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(71) Applicant *(for all designated States except US)*: **1994 WEYER FAMILY LIMITED PARTNERSHIP** [US/US]; 225 Battersby Avenue, Enumclaw, WA 98022 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **WEYER, Dean, R.** [US/US]; 1316 Florence Street, Enumclaw, WA 98022 (US).

(74) Agents: **BAYNHAM, Robert, J.** et al.; Seed Intellectual Property Law Group PLLC, Suite 6300, 701 Fifth Avenue, Seattle, WA 98104-7092 (US).

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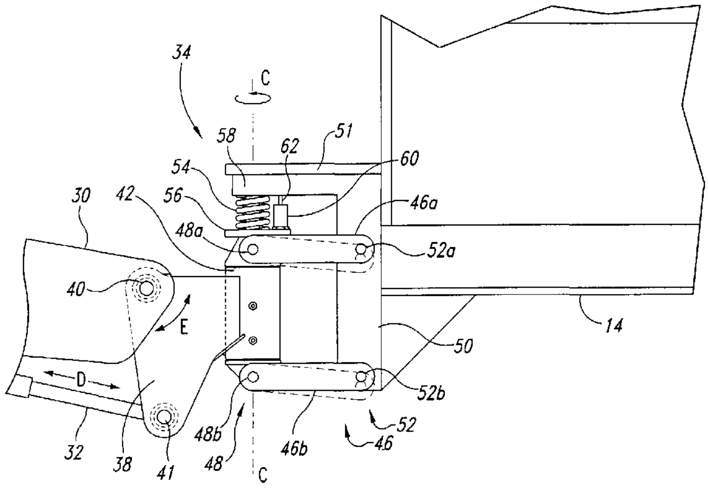
(54) **Title:** WORK PLATFORM WITH ROTARY ACTUATOR



(57) **Abstract:** A fluid-powered rotatable work platform assembly for use with a vehicle such as a vehicle having an arm for positioning the assembly. The assembly includes a work platform or support configured to support a load, a body having a cavity extending along a longitudinal axis, and an output shaft rotatably disposed within the body generally coaxial with the longitudinal axis. A linear-to-rotary force transmitting member is positioned within the cavity of the body and engaged with the body and the output shaft to translate linear motion of the force transmitting member to rotational motion of one of the output shaft and the body relative to the other. The work platform is coupled to one of the body and the output shaft with at least one link and the arm of the vehicle is coupled to the other of the body and the output shaft so that when the output shaft and the body rotate relative to one another, the work platform rotates relative to the arm of the vehicle, while the pivoting link allows the work platform to move downward under the load. A sensor is operatively coupled to the work platform to sense the downward movement and/or an increasing load on the work platform.

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WORK PLATFORM WITH ROTARY ACTUATOR

TECHNICAL FIELD

The present invention relates generally to aerial work platforms and, more particularly, to laterally rotatable work platforms.

BACKGROUND OF THE INVENTION

Aerial work platforms for the construction industry are typically mounted at the end of a boom that extends outwardly from a wheeled vehicle. The vehicle and the boom are movable to position the work platform at a desired location. The boom can extend and retract to raise and lower the work platform to a desired vertical location. Some work platforms can also be rotated relative to the boom in a lateral plane to point the work platform at a desired angle in the lateral plane relative to the boom. Accordingly, the work platform can be maneuvered to position a user adjacent to an elevated work site.

In one conventional device, the work platform is mounted to the boom of the vehicle with two parallel, pivotable links. The links and the work platform are biased to a horizontal position with a coiled spring. As the load on the work platform is increased, the spring compresses and the parallel links allow the work platform to descend slightly relative to the boom while the work platform remains approximately horizontal. A sensor coupled to the boom can trigger an alarm or a signal when the load on the platform (and therefore the vertical deflection of the platform) exceeds a selected amount. For example, the sensor can include a first switch that triggers an audible alarm when the load on the work platform exceeds a first selected value, and a second switch that shuts down motion of the work platform when the load thereon exceeds a second, greater value. Accordingly, the sensor can warn the user when the load on the work platform approaches a selected capacity and can prevent further movement of the work platform if the selected capacity is exceeded, reducing the likelihood for potential safety hazards associated with using the work platform.

In one aspect of this conventional device, the work platform can be rotated relative to the boom in the lateral plane with a rack and pinion arrangement. For example, a rack can be attached to the work platform and can engage the teeth of a pinion fixedly attached to the boom. As the rack is driven linearly back and forth in the lateral plane relative to the fixed pinion (for example, with a pressurized hydraulic fluid), the rack and the work platform will rotate in the lateral plane about the fixed pinion. Alternatively, the rack and pinion can be replaced with a worm gear drive for rotating the work platform relative to the boom, and/or the two parallel links can be replaced with a single link and a spaced-apart cam and cam follower combination.

One drawback with the foregoing attachment and rotation devices is that they can be heavy. The weight of the devices can reduce the weight that can be allocated to the load on the work platform, in effect reducing the capacity of the work platform. Alternatively, the weight of the devices can limit the lateral distance that the boom can extend relative to the vehicle before the vehicle becomes unstable.

Another drawback is that the foregoing attachment and rotation devices can be bulky, which can make the devices difficult to integrate with the work platform and/or difficult to install and maintain. Furthermore, it can be difficult to shield the bulky conventional devices from inadvertent contact with surrounding structures, making the devices more susceptible to damage during normal use.

SUMMARY OF THE INVENTION

The present invention is directed toward fluid-powered, rotatable support platform assembly usable with an assembly support such as a vehicle having an arm for selectively positioning such an assembly. In one embodiment, the assembly can include a load platform having a support surface for supporting a load, a body having a cavity extending along a longitudinal axis of the body, and a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body. One of the body or the shaft is configured to be coupled to the assembly support platform, and the other one of the body and the shaft is configured to provide rotary drive to the load support platform. A linear-to-rotary force-transmitting member is positioned within the cavity of the body and is mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto. The force-transmitting member engages the body and the shaft to translate longitudinal motion of the force-transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support platform about the longitudinal axis relative to the assembly support in a rotational plane in clockwise and counterclockwise rotational directions.

A load sensor is positioned to detect a load on the load support platform in a load direction out of alignment with the rotational plane. A platform connector member is coupled between the load support platform and the other one of the body and shaft. The platform connector member is configured to permit movement of the load support platform in the load direction while restricting movement in directions out of alignment with the load direction except rotation of the load support platform in the rotational plane in response to the rotary drive. A load transmission member may be included to transmit the rotary drive to the load support platform.

The assembly can further include a spring positioned between the load support platform and the load transmission member to bias the load support platform in a direction opposite the load direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a side elevational view of an aerial work platform supported relative to a vehicle with a rotator assembly in accordance with an embodiment of the invention.

Figure 1B is a side elevational view of an aerial work platform supported relative to a vehicle with a jib and a pair of rotator assemblies in accordance with another embodiment of the invention.

Figure 2 is a top plan view of the vehicle shown in Figure 1 with the work platform rotated in a lateral plane to a series of positions.

Figure 3 is an enlarged side elevational view of the rotator work platform assembly and a portion of the work platform shown in Figure 1.

Figure 4 is an enlarged, partially cut-away side elevational view of a rotary actuator of the rotator assembly shown in Figure 3.

Figure 5 is a partially cut-away side elevational view of a portion of a work platform assembly using a rotary actuator in accordance with another embodiment of the invention.

Figure 6 is a partially cut-away side elevational view of a portion of a work platform assembly using a rotary actuator in accordance with yet another embodiment of the invention.

Figure 7 is a partially cut-away side elevational view of a work platform assembly using a rotary actuator with a cantilever member having a strain gauge in accordance with yet another embodiment of the invention.

Figure 8 is a partially cut-away side elevational view of a work platform assembly using a rotary actuator with a fixedly attached link in accordance with still another embodiment to the invention.

Figure 9 is a partially cut-away side elevational view of a work platform assembly using a rotary actuator with a pair of fixedly attached links in accordance with still another embodiment of the invention.

Figure 10 is partially cut-away side elevational view of a work platform assembly using a rotary actuator with two links and a strain gaged spring in accordance with still another embodiment of the invention.

Figure 11A is a partial cut-away side elevational view of a work platform assembly using a hydraulic actuator with two plate links in accordance with yet another embodiment of the invention.

Figure 11B is a top plan view of the work platform assembly of Figure 11A taken substantially along the lines 11A-11A.

