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(54) **SUSPENSION FOR WHEELED VEHICLES**

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See application file for complete search history.

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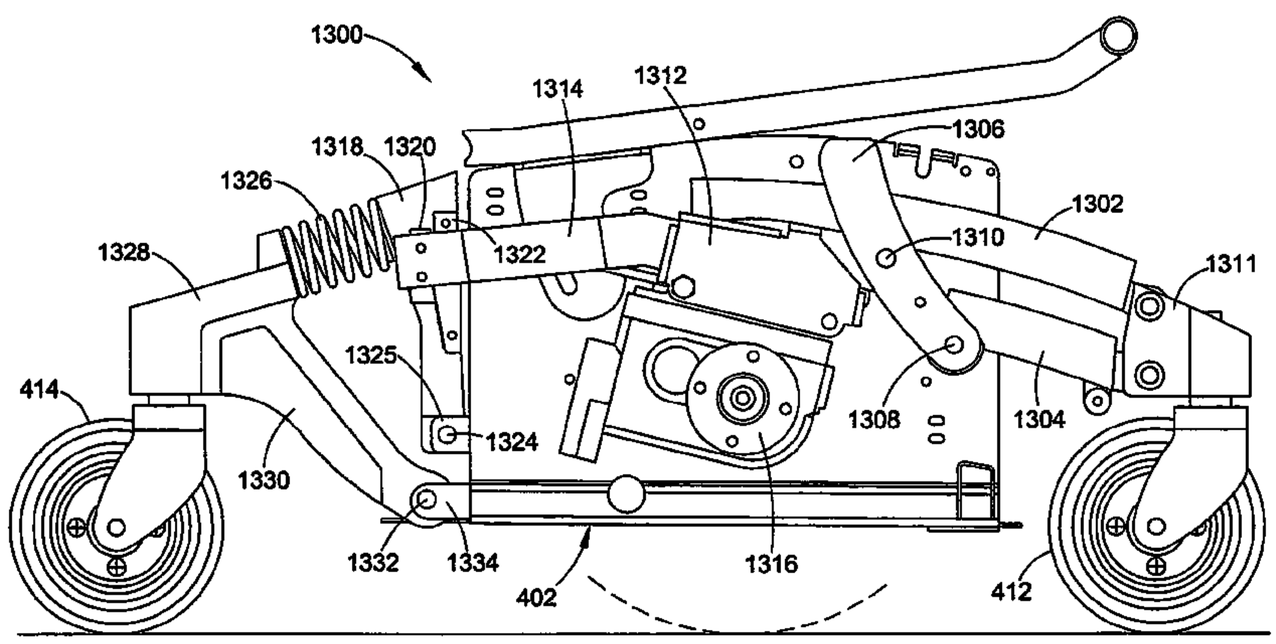
Amendment from U.S. Appl. No. 15/159,264 dated Apr. 26, 2018.
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(57) **ABSTRACT**

A wheelchair suspension comprises a frame, at least one pivot arm, at least one front caster, at least one rear caster, a stabilizing system, and a sensor. The pivot arm is coupled to the frame. The front caster is coupled to the pivot arm. The rear caster is coupled to the frame. The stabilizing system is coupled to the frame and the pivot arm. The sensor is arranged such that tipping of the frame causes actuation of the stabilizing system to at least partially resist further movement of the frame.

10 Claims, 32 Drawing Sheets



Related U.S. Application Data

division of application No. 14/486,766, filed on Sep. 15, 2014, now Pat. No. 9,364,377, which is a continuation of application No. 13/970,794, filed on Aug. 20, 2013, now Pat. No. 8,833,774, which is a division of application No. 11/472,509, filed on Jun. 20, 2006, now Pat. No. 8,534,679, which is a continuation-in-part of application No. 10/695,045, filed on Oct. 27, 2003, now Pat. No. 7,083,195, which is a continuation-in-part of application No. 10/643,010, filed on Aug. 18, 2003, now Pat. No. 6,851,711, said application No. 11/472,509 is a continuation of application No. 11/077,483, filed on Mar. 10, 2005, now Pat. No. 7,293,801, which is a continuation-in-part of application No. 10/695,045, filed on Oct. 27, 2003, now Pat. No. 7,083,195, which is a continuation-in-part of application No. 10/643,010, filed on Aug. 18, 2003, now Pat. No. 6,851,711.

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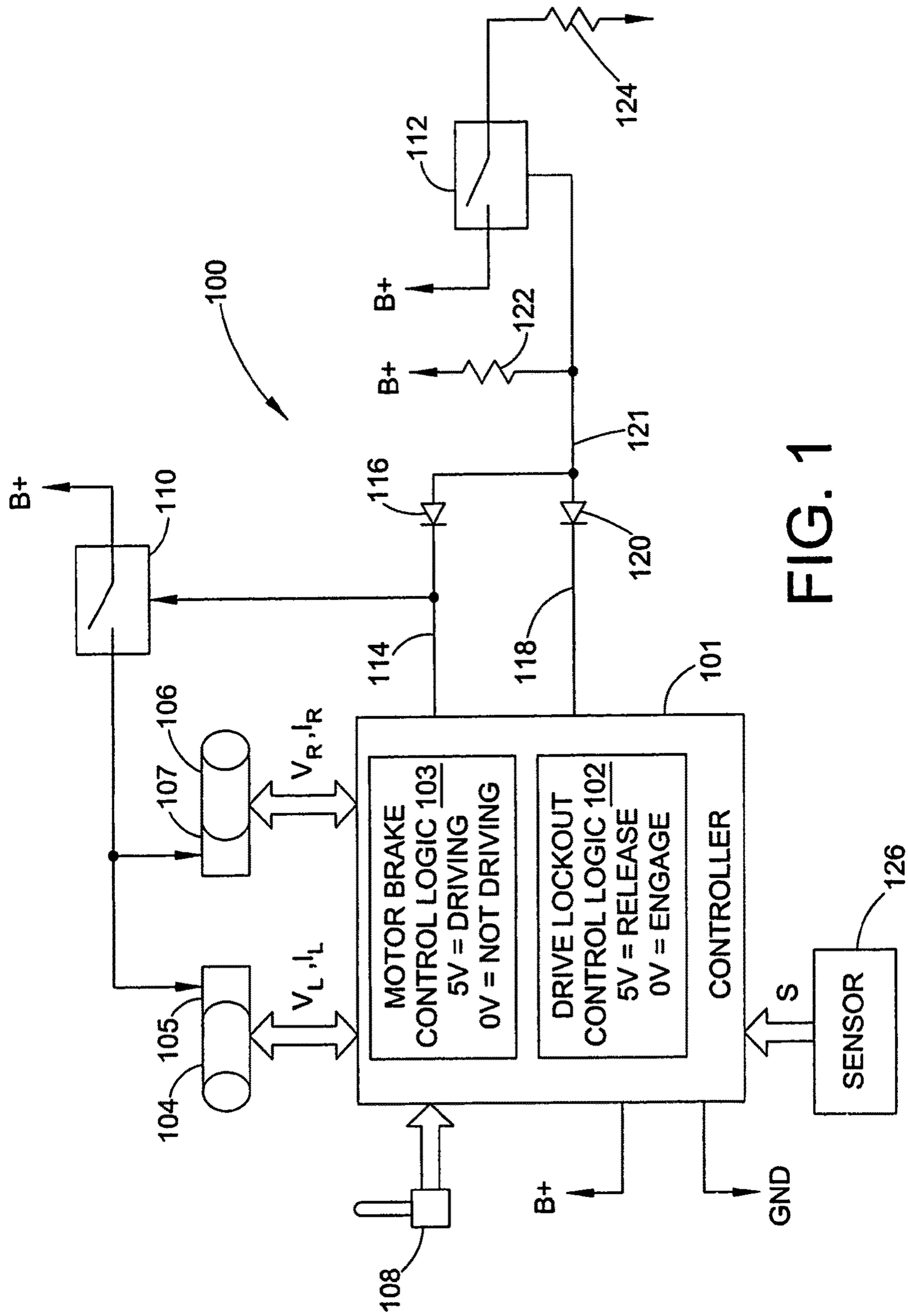

100
B+
110
106
107
V_R, I_R
105
104
V_L, I_L
108
114
116
118
120
121
122
124
126
101
MOTOR BRAKE CONTROL LOGIC 103
5V = DRIVING
0V = NOT DRIVING
DRIVE LOCKOUT CONTROL LOGIC 102
5V = RELEASE
0V = ENGAGE
CONTROLLER
S
SENSOR
B+
GND

FIG. 1

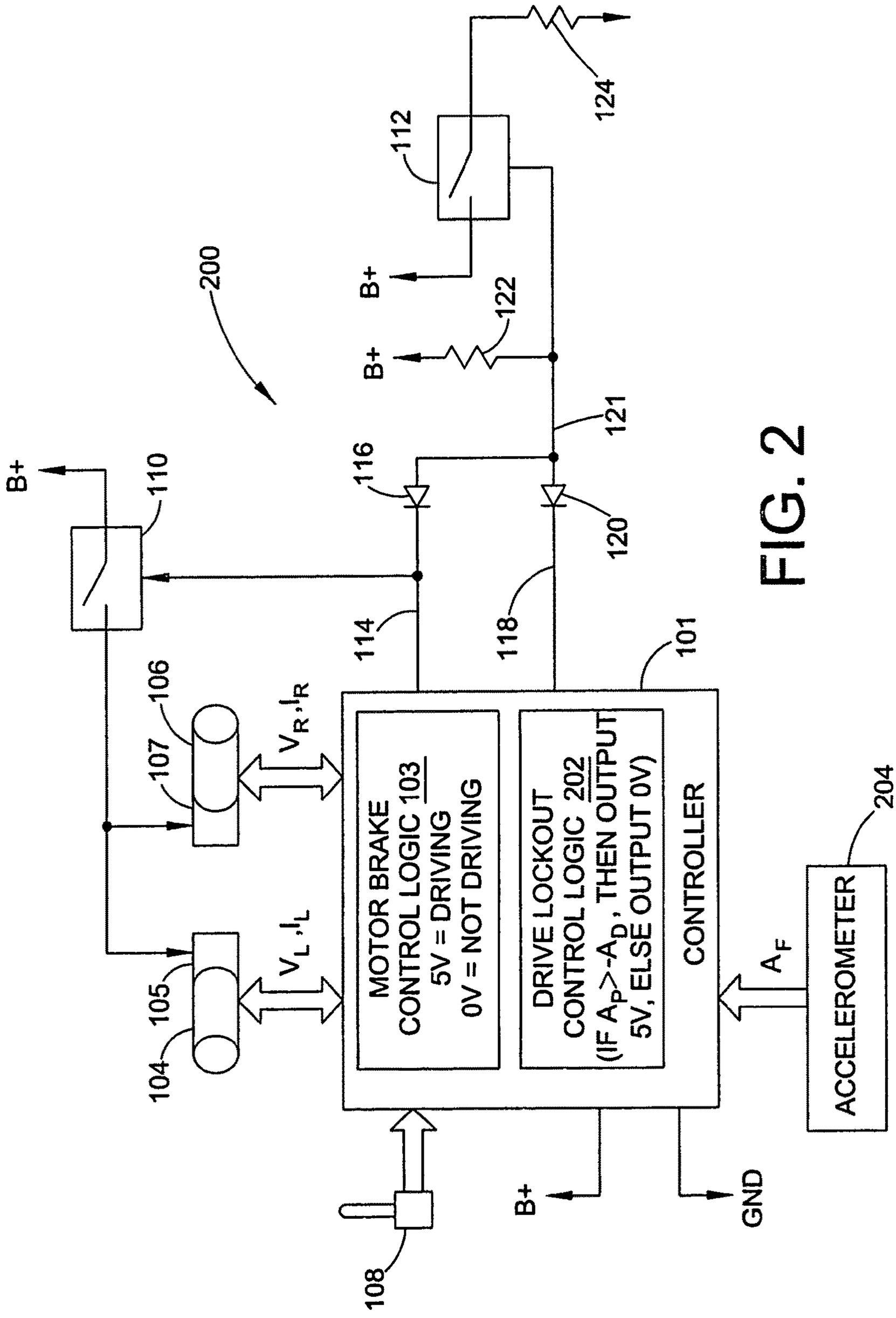

200
B+
112
124
122
B+
121
116
120
B+
110
114
118
101
106
107
V_R, I_R
MOTOR BRAKE CONTROL LOGIC 103
5V = DRIVING
0V = NOT DRIVING
DRIVE LOCKOUT CONTROL LOGIC 202
(IF A_P>-A_D, THEN OUTPUT 5V, ELSE OUTPUT 0V)
CONTROLLER
204
ACCELEROMETER
A_F
105
104
V_L, I_L
108
B+
GND

FIG. 2

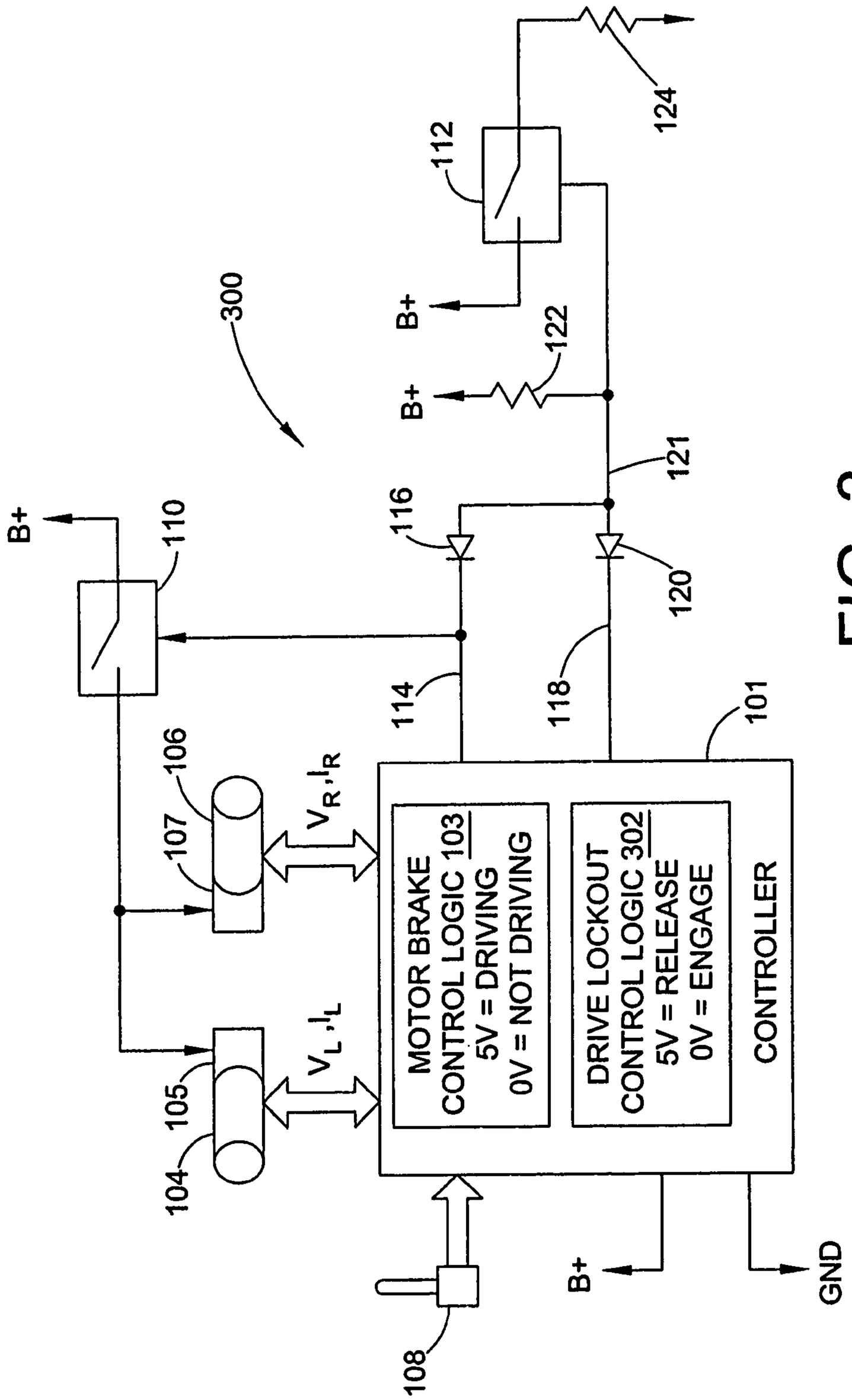

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B+
112
124
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B+
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116
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B+
110
114
118
101
106
107
V_R, I_R
MOTOR BRAKE
CONTROL LOGIC 103
5V = DRIVING
0V = NOT DRIVING
DRIVE LOCKOUT
CONTROL LOGIC 302
5V = RELEASE
0V = ENGAGE
CONTROLLER
105
104
V_L, I_L
108
B+
GND

