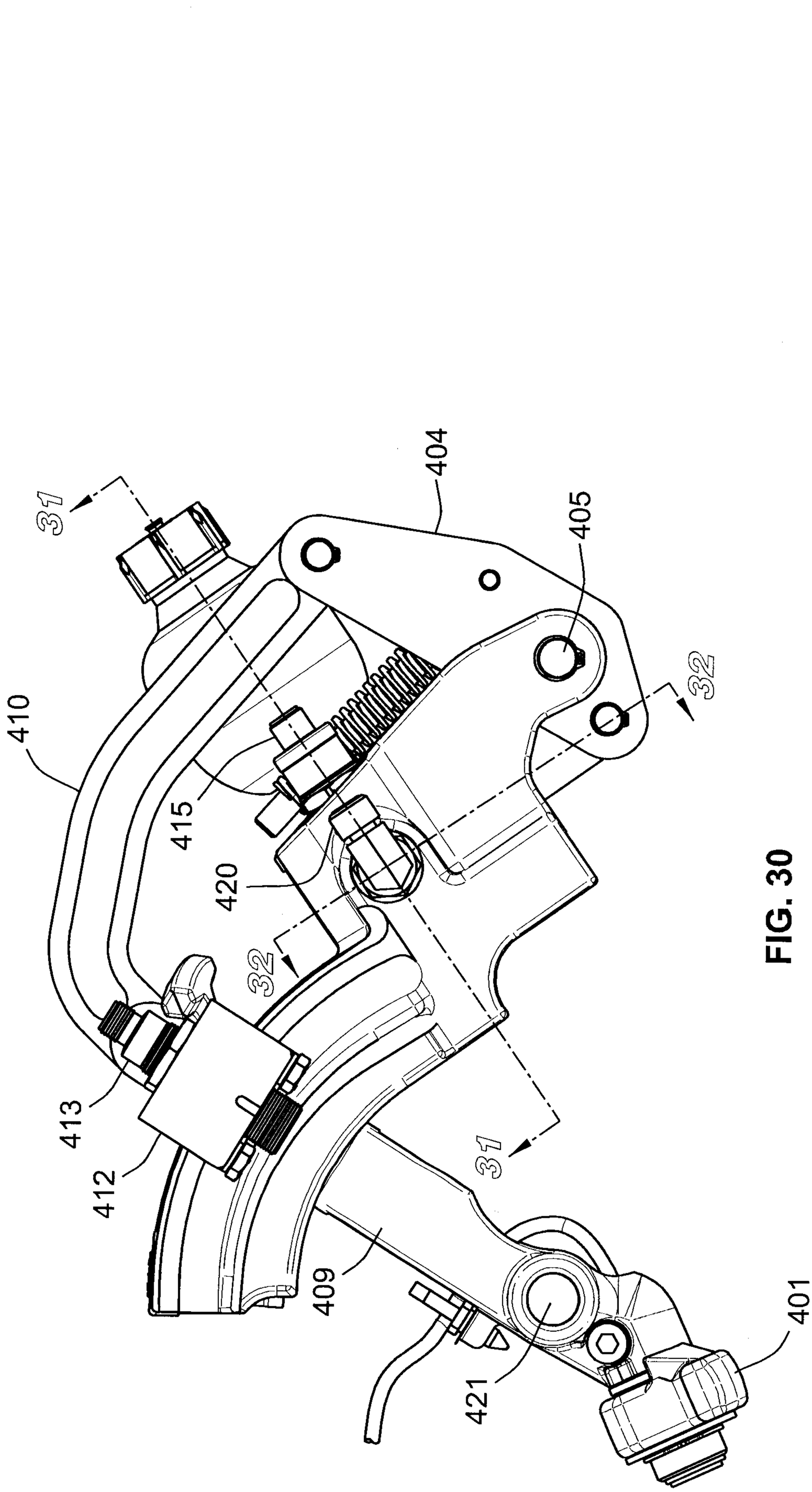


FIG. 30

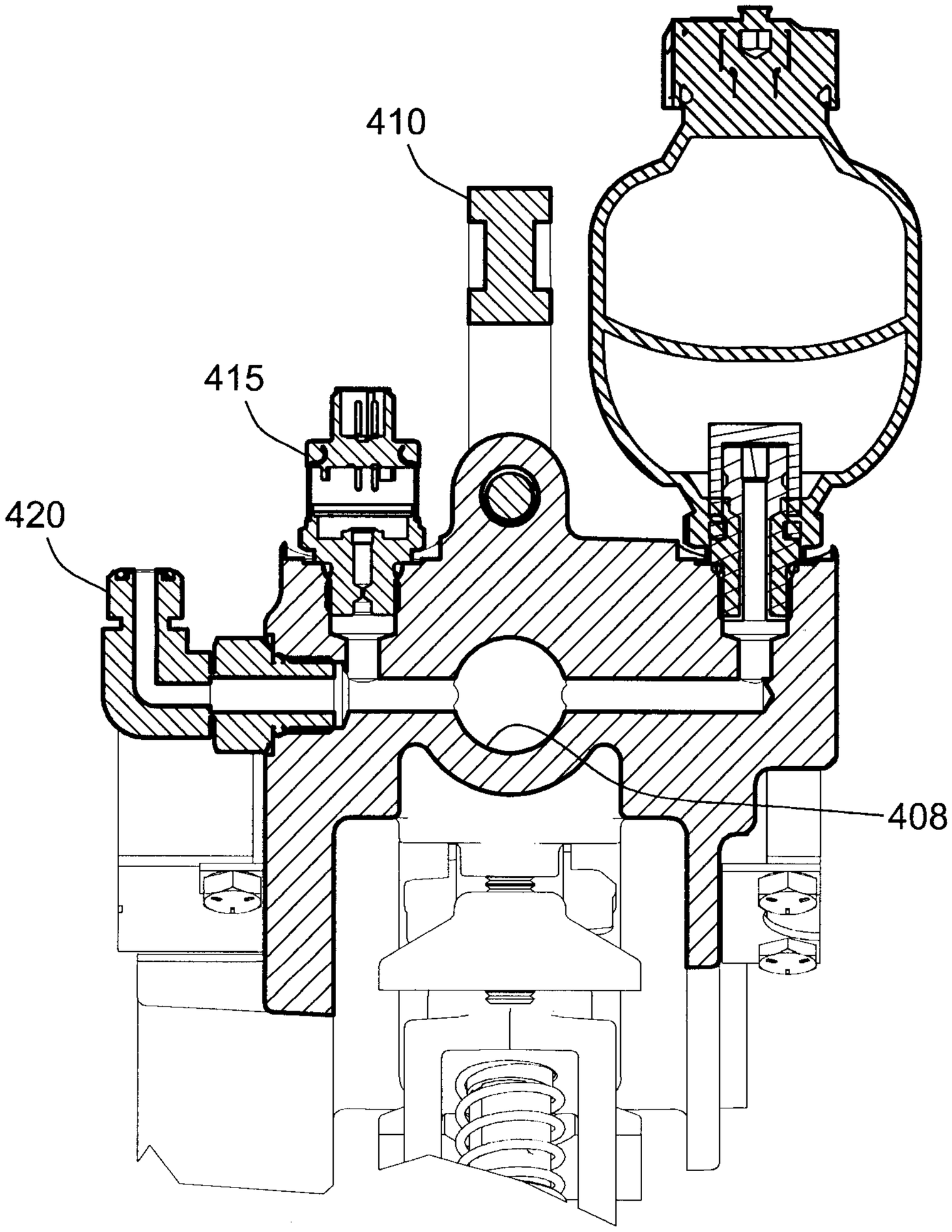


FIG. 31

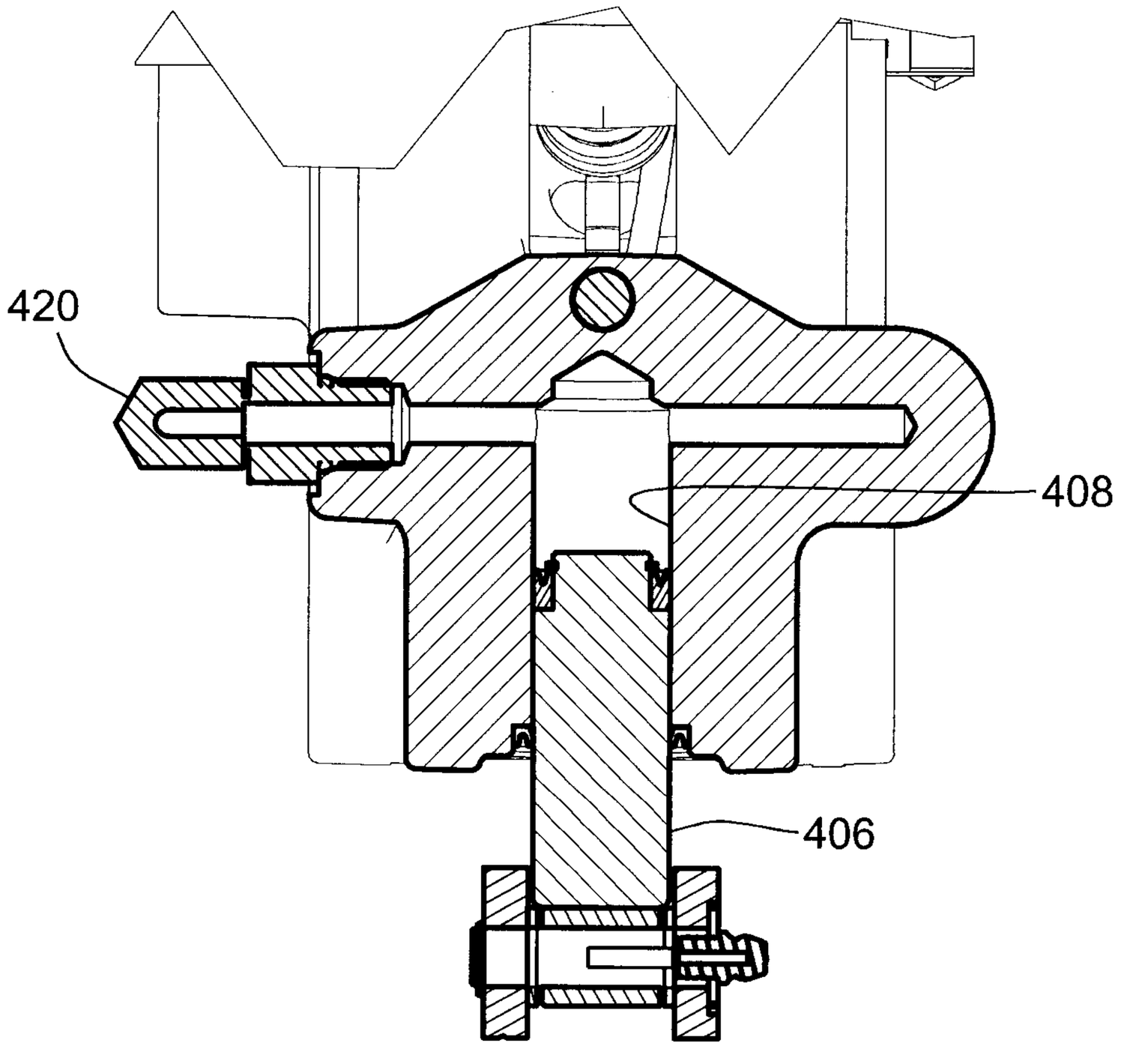


FIG. 32

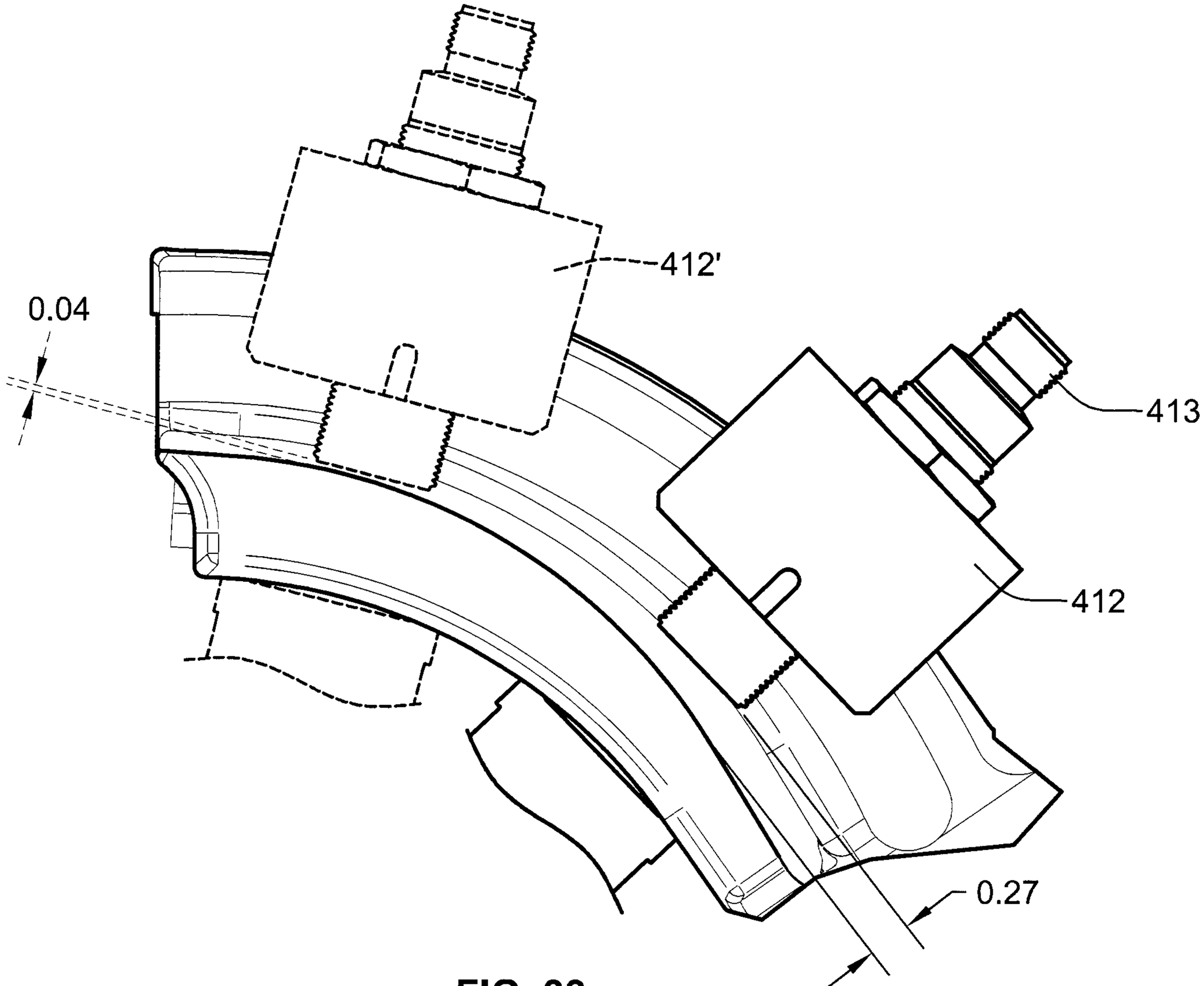