Figure 12A is a partial cut-away side elevational view of a work platform assembly using a rotary actuator with two plate links in accordance with another embodiment of the invention.

Figure 12B is a top plan view of the work platform assembly of Figure 12A.

Figure 12C is a bottom plan view of the work platform assembly of Figure 12A.

Figure 13A is a partial cut-away side elevational view of a work platform assembly using a hydraulic actuator in accordance with another embodiment of the invention.

Figure 13B is a top plan view of the work platform assembly of Figure 13B.

Figure 13C is a side elevational view of the work platform assembly of Figure 13A from an opposite side and shown rotated 180° about a horizontal axis from the view of Figure 13A.

Figure 14A is a partial cut-away side elevational view of a work platform assembly using a hydraulic actuator in accordance with yet another embodiment of the invention.

Figure 14B is a top plan view of the work platform assembly of Figure 14A.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed toward devices for rotating an aerial work platform or other support structure. The device can include a rotary actuator having a body, an output shaft within the body and a movable piston that rotates the output shaft relative to the body. One or the other of the output shaft and the body can be coupled to the work platform to rotate the work platform in a lateral plane. Many specific details of certain embodiments of the invention are set forth in the following description and in Figures 1A-10 to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments and that they may be practiced without several of the details described in the following description.

An apparatus 10 in accordance with an embodiment of the invention is shown in Figure 1A as including a vehicle 12 that supports a load support member such as a work platform 14. The work platform 14 can have a support surface 16 for supporting a load that can include a user 18, tools, equipment and/or materials (not shown). A rear portion 20 of the work platform can face generally toward the vehicle 12 and a forward portion 22 can face away from the vehicle. In one embodiment, the vehicle 12 includes a drive unit 24 having wheels 26 for propelling the vehicle and the work platform 14 to a desired location. In other embodiments, the vehicle 12 can have tracks instead of wheels, or the wheels can engage rails, or the vehicle can be an unpowered vehicle, such as a towed trailer. In still further embodiments, the vehicle 12 can be a multi-purpose vehicle, such as a truck that can support the work platform 14 in addition to a separate payload. While the assembly support is shown as a vehicle, a stationary support platform which can position the apparatus 10 is contemplated.

The vehicle 12 can also include an articulated boom 28 and a telescoping arm 30 for supporting the work platform 14 and moving the work platform vertically and laterally relative to the vehicle 12. An actuator link 32 can adjust the tilt of the work platform 14 when the work platform moves up and down, as will be discussed below with reference to Figure 3. The work platform 14 is coupled to the arm 30 with a rotator assembly 34 that can rotate the work platform 14 in a lateral plane (generally perpendicular to the plane of Figure 3) relative to the arm 30. Accordingly, the work platform 14 can be maneuvered to place the load in a desired position adjacent a building wall 36 or other structure, for example during construction or maintenance activities.

Figure 1B is a side elevational view of vehicle 12a that supports the work platform 14 with a telescoping arm 30 coupled to a rotating jib 30a. The jib 30a is coupled between the work platform 14 and arm 30 by the rotator assembly 34 and a jib rotator assembly 34a. An actuator link 32a is coupled between the telescoping arm 30 and the jib 30a to pivot the work platform 14 upwardly and downwardly as shown in phantom lines in Figure 1B. The jib rotator assembly 34a can pivot the jib 30a into and out of the plane of Figure 1B, in a manner generally similar to that discussed below with reference to the rotator assembly 34.

Figure 2 is a top plan view of the apparatus 10 shown in Figure 1A. As is shown in dashed lines, the arm 30 and the boom 28 of the apparatus 10 can rotate relative to the drive unit 24, as indicated by arrow A. The rotator assembly 34 can rotate the work platform 14 relative to the arm 30, as indicated by arrow B. Accordingly, the work platform 14 can be moved laterally to a variety of locations without moving the vehicle 12. For example, the work platform 14 can be moved along two adjoining building walls 36, while the vehicle 12 remains in a fixed position, as shown in Figure 2.

Figure 3 is an enlarged side elevational view of the rotator assembly 34 and a portion of the work platform 14 shown in Figure 1A. The rotator assembly 34 is coupled between the arm 30 and the work platform 14 to support the work platform. For example, in one embodiment, the rotator assembly 34 includes an arm bracket 38 pivotally attached to the arm 30 at an arm pivot joint 40. The actuator link 32 is pivotally attached to the arm bracket 38 at pivot joint 41 below the pivot joint 40 and can extend and retract (as indicated by arrow D) to rotate the arm bracket 38 about the arm pivot joint 40 (as indicated by arrow E). Accordingly, the actuator link 32 can tilt the rotator assembly 34 and the work platform 14, or keep the work platform 14 approximately horizontal as the arm 30 moves the work platform about.

The rotator assembly 34 can further include a rotary actuator 42 that rotates the work platform 14 relative to the arm 30 in a rotational plane in clockwise and counterclockwise rotational directions about a longitudinal axis C-C, as will be discussed in greater detail below with reference to Figure 4. The rotary actuator 42 can be rigidly welded to the arm bracket 38 to move with the arm bracket, or alternatively, the rotary actuator 42 can be rigidly connected to the arm bracket 38 with other connection arrangements. For example, the arm bracket 38 can include two flat panels that clamp the rotary actuator 42 therebetween and that are both coupled to the arm 30 at the pivot joint 40. In either embodiment, the rotator assembly 34 can also include two pairs of parallel corrector members or links 46 (shown as first and second upper links 46a and first and second lower links 46b) that allow the work platform 14 to rotate about an axis extending into the plane of Figure 3 and perpendicular to axis C-C. The second upper link 46a is hidden behind the first upper link, which is visible in Figure 3, and the second lower link 46b is hidden behind the first lower link, which is visible in Figure 3. In one embodiment, the links 46 are pivotally attached at one end to the rotary actuator 42 with pivot joints 48 (shown as an upper pivot joint 48a and a lower pivot joint 48b). The opposite ends of the links 46 are pivotally attached to a platform bracket 50 at two pivot joints 52 (shown as an upper pivot joint 52a and a lower pivot joint 52b). The platform bracket 50 is fixedly attached to the work platform 14. Alternatively, single upper and lower links 46a, 46b can couple the rotary actuator 42 to the platform bracket 50. In either case, the links 46 can rotate about the pivot joints 48 and 52 to allow the work platform 14 to move upwardly and downwardly relative to the rotary actuator 42 while the work platform maintains a substantially horizontal orientation.

The links 46 can be biased to horizontal positions (shown in solid line in Figure 3) with a spring 54 that fits between a spring support 56 of the rotary actuator 42 and a spring engaging portion 58 of a rearwardly extending load transfer arm 51 of the platform bracket 50. The load transfer arm 51 transmits at least a portion, and in this embodiment substantially all of the load supported by the work platform 14 through the spring 54 to an output shaft of the rotary actuator 42 and thereby supports the work platform against movement under a load in the downward direction. In one aspect of this embodiment, the spring 54 can be a coil spring that exerts an upward force on the spring engaging portion 58 of the platform bracket 50 to maintain the links 46 in their substantially horizontal orientations when the work platform 14 is unloaded. When a load is placed on the work platform 14, the spring 54 tends to compress and the work platform 14 moves downwardly as the links 46 rotate about the pivot joints 48 and 52 away from their horizontal positions (as shown in dashed lines in Figure 3). For purposes of clarity, only the links 46 are shown in dashed lines in the downwardly rotated position. It will be understood that, although not shown in dashed lines in Figure 3, the support bracket 50 and the work platform 14 swing downwardly with the links 46. The amount of the downward motion is exaggerated in Figure 3 for purposes of illustration, and depends on the amount of compression the spring 54 experiences under the load on the work platform 14. While permitting movement of the work platform 14 in the selected downward direction under a load, and return in the upward direction when unloaded, the links 46 restrict movement in directions out of alignment with the selected load direction except for rotation of the work platform in the rotational plane in response to operation of the rotary actuator 42.