FIG. 3

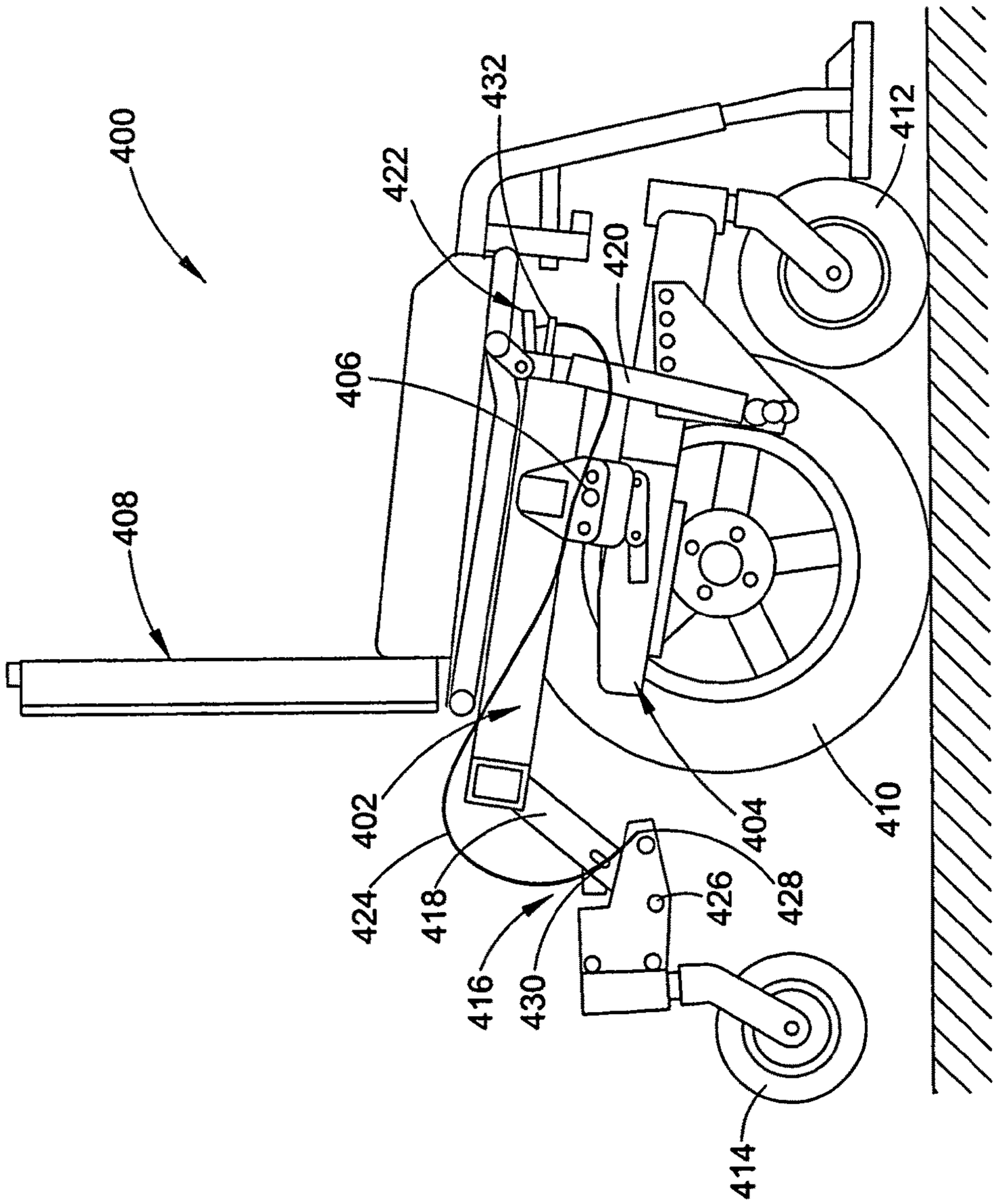

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FIG. 4

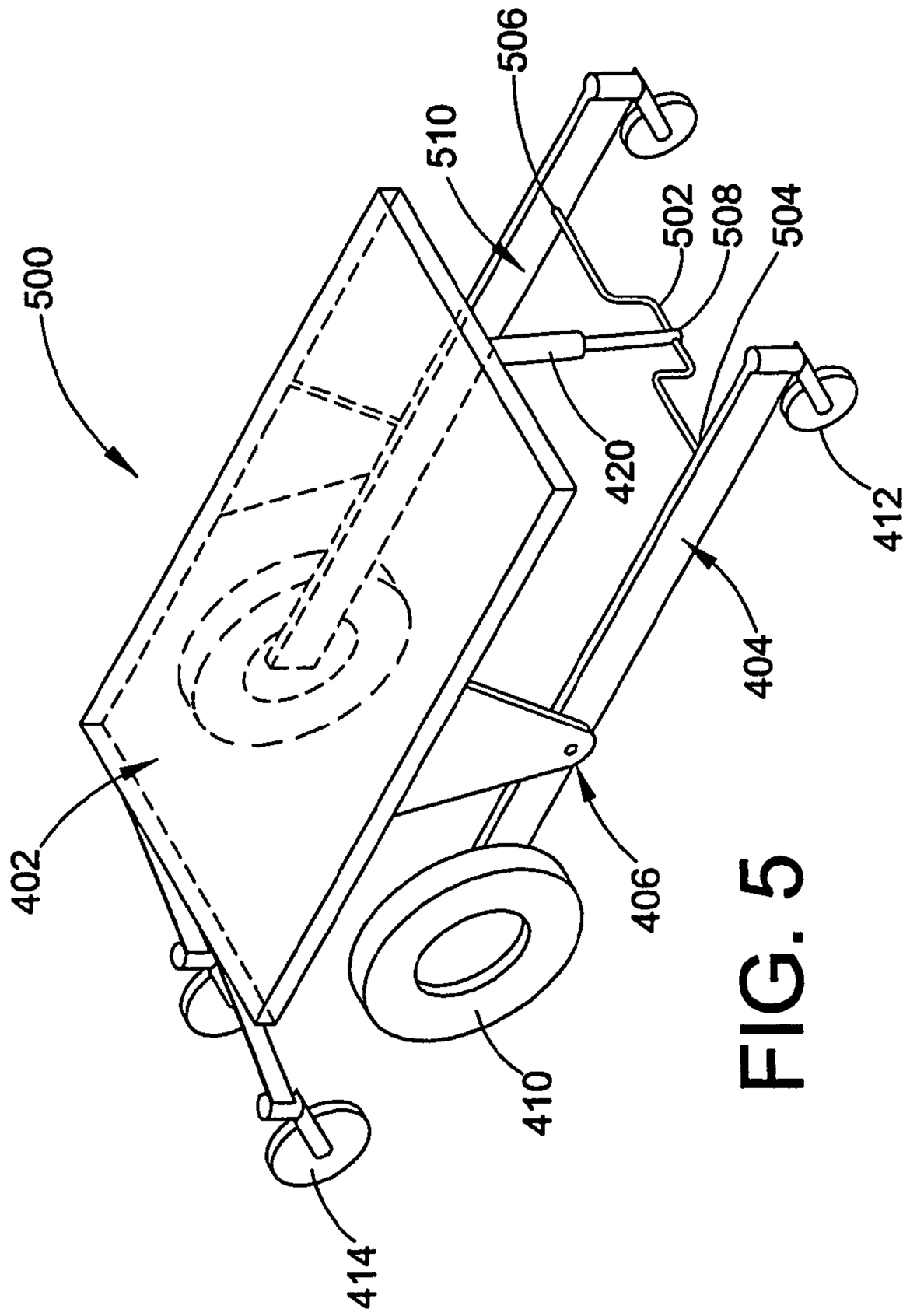


FIG. 5

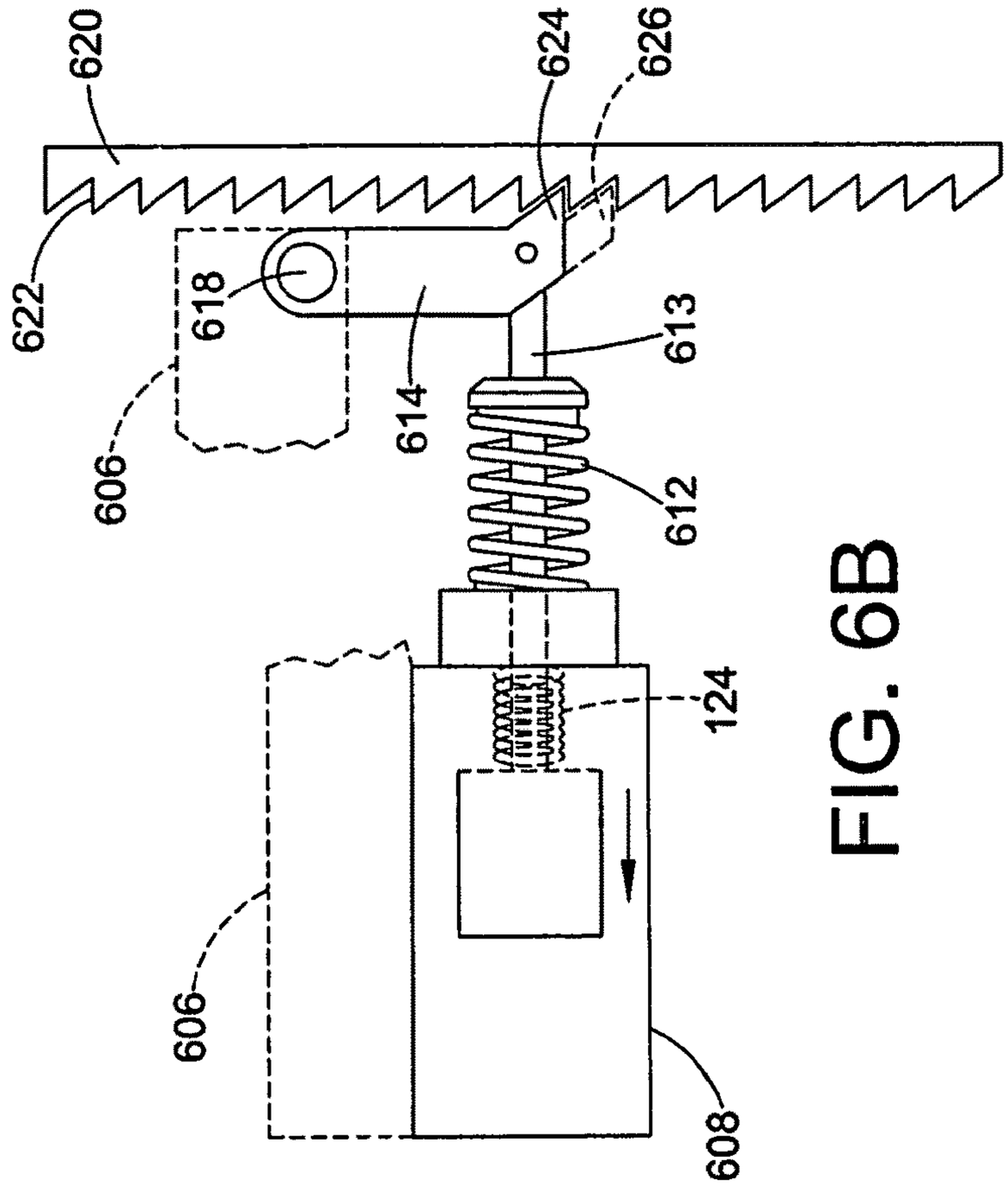

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FIG. 6B

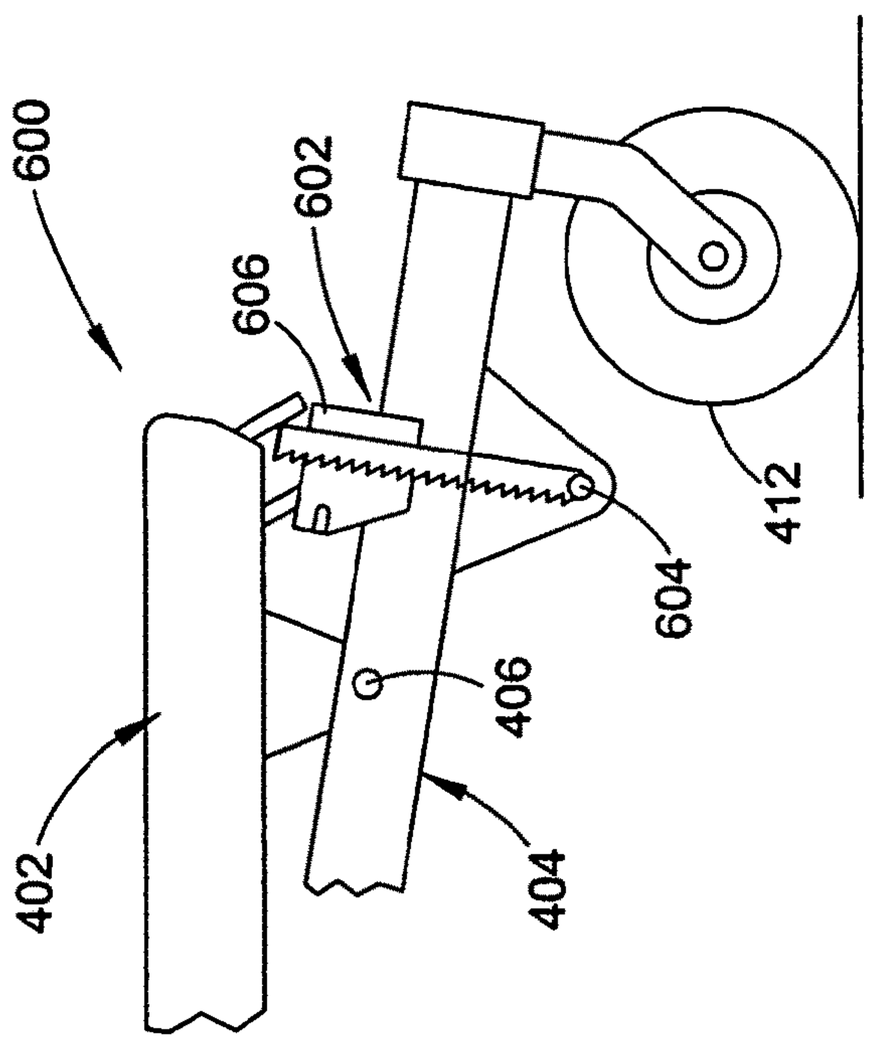

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FIG. 6A

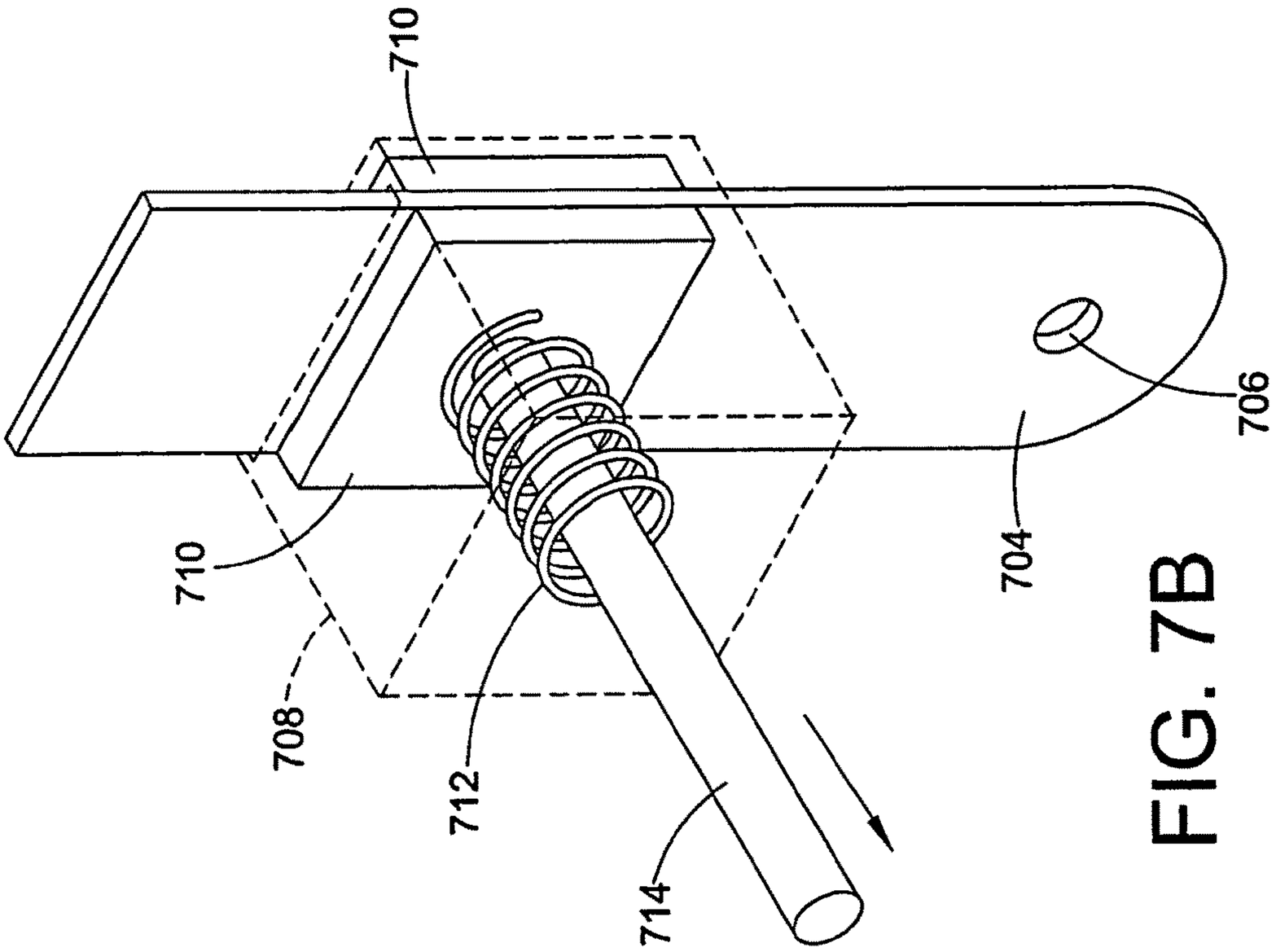


FIG. 7B

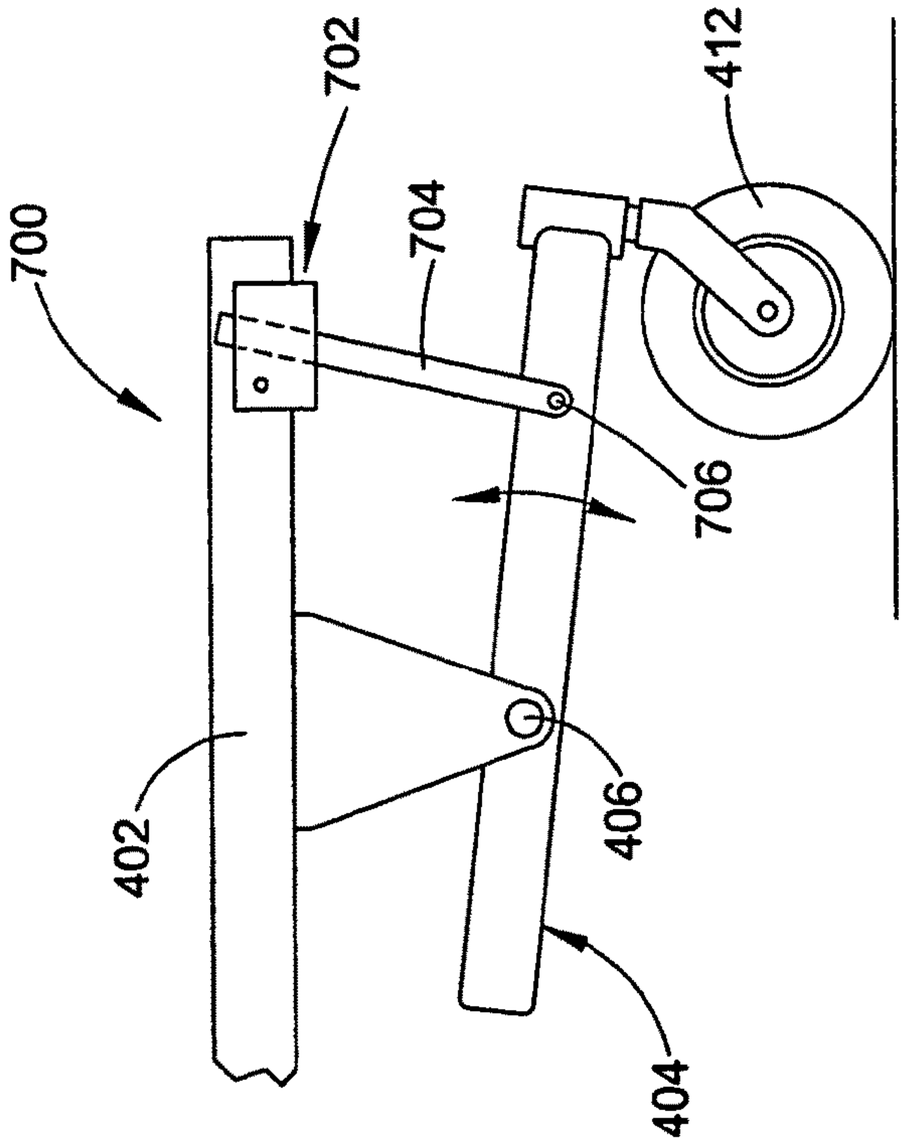


FIG. 7A

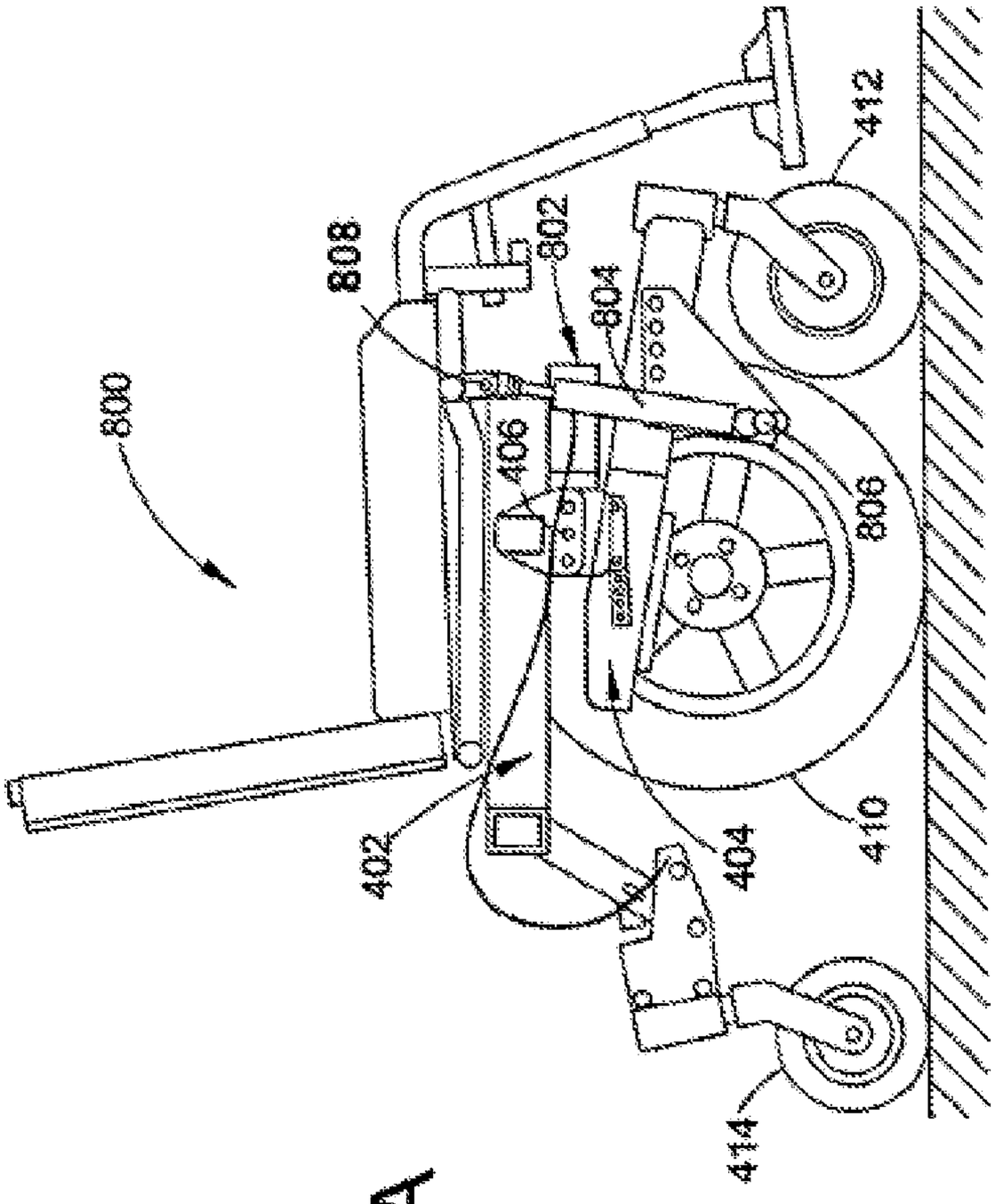


FIG. 8C

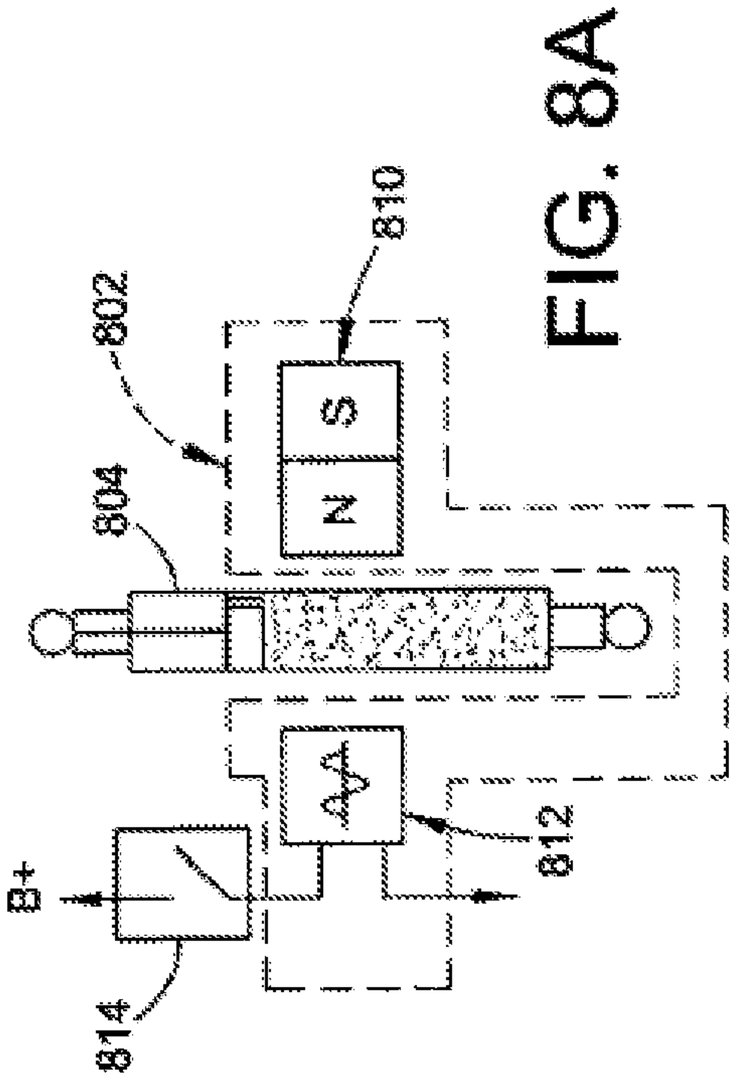


FIG. 8A

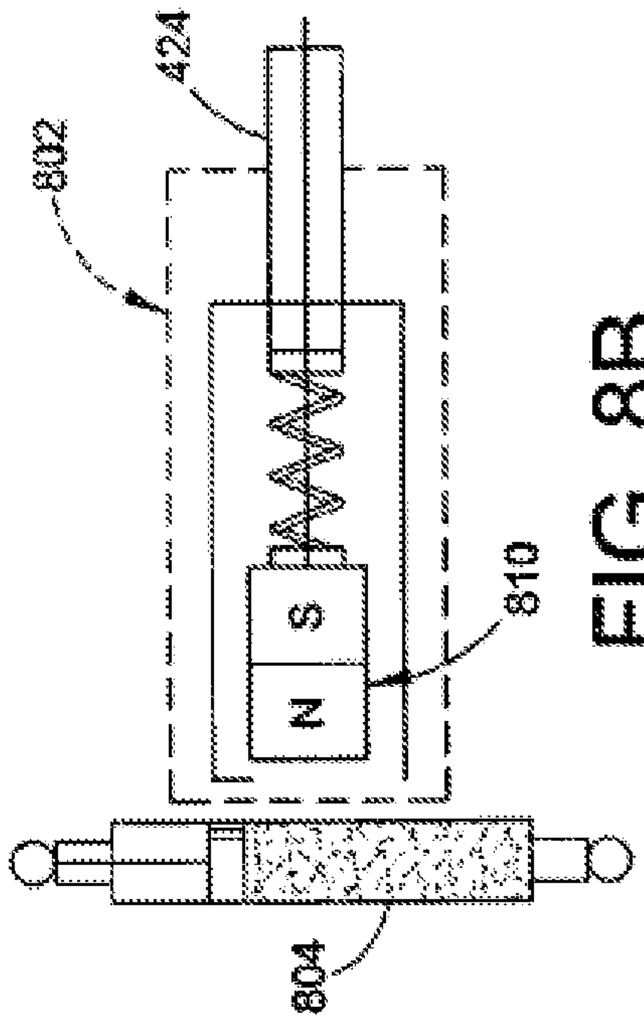


FIG. 8B

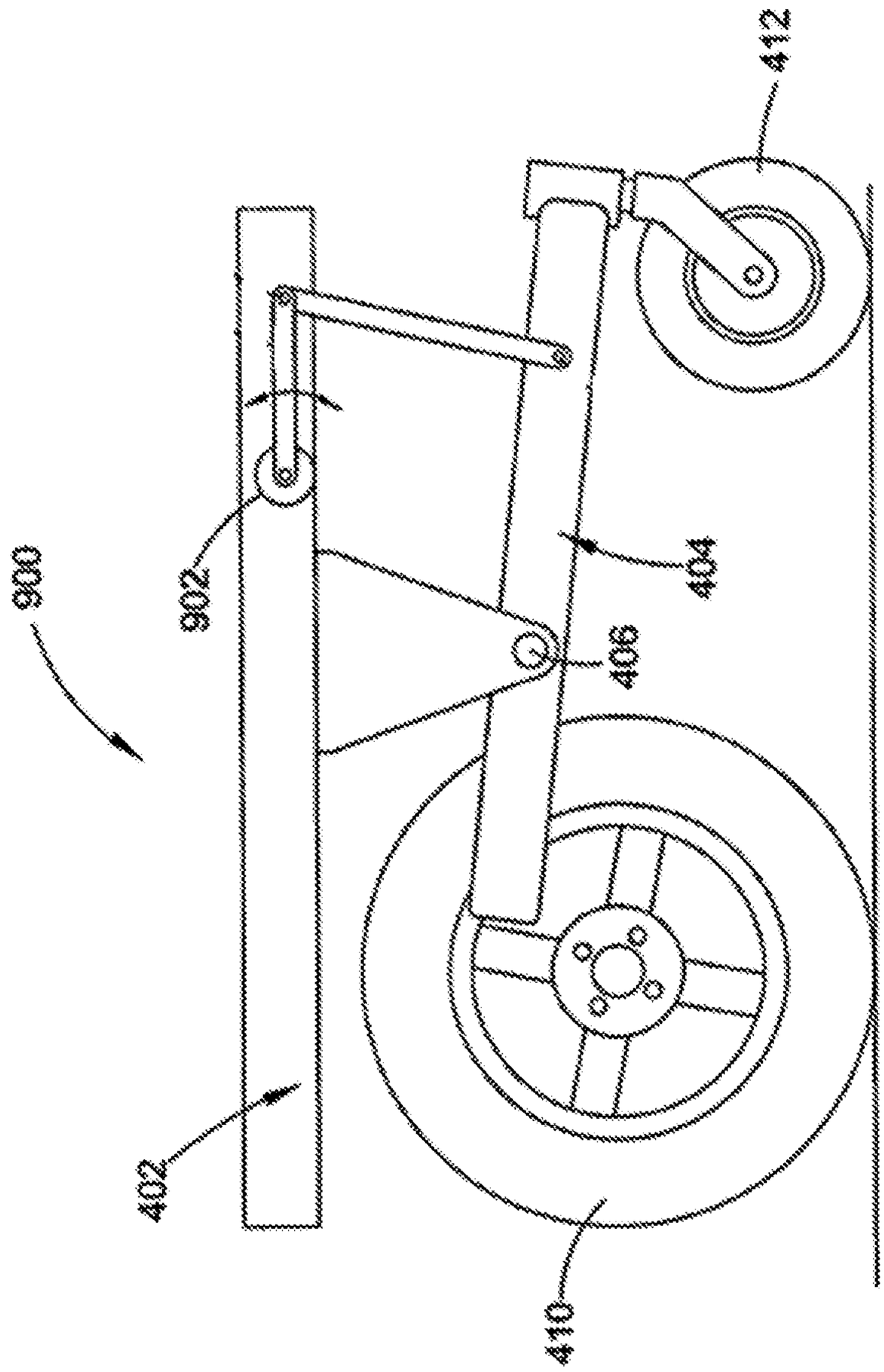


FIG. 9

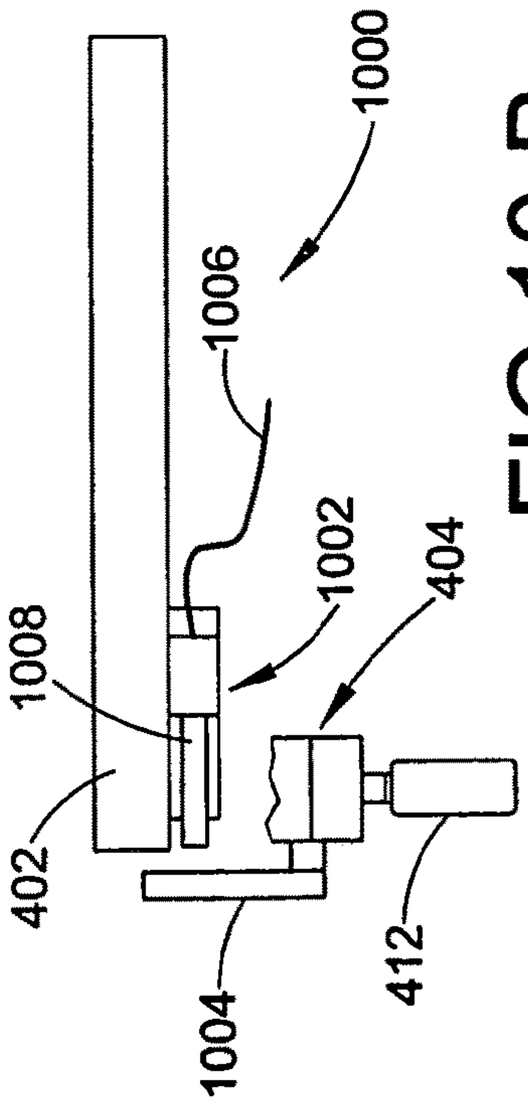


FIG 10 B

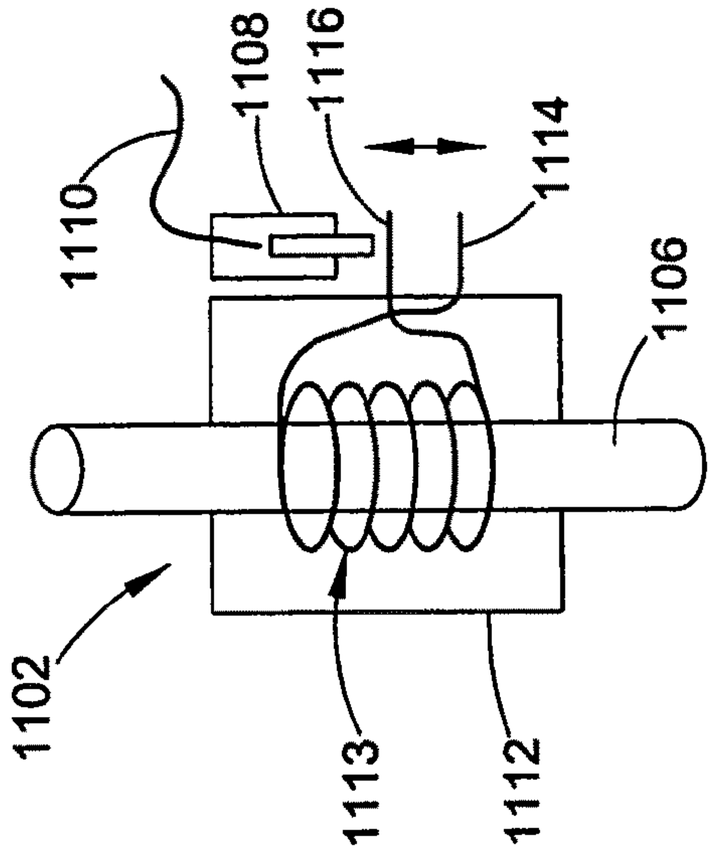


FIG 11B

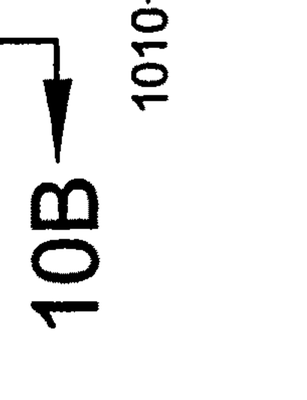


FIG 10 C