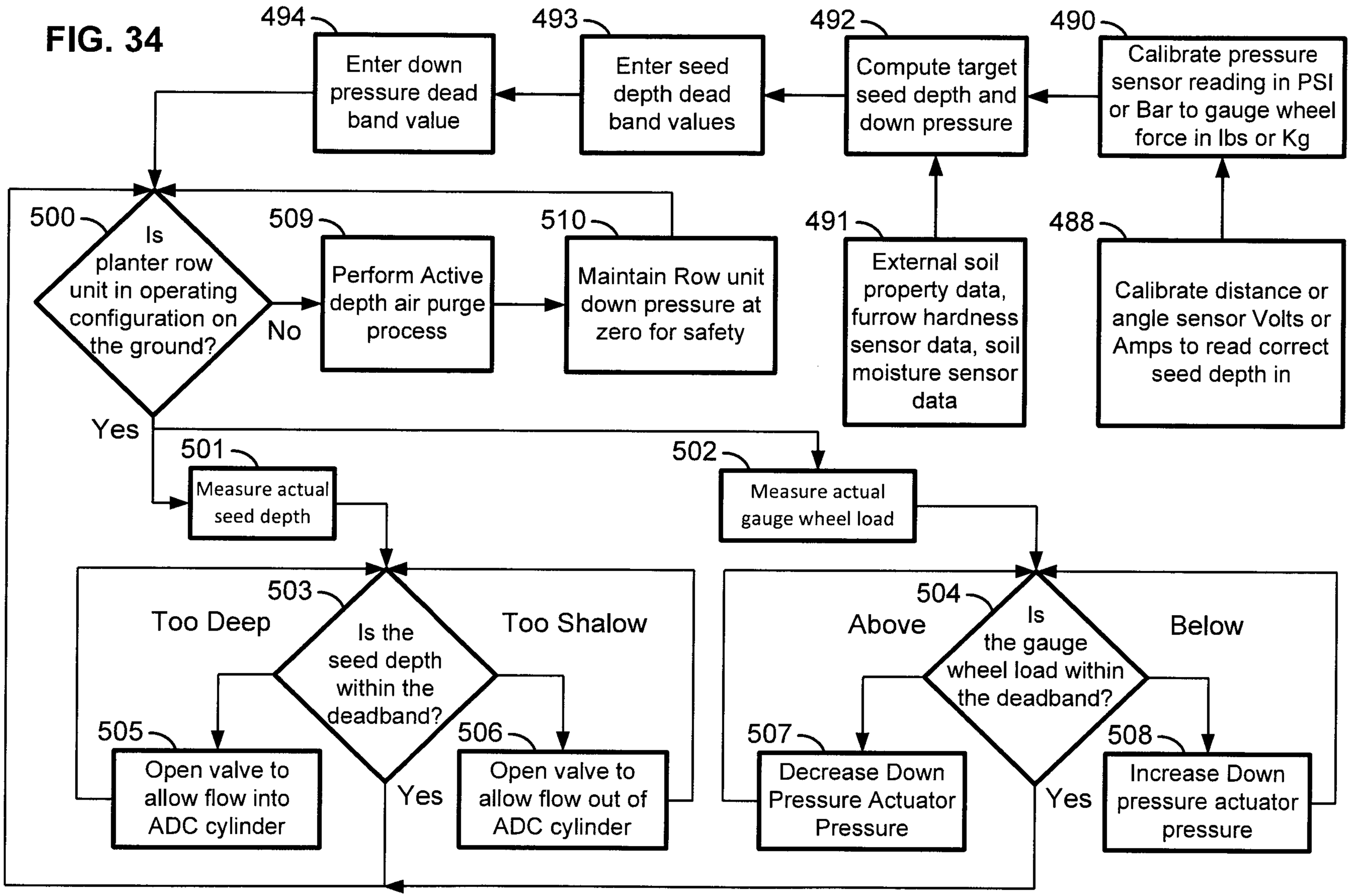
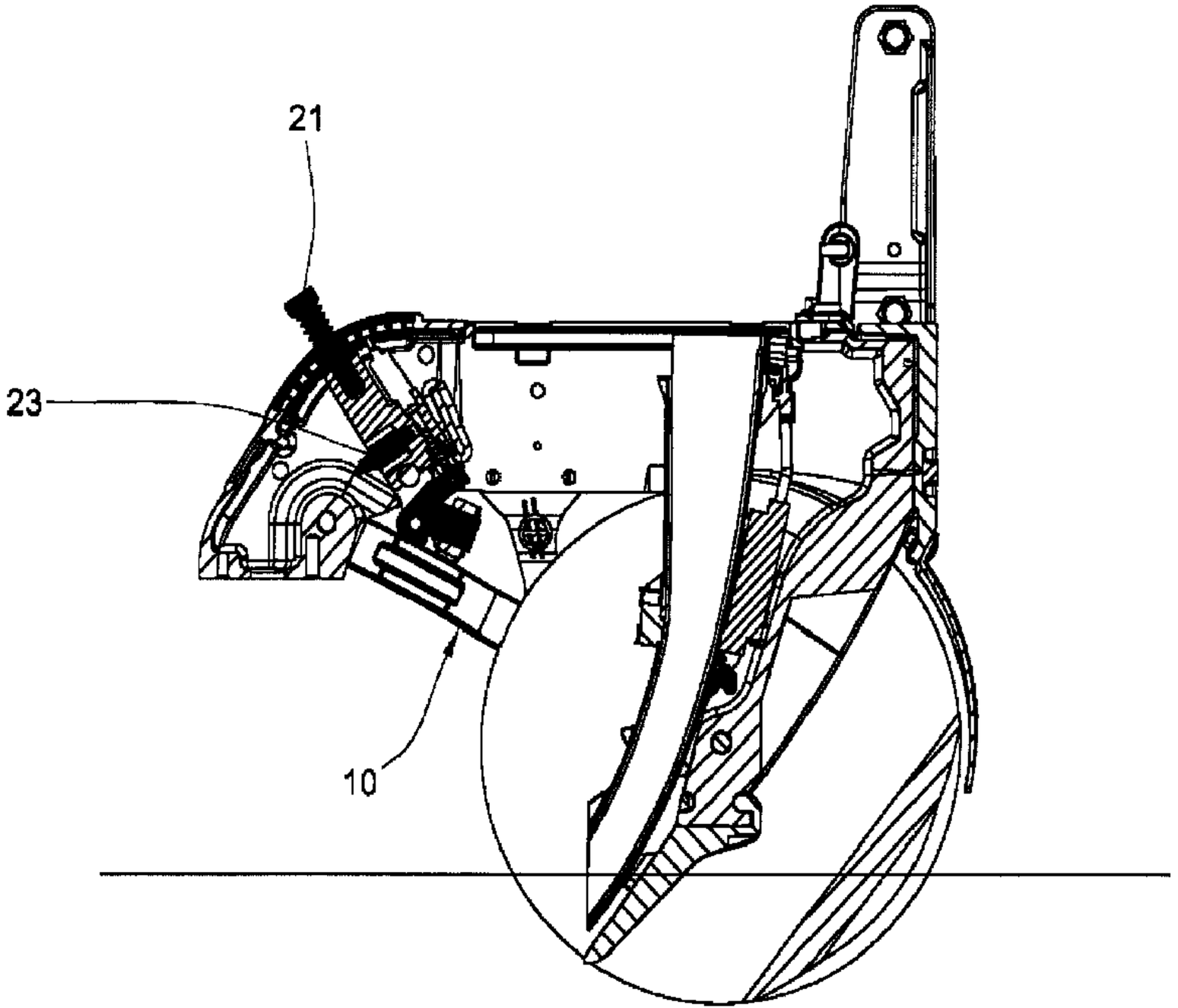


FIG. 33

FIG. 34


494
Enter down pressure dead band value
493
Enter seed depth dead band values
492
Compute target seed depth and down pressure
490
Calibrate pressure sensor reading in PSI or Bar to gauge wheel force in lbs or Kg
500
Is planter row unit in operating configuration on the ground?
No
509
Perform Active depth air purge process
510
Maintain Row unit down pressure at zero for safety
491
External soil property data, furrow hardness sensor data, soil moisture sensor data
488
Calibrate distance or angle sensor Volts or Amps to read correct seed depth in
Yes
501
Measure actual seed depth
502
Measure actual gauge wheel load
503
Too Deep
Is the seed depth within the deadband?
Too Shalow
505
Open valve to allow flow into ADC cylinder
Yes
506
Open valve to allow flow out of ADC cylinder
504
Above
Is the gauge wheel load within the deadband?
Below
507
Decrease Down Pressure Actuator Pressure
Yes
508
Increase Down pressure actuator pressure


21
23
10