In a further aspect of this embodiment, the rotator assembly 34 can include a sensor 60 attached to the spring support 56 and engaging the spring engaging portion 58 of the platform bracket 50 for detecting vertical motion of the work platform 14 relative to the rotary actuator 42. In one aspect of this embodiment, the sensor 60 can include a normally open switch having a lever 62 that closes the switch when the work platform 14 descends by a selected amount under the weight of a selected load. In one aspect of this embodiment, the sensor 60 can trigger an audible or visual signal when the switch is closed. In a further aspect of this embodiment, the closed position of the switch can be the first of two closed positions. The switch can move to the second closed position when the work platform load exceeds a value larger than the load that moved the switch to the first position. When the switch is in the second closed position, it can be connected to halt further motion of the work platform 14 relative to the vehicle 10 (Figure 1). For example, the switch can move to the first closed position (and trigger the audible or visual signal) when the load applied to the work platform 14 is 90% of a rated capacity. The switch can move to the second closed position (and halt further motion of the work platform) when the load reaches 125% of the rated capacity. In an alternate arrangement, the sensor 60 can have two separate switches or two separate sensors can be used to detect the two different load values. In any case, both the sensor 60 and the spring 54 rotate with the work platform 14 when the rotary actuator 42 rotates the work platform 14 about the longitudinal axis C-C, as will be discussed in greater detail below.

Figure 4 is an enlarged, partially cut-away side elevational view of the rotary actuator 42. The rotary actuator 42 has an elongated housing or body 64 with a cylindrical sidewall 66 and first and second ends 68 and 70, respectively. Removable plugs 44 provide access to the interior of the housing 64. The body 64 includes an attachment portion 72 connected to the arm bracket 38, as discussed above. An elongated rotary drive or output shaft 74 is coaxially positioned within the body 64 and is supported for rotation relative to the body.

In one embodiment, the shaft 74 extends the full length of the body 64 and has an interior flange portion 76 at the first body end 68, and an exteriorly extending first attachment flange portion or clevis 78 extending exterior of the body at the first body end. Alternatively, the shaft 74 can extend less than the full length of the body 64, and/or can include two or more segments. The first attachment flange portion 78 is pivotally attached to the lower links 46b (the second of which is visible in Figure 4) at the pivot joint 48b. The shaft 74 also has an extending shaft portion 80 extending beyond an exterior of the body 64 at the second body end 70. The shaft 74 has an annular carrier or endcap 82 threadably attached to the shaft toward the second body end 70, and secured to the shaft with pins 84 to prevent rotation of the endcap 82 relative to the shaft. The endcap 82 includes a second attachment flange portion 86 extending exterior of the body 64 at the second body end 70. The second attachment flange portion 86 is pivotally attached to the upper links 46a (the second of which is visible in Figure 4) at the pivot joint 48a. In an alternate arrangement, the shaft portion 80 of the shaft 74 can be integrally formed with the second attachment flange portion 86, generally similar to the attachment arrangement between the shaft 74 and the first attachment flange portion 78.

Seals 88 are disposed between the endcap 82 and the shaft 74 and between the endcap 82 and the body sidewall 66 to provide a fluid-tight seal therebetween. A seal 90 is disposed between the interior flange portion 76 and the body sidewall 66 to provide a fluid-tight seal therebetween. A radial bearing 92 is disposed between the interior flange portion 76 and the body sidewall 66, and a radial bearing 94 is disposed between the endcap 82 and the body sidewall 66 to support the shaft 74 against radial loads. Thrust washers 95 are positioned between the first body end 68 and the interior flange portion 76 and between the second body end 70 and the endcap 82 to provide axial support for the interior flange portion and the endcap.

An annular piston sleeve 96 is reciprocally mounted within the body 64 coaxially about the output shaft 74. The piston sleeve 96 has outer splines, grooves or threads 98 over a portion of its length which mesh with inner splines, grooves or threads 100 of a ring gear portion 101 of the body sidewall 66. The piston sleeve 96 is also provided with inner splines, grooves or threads 102 which mesh with outer splines, grooves or threads 104 provided on a portion of the output shaft 74. At least one pair of meshing splines is helical to convert axial motion of the piston sleeve 96 to rotary motion of the output shaft 74. Alternatively, all the splines can be helical and/or can be threaded in the same direction (*e.g.*, left-handed or right- handed) or different directions, depending on the desired direction and amount of output shaft rotation per unit of axial motion of the piston sleeve 96. It should be understood that while splines are shown in the drawings and described herein, the principle of the invention is equally applicable to any form of linear-to-rotary motion conversion arrangement, such as balls or rollers, and that the splines can include any type of groove or channel suitable for such motion conversion.

In one embodiment, the piston sleeve 96 has an annular piston head 108 positioned toward the second body end 68 with the shaft 74 extending therethrough. The shaft flange portion 76 has a circumferentially extending recess 106 which opens facing toward the second body end 70 and is sized to receive a lengthwise end portion of the piston head 108 of the splined piston sleeve 96 therein when the piston sleeve moves axially toward the first body end 68. The piston head 108 is sealed against a smooth inner wall surface 109 of the body sidewall 66 with an outer seal 110, and is sealed against a smooth outer wall surface 111 of the shaft 74 with an inner seal 112. The piston head 108 is slidably maintained within the body 64 for reciprocal movement, and undergoes longitudinal and (where the splines 98 and 102 are helical) rotational movement relative to the inner wall surface 109 of the body sidewall 66, as will be described in greater detail below.

The piston head 108 reciprocates within the body 64 when hydraulic oil, air, or any other suitable fluid under pressure selectively enters through one or the other of a first port P1 (which is in fluid communication with a fluid-tight compartment within the body 64 defined in part by the inner seal 112 and a first surface 113 of the piston head 108 facing toward the first body end 68), or through a second port P2 (which is in fluid communication with a fluid-tight compartment within the body 64 defined in part by the outer seal 110 and a second surface 114 of the piston head 108 facing toward the second body end 70). As the piston head 108 and the piston sleeve 96, of which the piston head is a part, linearly reciprocate in an axial direction within the body 64, the outer splines 98 of the piston sleeve engage or mesh with the inner splines 100 of the body sidewall 66 to cause rotation of the piston sleeve, where both the outer splines 98 and the inner splines 100 are helical. The linear and rotational movement of the piston sleeve 96 is transmitted through the inner splines 102 of the piston sleeve 96 to the outer splines 104 of the shaft 74 to rotate the shaft. The smooth wall surface 111 of the shaft 74 and the smooth wall surface 109 of the body sidewall 66 have sufficient axial length to accommodate the full end-to-end reciprocating stroke travel of the piston sleeve 96 within the body 64. Longitudinal movement of the shaft 74 is restricted, thus most movement of the piston sleeve 96 is converted into rotational movement of the output shaft 74. Depending on the slope and direction of turn of the various splines, there may be provided a multiplication of the rotary output of the shaft 74.

The application of fluid pressure to the first port P1 produces axial movement of the piston sleeve 96 toward the second body end 70. The application of fluid pressure to the second port P2 produces axial movement of the piston sleeve 96 toward the first body end 68. The rotary actuator 42 provides relative rotational movement between the body 64 and the shaft 74 through the conversion of linear movement of the piston sleeve 96 into rotational movement of the shaft 74, in a manner known in the art. The shaft 74 is selectively rotated by application of fluid pressure, and the rotation is transmitted to the work platform 14 (Figure 3) to selectively rotate the work platform 14 about the longitudinal axis C-C. The rotary actuator 42 provides a rotational force sufficient to selectively rotate the work platform 14 when bearing a load relative to the vehicle 12 in the rotational plane. In the embodiment of Figures 3 and 4, the links 46 transmit the rotary drive of the shaft 74 to the work platform 14.

An advantage of the rotator assembly 34 shown in Figures 1A-4 is that it can be more compact than conventional arrangements. Accordingly, the rotator assembly 34 can be more easily shielded by surrounding portions of the apparatus 10, such as the work platform 14, and is less likely to come into incidental contact with structures around which the work platform is used. In addition, the rotator assembly 34 can have fewer parts than some conventional devices, and the body 64 of the rotator assembly can shield the internal components from incidental contact with users, increasing the safety and overall appearance of the rotator assembly. Furthermore, the more compact rotator assembly 34 can be more versatile than conventional arrangements because it can be attached to one or more of several portions of the work platform 14. For example, the rotator assembly 34 can be attached toward the rear of the work platform 14, as shown in Figures 1A-4, or alternatively, the rotator assembly can be attached to the bottom of the work platform 14 or toward the front of the work platform.

Another advantage is that the more compact rotator assembly 34 can be easier to install and maintain. Furthermore, the rotator assembly 34 can be lighter than conventional arrangements, effectively increasing the payload weight that can be supported by the work platform 14. Still further, the rotator assembly 34 can be more robust than some conventional arrangements, reducing the likelihood that the rotator assembly will be damaged in the event it does come into incidental contact with surrounding structures.