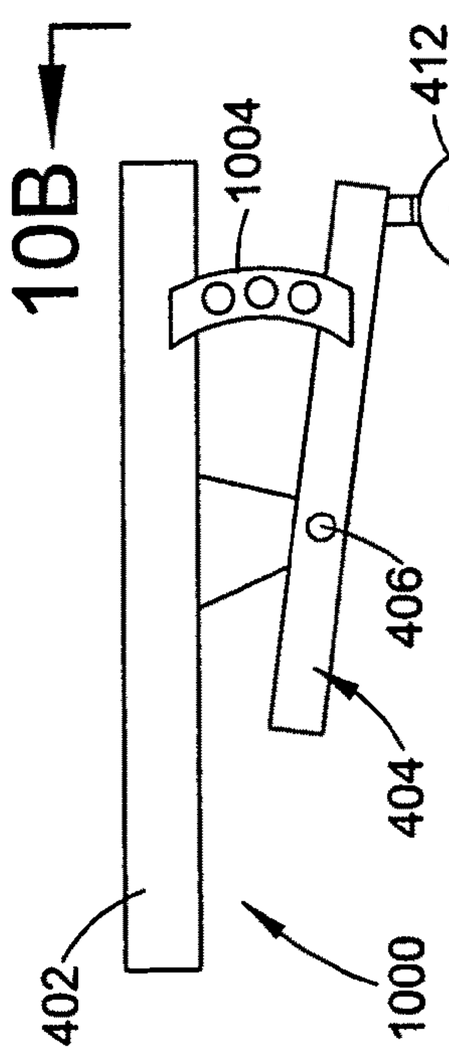


FIG 10 A

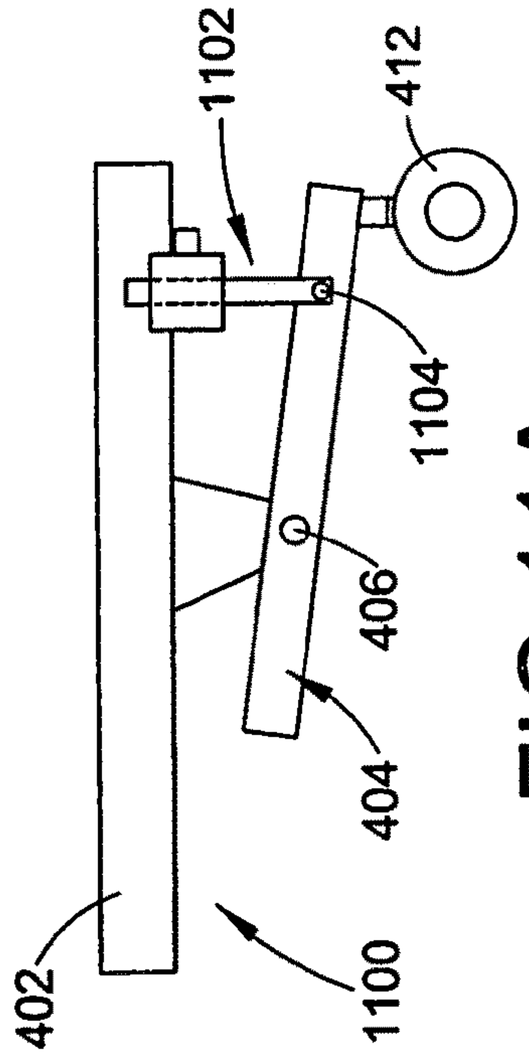


FIG 11A

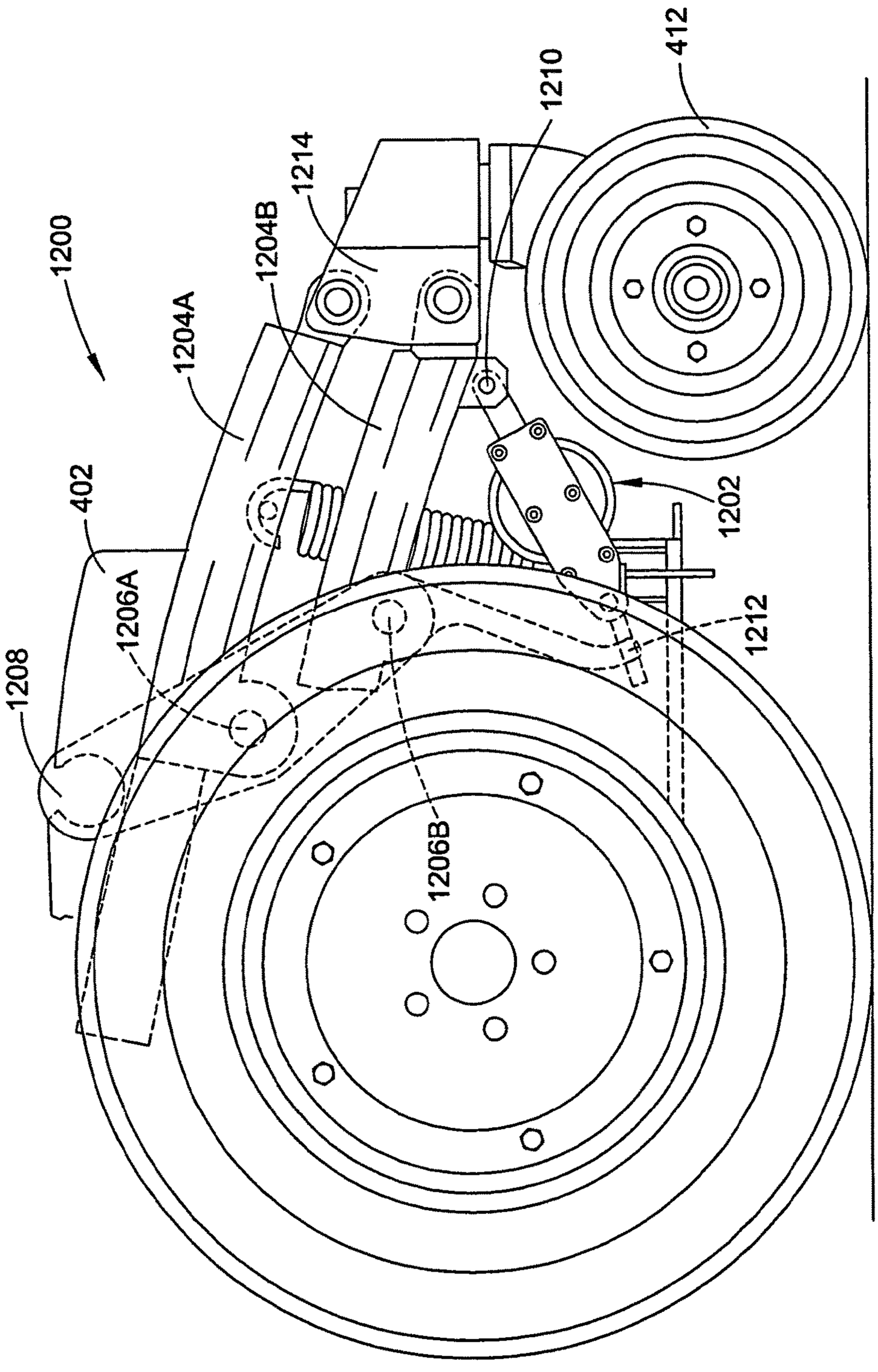

1200
1204A
1204B
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1210
412
402
1206A
1208
1202
1212
1206B

FIG. 12A

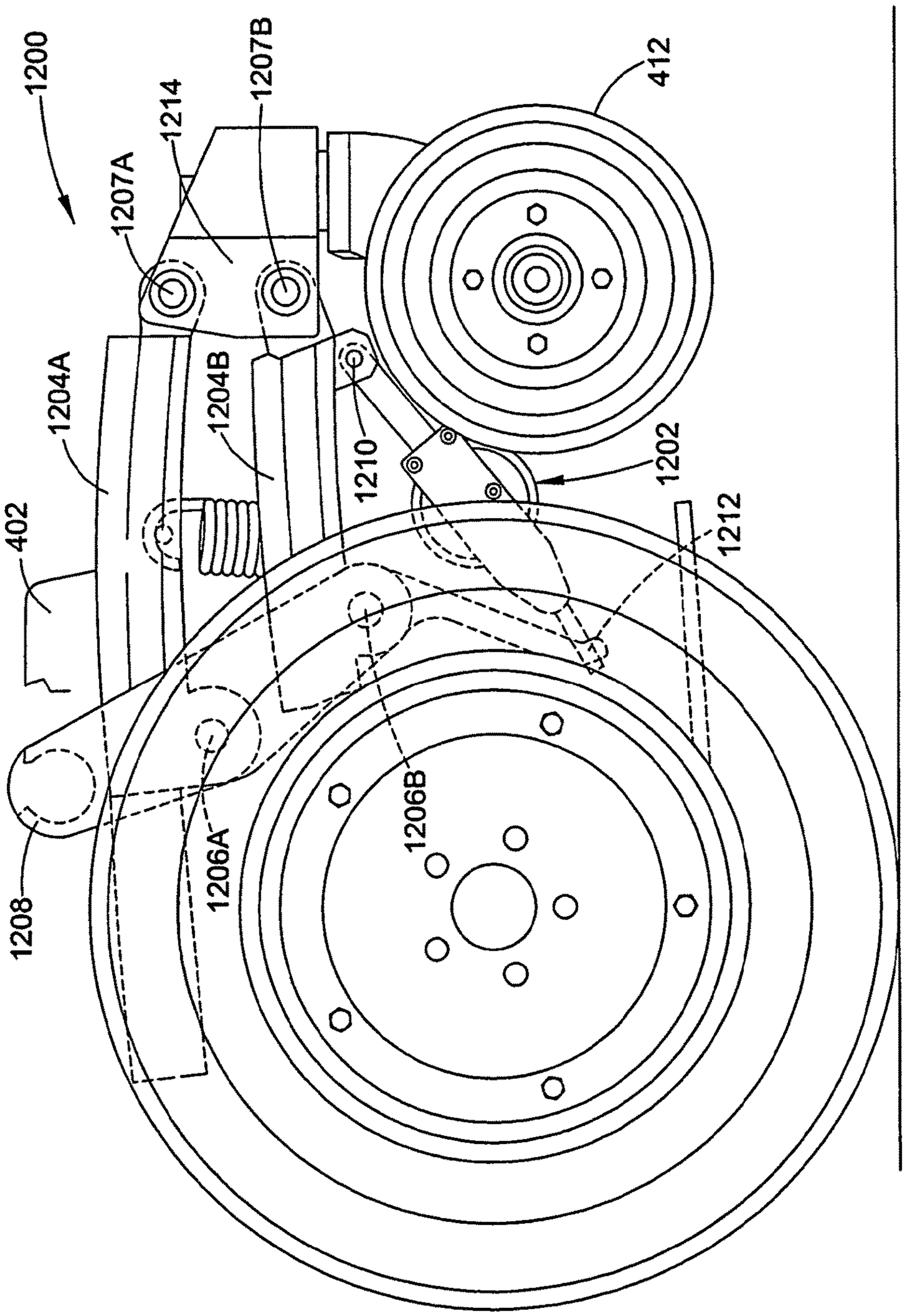

1200
1207A
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1206B

FIG. 12B

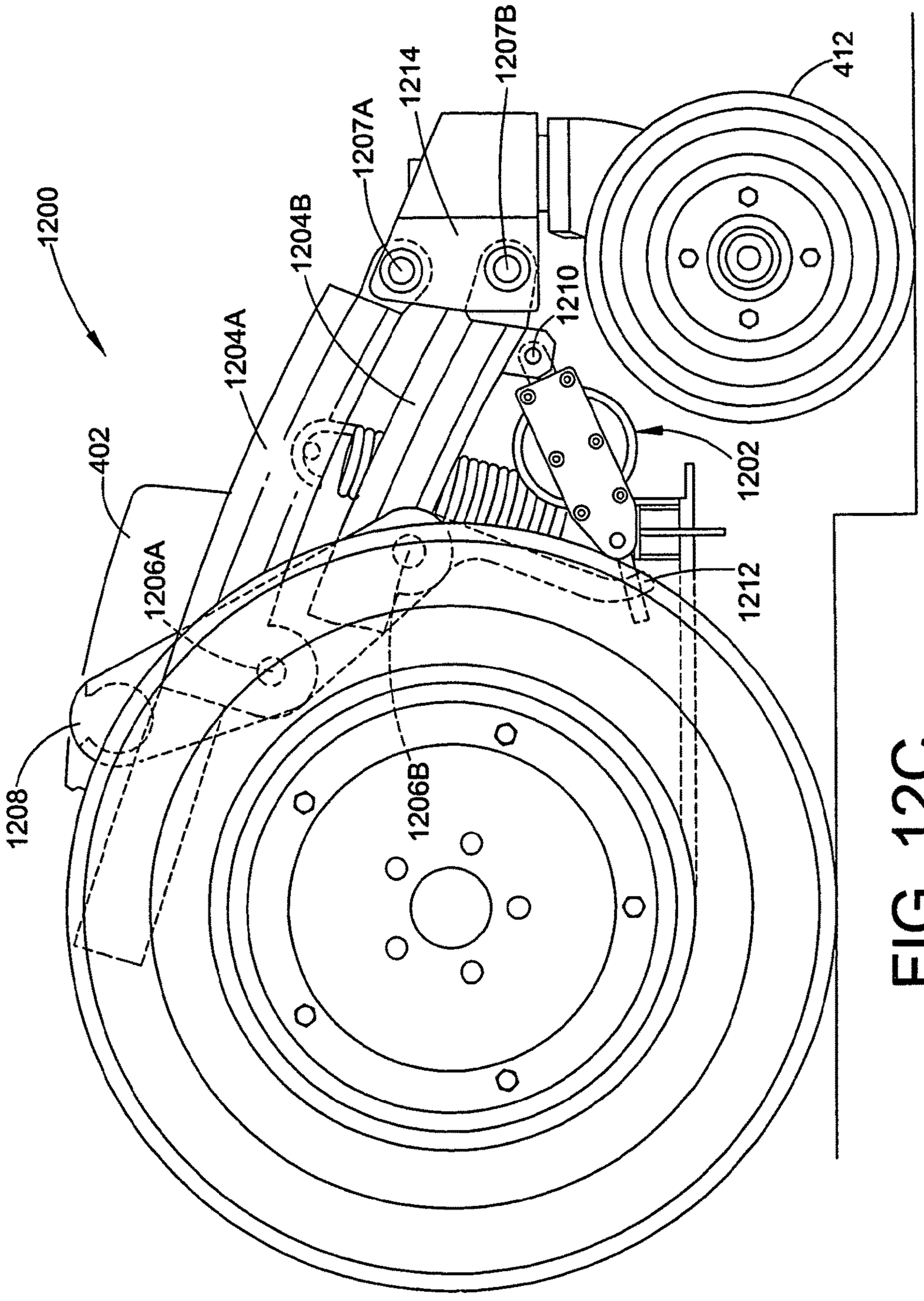

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1206A
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1206B

FIG. 12C

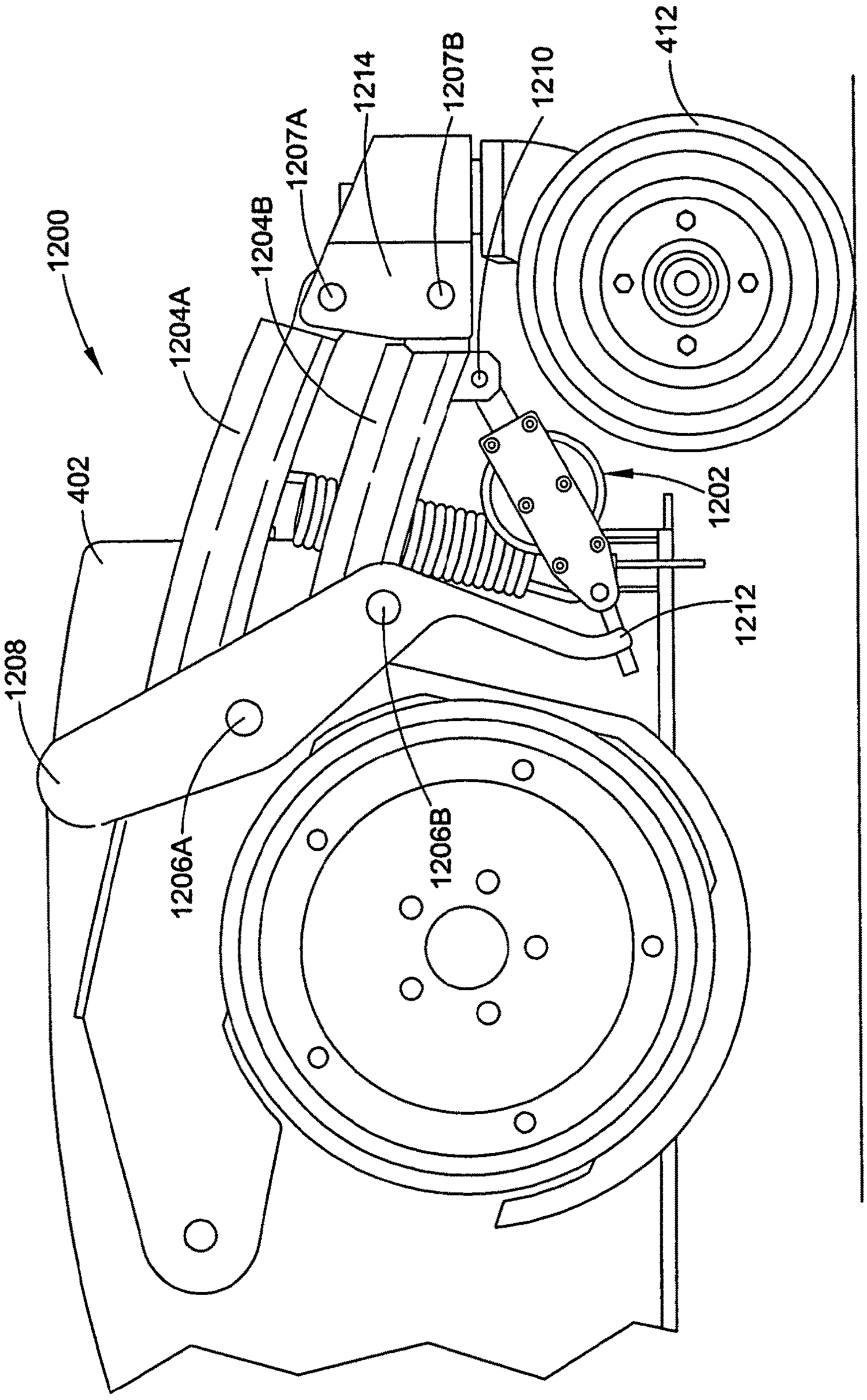

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1206A
1206B

FIG. 12D

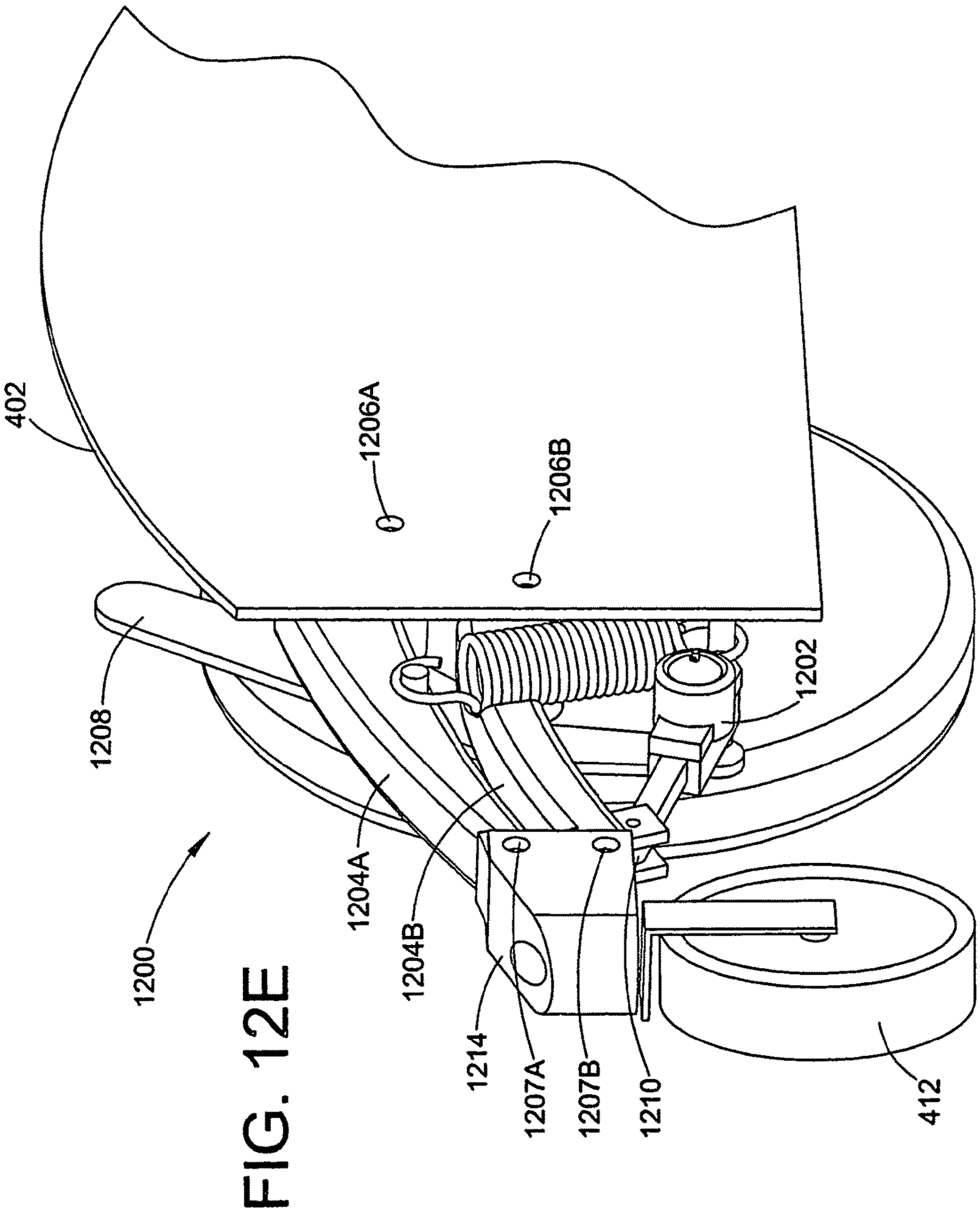

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1206A
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412