Figure 5 is a partially cut-away side elevational view of a rotator assembly 34a coupled between the work platform 14 and the arm bracket 38 in accordance with another embodiment of the invention. The rotator assembly 34a can include a rotary actuator 42a having an endcap 82 and an output shaft 74a. The endcap 82 and the output shaft 74a are coupled to the second flange attachment portion 86 to pivotally support the upper links 46a (one of which is visible in Figure 5) in a manner generally similar to that described above with reference to Figure 3. The output shaft 74a can also be coupled to a first attachment flange portion 78a, which pivotally supports the lower links 46b (one of which is visible in Figure 5) at the pivot joint 48b. In this embodiment a spring support portion 56a is attached to the output shaft 74a and can be formed as a part thereof, and extends laterally away from the rotary actuator 42a between the lower links 46b. The spring support portion 56a supports one end of a spring 54a which extends upwardly therefrom. The other end of the spring 54a is engaged by a spring bracket 118 attached to a platform bracket 50a that is in turn attached to the platform 14. The spring support portion 56a of the output shaft 74a also serves with the spring bracket as load transfer members to transmit at least a portion of the load supported by the work platform 14 to the output shaft and supports the work platform against significant movement under load in the downward direction. In one aspect of this embodiment, the spring 54a can be pre-loaded by tightening a bolt 120 extending longitudinally through the spring and a nut 122 to compress the spring 54a. An advantage of this arrangement is that the spring 54a will tend to remain in contact with both the spring bracket 118 and the spring support portion 56a, and the upward movement of the platform limited by the bolt 120, even when movement would otherwise tend to bounce the work platform up and down, for example, when the vehicle 12 (Figure 1A) is in transit.

A sensor 60a is mounted to the spring support portion 56a and has a switch with a plunger or lever 124 that engages a contact plate 126 attached to the lower links 46b. In one aspect of this embodiment, the switch can be in a normally open position when the lever 124 contacts the contact plate 126 and can close when the contact plate descends away from the sensor 60a, for example, when a sufficient load is placed on the work platform 14. As was discussed above with reference to Figure 3, the switch can be a three-position switch, to sense two different load values, or the sensor 60a can be one of two sensors, each of which detects a different load value.

The rotator assembly 34a can also include a counterbalance or other hydraulic valve 128 that receives pressurized fluid and delivers the fluid through the ports P1 and P2 of the rotary actuator 42a. The valve 128 can isolate the fluid within the rotary actuator 42a in a manner generally known to those skilled in the art, to prevent the pressurized fluid from leaking from the cylinder if fluid power to the rotary actuator 42a is unexpectedly interrupted. The valve 128 can accordingly maintain pressure on the piston sleeve 96 and prevent unexpected rotation of the output shaft 74a if power to the rotator assembly 34a is interrupted.

An advantage of the arrangement shown in Figure 5 is that the sensor 60a and the spring 54a are positioned between the rotary actuator 42a and the work platform 14. Accordingly, the rotator assembly 34a can be more compact in a vertical direction than the rotator assembly 34 discussed above with reference to Figure 3. Conversely, an advantage of the rotator assembly 34 shown in Figure 3 is that by placing the spring 54 and the sensor 60 above the rotary actuator 42, the rotator assembly can be more compact in a forward direction.

Figure 6 is a partially cut-away side elevation view of a rotator assembly 34b coupled between the work platform 14 and the arm bracket 38 in accordance with yet another embodiment of the invention. The rotator assembly 34b includes the rotary actuator 42b that rotates the work platform 14 in a manner generally similar to that discussed above with reference to Figures 4 and 5. The rotary actuator 42b is coupled with two parallel upper and lower links 130 (shown as an upper link 130a and a lower link 130b) to a platform bracket 50b to allow vertical motion of the platform 14 relative to the rotary actuator 42b. The platform bracket 50b includes two generally flat parallel flanges (one of which is visible in Figure 6) spaced apart in a direction perpendicular to the plane of Figure 6 with the links 130 extending between the two panels. Each link 130 has a channel shape defined by a laterally-extending web 132 and two upwardly-extending flanges 134, one of which is visible in Figure 6. In one aspect of this embodiment, the lower link 130b is pivotally connected between the platform bracket 50b and the lower attachment flange portion 78a of the rotary actuator 42b to operate in a manner generally similar to that discussed above with reference to Figure 5. The lower attachment flange portion 78a includes a spring support portion 56a that supports the spring 54a, also in a manner generally similar to that discussed above with reference to Figure 5. The upper link 130a is pivotally coupled at one end to an endcap 82b of the rotary actuator 42b, as will be discussed in greater detail below.

The endcap 82b is threaded to an output shaft 74b of the rotary actuator 42b and is pinned to the output shaft with pins 84 to prevent rotation of the endcap relative to the output shaft. The endcap 82b includes a shoulder 136 that is coaxial with an extends laterally away from the longitudinal axis C-C of the output shaft 74b and further includes a projection 138 that extends upwardly away from the shoulder 136. The projection 138 extends through an aperture 140 in the web 132 of the upper link 130a. A retainer 142 extends coaxially around the projection 138 and is held in place with a retainer clip 144. An upper O-ring 146 is positioned between the retainer 142 and an upper face of the web 132, and a lower O-ring 148 is positioned between a lower face of the web 132 and the shoulder 136. Accordingly, the upper link 130a can tilt up and down relative to the endcap 82b about an axis perpendicular to the longitudinal axis C-C by compressing portions of the upper O-ring 146 and the lower O-ring 148. This allows the up and down rotation of the upper and lower links 130a and 130b to permit the movement sensed by the sensor 60a. In an alternate arrangement, the O-rings 146, 148 can be replaced with other compressible members, such as wave washers.

Figure 7 is a partially cut-away side elevational view of a rotator assembly 34c coupled between the work platform 14 and the arm bracket 38 in accordance with still another embodiment of the invention. The rotator assembly 34c includes upper and lower parallel links 130a and 130b coupled between a rotary actuator 42c and two platform brackets 50c to pivotally support the work platform 14 relative to the rotary actuator in a manner generally similar to that discussed above with reference to Figure 6. In one aspect of this embodiment, the rotary actuator 42c includes an endcap 82c threaded and pinned to an output shaft 74c (to prevent relative motion between the endcap 82c and the output shaft 74c) and extending upwardly through the aperture 140 of the upper link 130a. A retainer 142c is connected to the output shaft 74c with a bolt 150. Upper and lower O-rings 146 and 148 (or other compressible members) are positioned between the retainer 142c and an upper face of the upper link 130a, and between a lower face of the upper link 130a and the endcap 82c, respectively, generally in a manner as described above with reference to Figure 6.

In a further aspect of this embodiment, the rotator assembly 34c includes a flexible and resilient cantilever member 54c attached at one end to the platform 14 with a spring bracket 152. The cantilever member 54c extends toward the rotary actuator 42c in a cantilevered fashion over the upper link 130a and has a free end 55 that rotatably bears against the rotary actuator through an adjustment bolt 154 to act as a spring. The cantilever member 54c transmits at least a portion of the load supported by the work platform 14 to the output shaft 74c and supports the work platform against downward movement under load except for the limited range of movement that results from flexure of the cantilever members. In one embodiment, the adjustment bolt 154 bears on the head of the bolt 150 that connects the retainer 142c to the output shaft 74c. In a further aspect of this embodiment, a retainer 143 adjacent to the upper O-ring 146 provides an additional load path between the endcap 82c and the upper link 130a. Alternatively, the adjustment bolt 154 can bear directly against the output shaft 74c, the endcap 82c, the body 64, or the upper link 130a, preferably at a position on the upper link adjacent to its attachment to the output shaft. In further alternative embodiments, the adjustment bolt 154 can bear against the upper link 130a, for example, by bearing against the web 132 of the upper link. In any of these embodiments, the cantilever member 54c resists downward rotation of the work platform 14 relative to the rotary actuator 42c, while still deflecting or bending when the load exceeds a selected value. In the illustrated embodiment, the adjustment bolt 154 can be tightened or loosened to adjust the height of the work platform 14 relative to the rotary actuator 42c and can be held against further rotation with a locknut 56. Alternatively, the adjustment bolt 154 can be configured to pre-tension the cantilever member 54c and restrict upward movement of the platform 14 during transit, as was discussed above with reference to Figure 5. As noted above, the cantilever member 54c also resists downward motion of the platform 14 when the platform is loaded.

The rotator assembly 34c also includes a strain gauge 60c attached to a surface of the cantilever member 54c in a manner known to those skilled in the art to detect a strain (such as is caused by bending) of the cantilever member 54c. Accordingly, the strain gauge 60c detects the strain or deflection of the cantilever member 54c as the platform 14 is loaded, and triggers one or more warning signals in a manner generally similar to that discussed above with reference to the sensor 60 of Figure 3. The strain gauge 60c can be coupled with a lead 158 to a signal processor (not shown) to process the strain gauge signals. In one embodiment, a single strain gauge 60c generates both a warning signal and a shut-down signal. Alternatively, multiple strain gages can be attached to the upper link 130a to generate multiple signals. The cantilever member 54c can have other strain gauge arrangements in other embodiments, and/or the strain gauge 60c can be coupled to members other than the cantilever member 54c that also deflect and/or strain when the platform 14 is loaded. Alternatively, the cantilever member 54c or other member can have a device other than a strain gauge 60c that detects deflection and/or deformation of the cantilever member. The strain gauge 60c or other device can also be configured to generate a read-out signal (corresponding to the load on the work platform 14) which is accessible to the user via a digital display or other display device.

Figure 8 is a partially cut-away side elevational view of a rotator assembly 34d having a rotary actuator 42d coupled to the work platform 14 and the arm bracket 38 in accordance with yet another embodiment of the invention. The rotator assembly 34d includes an upper link 230a pivotably coupled to an endcap 82d of the rotary actuator 42d (in a manner generally similar to that discussed above with reference to Figure 7) and pivotably coupled to the work platform 14 at the upper pivot joint 52a. A lower link 230b is fixedly and rigidly coupled to an attachment flange portion 78d of the shaft 74d of the rotary actuator 42d with bolts 160 and is pivotably coupled to the work platform 14 at the lower pivot joint 52b. As such, the lower link 230b is non-pivotally attached to prevent pivoted movement in the vertical direction. A platform bracket 50d is fixedly attached to the rear portion of the work platform 14 and has a relatively stiff support bar 118a that extends over the lower link 230b. The support bar 118a is attached to the lower link 230b with a bolt 162 and a nut 164 to resist downward motion of the work platform 14 relative to the rotary actuator 42d. In one embodiment, the bolt 162 and the nut 164 can be tightened to draw the lower link 230b toward the support bar 118a, pre-loading the lower link and/or resisting the likelihood for the work platform 14 to bounce during transit, as was discussed above with reference to Figure 5. The support bar 118a can also include a stop bolt 166 and nut 168 to adjust the maximum deflection (under load) of the work platform 14 relative to the lower link 230b and the rotary actuator 42d.

In one aspect of the embodiment shown in Figure 8, the lower link 230b is rigid enough to support the load of the work platform 14 and transfer that load to the shaft 74d of the rotary actuator 42d, but is at least somewhat flexible and resilient so that it bends very slightly as the load supported by the work platform 14 increases. Accordingly, the lower link 230b can include a strain gauge 60d or other device to detect deformation or deflection of the lower link 230b under load. The strain gauge 60d can be coupled to a signal processor to generate a warning signal and/or a shut down signal, generally as was discussed above with reference to Figure 7.

Figure 9 is a partially cut-away side elevational view of a rotator assembly 34e having a rotary actuator 42e coupled between the work platform 14 and the arm bracket 38 in accordance with yet another embodiment to the invention. The rotator assembly 34e has links 330, including an upper link 330a and a lower link 330b, each fixedly coupled to the shaft 74e of the rotary actuator 42e with a bolt 170 and a nut 172. The bolt 170 passes through an axially extending opening extending fully through the shaft 74e. The upper link 330a is coupled to the work platform 14 with an upper spherical pivot joint 352a and the lower link 330b is coupled to the work platform with a lower spherical pivot joint 352b. Alternatively, the links 330 can be rigidly attached to the work platform 14. In either embodiment, the upper link 330a and the lower link 330b are flexible to allow the work platform 14 to swing downward slightly relative to the rotary actuator 42e when the work platform is under load. The upper and lower links 330 and 330b also transmit rotary motion from the rotary actuator 42e to the work platform 14 in a manner generally similar to that discussed above.

A bracket 50e extends rearwardly from the rear of the support platform 14 and is attached to the support bar 118a which extends over the lower link 330b. A spring bar 354 is rigidly attached to and extends from the shaft 74e toward the work platform 14 to engage a lower edge 51 of the bracket 50e. Accordingly, vertical loads are transmitted from the work platform 14 to the rotary actuator 42e and the arm bracket 38 via the bracket 50e and the spring bar 354. The spring bar 354 can include a strain gauge 60e or other load sensor to detect the load borne by the work platform 14 in a manner generally similar to that discussed above with reference to Figure 7. While the upper and lower links 330 transmit some load of the work platform 14 to the shaft 74e, they have much greater flexibility than spring bar 354 and hence the primary transfer of the load of the work platform is transmitted to the shaft by the spring bar. The vertical travel of the work platform 14 can be limited by adjusting the stop bolt 166, and the spring bar 354 can be pre-loaded by tightening the bolt 162 and the nut 164 coupled between the support bar 118a, the spring bar 354 and the lower link 330b.

Figure 10 is a partially cut-away side elevational view of a rotator assembly 34f having a rotary actuator 42f coupled between the work platform 14 and the arm bracket 38 in accordance with still another embodiment of the invention. The rotary actuator 34f includes an upper link 430a and a lower link 430b, each rotatably coupled to the shaft 74f of the rotary actuator 42f in a manner generally similar to that discussed above with reference to Figure 7. The links 430a, 430b are rotatably coupled to the work platform 14 at an upper pivot joint 352a and a lower pivot joint 352b, respectively, in a manner generally similar to that discussed above with reference Figure 9. The rotator assembly 34f further includes a rotating arm 456, fixedly connected to the shaft 74f to rotate with the shaft, and extending toward the work platform 14 between two flanges 50f, one of which is visible in Figure 10. The sides of the arm 456 engage the faces of the flanges 50f to transmit rotational motion from the shaft 74f to the work platform 14. The load of the work platform 14 is transmitted to the shaft 74f almost completely by the arm 456, and hence the arm 456 primarily support the work platform against downward movement under a load in the downward direction.

The work platform 14 further includes a spring support 118b extending rearwardly from the rear surface of the work platform over the arm 456. An S-shaped spring 454 is coupled between the rotary arm 456 and the spring support 118b with bolts 174 to resist downward motion of the work platform 14 relative to the rotary actuator 42f. In one aspect of this embodiment, the S-shaped spring 454 has an aperture in which is positioned a strain gauge 60f for measuring the strain and/or deformation of the spring 454 as the work platform 14 is loaded.

Figures 11A and 11B show a rotator assembly 34g operated by a telescopically extensible hydraulic cylinder 500. Much like in the embodiment of Figure 9, the embodiment of Figures 11A and 11B has links 330, including an upper plate link 330a and a lower plate link 330b, each having a generally triangular plate shape with an apex portion thereof pivotally coupled through a pivot joint 502 to the arm bracket 38, which is attachable to the arm 30 of the vehicle 12. As with the rotary actuator 42 of prior embodiments, the pivot joint 502 rotates the work platform about a longitudinal axis C-C. The pivot joint 502 has a stationary member 502a rigidly attached to the arm bracket 38. A rotating member 502b is rotatably disposed within the stationary member 502a. The wide ends of the triangular plate links 330a and 330b are rigidly attached to the work platform 14 by welds or other manners of attachment. The apex end of the triangular plate links 330a and 330b are rigidly attached to the rotating member 502b of the pivot joint 502 to permit the free clockwise and counterclockwise rotation of the work platform 14 relative to the arm bracket 38 and hence the vehicle 12. The hydraulic cylinder 500 has an extensible arm 500a pivotally coupled between a pair of mounting brackets 504 fixedly attached to the work platform 14 and has its cylinder portion 500b connected through a pair of progressive link connectors 506 to the pivot joint 502 and the mounting plates 504 such that extension and retraction of the arm 500a of the hydraulic cylinder 500 causes the work platform 14 to rotate clockwise and counterclockwise about the longitudinal axis C-C of the pivot joint 502.