FIG. 12E

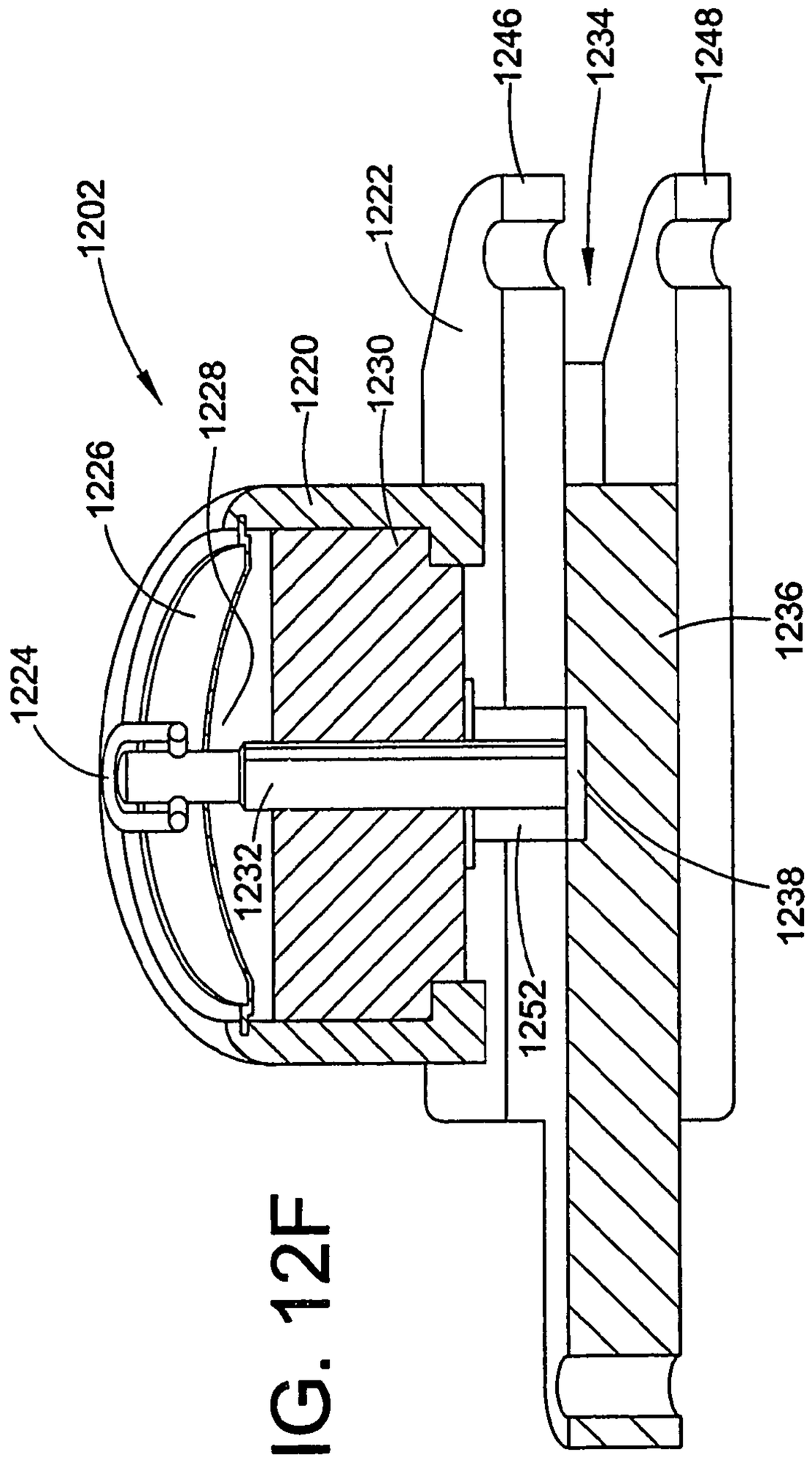

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FIG. 12F

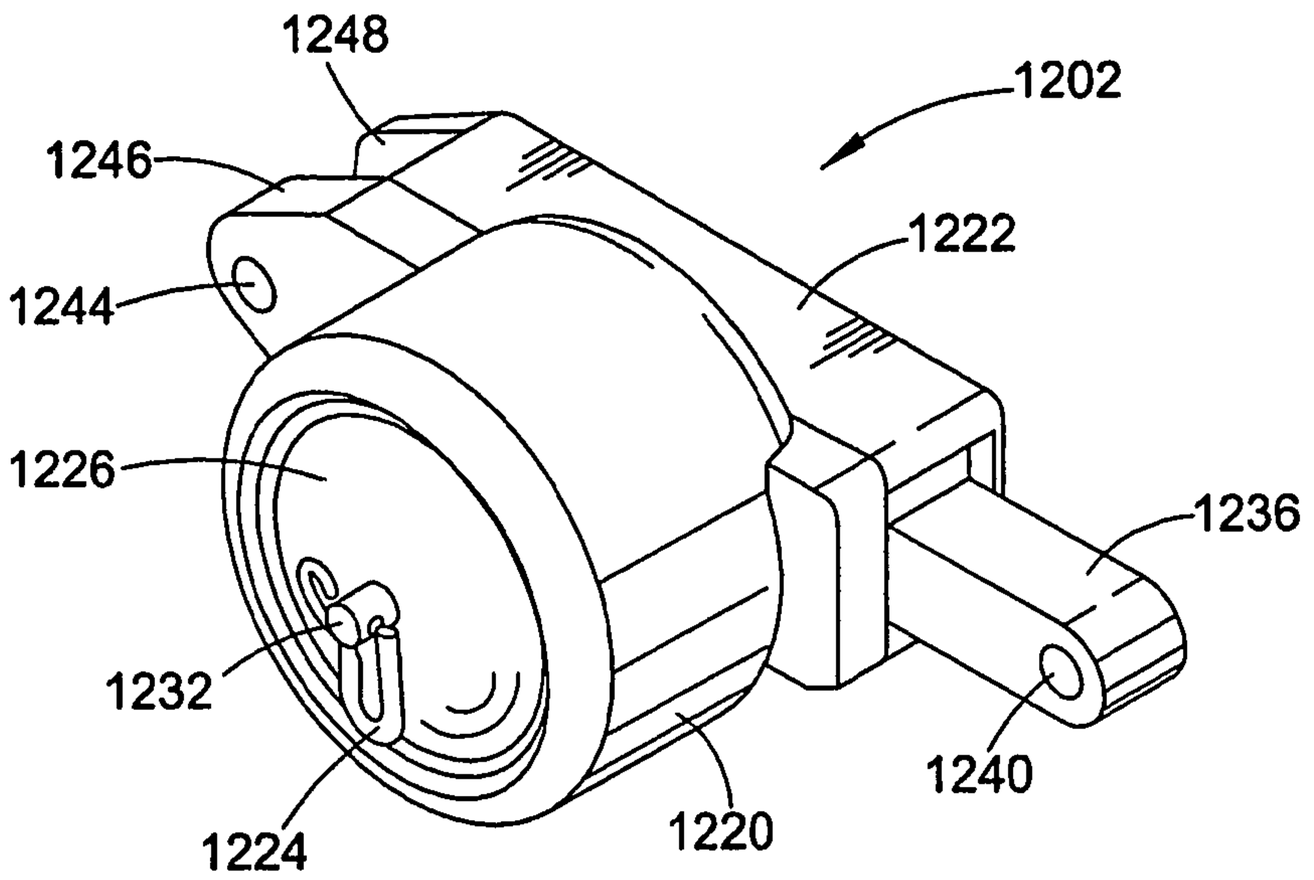


FIG. 12G

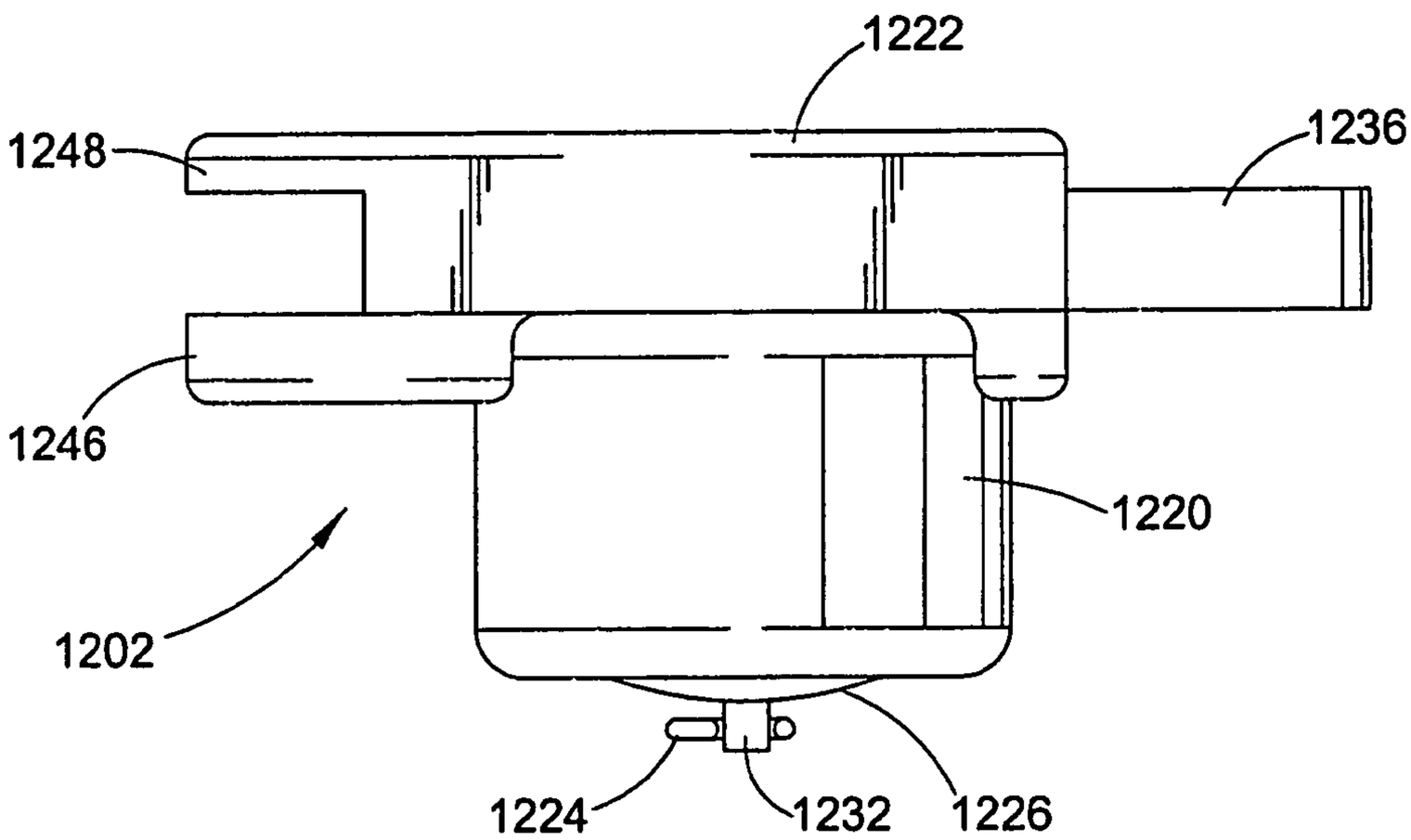


FIG. 12H

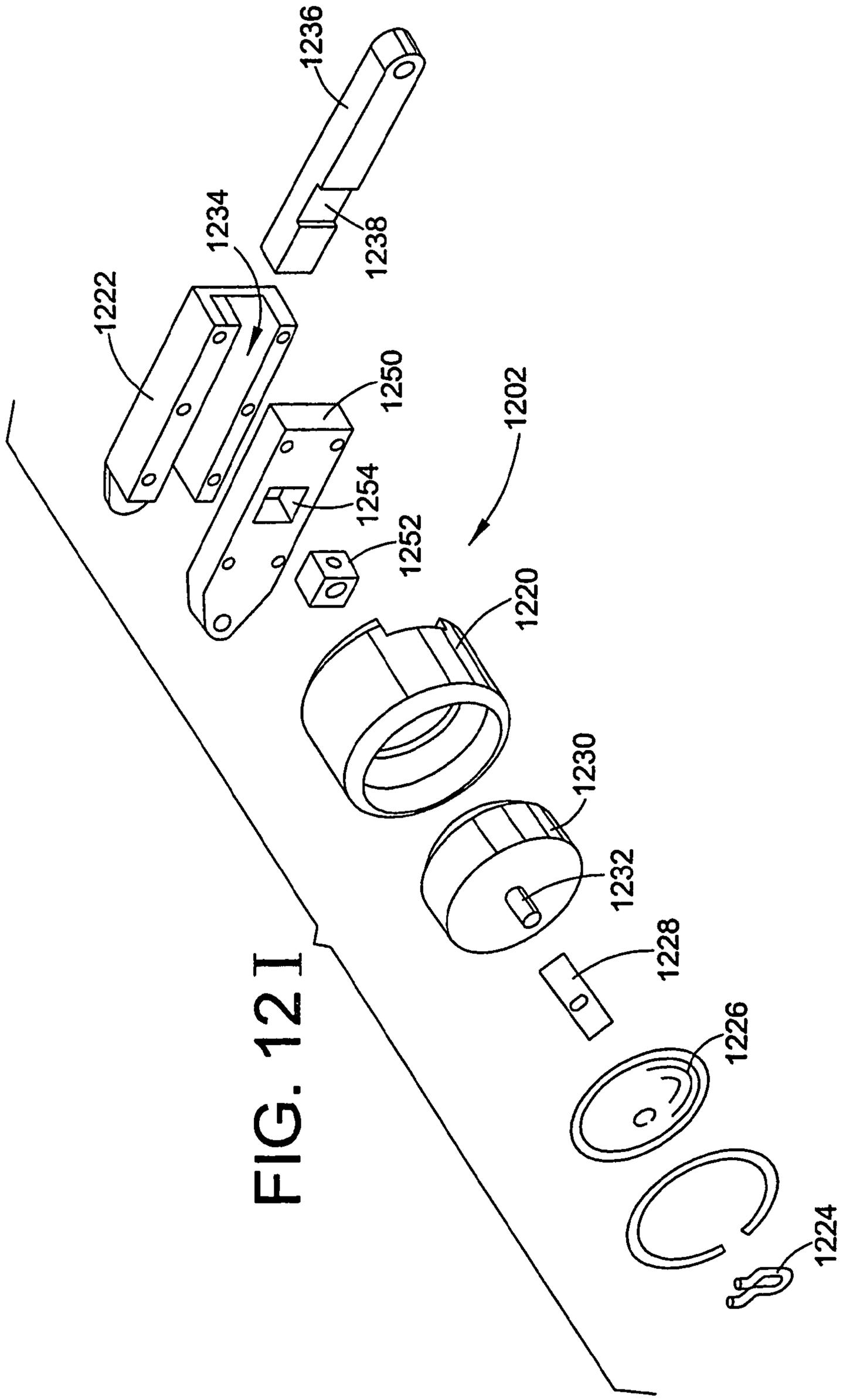

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FIG. 12I

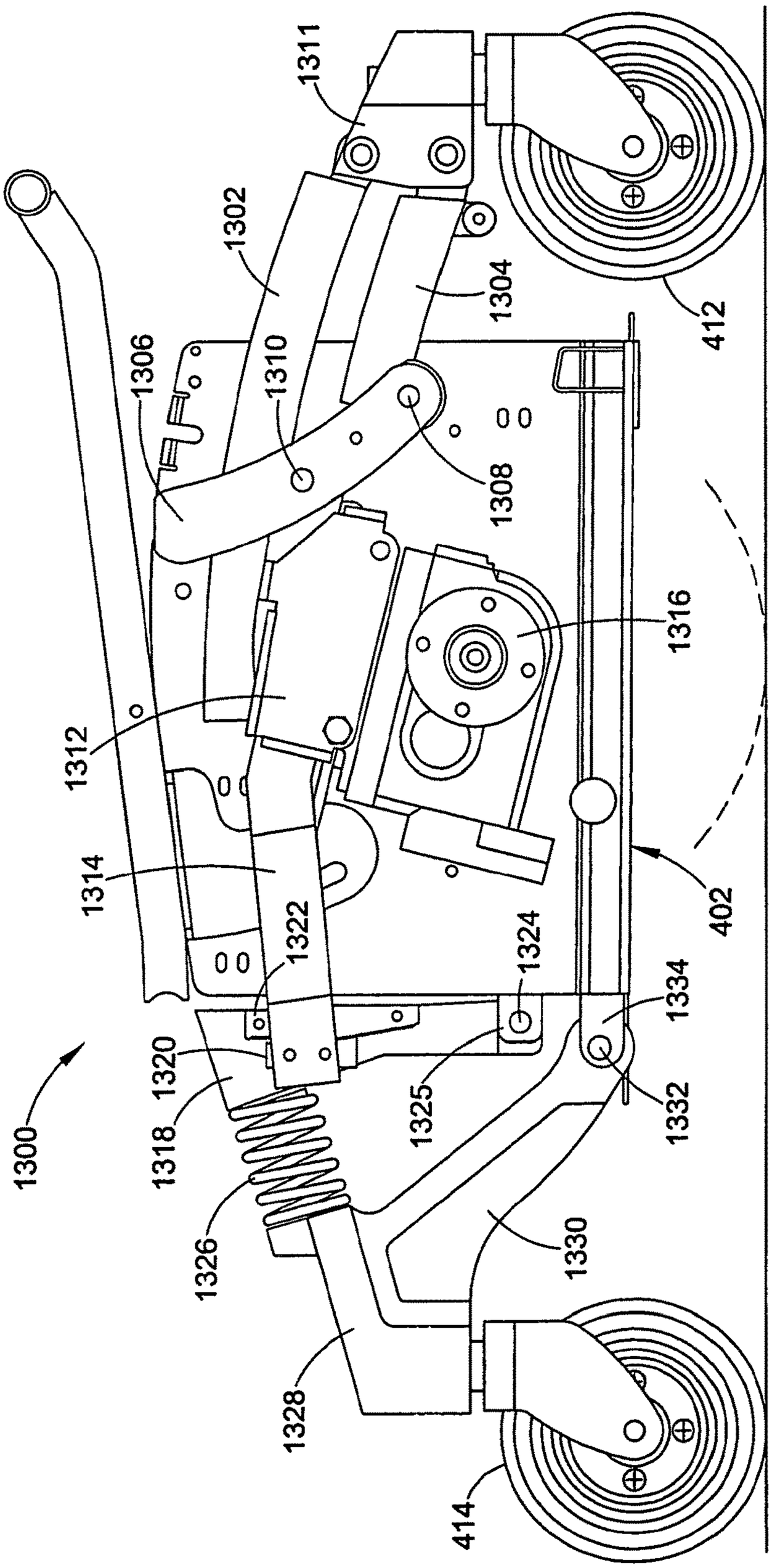

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1334
402
412
414

FIG. 13

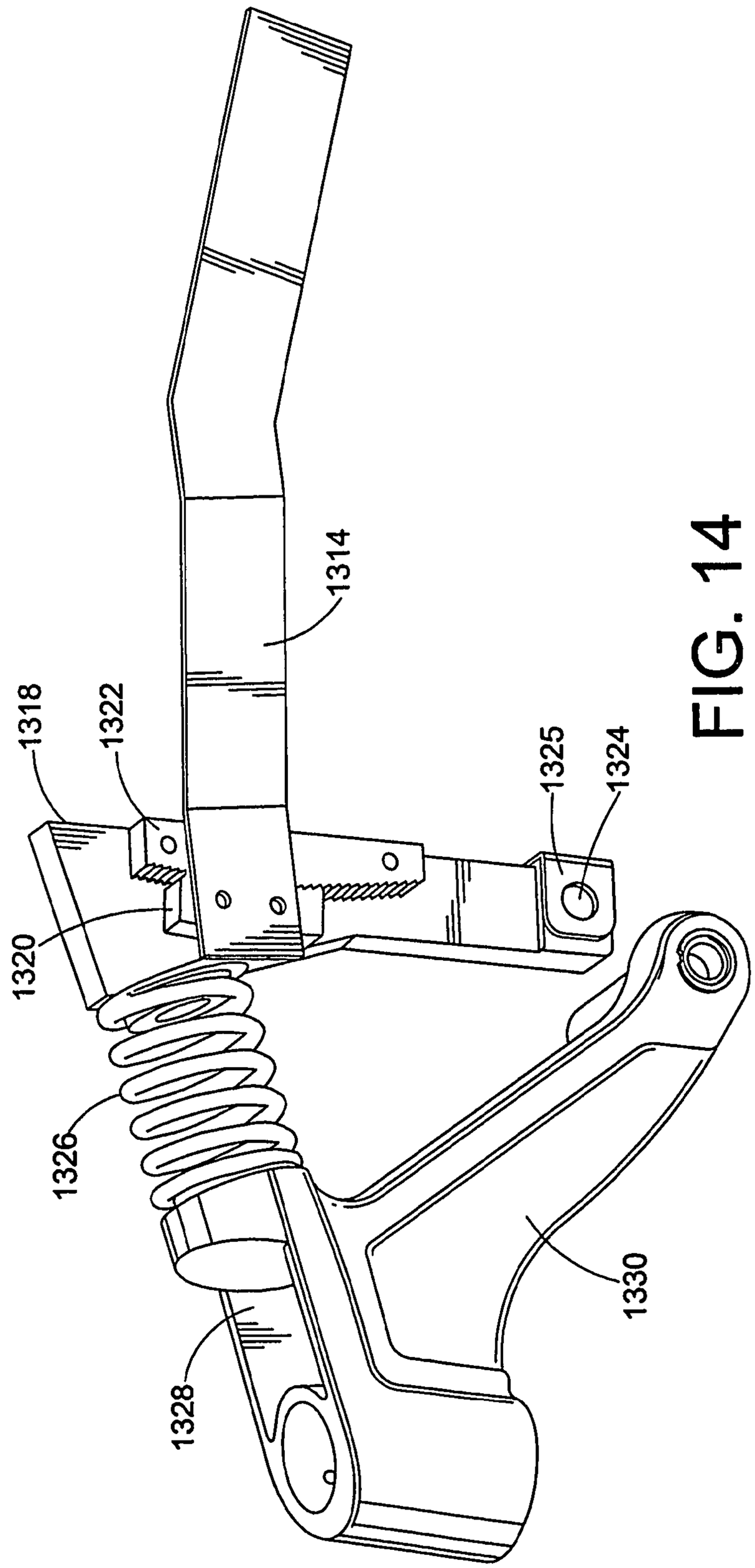


FIG. 14

FIG. 16

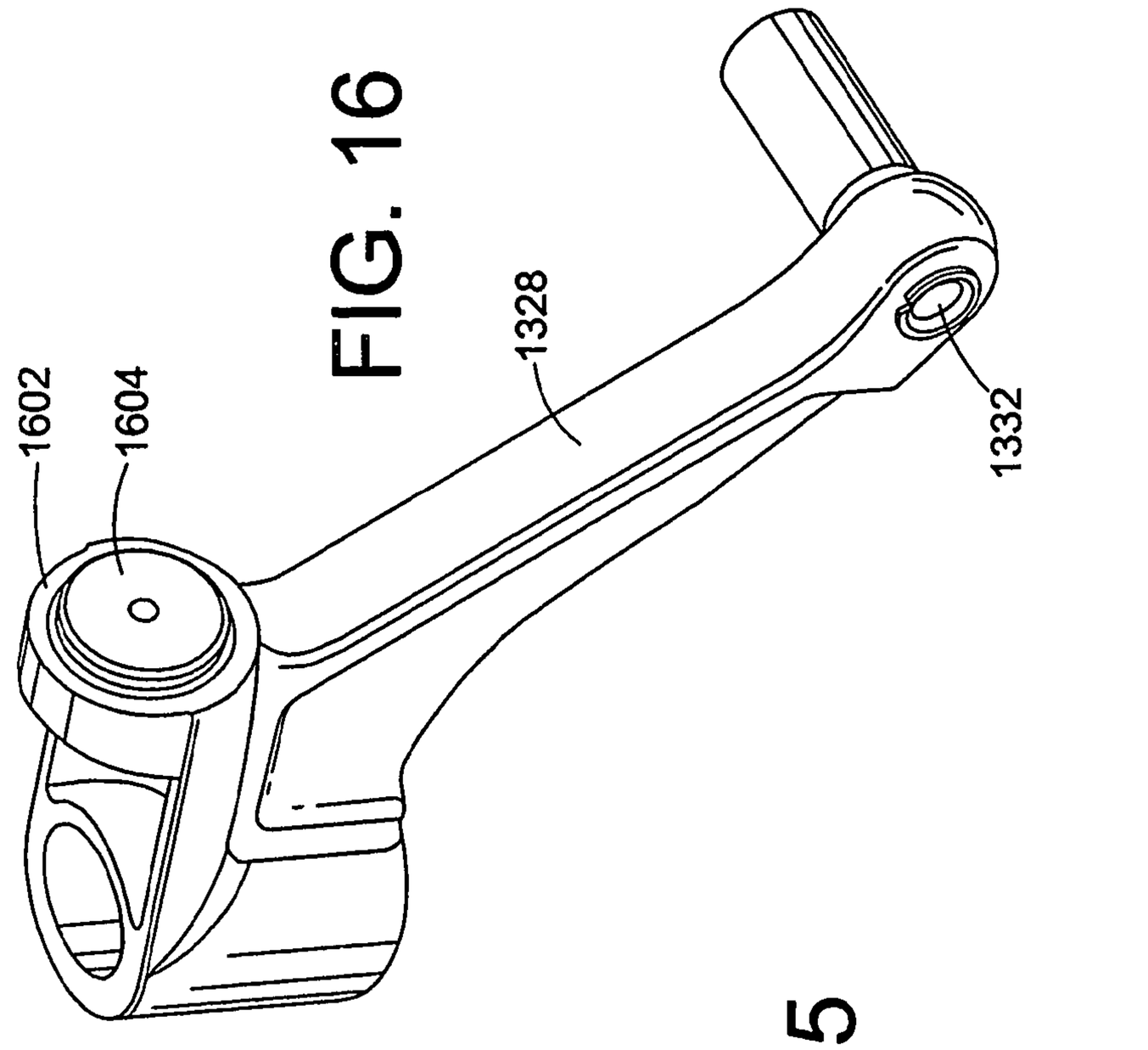
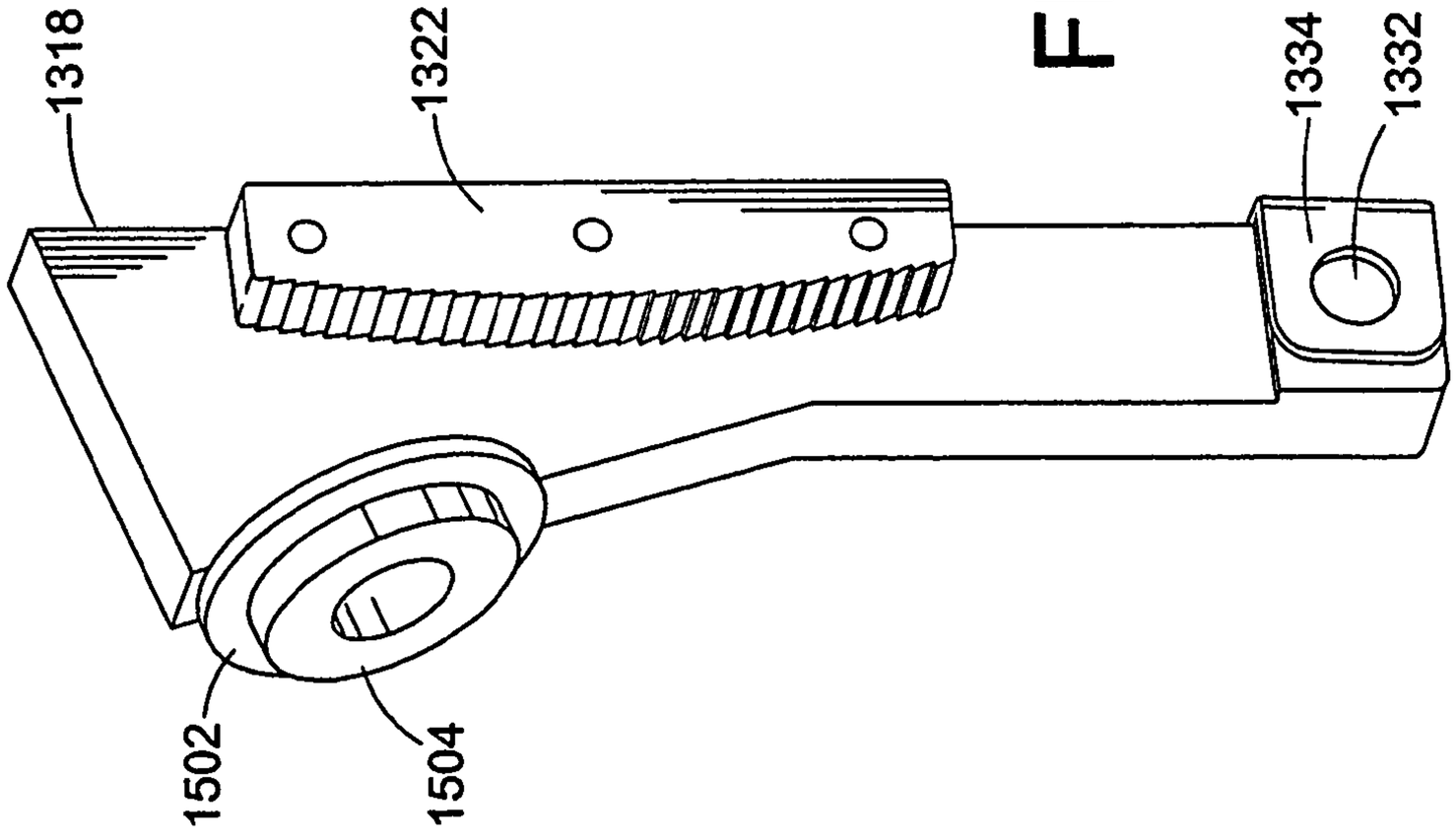