Much as in the embodiment of Figure 9, the upper plate link 330a and the lower plate link 330b are manufactured from a sufficiently flexible and resilient spring plate to flex downward somewhat under the load applied in the downward direction to the work platform 14, but yet rigid enough to support the load of the work platform and transfer that load to the pivot joint 502. In the illustrated embodiment the upper and lower plate links 330a and 330b are of the same thickness and are sufficiently thin to bend or flex under load along a substantial portion of their length. The flexure is not inhibited by use of gussets or other members that prevent bending. A strain gauge 60g, or other load sensor or motion sensor, is mounted to the lower plate link 330b to detect the load borne by the work platform 14 that is transmitted to the pivot joint 502 through the lower plate link 330b. In the alternative or in addition thereto, a strain gauge may be mounted to the upper plate link 330a.

An upper bracket 508 and a lower bracket 510 extend rearwardly from the rear of the sport platform 14 and are rigidly attached to the support platform 14. The upper and lower brackets 508 and 510 are in a coplanar arrangement in a plane extending generally transverse to a horizontal plane within which the triangular plate comprising the lower plate link 330b lies. Each of the brackets 508 and 510 has a rearward end portion thereof 508a and 510a, respectively, located adjacent to the pivot joint 502 and spaced apart to define a gap 512 therebetween. The lower plate link 330b passes through the gap 512. The gap 512 is sized sufficiently large to permit a desired flexure of the lower plate link 330b under a load for which the vehicle 12 has been rated applied to the work platform 14 in the downward direction. In the event that the flexure of the lower plate link 330b exceeds a desired amount, the rearward portion 508a of the upper bracket 508 will engage the upper surface of the lower plate link 330b and prevent further downward movement of the work platform 14. In a similar manner, if a sufficient upward force is applied to the work platform 14, the rearward portion 510a of the lower bracket 510 will engage the lower surface of the lower plate link 330b and prevent further upward travel of the work platform 14. The upper and lower brackets 508 and 510 serve to transmit overloads on the work platform 14 in the vertical direction, both upward and downward, more directly to the pivot joint 502 without passing the overload through the full length of the lower plate link 330b.

While the upper and lower plate links 330a and 330b have been described as having a triangular shape, other shapes can be utilized so long as they provide sufficient rigidity and strength to support the load on the work platform 14 but yet provide adequate flexibility and resiliency. The flexibility is particularly necessary when sensing the load using a motion sensor rather than a strain sensor, but so long as the sensor can sense the load on the one of the upper or lower plate links to which it is attached, so as to indicate the relative loading of the work platform, the requirement for flexibility is diminished.

Another embodiment of the invention is shown in Figures 12A, 12B and 12C. In this embodiment, a rotary assembly 34h includes a rotary actuator 42h coupled between the work platform 14 and the arm bracket 38 using links 330, much as used in the embodiment of Figures 11A and 11B. The links 330 include the upper plate link 330a and the lower plate link 330b both having a triangular shape with the apex portion rigidly coupled to the shaft 74h of the rotary actuator 42h by the bolt 170, as is done in the embodiment of Figure 9, and also by bolts 160 as used in the embodiment of Figure 8, to ensure that the links 330 rotate with the shaft 74h and transmit the rotary drive of the rotary actuator 42h to the work platform 14 and deliver sufficient rotational force to rotate the work platform when it is carrying a load.

As with the embodiment of Figures 11A and B, the wide ends of the triangular plates used for the upper and lower plate links 330a and 330b are rigidly attached to the work platform 14. The upper and lower plate links 330a and 330b are sufficiently flexible and resilient to allow the work platform 14 to swing downward slightly relative to the rotary actuator 42h when the work platform is under load. However, in this embodiment, the lower plate link 330b has a greater thickness than the upper plate link 330a and hence provides greater support for the work platform and transmits the primary portion of the load on the work platform 14 to the rotary actuator 42h. Nevertheless, the lower plate link 330b still has sufficient flexibility and resiliency to allow the work platform 14 to swing downward slightly relative to the rotary actuator 42h when the work platform is under load.

The upper and lower plate links 330a and 330b must have sufficient strength in the lateral direction to transmit the rotary motion of the rotary actuator 42h to the work platform 14 in a manner generally similar to that discussed above for other embodiments. A strain gauge 60, or other load or motion sensor, is attached to the lower plate link 330b to detect the load borne by the work platform 14 in a manner generally similar to that discussed above.

In the embodiment of Figures 12A-12C, a single bracket 514 is positioned between the upper and lower plate links 330a and 330b, and is rigidly attached to the rear of the support platform 14 and extends rearwardly therefrom. As with the brackets 508 and 510 of the embodiment of Figure 11A and 11B, the bracket 514 of this embodiment serves to transmit overloads in the vertical direction from the work platform 14 to the upper and lower plate links 330a and 330b, at a location close to the rotary actuator 42h. In particular, the bracket 514 is a plate oriented in a plane transverse to the triangular plates of the upper and lower plate links 330a and 330b, and has rearward upper and lower engagement portions 514a and 514b which are positioned in spaced apart arrangement from the lower side of the upper plate link 330a and the upper side of the lower plate link 330b, respectively when the work platform 14 is unloaded. When a sufficiently great load in the upward or downward direction is applied to the work platform 14 movement is limited and the overload is transferred more directly to the shaft of the rotary actuator 42h rather than through the entire length of the plate link. The rearward engagement portion 514a will move upward under an upward load to engage the upper plate link 330a at a position close to the rotary actuator 42h, and the rearward engagement portion 514b will move downward under a downward load to engage the lower plate link 330b at a position close to the rotary actuator 42h. Thereby the excessive loads are prevented from being transmitted through the entire length of the upper and lower plate links.

Figures 13A, 13B and 13C show a rotary assembly 34i which is in many ways similar to the embodiment of Figures 11A and 11B. The rotator assembly 34i utilizes a hydraulic cylinder 500 to cause rotation of the work platform 14. In this embodiment, the hydraulic cylinder 500 has its cylinder portion 500b pivotally connected to a flange positioned toward the arm bracket 38 and its extensible arm 500a pivotally attached to the upper plate link 330a to cause selective rotation of the work platform 14 about the pivot joint 502 when the arm 500a is extended and retracted.

The upper and lower plate links 330a and 330b have the same triangular shape and attachments as described for the embodiment of Figures 11A and 11B, and have the same resiliency and flexibility described. In this embodiment, as described above for the embodiment of Figures 12A-12C, the single bracket 514 is used in a position between the upper and lower plate links 330a and 330b, with upper and lower engagement portions 514a and 514b. In the embodiment of Figures 13A-C, however, a strain gauge 60i, or other load or motion sensor, used to detect the load borne by the work platform 14, is attached to the upper plate link 330a. An alternative motion sensor 61i is shown in Figures 13A-13C as being attached to the bracket 514.

In Figures 14a and 14b, a rotor assembly 34j, using a hydraulic cylinder 500 much as described above for the embodiment of Figures 11A and 11B, is coupled between the work platform 14 and the arm bracket 38. In this embodiment, the upper and lower plate links 330a and 330b have spherical bushings at an end thereof which is connected to the pivot joint 502 and have opposite ends pivotally attached to the work platform 14. In this embodiment, the upper and lower plate links permit movement of the work platform 14 in the downward direction under a load, and return movement upon unloading, but restrict movement in directions out of alignment with the load direction except for rotation of the work platform in the rotational plane in response to operation of the hydraulic actuator 500. Since the upper and lower plate links 330a and 330b are pivotally attached to both the pivot joint 502 and the work platform 14, downward loading of the work platform is transmitted to the pivot joint 502 through a rearwardly extending load transfer arm 51 which is rigidly attached to the work platform 14, much as described with respect to the embodiment of Figure 3. The load transfer arm 51 has a spring engaging portion 58 which engages a spring 54. The spring 54 is positioned between the spring engaging portion 58 and a spring support 56 positioned above the rotatable portion 502b of the pivot joint 502. A sensor 60, in the form of a switch, is attached to sense vertical motion of the work platform 14 relative to the rotary joint 502.