FIG. 15



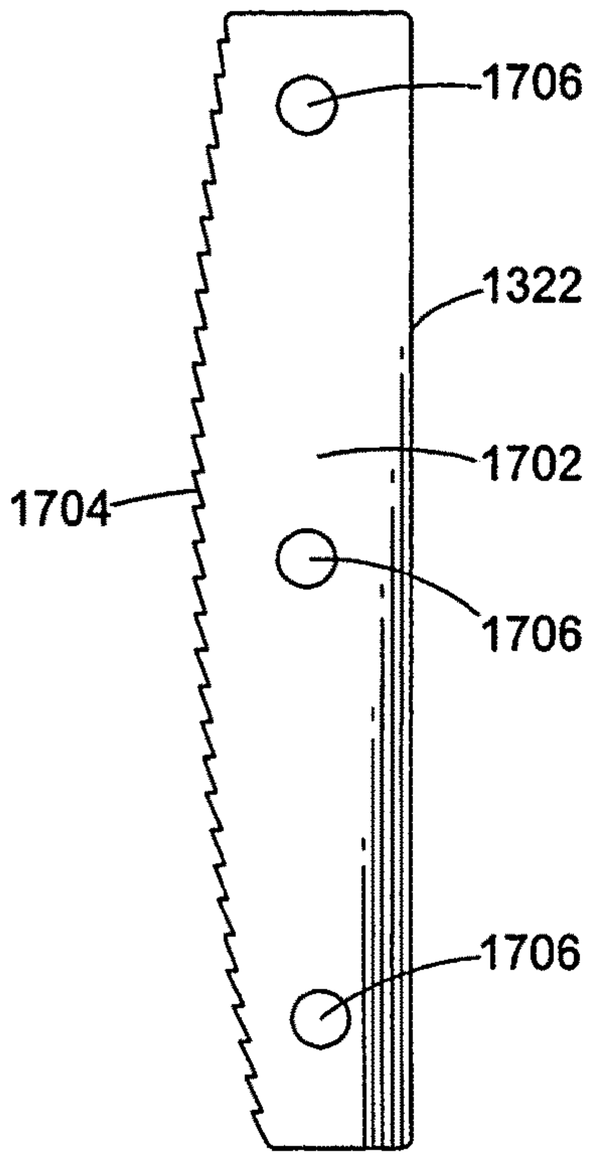


FIG. 17A

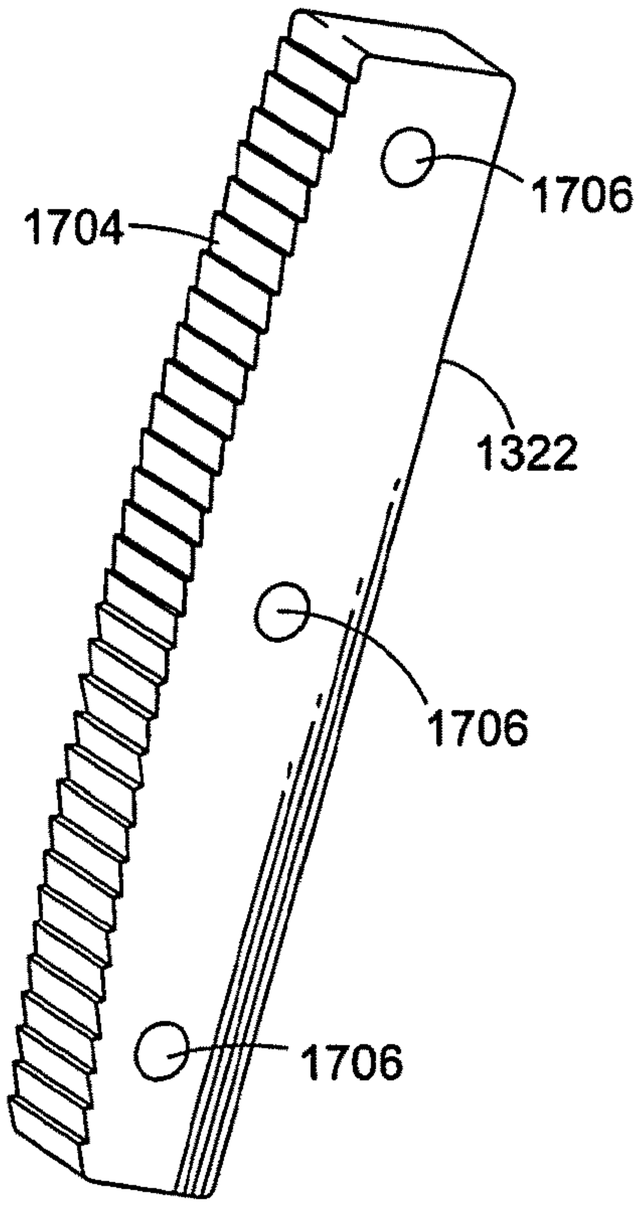


FIG. 17B

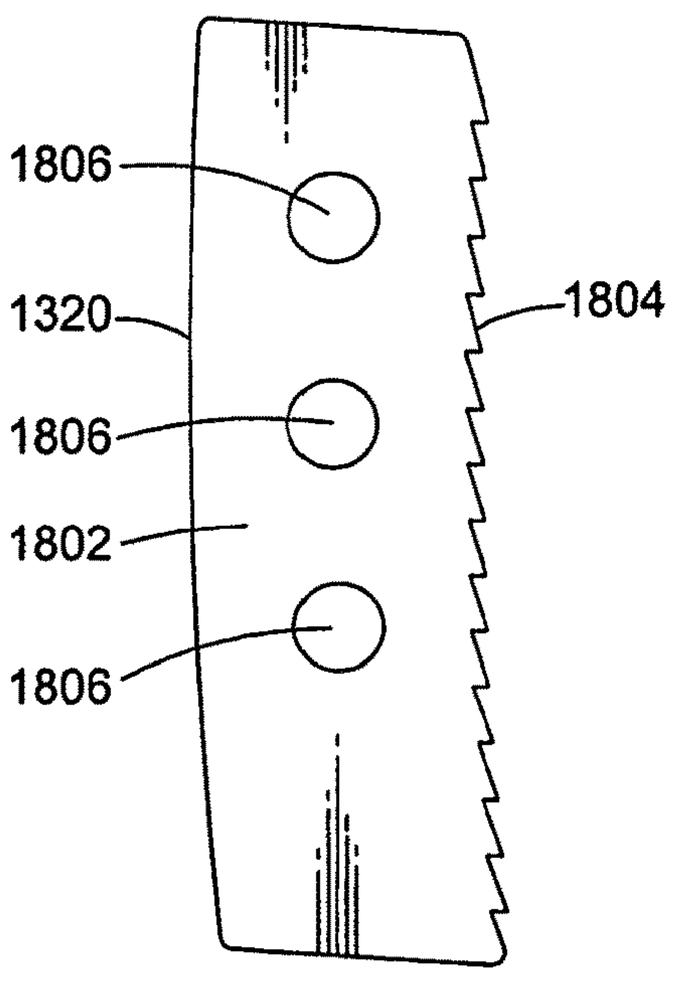


FIG. 18A

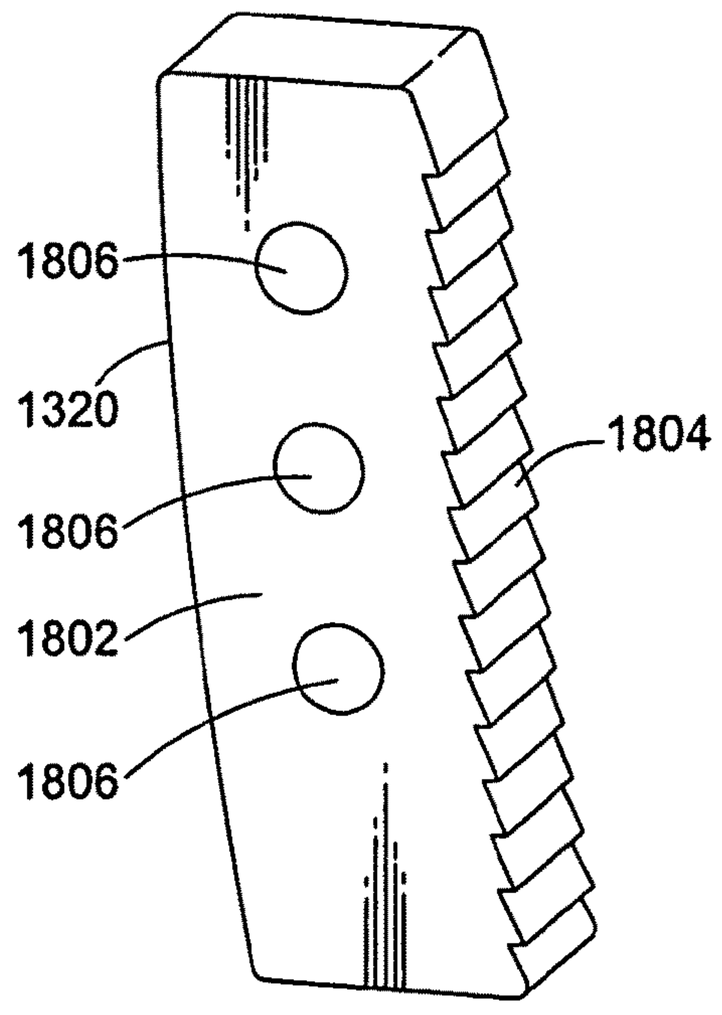


FIG. 18B

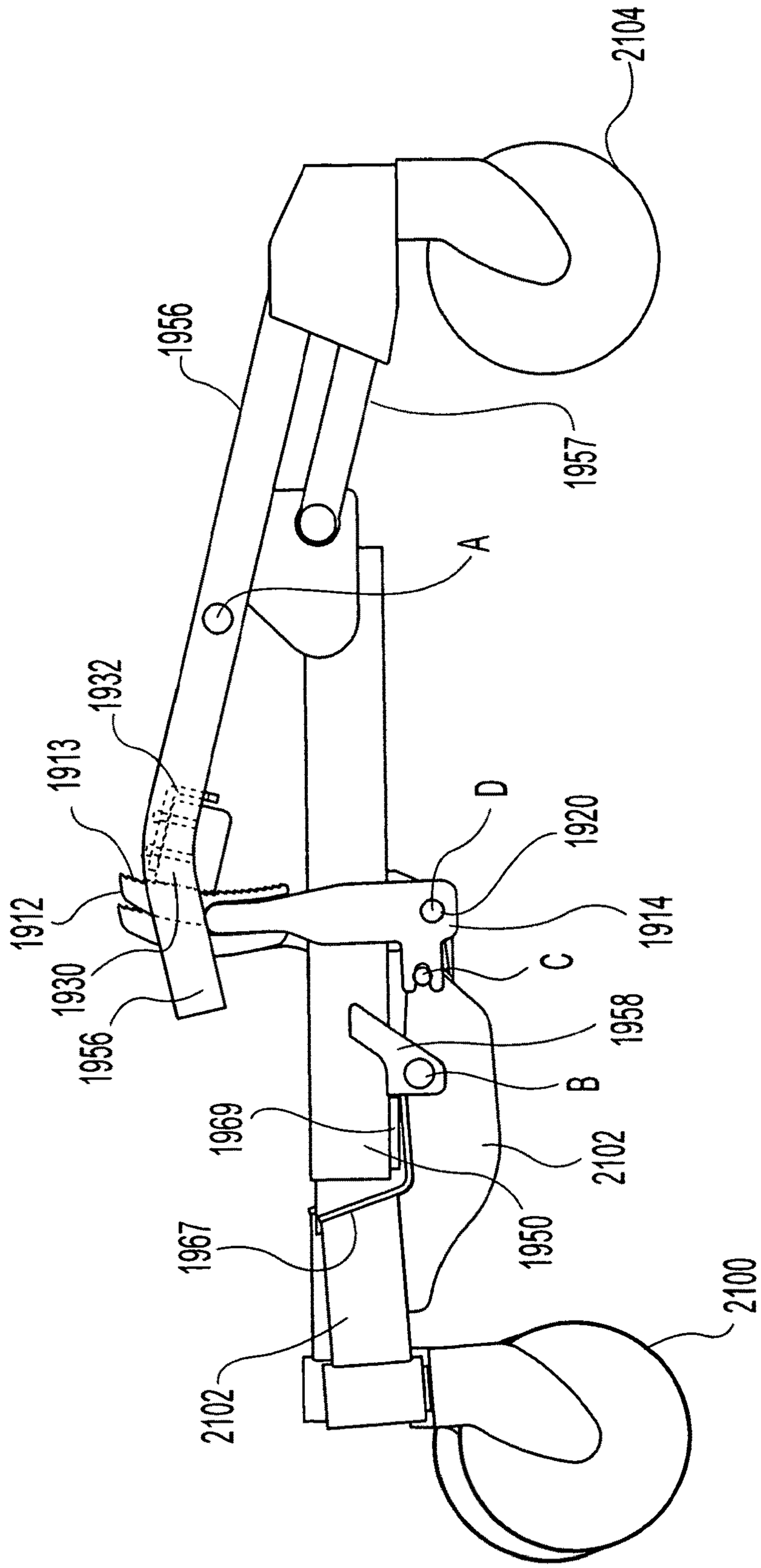

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Fig. 19

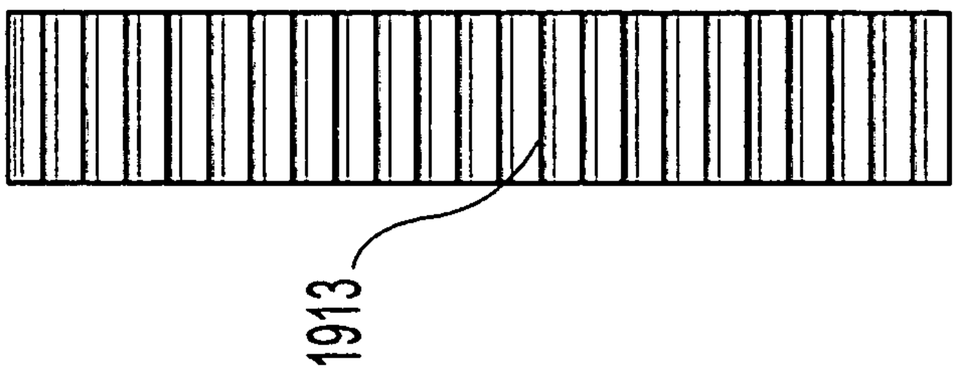


Fig. 20c

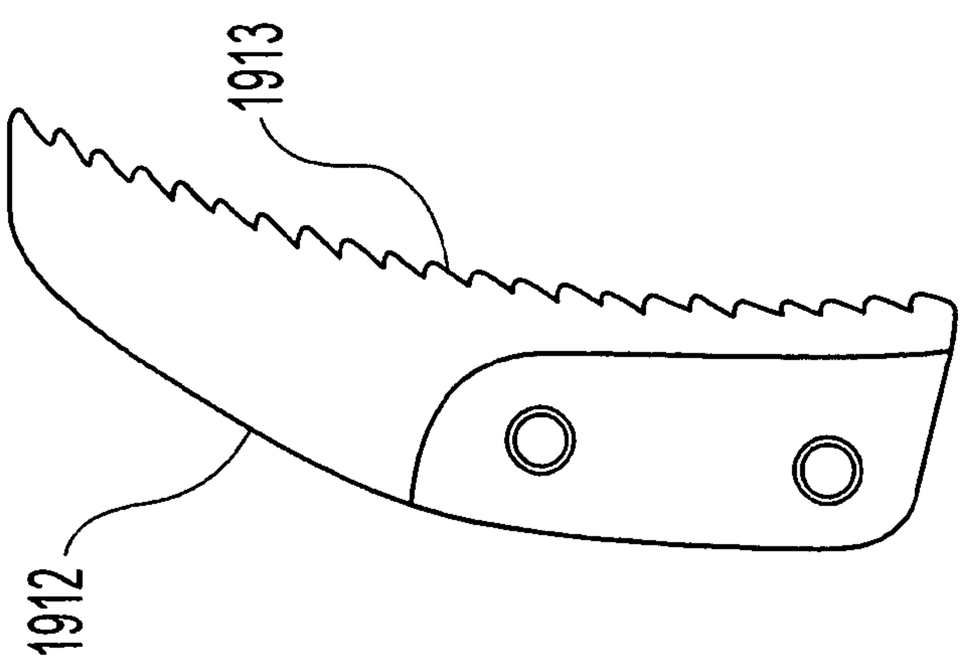


Fig. 20b

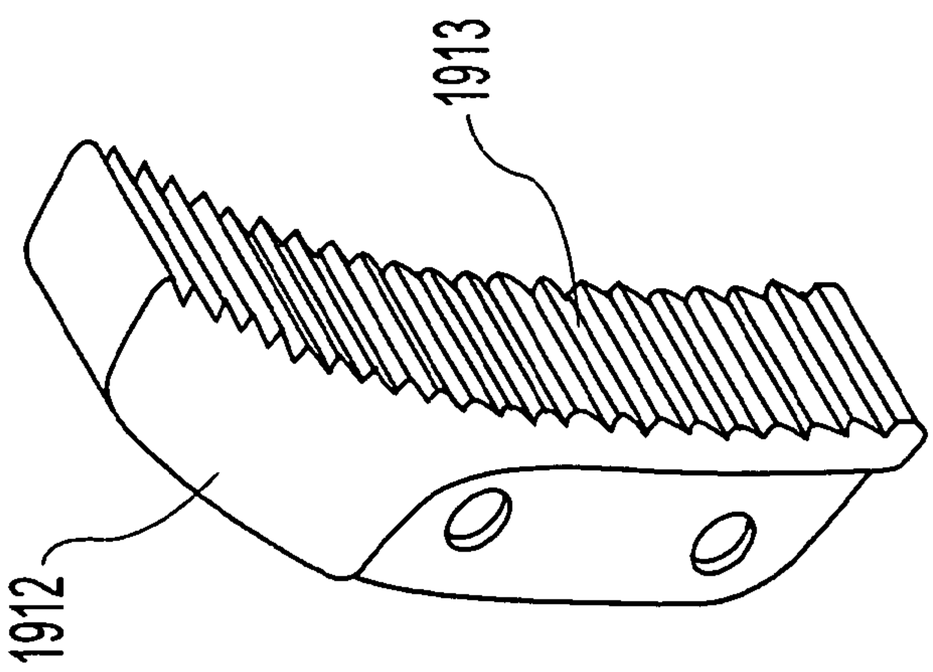


Fig. 20a

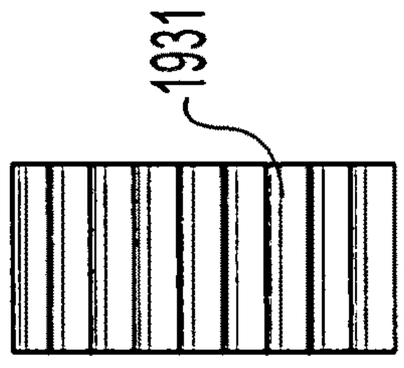


Fig. 21c

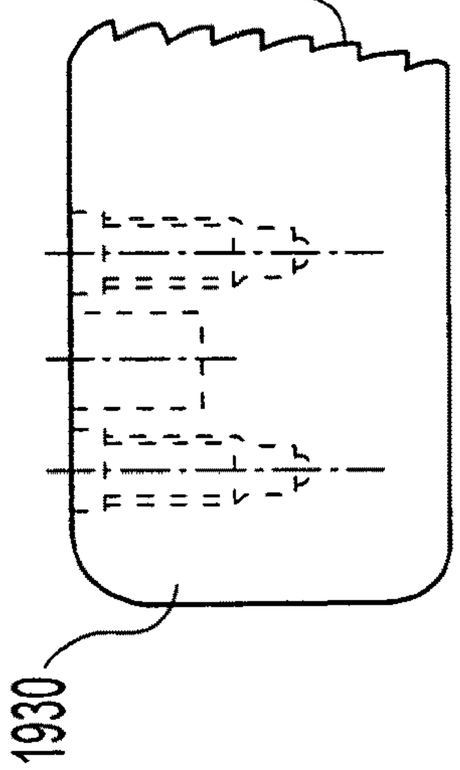


Fig. 21b

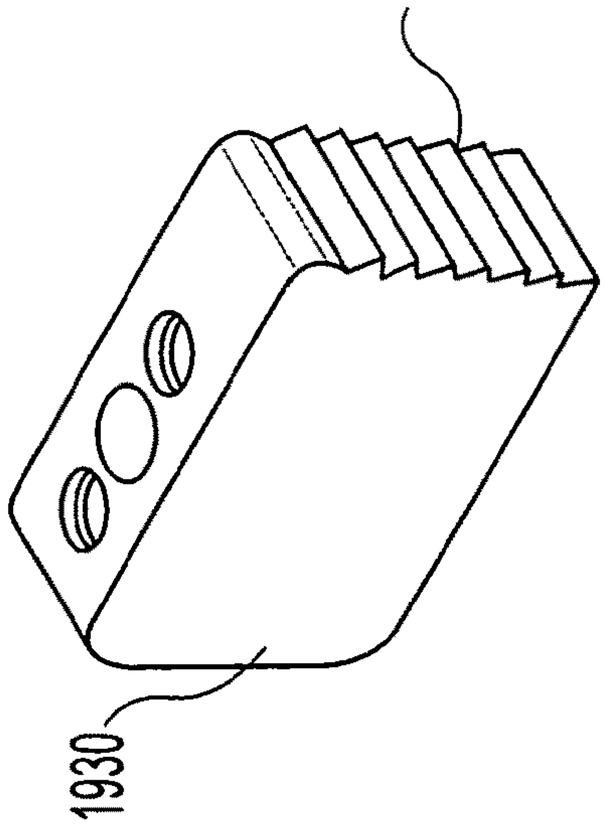


Fig. 21a

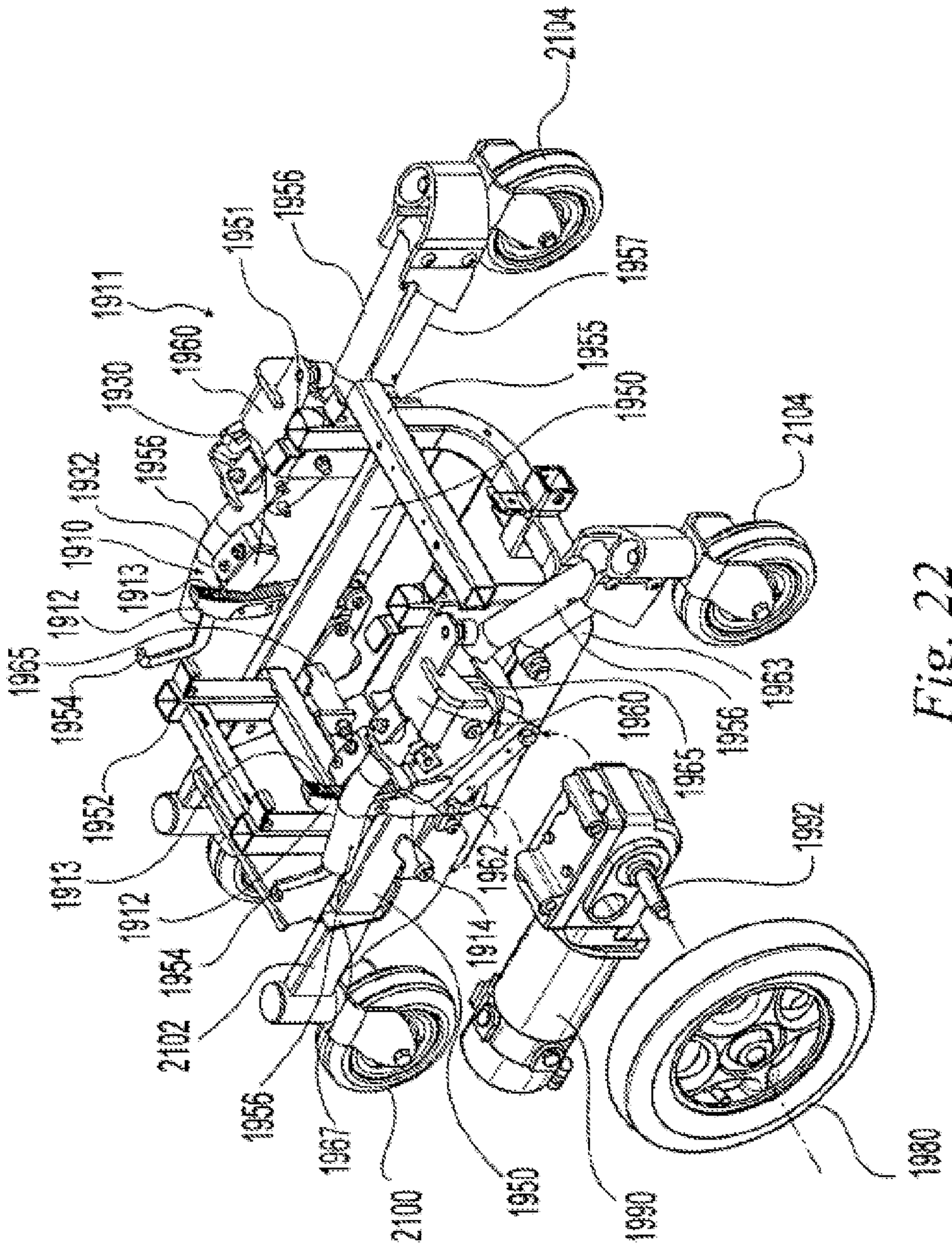

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Fig. 22

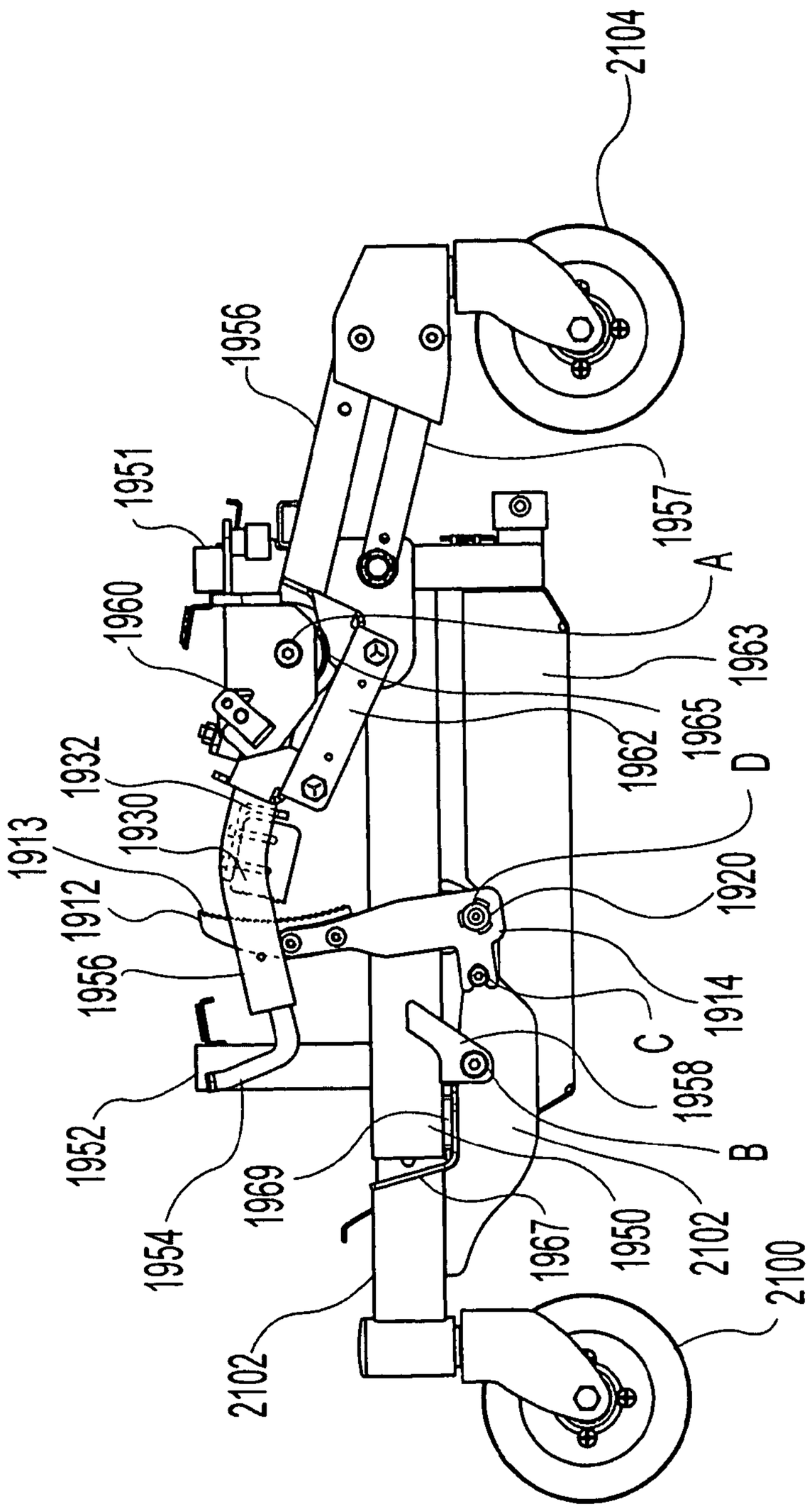

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Fig. 23

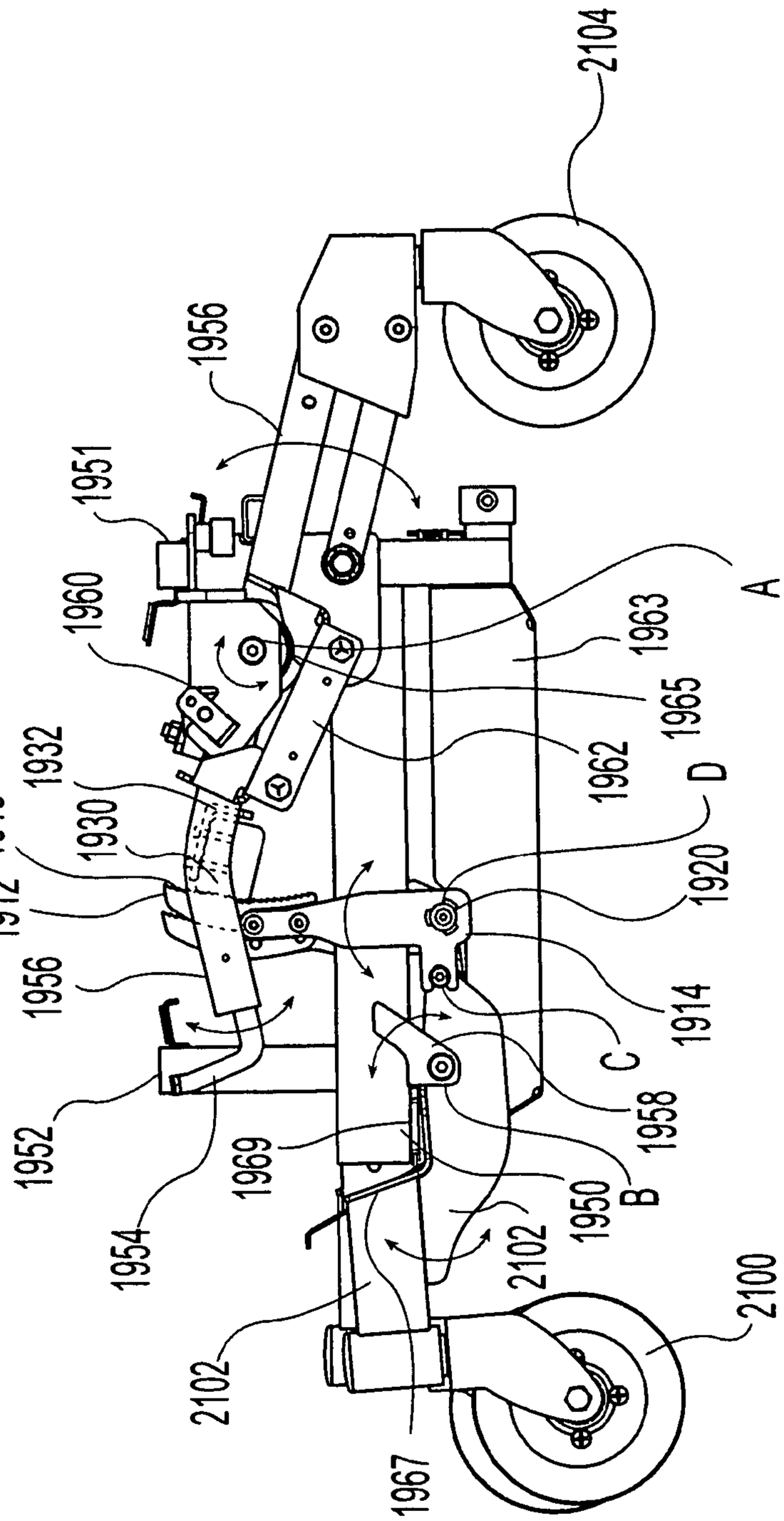
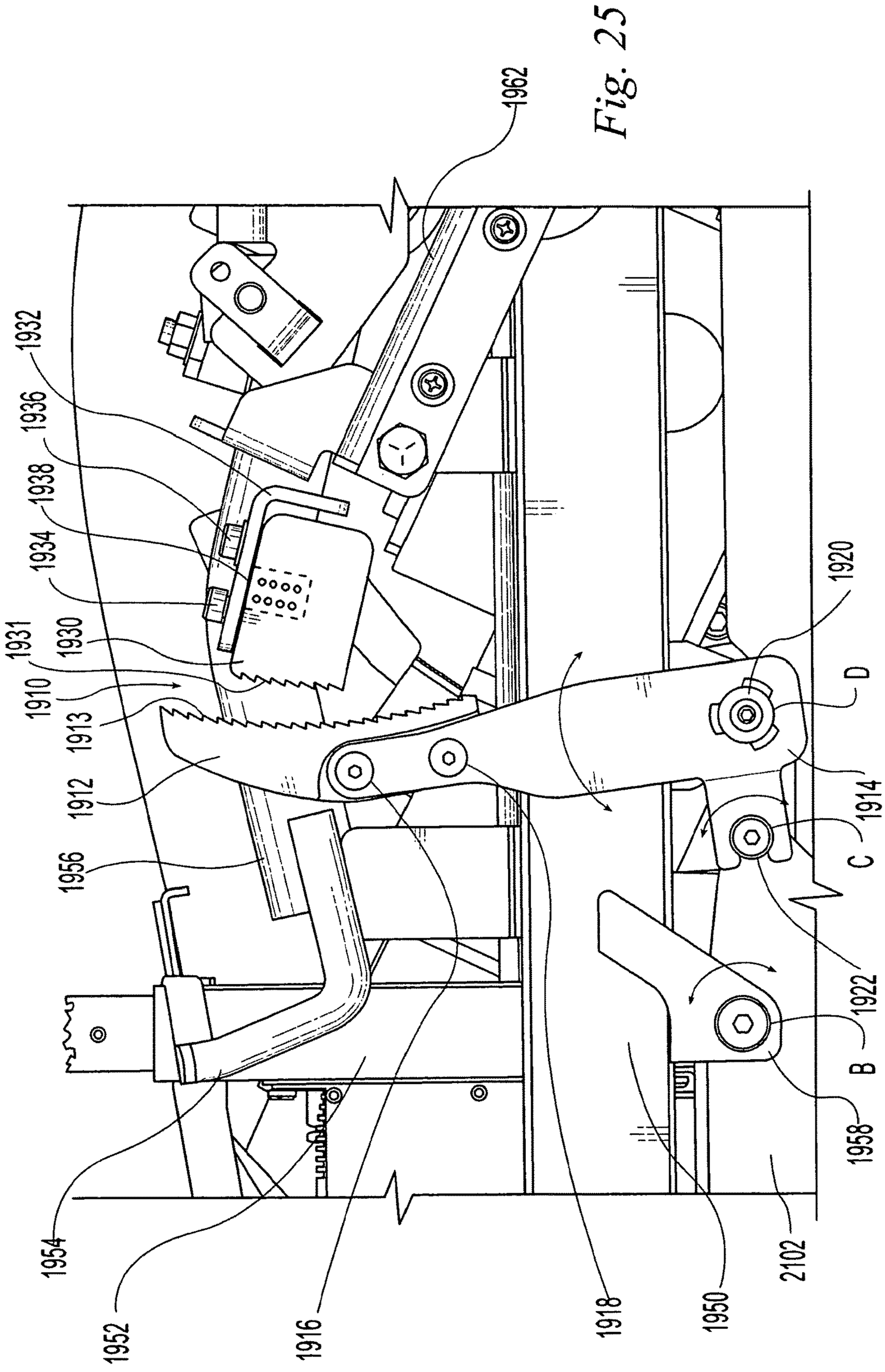

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Fig. 24

Fig. 25


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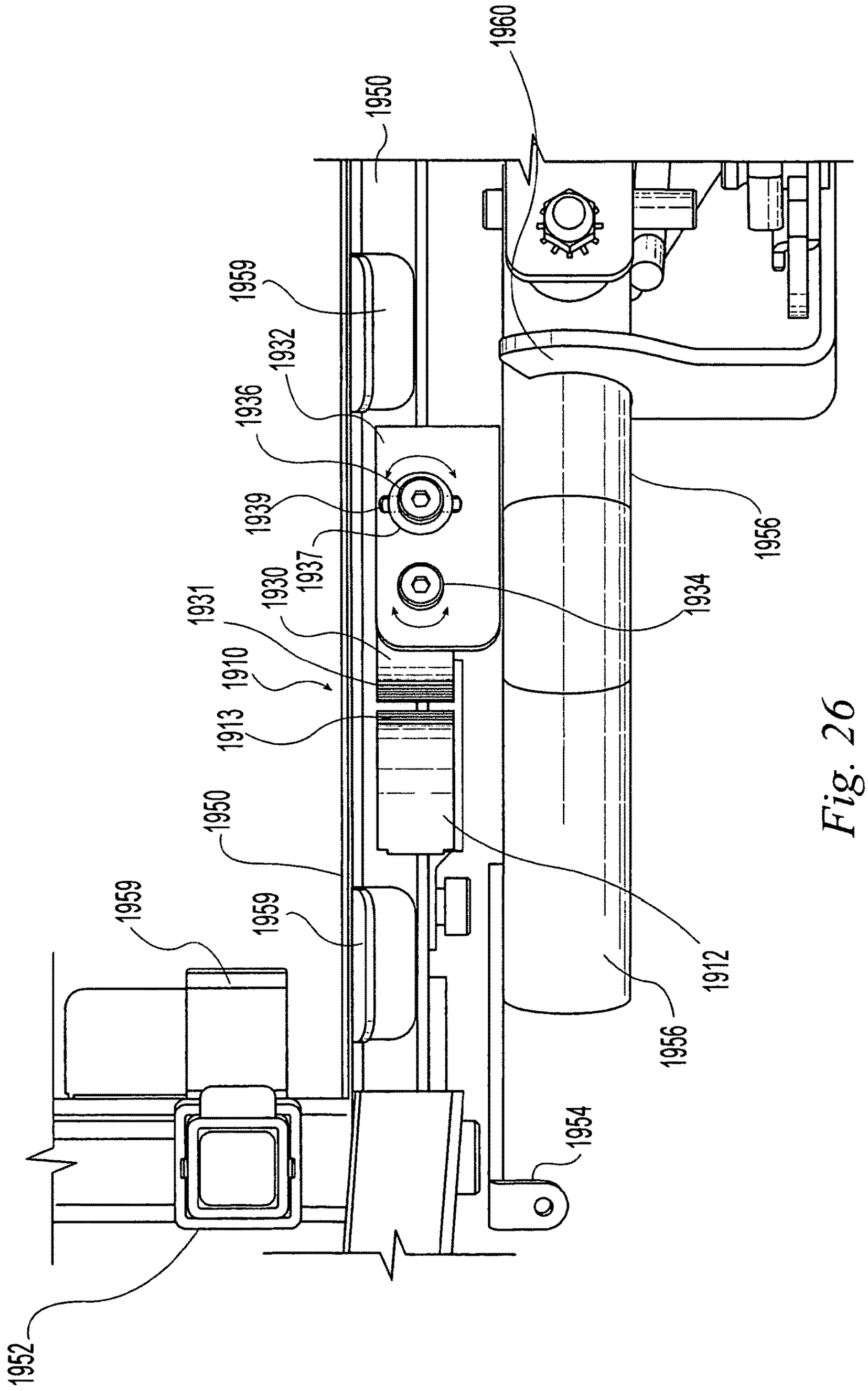

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Fig. 26

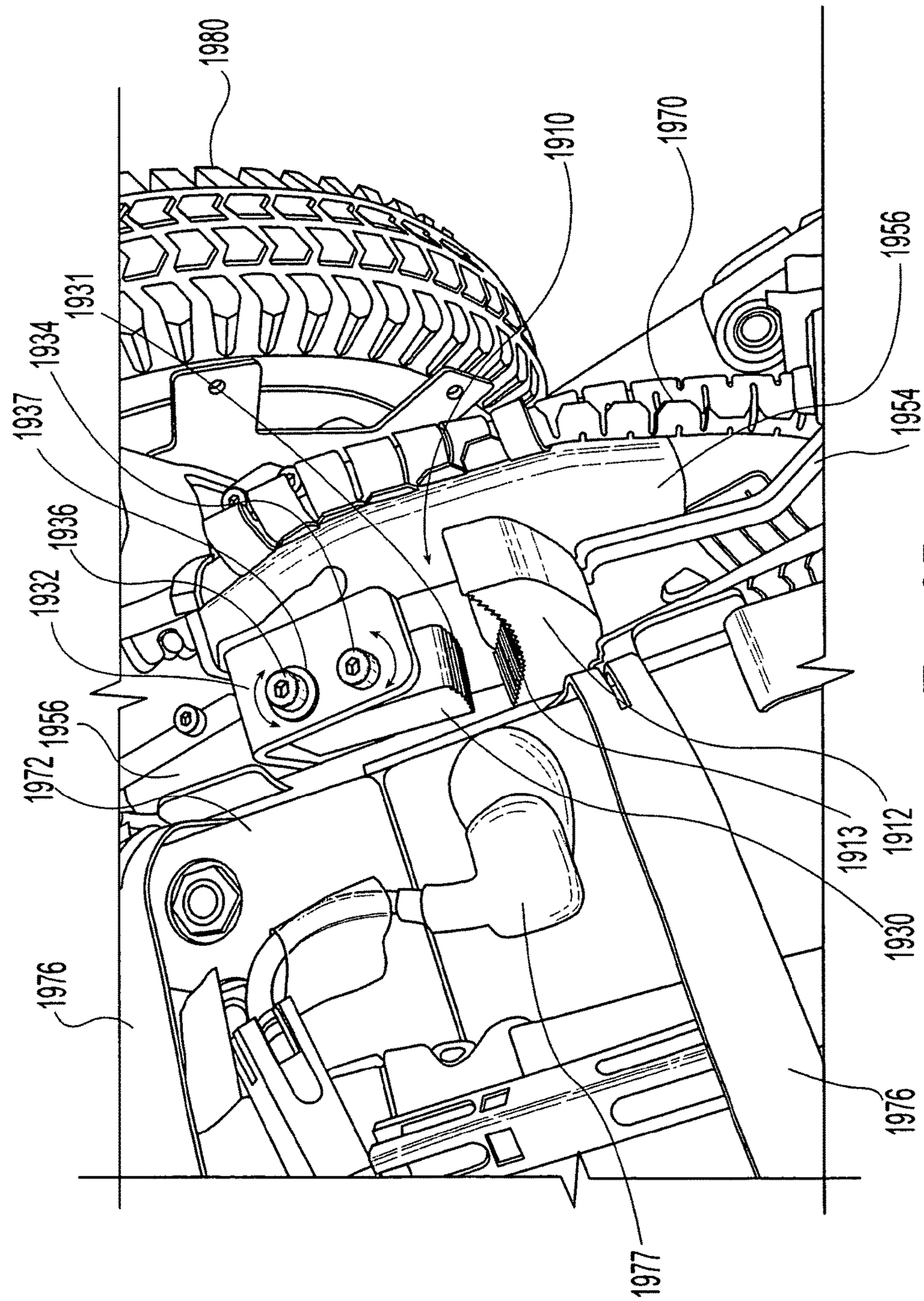

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Fig. 27

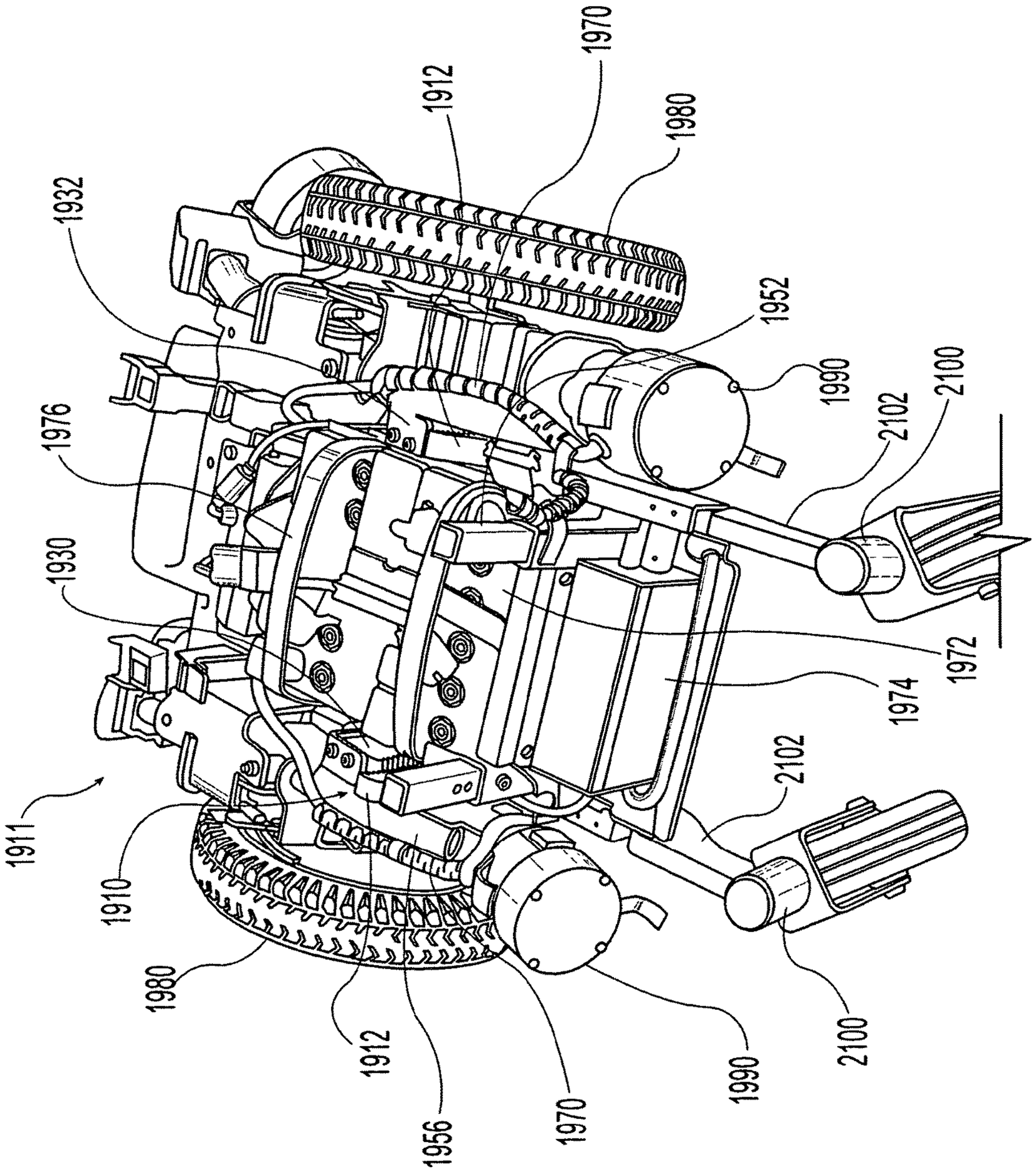

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Fig. 28

SUSPENSION FOR WHEELED VEHICLES

CROSS-REFERENCES TO RELATED APPLICATIONS

This patent application is a continuation of U.S. Ser. No. 15/151,929 filed May 11, 2016, titled "Suspension for Wheeled Vehicles," which is a divisional application of U.S. Ser. No. 14/486,766 filed Sep. 15, 2014, titled "Suspension for Wheeled Vehicles," which is a continuation application of U.S. Ser. No. 13/970,794, now U.S. Pat. No. 8,833,774, titled "Suspension for Wheeled Vehicles", which is a divisional application of and claims priority from U.S. application Ser. No. 11/472,509, now U.S. Pat. No. 8,534,679, entitled "Suspension for Wheeled Vehicles," which is a continuation-in-part of U.S. application Ser. No. 10/695,045, now U.S. Pat. No. 7,083,195, entitled "Suspension with Releasable Locking System" filed on Oct. 27, 2003, which is a continuation-in-part of U.S. application Ser. No. 10/643,010, now U.S. Pat. No. 6,851,711, entitled "Vehicle Having an Anti-Dive/Lockout Mechanism" filed on Aug. 18, 2003, which claims the benefit of U.S. Provisional Application Ser. No. 60/421,178 filed on Oct. 25, 2002. U.S. patent application Ser. No. 11/472,509 is also a continuation of U.S. application Ser. No. 11/077,483, entitled "Self-Stabilizing Suspension for Wheeled Vehicles" filed on Mar. 10, 2005, now U.S. Pat. No. 7,293,801. The entire disclosures of the U.S. application Ser. No. 11/472,509 and U.S. Pat. Nos. 7,293,801; 7,083,195 and 6,851,711 are incorporated by reference in their entirety.

FIELD OF THE INVENTION

The invention relates generally to conveyances and, more particularly, to motorized conveyances (vehicles) such as wheelchairs and scooters.

BACKGROUND OF THE INVENTION

Wheelchairs and scooters are an important means of transportation for a significant portion of society. Whether manual or powered, these vehicles provide an important degree of independence for those they assist. However, this degree of independence can be limited if the wheelchair is required to traverse obstacles such as, for example, curbs that are commonly present at sidewalks, driveways, and other paved surface interfaces. This degree of independence can also be limited if the vehicle is required to ascend inclines or descend declines.

In this regard, most wheelchairs have front and rear casters to stabilize the chair from tipping forward or backward and to ensure that the drive wheels are always in contact with the ground. One such wheelchair is disclosed in U.S. Pat. No. 5,435,404 to Garin. On such wheelchairs, the caster wheels are typically much smaller than the driving wheels and located both forward and rearward of the drive wheels. Though this configuration provides the wheelchair with greater stability, it can hamper the wheelchair's ability to climb over obstacles such as, for example, curbs or the like, because the front casters could not be driven over the obstacle due to their small size and constant contact with the ground.

U.S. Pat. No. 6,196,343 to Strautnieks also describes a wheelchair having front and rear casters. The front casters are each connected to a pivot arm that is pivotally attached to the sides of the wheelchair frame. Springs bias each pivot arm to limit the vertical movement thereof. So constructed, each front caster can undergo vertical movement when running over an obstacle.

While the above-mentioned art provides various ways of addressing the need for stabilizing mid-wheel drive vehicles, a need for further stabilization exists. For example, though equipped with front and rear suspended casters, most mid-wheel drive wheelchairs exhibit various degrees of tipping forward or rearward when descending declines or ascending inclines. This is because the suspensions suspending the front or rear stabilizing casters are compromised so that they are not made too rigid, which would prevent tipping and also not provide much suspension or are made too flexible thereby effectively not providing any degree of suspension or stabilization. Hence, a need exists for addressing the tipping or "diving" experienced by most mid-wheel drive vehicles that have suspension systems included with their stabilization mechanisms.

SUMMARY OF THE INVENTION

An embodiment of a wheelchair suspension comprises a frame, at least one pivot arm, at least one front caster, at least one rear caster, a stabilizing system, and a sensor. The pivot arm is coupled to the frame. The front caster is coupled to the pivot arm. The rear caster is coupled to the frame. The stabilizing system is coupled to the frame and the pivot arm. The sensor is arranged such that tipping of the frame causes actuation of the stabilizing system to at least partially resist further movement of the frame.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which are incorporated in and constitute a part of the specification, embodiments of the invention are illustrated, which together with a general description of the invention given above and the detailed description given below, serve to example the principles of this invention.

FIG. **1** is a block diagram of a first embodiment of an electronic-based stabilization system.

FIG. **2** is a block diagram of a second embodiment of an electronic-based stabilization system.

FIG. **3** is a block diagram of a third embodiment of an electronic-based stabilization system.

FIG. **4** is a side elevation overview of a first embodiment of a mechanically-based stabilization system.

FIG. **5** is a partial perspective view of a second embodiment of a mechanically-based stabilization system.

FIGS. **6**A and **6**B illustrate a first embodiment of a locking member or assembly.

FIGS. **7**A and **7**B illustrate a second embodiment of a locking member or assembly.

FIGS. **8**A, **8**B, and **8**C illustrate a third embodiment of a locking member or assembly.

FIG. **9** illustrates a fourth embodiment of a locking member or assembly.

FIGS. **10**A, **10**B, and **10**C illustrate a fifth embodiment of a locking member or assembly.

FIGS. **11**A and **11**B illustrate a sixth embodiment of a locking member or assembly.

FIGS. **12**A through **12**I illustrate a seventh embodiment of a locking member or assembly.

FIGS. **13-18**B illustrate an eighth embodiment of a locking member or assembly.

FIG. **19** is a right side elevational view of a portion of a wheeled vehicle with an exemplary stabilization system having a self-aligning locking member.

FIGS. **20**A-**20**C and **21**A-**21**C illustrate other locking members.

FIGS. **22-28** illustrate another exemplary wheeled vehicle with an exemplary stabilization system having a self-aligning locking member.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENT

Generally, a mid-wheel drive wheelchair or scooter is a vehicle used to assist those having an impaired ability to transport themselves. As such, the mid-wheel drive wheelchairs and scooters of the present invention have at least two drive wheels that are positioned approximately below the center of gravity of the vehicle when loaded with a user. This results in a majority of the total wheelchair or scooter weight being on the two drive wheels. Mid-wheel drive wheelchairs and scooters also include one or more casters for forward and rearward stability, respectively positioned forward and rearward of the drive wheels. One example of a mid-wheel drive wheelchair can be found in U.S. Pat. No. 5,435,404 to Garin, which is hereby fully incorporated by reference.

At least one motor or combination motor/gear box is provided to drive the drive wheels. The motor is typically controlled by an electronic controller connected to one or more user control devices. The user control devices generally provide selection of forward and reverse movement of the vehicle, as well as controlling the velocity or speed. A battery typically supplies the controller and drive motors with an energy supply. Dynamic braking and an automatic park brake are also incorporated into the vehicle. The dynamic brake allows the operator to proceed safely, even down a slope, without worrying that the vehicle will unreasonably increase in speed while going down the slope. Further, the park brake automatically engages to hold the vehicle in place when the vehicle is standing still.

The present invention provides multiple embodiments of a stabilization system that provides mid-wheel drive vehicles with an anti-dive or lock out mechanism. Generally, the stabilization system includes a trigger or sensor for sensing when conditions exist that may cause the mid-wheel drive vehicle to exhibit a tipping behavior, which can be either forward or rearward, and a locking member or assembly that locks the suspension system to prevent any further tipping behavior. The trigger or sensor also senses when the mid-wheel drive vehicle is no longer subject to conditions that may cause it to exhibit a tipping behavior and causes the locking member or assembly to no longer lock the suspension system.

Referring now to FIGS. **1** and **4**, a block diagram of a first embodiment **100** of an electronic-based stabilization system is shown and a representative mid-wheel drive wheelchair is shown, respectively. Referring more specifically to FIG. **4**, the mid-wheel drive wheelchair has a frame **402** and pivot arm **404**. A pivotal connection **406** connects frame **402** and pivot arm **404**. Attached to pivot arm **404** is a drive wheel **410**. This attachment is typically provided through a motor or motor/gear box that is attached to pivot arm **404**. Pivot arm **404** further has a front caster **412** attached to a forward portion thereof, while the motor or motor/gear box is attached to a more distal opposite portion. Mounting brackets and/or apertures are provided in pivot arm **404** for connecting pivot arm **404** to frame **402** via pivotal connection **406**. A rear caster assembly **416** is provided that includes a frame member **418** and caster **414**. A second pivot arm and assembly is similarly provided on the opposite of the wheelchair, as shown in FIG. **5**.

Referring now to FIG. **1**, the stabilization system triggers a locking member or assembly whenever the summation of moments or torque about pivotal connection **406** exceeds a pre-loaded value or, in other words, causes the frame **402** of the wheelchair to tip forward. One of the moment arms that influences this loading is the moment arm defined by the distance from the center of gravity Cg of the mass of the wheelchair occupant and seat **408** to pivotal connection **406**. The torque or moment acting on the center of gravity Cg is generally defined by: (mass of the wheelchair occupant and seat).times.[(wheelchair acceleration)+(sine of the slope angle).times.(acceleration of gravity)]. The slope angle is the slope of the angle measured from a horizontal. For example, if the wheelchair is traveling on a horizontal surface, the slope angle is zero (0) degrees. If the wheelchair is traveling up an incline, the slope angle may be, for example, five (5) degrees. If the wheelchair is traveling down a decline, the slope angle may be, for example, minus five (−5) degrees. As such, the present invention is configured to trigger the locking member or assembly sooner when traveling down declines (i.e., negative slope angle), compared to when traveling up inclines (i.e., positive slope angle).

As illustrated in FIG. **1**, the system **100** includes a controller **101**, dive lockout control logic **102**, and motor/brake logic **103**. Controller **101** is any computer-based controller suitable for controlling a vehicle. In this regard, controller **102** generally has a processor, memory, and input/output components (not shown). Controller **101** can also have electric motor drive circuitry associated therewith (not shown) that connects to drive motors **104** and **106**. A user input device **108** such as, for example, a joystick, provides control information to the controller **101** for driving the wheelchair. A sensor **126** is provided for sensing the force acting on the center of gravity Cg of the wheelchair occupant and seat and outputs a signal S to controller **102**. As will be presently described, sensor **126** can be any one of several embodiments. The remainder of system **100** includes electronic switches **110** and **112**, nodes **114**, **118**, and **121**, diodes **116** and **120**, resistor **122** and solenoid coil **124**. Solenoid coil **124** is part of an electronic locking member or assembly such that the state of the coil (i.e., energized or unenergized) defines the state of the locking member or assembly (i.e., locking or not locking the suspension system).

In operation, controller **101** receives driving command inputs from joystick **108**. This causes controller **101** to output voltages V.sub.L and V.sub.R and current I.sub.L and I.sub.R to the left and right motors **104** and **106**, respectively. Attached to each motor is a motor lock **105** and **107**, respectively. All the components of the system are typically powered by battery having a positive voltage potential B+ and a ground potential "Gnd." The sensor **126** is mounted on the wheelchair so as to generate a trigger signal S when the wheelchair is tipping forward. In the presently described embodiment, the trigger signal S is an electronic signal. In other embodiments, this can be a mechanical signal such as that generated by a push-pull cable assembly.