In the embodiments discussed with reference to the Figures, the link or links, the rotary arm 456, or other member or members, provided between the work platform 14 and the rotary actuator 42 allow the rotary motion of the drive shaft 74 to be transmitted to the work platform and enables all or nearly all other loads, movements, torques, horizontal forces and the like to be transmitted to the rotary actuator in a manner which does not significantly affect the measuring of the vertical load by the load sensor. In effect, the load sensor is substantially isolated from all but the vertical load. Accordingly, the strain gauge switch or other load sensing device is able to measure the vertical load accurately and consistently. Alternatively, the load sensor and the link between the rotary actuator 42 and the work platform 14 can be configured to isolate loads in directions other than the vertical direction. In any embodiment, an advantage of this arrangement is that only a selected component of the load borne by the work platform 14 is transmitted to the load sensor, so that the load sensor more accurately determines the load in the selected direction.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. For example, the work platform and rotator assembly can be coupled to vehicles other than the one shown in Figure 1, such as utility trucks and the like. Alternatively, the vehicle can include a fork lift and the work platform can include forks coupled to forklift with a rotary actuator in a manner generally similar to that discussed above with reference to Figures. Accordingly, the work platform discussed above with reference to Figures can include any load support member configured to support a load. Further, the output shaft of the rotary actuator can be coupled to the arm of the vehicle and the body of the rotary actuator can be coupled to the work platform to provide for relative lateral rotation of the work platform relative to the arm. The spring can be a coil spring, a cantilever member or other types of spring devices that support the work platform and deflect or deformat as the load applied to the platform changes. Accordingly, the invention is not limited except as by the appended claims.

CLAIMS

1. A fluid-powered laterally rotatable work platform assembly useable with a vehicle having an arm for positioning the work platform assembly, the work platform assembly comprising:

a work platform having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends, the body having a body connection portion configured to be coupled to one of the work platform and the arm of the vehicle;

an output shaft rotatably disposed within the body and having a shaft axis generally coaxial with the longitudinal axis of the body, the shaft having a shaft connection portion configured to be coupled to the other of the arm and the work platform;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the output shaft to translate longitudinal motion of the force transmitting member to rotational movement of one of the output shaft and the body relative to the other of the output shaft and the body; and

at least one link member coupled between the work platform and the one of the body and output shaft connection portions to which the work platform is coupled, the at least one link member being coupled to transmit rotational force to the work platform to selectively laterally rotate the work platform about the longitudinal axis relative to the arm of the vehicle as one of the output shaft and the body rotates relative to the other, while permitting at least limited downward movement of the work platform under the load supported by the work platform.

2. The assembly of claim 1, further comprising at least one load sensor and positioned to detect the downward movement of the work platform relative to the arm under the load supported by the work platform.

3. The assembly of claim 2 wherein the load sensor includes an electrical switch coupled between the output shaft and the work platform, the switch being in an open position when the work platform is in a first position, the switch being in a closed position when the work platform moves downward to a second position beneath the first position.

4. The assembly of claim 2 wherein the load sensor includes an electrical switch coupled between the output shaft and the work platform, the switch being in a closed position when the work platform is in a first position, the switch being in an open position when the work platform moves downward to a second position beneath the first position.

5. The assembly of claim 1, further comprising a load sensor operatively coupled to the work platform and configured to trigger a warning signal when a load on the work platform exceeds a first selected value and the work platform moves downward to a first lowered position, the load sensor being configured to trigger a signal halting motion of the work platform when the load on the work platform exceeds a second value greater than the first value and the work platform moves downward to a second lowered position.

6. The assembly of claim 1, further comprising:

a cantilever member coupled between the work platform and at least one of the at least one link member, the body and the output shaft to bend as the work platform moves downward relative to the arm under the load supported by the work platform; and a strain sensor attached to the cantilever member to detect a deformation of the cantilever member as the work platform moves downward.

7. The assembly of claim 1 wherein the at least one link member has a first end and a second end opposite the first end, the at least one link member being pivotably coupled toward the first end to the work platform to be pivotable relative to the work platform in at least one of a first upward and a first downward direction, the at least one link member being pivotably coupled toward the second end to the shaft connection portion of the output shaft to be pivotable relative to the output shaft in at least one of a second upward and a second downward direction.

8. The assembly of claim 1 wherein the body connection portion is coupled to the arm of the vehicle, further wherein the output shaft has a first end and a second end opposite the first end, the shaft connection portion being a first shaft connection portion positioned toward the first end of the shaft, the shaft having a second shaft connection portion toward the second end of the shaft, the at least one link member being a first link member pivotably coupled between the work platform and the first shaft connection portion, further comprising a second link member pivotably coupled between the work platform and the second shaft connection portion and extending generally parallel to the first link member.

9. The assembly of claim 1, further comprising:

an endcap sealing an end of the cavity of the body and connected to the output shaft, the endcap having a shoulder and a projection extending away from the shoulder, further wherein the at least one link member has an aperture that receives the projection of the endcap;

a retainer connected to the projection of the endcap and spaced apart from the shoulder of the projection so that the aperture of the at least one link member fits around the projection between the shoulder and the retainer;

a first compressible member positioned between the retainer and the at least one link member; and

a second compressible member positioned between the at least one link member and the shoulder of the endcap, the first and second compressible members being compressible to permit pivotal motion of the at least one link member relative to the endcap and the output shaft.

10. The assembly of claim 9 wherein at least one of the compressible members includes an O-ring.

11. The assembly of claim 1, further comprising:

a spring support coupled to one of the body and the output shaft; and

a spring extending between the spring support and the work platform, the spring biasing the work platform in an upward direction.

12. The assembly of claim 11 wherein the spring is positioned to restrict separation between the spring and the spring support when the work platform rotates about an axis offset from the longitudinal axis of the body.

13. The assembly of claim 11 wherein the spring is pre-loaded.

14. The assembly of claim 1 wherein the output shaft has an upper end and a lower end beneath the upper end, further comprising:

a spring support coupled to the output shaft toward the lower end thereof and extending toward the work platform;

a bracket extending rearwardly from the work platform toward the output shaft; and

a spring coupled between the spring support and the bracket, the spring biasing the work platform in an upward direction.

15. The assembly of claim 1 wherein the output shaft has an upper end and a lower end beneath the upper end, further comprising:

a spring support coupled to the output shaft toward the upper end thereof;

a bracket extending rearwardly from the work platform toward the output shaft; and

a spring coupled between the spring support and the bracket, the spring biasing the work platform in an upward direction.

16. The assembly of claim 1 wherein the body has internal grooves, the output shaft has external grooves and the force transmitting member has external grooves engaged with the internal grooves of the body and internal grooves engaged with the external grooves of the output shaft for rotating at least one of the output shaft and the body relative to the other as the force transmitting member moves axially relative to the body.

17. The assembly of claim 1 wherein the work platform has a rear portion toward the vehicle, a forward portion facing opposite the rear portion and a support surface between the forward and rear portions, further wherein the at least one link member is coupled to the rear portion of the work platform.

18. A fluid-powered laterally rotatable work platform assembly useable with a vehicle having an arm for positioning the work platform assembly, the work platform assembly comprising:

a work platform having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends, the cavity having a cavity wall with internal grooves, the body having a body connection portion configured to be coupled to the arm of the vehicle;

an output shaft disposed at least partially within the body and having first and second ends with a first shaft connection portion toward the first end and a second shaft connection portion toward the second end, the output shaft being rotatable relative to the body about a shaft axis extending between the first and second ends generally coaxial with the longitudinal axis of the body, the shaft having external grooves, at least one of the cavity and shaft grooves being helical;

a linear-to-rotary force transmitting member positioned within the cavity of the body between the output shaft and a wall of the cavity, the torque transmitting member being mounted for axial movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member having external grooves engaging the internal grooves of the cavity and internal grooves engaging the external grooves of the output shaft to translate axial motion of the force transmitting member to rotational movement of the output shaft relative to the body about the longitudinal axis;

a first link member having a first end pivotably coupled to the work platform and a second end pivotably coupled to the first shaft connection portion of the output shaft;

a second link member generally parallel to the first link member and having a first end pivotably coupled to the work platform and a second end pivotably coupled to the second shaft connection portion of the output shaft, at least one of the first and second link members rotating the work platform relative to the arm of the vehicle about the longitudinal axis as the output shaft rotates relative to the body, while permitting at least limited downward movement of the work platform under the load supported by the load supported by the work platform;

a load sensor operatively coupled to the work platform to detect a load on the work platform; and

a spring coupled to the work platform to bias the work platform toward a selected orientation.

19. The assembly of claim 18, further comprising an endcap connected to the second shaft connection portion of the output shaft and sealing an end of the cavity of the body, further wherein the second link member is pivotably coupled to the endcap.