Solenoid coil **124** is controlled by the state of electronic switch **112**. The locking member or assembly associated with solenoid coil **124** is preferably in its unlocked state when solenoid coil **124** is energized and in its locked state when solenoid coil **124** is unenergized. Alternatively, the opposite configuration can also be employed.

Nodes **114** and **118** and diodes **116** and **120** form an OR circuit that controls the state of electronic switch **112** and, hence, the energy state of solenoid coil **124**. More specifically, node **114** forms one input to the OR circuit and relates to the state of the motor brakes. For example, when the motors are being driven, the brakes disengage and motor/brake logic **103** causes node **114** to be at 5V. This, in turn, causes electronic switch **112** to close thereby energizing solenoid coil **124** and releasing the locking member or assembly from locking the wheelchair suspension. When the motors are not being driven, the brakes are engaged and motor/brake logic **103** causes node **114** to be at 0V. This causes electronic switch **112** to open, which de-energizes solenoid coil **124** thereby engaging the locking member or assembly to lock the suspension.

Node **118** forms the second input to the OR circuit and relates to input provided by sensor **126** for detecting when conditions may exist that indicate the wheelchair may start exhibiting a tipping behavior. More specifically, if sensor **126** is not indicating that conditions exist under which wheelchair may exhibit a tipping behavior, dive lockout control logic **102** interprets this state and causes node **118** to be at 5V. This, in turn, causes electronic switch **112** to close thereby energizing solenoid coil **124** and releasing the locking member or assembly from locking the wheelchair suspension. When sensor **126** senses that conditions exist for a tipping behavior, dive lockout control logic **102** interprets this state and causes node **118** to be at 0V. This, in turn, causes electronic switch **112** to open thereby de-energizing relay **124** and engaging the locking member or assembly to lock the wheelchair suspension.

Illustrated in FIG. **2** is an embodiment **200** of a stabilization system similar to embodiment **100** of FIG. **1**. In embodiment **200**, the sensor **126** (of embodiment **100**) includes an accelerometer **204** that produces an acceleration input signal A.sub.F to controller **101**. Accelerometer **204** can be any convention accelerometer that provides an output signal that is proportional to the sensed acceleration. In one embodiment, accelerometer **204** can be an appropriately damped pendulum mercury switch. In another embodiment, accelerometer **204** can be an electronic accelerometer such model no. ADXL202 manufactured by Analog Devices of Norwood, Mass. Accelerometer **204** is preferably located on or near the wheelchair seat proximate the center of gravity Cg of the wheelchair seat and occupant.

The operation of embodiment **200** is substantially the same as embodiment **100**, except that the state of node **118** is dependent on acceleration signal A.sub.F. The acceleration signal A.sub.F is compared by the dive lockout control logic **202** to a dive threshold acceleration parameter A.sub.D, which may be negative (−A.sub.D) indicating wheelchair deceleration. The value of dive threshold acceleration parameter A.sub.D can be either calculated based on the weight of the wheelchair and occupant or determined experimentally with the actual wheelchair and a range of seat occupant weights. As such, dive threshold acceleration parameter −A.sub.D is a parameter that is used by the dive lockout control logic **202** to determine if conditions are present under which the wheelchair may exhibit a tipping behavior. When dive lockout control logic **202** determines that acceleration signal A.sub.F is more negative than dive threshold parameter −A.sub.D, it drives node **118** to 0V. This causes electronic switch **112** to open thereby de-energizing solenoid coil **124** and causing the locking member or assembly to lock the wheelchair suspension. Acceleration signal A.sub.F is negative when the wheelchair is decelerating or facing a downward slope or decline. Otherwise, node **118** is maintained at 5V thereby causing electronic switch to close. This, in turn, causes solenoid coil **124** to be energized thus releasing the locking member or assembly from locking the wheelchair suspension.

Referring now to FIG. **3**, an embodiment **300** of an electronically-based stabilization system is shown. Embodiment **300** is substantially similar to embodiment **100**, except that sensor **126** includes a motor voltage and/or current sensor, which can be incorporated into controller **101**. In this regard, controller **101** can incorporate an analog-to-digital (A/D) converter circuit or can include an external A/D circuit. This A/D circuit converts analog signals such as, for example, voltage or current signals, to digital or binary signals for input into or interpretation by controller **101**. Connected therewith, controller **101** also includes dive lockout control logic **302** for interpreting these voltage and/or current signals.

The operation of embodiment **300** is substantially similar to embodiment **200**, except that dive lockout control logic **302** interprets how hard the motor is being driven and dynamically braked to determine whether the locking member or assembly will lock or release the suspension system. In this regard, node **114** behaves as earlier described. Node **118** is driven to 0V when the wheelchair is traveling forward and there is a large amount of dynamic braking being generated by motors **104** and **106**. Node **118** is also driven to 0V if the wheelchair is accelerating hard in the reverse direction of travel. Otherwise, node **118** is driven to 5V. As used herein, dynamic braking generally refers to the process by which a motor's windings are short-circuited when the motor is not being driven so that the residual rotational energy of the motor causes the motor to act as a generator that generates a voltage and current. By recirculating the current generated of this configuration, the motor dynamically brakes itself. The behavior of node **118**, as described above, is further embodied by Equations (1) and (2) below: If (V.sub.L+V.sub.R)>0 and (I.sub.L+I.sub.R)<−I.sub.D, then output 0V on node **114** Eq. (1) If (V.sub.L+V.sub.R)<0 and (I.sub.L+I.sub.R)>I.sub.D, then output 0V on node **114** Eq. (2) In the above equations, V.sub.L, V.sub.R, I.sub.L, and I.sub.R are the approximate terminal voltages and currents of motors **104** and **106**, respectively. Variable I.sub.D is a threshold parameter representing a current level that is used to determine when the motors are being dynamically braked. The value of threshold parameter I.sub.D can be calculated based on the motor specification and weight of the wheelchair and occupant or determined experimentally based on the actual wheelchair weight and a range of seat occupant weights. Equation (1) causes node **118** to be driven to 0V when the wheelchair is traveling forward ((V.sub.L+V.sub.R)>0) and the motors are dynamically braking themselves ((I.sub.L+I.sub.R)<−I.sub.D). Equation (2) also causes node **118** to be driven to 0V when the wheelchair is accelerating hard in the reverse direction ((V.sub.L+V.sub.R)<0) and the motors are not dynamically braking themselves ((I.sub.L+I.sub.R)>I.sub.D). As described earlier, when node **118** is driven to 0V, electronic switch **112** opens thereby causing solenoid coil **124** to de-energize. De-energizing solenoid coil **124** causes the locking member or assembly to lock the suspension system. Otherwise, node **118** is driven to 5V, which causes electronic switch **112** to close thereby energizing solenoid coil **124**. Energizing solenoid coil **124** causes the locking member or assembly to unlock or release the suspension system. Alternatively, energizing solenoid coil **124** can cause the locking member or assembly to unlock or release the suspension system and

de-energizing solenoid coil **124** can cause the locking member to lock the suspension system.

Referring now to FIG. **4**, one embodiment of a mechanically-based stabilization system is shown. In this regard, a locking member **420**, push-pull cable **424**, and pivotal rear castor assembly **416** are provided. Push-pull cable **424** has a first conduit portion attached to a bracket **430** on rear caster frame member **418** and a second portion attached to a locking member control bracket assembly **432**. Push-pull cable **424** also has a first cable portion attached to a rear castor pivot bracket portion **428** and a second cable portion attached to a locking member control arm **422**.

Locking member **420** is pivotally connected to frame **402** and pivot arm **404**. This is accomplished through a conventional pivot assembly that includes pins or bolts extending through mounting brackets. A second similar locking member and push-pull cable are associated with a second pivot arm on the other side of frame **402** and identically configured to locking members **404** and push-pull cable **424**.

In this regard, locking member **420** is preferably a lockable spring device. Examples of such devices include lockable gas or hydraulic springs that include piston valve assemblies for locking the springs in a predetermined position. Such lockable gas or hydraulic springs include, for example, the BLOC-O-LIFT®, STAB-O-MAT®, and STAB-O-BLOC® models of gas springs as manufactured by STABILUS GMBH, Koblenz, Germany. In the preferred embodiment, arm **422** is mechanically linked to the reciprocating rod that opens and closes the piston valve assembly of the locking member **404**.

In operation, when rear castor **414** is contacting the driving surface, push-pull cable **424** causes arm **422** to be pulled toward bracket **432**. This state causes locking member **420** to be in its unlocked state thereby allowing pivot arm **404** to pivot about pivotal connection **406** as front castor **412** traverses bumps and obstacles on the drive surface. However, when the wheelchair begins to exhibit a tipping behavior (e.g., tipping forward), rear caster **414** will pivot about connection **426**. Rear castor **414** may or may not completely come off of the driving surface. This causes the cable within push-pull cable **424** to displace. This displacement is translated to arm **422**, which begins to separate from control bracket **432**. When arm **422** separates from control bracket **432**, the locking member enters the locked state thereby locking pivot arm **404** from pivotal motion about connection **406**. When the wheelchair returns to its normal position, rear caster **414** pivots back to its normal ground-engaging position thereby releasing locking member **420** via push-pull cable **424**. This allows pivot arm **404** to once again pivot about connection **406**. Most preferably, the system is configured that if push-pull cable **424** breaks, locking member **420** automatically locks pivot arm **404**. Additionally, a resilient spring device can be placed between rear caster pivot bracket portion **428** and rear caster frame member **418** to bias rear caster **414** around connection **426** towards the driving surface.

As an alternative to FIG. **4**, push-pull cable **424** can be replaced by a limit switch designed to sense the motion of rear caster pivot bracket portion **428** and a solenoid actuator configured to act upon arm **422** upon movement of the rear caster pivot bracket portion **428** during a wheelchair tipping motion. In this regard, one or more wires connect the limit switch to the solenoid actuator. In yet another alternative, push-pull cable **424** can be replaced with a plurality of mechanical linkages that provide the same effect on arm **422**.

Illustrated in FIG. **5** is another alternate embodiment **500** to that FIG. **4**. The embodiments of FIGS. **4** and **5** are substantially similar, except that the embodiment of FIG. **5** includes only one locking member **420** that is associated with both pivot arms **404** and **510**. To facilitate this configuration, a link **502** is provided between the pivot arms **404** and **510**. Link **502** has a first portion **504** that is pivotally connected to first pivot arm **404** and a second portion **506** that is pivotally connected to second pivot arm **510**. Link **502** also has a third portion that is pivotally connected to a bottom portion of locking member **420**. A top portion of locking member **420** is pivotally connected to frame **402**. Though not illustrated, a push-pull cable mechanically links locking member **420** to rear caster **414** or its parallel equivalent in the same fashion as that shown in FIG. **4**. The operation of embodiment **500** is similar to that described for FIG. **4**, except that when locking member **420** is in the locked state, it prevents link **502** from displacement. This, in turn, prevents either pivot arm **404** or **510** from movement.

Referring now to FIGS. **6**A and **6**B, an embodiment **600** of a stabilization system having ratchet-type locking member or assembly **602** is shown. The locking member **602** has a pawl member **614**, ratchet member **620**, and a solenoid actuator **608**. Pawl member **614** and solenoid actuator **608** are rigidly fixed to frame **402** via a bracket **606**. Bracket **606** also serves as a guide bracket for ratchet member **620**, though this function can be provided by a separate guide member. Solenoid actuator **608** has a coil **124**, spring **612** and pin **613**. Pawl member **614** has a first portion pivotally connected to bracket **606** and a second portion pivotally connected to pin **613**. Ratchet member **620** has a plurality of cammed extensions **622** between which pawl member **614** is configured to engage and disengage. A bottom portion of ratchet member **620** is pivotally connected to pivot arm **404** at connection **604**. So configured, ratchet member **620** is free to undergo reciprocating movement within the guide portion of bracket **606** as pivot arm **404** pivots about connection **406**. As described earlier, solenoid actuator **608** can be controlled by any of the embodiments of FIGS. **1-4**.

As such, when the wheelchair exhibits a tipping behavior, solenoid actuator **608** is de-energized causing spring **612** to urge pin **613** and pawl member **614** against ratchet member **620**. This causes pawl member **614** to be locked against ratchet member **620** so as to prevent ratchet member **620** from any further upward motion, which causes tipping of the wheelchair. This state prevents the forward portion of pivot arm **404** from exhibiting any upward motion that is associated the wheelchair's tipping behavior. However, it may be desirable to allow ratchet member **620** to further move in the downward direction while pawl member **614** remains engaged therewith. This is accomplished by appropriately camming the engaging surfaces of pawl member **614** and ratchet member **620**, as shown. In this manner, pivot arm **404** is free to move in a direction that would lessen the tipping behavior of the wheelchair but not increase such behavior. If the wheelchair is not exhibiting a tipping behavior or has ceased to exhibit a tipping behavior, solenoid actuator **608** is energized causing pin **613** and pawl member **614** to disengage from ratchet member **620**. This allows pivot arm **404** to freely pivot about connection **406**. As described earlier in connection with FIGS. **4** and **5**, one or two or more locking members can be provided. Additionally, pawl member **614** can be triggered by a inertial switch or method instead of solenoid actuator **608** or one which actuates a solenoid actuator.

Referring now to FIGS. **7**A and **7**B, an embodiment **700** of a stabilization system having a caliper-type locking

member or assembly **702** is shown. The locking member **702** has a spring **712**, pin **714**, one or more friction plates **710**, and a linear reciprocating link **704**. Pin **714** has a first portion connected to friction plate **710** and a second portion connected to either a solenoid actuator or push-pull cable, or equivalent, as described earlier for locking and unlocking the suspension system. Spring **712** is located between these portions and biases pin **714** and friction plate **710** toward link **704**. The friction plates **710**, spring **712**, and pin **714** are housed within a frame attachment **708**, which rigidly connects these components to frame **402**. Attachment **708** also functions as a guide for link **704** so as to always maintain link **704** between friction plates **710**. This function can also be provided by a separate guide bracket.

Link **704** has a first portion that is pivotally connected to pivot arm **404** and a second portion that travels within attachment or guide **708** so as to be engagable by friction plates **710**. In this manner, as pivot arm **404** rotates about connection **406**, link **704** exhibits a reciprocating up and down motion with respect to attachment **708** and friction plates **710**. Preferably, two friction plates **710** are provided facing each other with a gap therebetween. The space or gap exists between friction plates **710** so as to allow link **704** to freely move therethrough until such time as the friction plate **710** connected to pin **714** is moved toward link **704** and the opposing friction plate **710**. This movement causes both friction plates **710** to engage the link **704** and to lock it in position. This, in turn, prevents pivot arm **404** from pivoting about connection **406**. Hence, when the wheelchair is exhibiting a tipping behavior, pin **714** is extended allowing friction plate **710** to engage against link **704**. When link **704** is locked between friction plates **710**, the wheelchair will not exhibit any tipping behavior. When the conditions for a tipping behavior are absent, pin **714** is in its retracted position and link **704** can move freely between friction plates **710**.

Referring now to FIGS. **8**A, **8**B, and **8**C, an embodiment **800** of a stabilization system having a magnetic-field actionable locking member is shown. Referring specifically to FIG. **8**C, embodiment **800** has a locking member **804** and an actuator assembly **802** associated therewith. Locking member **804** has a first portion **806** that is pivotally connected to pivot arm **404** and a second portion **808** that is pivotally connected to frame **402**. Locking member **802** is a hydraulic piston assembly having a magnetic fluid. The piston within the assembly has a valve that allows the fluid to pass from one side of the piston to the other. However, when a magnetic field is brought near the proximity of the fluid, the magnetic field causes the fluid viscosity to greatly increase thereby not allowing the fluid to flow through the valve in the piston. This, in turn, locks the piston in position.

Illustrated in FIG. **8**A is a first embodiment of the actuator assembly **802**. The assembly **802** has a permanent magnet **810** that is fixed directly or indirectly to frame **802**, a solenoid coil **812** and a switch **814**. Solenoid coil **812** can be the same component as solenoid coil **124** and switch **814** can be mechanical or electronic, as described in connection with FIGS. **1-4**. In operation, magnet **810** causes the fluid in locking member **804** to have a very high viscosity and, hence, almost no ability to flow. This maintains locking member **804** in a locked stated thereby locking pivot arm **404** from pivoting about connection **406**. However, when solenoid coil **812** is energized by switch **814**, its magnetic field cancels with the magnetic field generated by magnet **810** and allows the fluid in locking member **812** to have a very low viscosity and, hence, the ability to flow relatively easily. This allows locking member **804** to move in accordance with the movement of pivot arm **404** about pivotal connection **406**. Hence, if power is lost, magnet **810** provides a failsafe condition which automatically locks locking member **804**. Therefore, it can be seen that when the wheelchair exhibits a tipping behavior, solenoid coil **812** is de-energized causing locking member **804** to lock pivot arm **404**. When no tipping behavior is exhibited by the wheelchair, solenoid coil **812** is energized and locking member **804** is not in its locked state.

Illustrated in FIG. **8**B is a second embodiment of an actuator assembly **802**. This embodiment has the earlier described push-pull cable **424** spring-loaded against magnet **810**. In this embodiment magnet **810** moves either toward or away from the locking member **804** so as to either bring its magnetic field in operative proximity to the locking member or away from the locking member. As described in connection with FIG. **4**, push-pull cable **424** provides for linear mechanical movement upon a tipping condition of the wheelchair. By having push-pull cable **424** fixed to magnet **810**, the linear movement of push-pull cable **424** can be used to move magnet **810** closer to locking member **804** so as place it in its locked state, or away from locking member **804** so as to place it in its unlocked state. Spring is also provided so as to bias magnet **810** towards locking member **804** ensuring that locking member **804** is in its locked state should push-pull cable **424** break.

Referring now to FIG. **9**, an embodiment **900** of a suspension system having a sprag clutch locking member **902**. Sprag clutch locking member **902** allows rotational movement in one direction and not in the other. Alternatively, locking member **902** can be a bi-directional clutch. Bi-directional clutches allow their input to drive their output in either rotational directions, but do not allow the output to drive the input.

FIGS. **10**A, **10**B and **10**C illustrate one embodiment **1000** of a suspension system having a direct acting pin locking member **1002**. Locking member **1002** extends and retracts its pin **1008** so as to enter one of a plurality of slots or apertures in locking bracket **1004**. In this regard, locking member **1002** has a spring-loaded pin **1008** and an actuator cable **1006**. If locking member **1002** is mechanical, then actuator cable **1006** can be a push-pull cable, as described earlier. If locking member **1002** is solenoid driven, then actuator cable **1006** can be an electric cable that carries the signal that actuates the solenoid. The locking member **1002** can also be pneumatically actuated through known means. So configured, locking member **1002** is affixed to the frame **402** through mounting brackets (not shown) or its housing.

Locking bracket **1004** is affixed to pivot arm **404** and moves therewith. In this regard, locking bracket **1004** preferably includes an arcuate shape so as to maintain alignment with locking member **1002** as pivot arm **404** pivots or rotates. Locking bracket **1004** includes a plurality of apertures or slots that disposed along the bracket's arcuate body. The apertures can be any shape such that pin **1008** can enter thereinto. Pivot arm **510** (not shown) would have a similar suspension system.

Illustrated in FIG. **10**C is detail of an alternative embodiment of pin **1008**. More specifically, FIG. **10**B shows pin **1008** having flat head portion at its engaging distal end. FIG. **10**C shows an embodiment of pin **1008** having a cammed surface **1010** at its engaging distal end. Cammed surface **1010** is provided so that when pin **1008** is engaged in locking bracket **1004**, pivot arm **404** can pivot in the downward direction. This causes a ratcheting effect where cammed surface **1010** causes pin **1008** to retract under the downward tendency (i.e., clockwise rotation) of pivot arm

404. However, configured as such, pin **1008** does not allow a corresponding ratcheting in the upward direction (i.e., counter-clockwise rotation) of pivot arm **404**.

In operation, pin **1008** of locking member **1002** is spring-engaged into an aperture of locking member **1004**. Actuator cable **1006**, when active, causes pin **1008** to retract from locking bracket **1004**. In this manner, a failsafe configuration is provided should actuator cable **1006** fail. The triggering of locking member **1002** can be by any of the embodiments described in FIGS. **1-4**.

Illustrated in FIGS. **11**A and **11**B an embodiment **1100** of a suspension system having an axial spring locking member **1102**. In particular, locking member **1102** has an actuator member **1108**. Actuator member **1108** can be a spring-loaded pin, solenoid driven pin, or a mechanical clamp (not shown). Actuator member **1108** is actuated by an actuator cable **1110**, which can be an electric cable, pneumatic hose, or push-pull cable. Locking member **1102** further has a housing **1112** that includes a spring **1113** that axially receives a locking rod or tube **1106** therein. Locking member **1102** is rigidly affixed to frame **402** with mounting brackets (not shown).

Spring **1113** is a coil spring that includes first and second extensions **1114** and **1116**, respectively. Spring **1113** is arranged so that when extensions **1114** and **1116** are not acted upon by any force, spring **1113** is tightly coiled around locking rod or tube **1106** so as to prevent any axially movement of locking rod or tube **1106** within spring **1113**. Since locking rod or tube **1106** has one of its distal ends pivotally fixed to pivot arm **404** at **1104**, pivot arm **404** is also locked from any rotational movement. In this manner, a failsafe configuration is provided should actuator cable **1110** fail. The triggering of locking member **1102** can be by any of the embodiments described in FIGS. **1-4**.

To release locking rod or tube **1106** from spring **1113**, extensions **1114** and **1116** are acted upon by a force. In this regard, extensions **1114** and **1116** can be configured so that either a force that brings them closer together or a force that brings them farther apart causes spring **1113** to become loosely coiled around locking rod or tube **1106**. Once loosely coiled, spring **1113** allows locking rod or tube **1106** to axially move therein. This, in turn, allows pivot arm **404** to pivot about its connection at **403**. Pivot arm **510** (not shown) would have a similar suspension system.

Referring now to FIGS. **12**A, **12**B, **12**C, **12**D, and **12**E, an embodiment of a suspension system **1200** having an linear locking member **1202** is shown. FIG. **12**A shows the suspension system on a level driving surface. FIG. **12**B illustrates the suspension system wherein front caster **412** is lifted by the suspension off of the driving surface. FIG. **12**C shows the suspension system wherein front caster **412** has been lowered onto a lower driving surface. FIG. **12**D illustrates the suspension **1200** with the drive wheel removed and FIG. **12**E is a partial perspective view of the suspension **1200**.

Suspension system **1200** further includes a four-bar pivoting assembly that includes pivot arms **1204**A and **1204**B, caster head tube bracket **1214**, and frame **402**. Bracket **1208**, while a separate component, can be considered as part of frame **402**. Pivot arms **1204**A and **1204**B are pivotally connected to frame **402** via pivotal connections **1206**A and **1206**B. Pivot arms **1204**A and **1204**B are also pivotally connected caster head tube bracket **1214** via pivotal connections **1207**A and **1207**B.

Locking member **1202** is shown having a first pivotal connection **1210** to pivot arm **1204**B and a second pivotal connection **1212** to bracket **1208**. So connected locking member is under the influence of pivot arms **1204**A and **1204**B. It should be noted that locking member **1202** pivotal connection **1210** can be alternatively located on pivot arm **1204**A or caster head tube bracket **1214**, as well.

FIG. **12**F illustrates a partial cross-section of locking member **1202**. Locking member **1202** has a first housing **1220** and a second housing **1222**. First housing **1220** retains therein a electric solenoid actuator **1230** that includes a coil and a plunger **1232** biased by leaf spring **1228**. A cover **1226** is provided on housing **1220** that has an aperture that allows plunger **1232** to at least partially project there from. The projecting portion of plunger **1232** has a pivotable lever **1224** connected thereto. Pivoting of the lever through manual actuation causes plunger **1232** to move without the need for electrical energy.

Second housing **1222**, which is attached to first housing **1220** includes a channel or passage **1234** therein. A rod member **1236** moves within passage **1234** and includes a notch **1238** therein. Notch **1238** is configured such that when plunger **1232** is biased into passage **1234**, plunger **1232** will come into locking engagement with notch **1238** and remain there until withdrawn. Alternatively, notch **1238** can be replaced by a ratcheting tooth configuration similar to that shown in FIG. **6**B.

Referring now to FIGS. **12**G and **12**H, perspective and top views of locking member **1202** are illustrated. Rod member **1236** includes at one distal end an aperture **1240**, which accepts a pin or similar fastener in forming pivotal connection **1210**. Additionally, second housing **1222** includes at one distal end first and second extensions **1246** and **1248**, each of which have aligned apertures **1244**. Extension **1246** and **1248** accept in the space between them a pivoting bracket member that is used secure the locking member **1202** to bracket **1208**.

Illustrated in FIG. **12**I is an exploded perspective view of locking member **1202**. In addition to the above-mentioned components, locking member **1202** further includes a block **1252** that is affixed to plunger **1232**. Block **1252** increases the effective cross-section of plunger **1238** which is responsible for locking engagement with rod member **1236**. Housing **1222** has a cover portion **1250** that includes an aperture **1254** having substantially the same shape as block **1252** and allows block **1252** to reciprocate there within.

In operation, locking member **1202** locks the suspension system when, for example, the vehicle is not moving and motor parking brake or lock is actuated. This creates a stable platform for the user to transport in and out of the vehicle or wheelchair. Locking member **1202** is also preferably configured to lock suspension system when the is no power or the power system has been shut off. This is achieved by always biasing plunger **1232** into locking engagement with rod member **1236**. Upon power-up, solenoid **1230** is actuated and plunger **1232** is withdrawn from the locking engagement.

So configured, locking member **1202** can be alternatively located among a plurality of positions the on suspension system **1200**. For example, locking member **1202** can be attached between the frame **402** and upper pivot arm **1204**A, attached between the upper and lower pivot arms **1204**A and **1204**B, or between any two components of the described four-bar pivoting assembly. Additionally, locking member **1202** can be triggered by any of the mechanisms described earlier electrical or mechanical.

Illustrated in FIG. **13** is an eighth embodiment **1300** of a locking assembly of the present invention. The locking assembly has a motor rack bracket **1314**, first ratchet **1320**, second ratchet **1322** and a spring mount **1318**. So config-

ured, the locking assembly is shown mounted on the vehicle frame **402**, which includes a four-bar linkage pivoting front caster assembly. The four-bar linkage pivoting caster assembly includes first and second linkages **1302** and **1304**. A third linkage is provided by frame **402** and its extension in the form of frame bracket **1306**. A fourth linkage is provided by caster head tube assembly **1311**. First linkage **1302** is pivotally connected to frame **402** at pivot **1310** and second linkage **1304** is pivotally connected to frame **402** at pivot **1308**. A more detailed discussion of this four-bar linkage pivoting front caster assembly can be found in pending U.S. patent application Ser. No. 09/974,348, filed on Oct. 10, 2001, which is hereby fully incorporated by reference.

The locking assembly's motor rack bracket **1314** is physically connected to first linkage **1302** through a motor/gearbox mount **1312**. The connection can also be made directly if desired. A gearbox **1316** is also shown connected to motor/gearbox mount **1312**. First ratchet **1320** is attached to motor rack bracket **1314** at an end portion opposite the connection to first linkage **1302**. So configured, motor rack bracket **1314** pivots when first linkage **1302** pivots.

The locking assembly's spring mount **1318** is pivotally connected to frame **402** through clevis **1325**. The second ratchet **1322** is affixed to a side portion of the spring mount **1318**. Clevis **1325** and its pivotal connection **1324** allow spring mount **1318** to pivot with respect to frame **402**. In an alternate embodiment, pivotal connections **1324** and **1332** and devises **1325** and **1334** can be combined into a single integrated clevis and pivotal connection. For example, clevis **1325** can be eliminated and pivotal connection **1324** integrated into pivotal connection **1332**.

In another embodiment, an elastic member such as, for example, a spring, can be positioned between spring mount **1318** and frame **402**. Such a spring would urge or assist the pivotal movement of spring mount **1318** away from frame **402**, as will be described below. To facilitate such a spring, spring mount **1318** would include a bearing surface for bearing against one end of the spring and a spring holder. This configuration can take the form of pin or bolt at least partially received within the spring, which such configuration may additionally be at least partially received within a recess in spring mount **1318**. The other end of the spring would bear against a bearing surface on frame **402**. Alternatively, such a configuration can be reversed between the spring mount **1318** and frame **402**.

A rear caster mount **1328** pivotally connects rear caster **414** to frame **402**. More specifically, rear castor mount **1328** has an extension **1330** that includes a first distal end pivotally connected to clevis **1334** and a second distal end connected to a head tube portion for mounting the rear caster **414**. A spring **1326** is situated between rear castor mount **1328** and spring mount **1318**. Spring **1326** compresses when rear caster mount **1328** pivots clockwise as shown in FIG. **13** toward frame **402**. In this manner, spring **1326** provides a degree of suspension for the rear caster mount **1328**. Alternatively, if no degree of suspension is desired, spring **1326** can be replaced by a non-resilient member resulting in spring mount **1318** and rear caster mount **1328** being an integrated and rigid structure. As described above, such an integrated structure can employ a single integrated pivot at pivotable connection **1332**, as opposed to pivotable connections at **1324** and **1332**.

In operation, first and second ratchets **1320** and **1322** engage each other in one of a plurality of releasable locking states whenever rear caster **414** is about to be lifted from its supporting surface. This condition occurs whenever the frame **402** pivots or tilts forward toward front caster **412**. When frame **402** pivots or tilts forward, first and second pivot arm linkages **1302** and **1304** correspondingly pivot about their pivotal connection **1310** and **1308**, respectively. Any pivotal movement of linkages **1302** or **1304** translates to pivotal movement of motor rack bracket **1314** and first ratchet **1320** by virtue of their mechanical coupling. As this condition occurs, rear caster mount **1328** pivots about its pivotal connection at **1332** causing spring mount **1318** to pivot about its pivotal connection at **1324** so that second ratchet **1322** comes into contact with first ratchet **1320**. When first and second ratchets **1320** and **1322** come into contact forming a releasable locking state, pivot arm linkages **1302** and **1304** are releasably locked thereby locking frame **402** from any additional pivoting or tilting forward. When frame **402** resumes its normal level position, rear caster mount **1328** pivots clockwise causing spring mount **1318** to pivot clockwise and disengage second ratchet **1322** from first ratchet **1320**. This releases first and second pivot arm linkages **1302** and **1304** from their locked state so that they may once again freely pivot.

FIGS. **14** through **16**, further illustrate the locking assembly and its components in perspective views. In particular, FIG. **15** is a perspective view of the spring mount **1318**. Spring mount **1318** further has a surface **1502** for bearing against spring **1326** and a structure **1504** holding spring **1326** in position relative spring mount **1318**. FIG. **16** is a perspective view of rear caster mount **1328**. Rear caster mount **1328** further has a surface **1602** for bearing against spring **1326** and a structure **1604** for holding spring **1326** in position relative to rear caster mount **1328**.

Referring now to FIGS. **17**A and **17**B, elevational and perspective views, respectively, of the second ratchet **1322** are illustrated. Second ratchet **1322** has a body **1702** that includes a plurality of mounting apertures **1706** that are used to fasten it to spring mount **1318**. Body **1702** also includes a toothed surface **1704**. The toothed or undulating nature of surface **1704** is configured to provide a plurality of releasable locking states when engaged with first ratchet **1320**. The number of releasable locking states can vary from 1 to 2 or more. For example, surface **1704** can have a single tooth any where along its length for engagement with first ratchet **1320**. Additionally, surface **1704** can have first and second teeth disposed at the proximal ends of its curved or arcuate length. This configuration provides two locking states that permit a range of tipping motion by the frame, but place limits on the range. In yet another embodiment, surface **1704** can have first and second teeth disposed at the proximal ends of its length and at least one tooth somewhere intermediate the ends. This configuration provides two locking states that permit a range of tipping motion by the frame, but which place limits on the range, and a third discrete locking state intermediate the limits. As further illustrated in FIGS. **17**A and **17**B, surface **1704** is slightly curved or arcuate to compensate for the nature of the pivotal motion first ratchet **1320** experiences as it pivots with pivot arm linkages **1302** and **1304**.

FIGS. **18**A and **18**B are elevational and perspective views, respectively, of first ratchet **1320**. First ratchet **1320** has a body **1804** that includes a plurality of mounting apertures **1806**, which are used to fasten first ratchet **1320** to motor rack bracket **1314**. Body **1804** also has a toothed surface **1804**, which is slightly curved or arcuate to accommodate the pivotal motion experienced by second ratchet **1322**. The tooth configuration of surfaces **1804** and **1704** are configured such that relative motion between first and second ratchets **1320** and **1322** is more or less permitted in one direction, but motion in the opposite direction is impeded.

Also, as described above in connection with second ratchet **1322**, the toothed or undulating nature of surface **1804** is configured to provide a plurality of releasable locking states when engaged with first ratchet **1320**. The number of releasable locking states can vary from 1 to 2 or more. For example, surface **1804** can have a single tooth any where along its length for engagement with second ratchet **1322**. Additionally, surface **1804** can have first and second teeth disposed at the proximal ends of its curved or arcuate length. This configuration provides two locking states that permit a range of tipping motion by the frame, but place limits on the range. In yet another embodiment, surface **1804** can have first and second teeth disposed at the proximal ends of its length and at least one tooth somewhere intermediate the ends. This configuration provides two locking states that permit a range of tipping motion by the frame, but which place limits on the range, and a third discrete locking state intermediate the limits.

Some of the exemplary vehicle stabilization systems described above may be modified. For example, one or more locking members may be movably connected to a respective pivot arm or assembly permitting one or both locking members to automatically align with the other locking member as they engage to lock the pivot arms or assemblies to limit further movement of the frame in at least one direction. One or more of such self-aligning locking members may permit solid engagement between locking members during much of the life of the vehicle, even as components of the vehicle wear and/or are deformed over time or as a result of collisions. The self-aligning locking member(s) may optionally be "floating" (e.g., freely movable in at least one direction or orientation) with respect to a respective pivot arm or assembly. The self-aligning locking member(s) may optionally include positional memory such that the relative position of the movable locking member(s) during an engagement with the other locking member with respect to at least one orientation or direction will be maintained after disengagement, but will also permit the movable locking member(s) to self-align in that direction for the next engagement, if necessary. Such a positional memory may be provided by a biasing member (e.g., a spring or a plastic material) operatively connected to bias the locking member against a surface to provide positional memory to the locking member relative to its respective assembly.

For example, referring back to FIGS. **17**A-B and **18**A-B (and the text and other figures accompanying that embodiment), first ratchet **1320** may be movably connected to motor rack bracket **1314** and/or second ratchet **1322** may be movably connected to spring mount **1318**. This may be accomplished, for example, by having any one or more bores used to fasten first ratchet **1320** to motor rack bracket **1314** and/or fasten second ratchet **1322** to spring mount **1318** be formed as slots or formed as bores significantly larger than fasteners passing therethrough. Additionally, or in the alternative, fasteners movably connecting the first ratchet **1320** to the motor rack bracket **1314** and/or fasteners movably connecting the second ratchet **1322** to the spring mount **1318** may be shoulder screws that when mounted permit a gap between the first ratchet **1320** and the motor rack bracket **1314** and/or a gap between the second ratchet **1322** and the spring mount **1318**, which permits significant freedom of movement of the first ratchet **1320** and/or second ratchet **1322**. The first ratchet **1320** and/or second ratchet **1322** may have positional memory (e.g., provided by a spring or other biasing member) in any one or more directions or orientations and may be "floating" in any one or more directions or orientations, as discussed herein.

As another exemplary modification, one or more pivot arms or assemblies may have an associated link pivotally connected to the frame, operatively connected to at least one pivot arm, and operatively connected to the associated locking member. Such a link may cooperate with the at least one pivot arm to cause the first locking member to engage the second locking member responsive to movement of the frame relative to at least one of the first and second assemblies. The use of such a link may permit a relatively wide spacing between the locking members, e.g., spaced apart by ⅜ of an inch or more (e.g., a half-inch or more) when the vehicle is at rest on a flat, level surface. Such a link may also permit exaggerated movement of the locking members responsive to movement of the at least one pivot arm, e.g., responsive to a specific angular movement of the pivot arm causing a greater angular movement of the link and perhaps other links to move corresponding locking members toward each other, which may permit greater sensitivity.

As yet another example, the geometry of the locking members may be such that one locking member is longer than the other and has a concave locking surface. Any combination of any two or more of these additional features—self-aligning locking members, a link, and/or different geometry—may be combined in a vehicle.

Referring now to FIG. **19**, a portion of another exemplary wheeled vehicle is shown as having a stabilization system with a self-aligning locking member, a link, and locking members with different geometry. This exemplary embodiment includes an "anti-dive" stabilization system or "stability lock" that works in combination with the frame of the wheelchair to prevent the chair from tipping over in a forward direction under certain circumstances. Thus, FIG. **19** shows an exemplary suspension for a wheeled vehicle, comprising a frame **1911**, a first assembly movably connected to the frame **1911**, a second assembly movably connected to the frame **1911**, a first locking member **1930** movably connected to the first assembly and a second locking member **1912** connected to the second assembly. In the exemplary suspension shown, movement of the frame **1911** relative to the at least one of the first and second assemblies causes the first and second locking members **1912**, **1930** to engage one another (here, the second locking member **1912** is moved toward the first locking member **1930** so that the first locking member **1930** engages the second locking member **1912**) to permit the first and second assemblies to cooperate to limit further movement of the frame **1911** in at least one direction. The first locking member **1930** automatically aligns with the second locking member **1912** as the locking members **1912**, **1930** engage. FIGS. **20**A-**20**C show various views of locking member **1912**, which has a generally concave shape at toothed surface **1913** that engages the other locking member **1930**. FIGS. **21**A-**21**C show various views of locking member **1930**, which is movably connected to the first assembly. Referring back to FIG. **19**, the second assembly-is shown as having an associated link **1914** that is pivotally connected to the frame **1911**, operatively connected to pivot arm **2102**, and operatively connected to the locking member **1912**. Such a link **1914** cooperates with the at least one pivot arm **2102** to cause the locking members **1912**, **1930** to engage each other responsive to movement of the frame **1911** relative to at least one of the first and second assemblies. The suspension of FIG. **19** may be used with an electric wheelchair, such as the Invacare M94 wheelchair or the Invacare

TDX wheelchair (Invacare Corporation, Elyria, Ohio), both of which utilize frames that include multiple pivot points.

Referring now to FIGS. **22-28**, various views of a wheelchair base having the suspension of FIG. **19** are shown. As shown in these figures, this embodiment includes a self-aligning "anti-dive" stabilization system **1910**. In FIGS. **22-28**, the upper portion of the exemplary wheelchair, including the seat and outer shroud, has been removed to better show relevant structural components. FIG. **22** is a semi-exploded, front-right-top isometric view of the exemplary wheelchair base, with a motor, gear box, and drive wheel exploded to show certain relationships between various components.

The exemplary wheelchair base of FIGS. **22-28** comprises a frame **1911**. As best shown in FIG. **22**, frame **1911** includes left and right side portions **1950**, a front portion **1951**, a rear portion **1952**, shroud mounting brackets **1954**, and a front support bracket **1955**. First and second assemblies are pivotally connected to the left and right sides of frame **1911** respectively, and each assembly includes an associated surface-engaging portion. As shown in FIGS. **19** and **22-28**, the assemblies comprise front pivot arms **1956** and rear pivot arms **2102**. The front pivot arms **1956** each have an associated front caster **2104** and the rear pivot arms **2102** each have an associated rear caster **2100**. The front pivot arms **1956** and the rear pivot arms **2102** are both pivotally connected to frame **1911** to increase overall maneuverability when the wheelchair travels across uneven surfaces or encounters street to curb interfaces or steps. The various attachments or connections described herein may accomplished with appropriate mounting screws, shoulder screws or similar attachment means, or by using other methods and devices known and accepted by those skilled in the art. Certain components are attached to one another by known welding techniques.

As shown in the figures, a swing arm bracket **1960** is used to attach each pivot arm **1956** to frame **1911** at pivot point A. A torsion spring **1965** mounted between pivot arm **1956** and frame **1911** biases the frame to the rear (counterclockwise from the perspective of FIGS. **19** and **23**). Each pivot arm **1956** may have an associated stabilization bar **1957** pivotally attached to the frame below and substantially parallel to the pivot arm **1956** to help keep front caster **2104** in a substantially vertical position as the pivot arm **1956** pivots about point A when the wheelchair is in use. This configuration is known as a "four bar linkage." A motor bracket **1962** may be attached to or formed as part of each front pivot arm **1956**.

As shown in FIG. **22**, an electric motor **1990** may be mounted on motor bracket **1962**. A drive wheel **1980** may be mounted on each motor **1990** by attaching the drive wheel **1980** to axle **1992** of the motor or an associated gear box. The motors **1990** are operated by an electronic controller which is connected to one or more user control devices (not shown in the Figures). The user control devices generally provide selection of forward and reverse movement of the vehicle, as well as controlling the vehicle's velocity or speed. A battery **1972** is seated in tray **1963**, held in position (kept from sliding from side to side) with battery brackets **1959**, and secured with a strap. The battery **1972** typically supplies the various electric components with an energy supply. In the exemplary embodiment shown in the figures, each of the stabilization systems **1910** is installed between a drive wheel **1980** and the portion of base assembly **1911** that supports the electronic components of the wheelchair (see FIG. **27-28**) and does not interfere with the placement or operation of other system components such as wire wrap **1970**, battery **1972**, charger **1974**, battery handle **1976** and terminal covers **1977** and **1978**. The drive wheels **1980** may be positioned relative to the frame **1911** so that most (e.g., greater than 50%) of the weight of the user of the wheelchair is directly over the drive wheels **1980**. Each front pivot arm **1956** may operate independently of the other front pivot arm and each allows its associated front caster **2104** and drive wheel **1980** to move with the pivot arm **1956** as the pivot arm pivots about point A when the wheelchair moves across an uneven surface.

As best shown in FIGS. **19** and **23-24**, each rear pivot arm **2102** may be pivotally attached to each side frame portion **1950** at the rear portion of frame **1911**. Each rear pivot arm **2102** is operatively connected to a frame-mounted pivot bracket **1958**, which allows rear pivot arm **2102** to pivot around pivot point B. A tube-is welded to each rear pivot arm **2102** to confer lateral stability to the arm. If the wheelchair tips forward, each rear pivot arm **2102** will drop (i.e., rotate counterclockwise around pivot point B from the perspective of FIGS. **19** and **23-24**) and each rear caster **2100** will drop or move in a downward direction. A stop, e.g., a plastic pad **1969**, may be mounted on both sides of the frame between the rear pivot arm **2102** and the frame **1911**. Also, as shown in FIG. **19**, a reinforcement flange **1967** adds structural stability to the two sections of each rear pivot arm **2102**. As with front pivot arms **1956**, each rear pivot arm **2102** pivots independently of the other rear pivot arm when the wheelchair moves across an uneven surface.

As best shown in FIGS. **19**, **20**A-**20**C, **21**A-**21**C and **25**, self-aligning stabilization system **1910** comprises, on each side of the wheelchair, a locking apparatus. Each locking apparatus further includes a pivoting locking member **1912** having a toothed surface **1913** and a floating locking member **1930** having a toothed surface **1931**. Toothed surfaces **1913** and **1931** engage one another under certain operating conditions to prevent the wheelchair from tipping over in a forward direction, as discussed in more detail below.

With reference to FIGS. **19** and **20**A-**20**C and **21**A-**21**C, each locking apparatus of stabilization system **1910** includes a pivoting locking member **1912**, also referred to as a "pivot rack" connected to or mounted on each side of the outer portion of the frame, and a floating locking member **1930**, also referred to as a "motor rack," connected to or mounted on each of the front pivot arms **1956**. Each of these locking members includes a substantially solid body manufactured from metal or other suitably rigid and durable material that includes on one of its sides a toothed or ratcheted surface. When properly installed, the toothed surfaces of each locking member face one another and when stabilization system **1910** is in operation, these teeth engage one another or "lock" together to prevent further movement the components to which the locking members are attached.

In the exemplary embodiment, each pivot rack **1912** typically includes an elongated piece of metal having slightly curved or arced front and rear edges (see FIG. **21**A-C). The toothed edge of pivot rack **1912** is slightly concave and includes the aforementioned ratchets or teeth. The toothed edge **1913** of pivot rack **1912** has a cross-sectional shape substantially like a section of a hypothetical circle, with the radius of the hypothetical circle being approximately the same length as a line segment (not shown) extending from a point (not shown) on pivot point A to a point (not shown) on the toothed surface **1932** of the other locking member **1930**. As shown in FIG. **25**, pivot rack **1912** is attached to pivoting link **1914** with screws **1916** and **1918**. Pivot rack **1912** may be rigidly attached to pivoting link **1914**. In the alternative, pivot rack **1912** may be

movably attached to pivoting link **1914** to provide additional self-alignment. This may be accomplished, for example, by having any one or more bores used to fasten pivot rack **1912** be formed as slots or formed as bores significantly larger than fasteners passing therethrough. The pivot rack **1912** may have positional memory (e.g., provided by a spring or other biasing member) in any one or more directions or orientations and may be "floating" in any one or more directions or orientations, as discussed herein. Pivoting link **1914** is pivotally attached to the frame **1911** at pivot point D via fastener **1920** and operatively connected to rear pivot arm **2102** at point C via fastener **1922**. As indicated by the arrows in FIG. **24**, rotation of rear pivot arm **2102** about pivot point B causes pivot link **1914** to pivot about pivot point D, causing pivot rack **1912** to move into or out of contact with motor rack **1930**. A rack bracket **1932** is utilized for attaching each motor rack **1930** to each front pivot arm **1956**.

Similar to pivot rack **1912**, and as previously described, one side of motor rack **1930** includes a series of ratchets or teeth that engage the teeth on the pivot rack **1912** when both components are properly oriented and stabilization system **1910** is in operation. In the exemplary embodiment, motor rack **1930** is movably attached to rack bracket **1932** by shoulder screws **1934**, **1936** fastened through bracket **1932** to threaded bores **2134**, **2136** (FIGS. **21**A-**21**B) in motor rack **1930**. Shoulder screws **1934**, **1936** do not tightly fasten the motor rack **1930** to the bracket **1932**; rather, the shoulder screws **1934**, **1936** engage corresponding shoulders in corresponding bores **2134**, **2136** so that the motor rack **1930** essentially hangs from bracket **1932**, leaving a slight gap between the top surface of motor rack **1930** and the bottom surface of rack bracket **1932** (see FIGS. **25**A-**25**B and **27**). Thus, the motor rack **1930** is free to move up and down. Additionally, the motor rack can move laterally. More specifically, as shown in FIG. **26**, a slot **1939** is formed through rack bracket **1932**, with shoulder screw **1936** extending through slot **1939**. Slot **1939** provides the motor rack **1930** with the ability to move laterally to some extent (i.e., the ability to rotate back and forth about a pivot point created by shoulder screw **1934**). A washer **1937** between shoulder screw **1936** and bracket **1932** provides a larger sliding surface as the motor rack **1930** moves back and forth, and provides a desired angle of the motor rack **1930** relative to the other locking member **1912**. Mounting motor rack **1930** to rack bracket **1932** in the described manner allows motor rack **1930** to "float" as it hangs off of the bracket **1932** to which it is mounted. In the exemplary embodiment, a biasing member or compression spring **1938** is mounted between motor rack **1930** and bracket **1932** inside a bore and confers a degree of positional memory to motor rack **1930**. More specifically, spring **1938** biases the motor rack **1930** against a surface of the bracket **1932** so that the relative position of the motor rack **1930** during an engagement with the other locking member **1912** with respect to slot **1939** will be maintained after disengagement, and the motor rack **1930** also remains movably connected to the bracket **1932** permitting the motor rack **1930** to self-align in that slot for the next engagement, if necessary. In the specific embodiment shown, even though the spring **1938** causes the motor rack **1930** to have positional memory with respect to slot **1939**, the motor rack **1930** is free to move up (e.g., rotate up) against the spring with each engagement with the other locking member **1912** and move down (e.g., rotate down) with each disengagement with the other locking member **1912** via the freedom of movement provided by shoulder screw **1934**. Although motor rack **1930** is shown in the figures as being mounted from its top, motor rack **1930** (and pivot rack **1912**) may be mounted in a manner other than as specifically shown. For example, motor rack **1930** may be movably mounted from its side via a bore and a slot and/or a pair of slots.

With specific reference to FIGS. **23-24**, pivot rack **1912** and motor rack **1930** are triggered to engage each other whenever rear caster **2100** is lifted from (or about to be lifted from) its supporting surface (i.e., when one or both of the rear casters **2100** are "unloaded"), such as when the wheelchair's user leans significantly forward or perhaps on certain surfaces. That is, motion of the frame **1911** relative to the rear pivot arm **2102** permits the caster-end of the rear pivot arm to drop under the force of gravity. From the perspective of FIGS. **19**, **23**, and **24**, the rear pivot arm **2102** drops (i.e., rotates counterclockwise in those figures) responsive to being unloaded. Right rear pivot arm in FIG. **19** is shown as having dropped, causing right pivot rack to move forward to engage right motor rack. Left rear pivot arm and left motor pivot rack are shown in the neutral position in FIG. **19** in which the lock is not engaged. The pivot link **1914** is pivotally connected to the frame at pivot point D and connected to the rear pivot arm at pivot point C. Thus, the relative motion between the frame and the rear pivot arm **2102** as the rear pivot arm is unloaded causes the pivot link **1914** to rotate in an opposite direction about its pivotal connection at pivot point D so that the pivot rack **1912** at the end of pivot link **1914** comes into contact with and engages motor rack **1930**. When pivot rack **1912** engages motor rack **1930**, the front pivot arm **1956** and rear pivot arm **2102** engage, which prevents any additional motion of the frame **1911** relative to the front pivot arm **1956** in that direction, which will tend to prevent any further tipping in that direction. When the wheelchair frame **1911** moves back in the opposite direction, so that the rear casters are re-loaded and pushed back up, the pivot rack **1912** disengages the motor rack **1930**, which permits the front pivot arm **1956** to once again freely pivot about pivot point A. More specifically, motion of the frame **1911** relative to the rear pivot arm **2102** in the opposite direction causes the pivot link **1914** to move in the opposite direction, which causes pivot rack **1912** to disengage from motor rack **1930**, which permits the front pivot arm **1956** to freely pivot about pivot point A.

In the exemplary embodiment shown in the figures, there are two independent stabilization systems installed on frame **1911**; one on the right side and the other on the left side. Thus, if an uneven surface encountered by the user of the wheelchair causes only one of the rear pivot arms to drop or rotate at pivot point B, the engagement of just one of the stabilization systems will typically be adequate to prevent the chair from tipping over in a forward direction.

The motor rack **1930** is essentially self-aligning with respect to the pivot rack **1912**. Such self-alignment is the result of the movable connection between motor rack **1930** and the front pivot arm **1956** via the bracket **1932**. In the specific embodiment shown, the motor rack **1930** has freedom of motion in several directions (the motor rack **1930** is capable of a certain degree of lateral rotation and vertical freedom of movement relative to front pivot arm **1956** (and ultimately freedom of movement relatively to pivot rack **1912**)). This self-aligning characteristic may help compensate for various factors, such as component wear patterns, user weight, deformations as a result of collisions, and other factors, any one or more of which may cause the pivot rack **1912** and motor rack **1930** to be horizontally offset from nominal alignment and/or non-coplanar and/or vertically offset from nominal alignment. Some overlap between the

two racks **1912**, **1930** will permit self-alignment of the motor rack **1930** relative to the pivot rack **1912** and perhaps result in sufficient overlap between the two racks **1912**, **1930** to help prevent tipping, as discussed above. In the exemplary embodiment, the ratcheted or toothed side of the pivot rack **1912** is significantly longer than that of the motor rack **1930**, thereby providing multiple engagement points along its length (see FIG. **25**). Thus, the relative vertical alignment of the two components need not be exact for effective engagement of the pivot rack **1912** and the motor rack **1930**. Accordingly, precise lengthwise and widthwise alignment is not required for effective engagement or "locking" of these components. Additionally, in the exemplary embodiment shown, the motor rack **1930** and the pivot rack **1912** may be spaced further apart than other embodiments of this invention, e.g., spaced apart by about a half-inch or more.

While the present invention has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. For example, pivotal connections can be made of any number of structures including bearing assemblies, pins, nuts and bolts, and frictionless sleeve assemblies. Additionally, springs or shock absorbers can be added between pivoting and non-pivoting components to limit, dampen, or somewhat resist the pivotal motions of these components. Also, a brake-disc locking mechanism could be integrated into pivotal connection **406** that locks pivotal connection **406** from rotation when actuated and freely allows pivotal motion about connection **406** when not actuated. Therefore, the invention, in its broader aspects, is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Accordingly, departures can be made from such details without departing from the spirit or scope of the applicant's general inventive concept.

What is claimed:

1. A wheelchair suspension comprising:

a frame;

a front caster assembly pivotally connected to the frame, the front caster pivot assembly comprising a front caster pivot arm and a front caster;

a rear caster assembly pivotally connected to the frame, the rear caster assembly comprising a rear caster arm and a rear caster; and

a link coupled to the front caster assembly and extending rearward from the front caster assembly toward the rear caster assembly;

wherein downward movement of the rear caster causes the link to lock thereby causing the front caster assembly to lock in a position relative to the frame.

2. The wheelchair suspension of claim **1**, wherein the rear caster assembly further comprises a first ratchet, wherein the link is connected to a second ratchet, and wherein engagement between the first ratchet and the second ratchet causes the link to lock.

3. The wheelchair suspension of claim **2**, wherein downward movement of the rear caster causes the first ratchet to engage the second ratchet.

4. The wheelchair suspension of claim **2**, wherein a spring is disposed between the first ratchet and the rear caster arm.

5. The wheelchair suspension of claim **1**, wherein the front caster assembly comprises a four-bar linkage that includes the front caster arm and a second front caster arm, wherein the front caster arm is coupled to the frame at a first pivot axis and the second front caster arm is coupled to the frame at a second pivot axis.

6. A wheelchair comprising:

a frame;

a seat supported by the frame;

a pair of drive wheels supporting the frame;

a front caster assembly pivotally connected to the frame, the front caster assembly comprising a front caster arm and a front caster;

a rear caster assembly pivotally connected to the frame, the rear caster assembly comprising a rear caster arm and a rear caster; and

a link coupled to the front caster assembly and extending rearward from the front caster assembly toward the rear caster assembly;

wherein downward movement of the rear caster causes the link to lock thereby causing the front caster assembly to lock in a position relative to the frame.

7. The wheelchair suspension of claim **6**, wherein the rear caster assembly further comprises a first ratchet, wherein the link is connected to a second ratchet, and wherein engagement between the first ratchet and the second ratchet causes the link to lock.

8. The wheelchair suspension of claim **7**, wherein downward movement of the rear caster causes the first ratchet to engage the second ratchet.

9. The wheelchair suspension of claim **7**, wherein a spring is disposed between the first ratchet and the rear caster arm.

10. The wheelchair suspension of claim **6**, wherein the front caster assembly comprises a four-bar linkage that includes the front caster arm and a second front caster arm, wherein the front caster arm is coupled to the frame at a first pivot axis and the second front caster arm is coupled to the frame at a second pivot axis.

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