20. The assembly of claim 18, further comprising:

an endcap sealing an end of the cavity of the body and connected to the second shaft connection portion of the output shaft, the endcap having a shoulder and a projection extending away from the shoulder, further wherein the second link member has an aperture that receives the projection of the endcap;

a retainer connected to the projection of the endcap and spaced apart from the shoulder of the projection so that the aperture of the second link member fits around the projection between the shoulder and the retainer, the retainer at least restricting motion of the second link member relative to the endcap;

a first compressible member positioned between the retainer and the second link member; and

a second compressible member positioned between the second link member and the shoulder of the endcap, the first and second compressible members being compressible to permit pivotal motion of the second link member relative to the endcap and the output shaft about an axis generally perpendicular to the shaft axis.

21. The assembly of claim 18 wherein the first link member includes two parallel links pivotably coupled between the work platform and the first shaft connection portion of the output shaft and the second link member includes two parallel links pivotably coupled between the work platform and the second shaft connection portion of the output shaft.

22. The assembly of claim 18 wherein the spring includes a resilient cantilever member having first and second opposite ends, the cantilever member being rigidly attached toward the first end to the work platform and coupled toward the second

end to at least one of the output shaft, the body, the first link member and the second link member.

23. The assembly of claim 22 wherein the cantilever member includes an adjustment bolt bearing against a bolt of the output shaft.

24. The assembly of claim 18 wherein the spring includes a resilient cantilever member rigidly attached at one end to the work platform and coupled at another end to the output shaft, further wherein the sensor includes a strain gauge connected to the cantilever member and positioned to detect a strain of the cantilever member as the cantilever member deflects under the load supported by the work platform.

25. The assembly of claim 18 wherein the first connection portion of the output shaft is beneath the second connection portion thereof, the assembly further comprising:

a spring support coupled to the output shaft toward the first connection portion;

a bracket connected to the work platform and extending rearwardly from the work platform toward the output shaft;

a spring engaging member connected to the bracket; and

a coil spring extending between the spring support and the spring engaging member, the coil spring biasing the work platform in an upward direction.

26.. The assembly of claim 18 wherein the spring is pre-loaded to resist vertical motion of the work platform relative to the body.

27. The assembly of claim 18 wherein the output shaft extends through the body with the first connection portion projecting from one end of the body and the second connection portion projection from an opposite end of the body.

28. The assembly of claim 18 wherein the load sensor is coupled to the output shaft and has a switch positioned to contact a contact member coupled to the work platform to move with the work platform, the switch being configured to trigger a warning signal when a load on the work platform exceeds a first selected value and the work platform moves downward to a first lowered position, the load sensor being configured to trigger a signal halting motion of the work platform when the load on the work platform exceeds a second value greater than the first value and the work platform moves downward to a second lowered position.

29. A fluid-powered rotatable support member assembly usable with an assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform in a rotational plane;

at least one link member coupled between the load support member and the other one of the body and the shaft, the at least one link member being coupled to transmit the rotary drive of the other one of the body and the shaft to the load support member to selectively rotate the load support member about the longitudinal axis relative to the assembly support platform in the rotational plane as one of the shaft and the body rotates relative to the other, and to permit movement of the load support member in a selected direction out of alignment with the rotational plane while restricting movement in directions out of alignment with the selected direction except rotation of the load support member in the rotational plane in response to the rotary drive transmitted thereto by the at least one link member;

a load transfer member coupled between the load support member and one of the body and the shaft to transmit at least a portion of the load supported by the load support member thereto and thereby support the load support member against movement in the selected direction; and

a load sensor positioned to detect a load on the load support member in the selected direction.

30. The assembly of claim 29 wherein the load sensor is attached to the load transfer member to detect the portion of the load supported by the load support member which is on the load transfer member in the selected direction.

31. The assembly of claim 30 wherein the load transfer member is rigidly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

32. The assembly of claim 31 wherein the load sensor includes a strain gauge attached to the load transfer member.

33. The assembly of claim 31 further comprising a first member with a first end portion rigidly attached to the load support member and a second end portion coupled to the load transfer member at a location between the load support member and the other one of the body and the shaft.

34. The assembly of claim 30 wherein the load transfer member is rigidly attached to the other one of the body and the shaft, and the load transfer member is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

35. The assembly of claim 34 wherein the load transfer member is pivotably attached to the load support member.

36. The assembly of claim 29 wherein the at least one link member is rigidly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

37. The assembly of claim 36 wherein the load transfer member is rigidly attached to the other one of the body and the shaft, and sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

38. The assembly of claim 37 wherein the at least one link member is pivotably attached to the load support member.

39. The assembly of claim 37 wherein the load transfer member is sufficiently resilient to allow resilient flexure in the selected direction.

40. The assembly of claim 37 further comprising a first member with a first end portion rigidly attached to the load support member and a second end portion coupled to the at least one link member at a location between the load support member and the other one of the body and the shaft.

41. The assembly of claim 29 wherein the load transfer member is rigidly attached to the load support member.

42. The assembly of claim 41 wherein the load transfer member is flexible and resilient to allow resilient flexure in the selected direction.

43. The assembly of claim 42 wherein the load sensor includes a strain gauge attached to the load transfer member.

44. The assembly of claim 29 wherein the load transfer member is rigidly attached to the other one of the body and shaft.

45. The assembly of claim 44 wherein the at least one link member is coupled between the shaft and the load support member, and the body is coupled to the assembly support platform, and wherein the load sensor is positioned to detect the portion of the load supported by the load transfer member.

46. The assembly of claim 45, further comprising:

a spring positioned between the load support member and the load transfer member, the spring biasing the load support member in a direction away from the selected direction.

47. The assembly of claim 46 wherein the load sensor is positioned between the at least one link member and the load transfer member.

48. A fluid-powered rotatable support member assembly usable with an assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform in a rotational plane;

a load transfer member coupled between the load support member and the other one of the body and the shaft, the load transfer member being coupled to transmit the rotary drive of the other one of the body and the shaft to the load support member to selectively rotate the load support member about the longitudinal axis relative to the assembly support platform in the rotational plane as one of the shaft and the body rotates relative to the other, and to transmit at least a portion of the load supported by the load support member to the other one of the body and shaft and thereby support the load support member against movement in a selected direction out of alignment with the rotational plane;

at least one link member coupled between the load support member and the other one of the body and the shaft, the at least one link member being coupled to permit movement of the load support member in the selected direction while restricting movement in directions out of alignment with the selected direction except rotation of the load support member in the rotational plane in response to the rotary drive transmitted thereto by the load transfer member; and

a load sensor positioned to detect a load on the load support member in the selected direction.

49. The assembly of claim 48 wherein the load sensor is positioned to detect the portion of the load supported by the load transfer member.

50. The assembly of claim 49 wherein the load sensor is positioned between the load transfer member and the load support member.

51. The assembly of claim 49 wherein the load transfer member is rigidly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

52. The assembly of claim 51 further comprising a first member with a first end portion rigidly attached to the load support member and a second end portion coupled to the load transfer member at a location between the load support member and the other one of the body and the shaft.

53. The assembly of claim 52, further comprising:

a spring positioned between the second end portion of the first member and the load transfer member, the spring biasing the load support member in a direction away from the selected direction.

54. The assembly of claim 48 wherein the at least one link member is pivotably attached to the other one of the body and the shaft, and pivotably attached to the load support member, and wherein the load transfer member is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

55. A fluid-powered rotatable support member assembly usable with an assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform in a rotational plane;

at least one link member coupled between the load support member and the other one of the body and the shaft, the at least one link member being coupled to transmit the rotary drive of the other of the body and the shaft to the load support member to selectively rotate the load support member about the longitudinal axis relative to the assembly support platform in a rotational plane as one of the shaft and the body rotates relative to the other, and to permit movement of the load support member in a selected direction out of alignment with the rotational plane while restriction movement in directions out of alignment with the selected direction except rotation of the load support member in the rotational plane in response to the rotary drive transmitted thereto by the at least one link member; and

a load sensor positioned to detect a load on the load support member in the selected direction.

56. The assembly of claim 55 wherein the at least one link member is configured to transmit at least a portion of the load supported by the load support member to one of the body and shaft, and the load sensor is attached to the at least one

link member to detect the portion of the load supported by the load support member which is transmitted by the at least one link member in the selected direction.

57. The assembly of claim 56 wherein the at least one link member is fixedly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

58. The assembly of claim 57 wherein the load sensor includes a strain gauge attached to the at least one link member.

59. The assembly of claim 57 further comprising a first member with a first end portion fixedly attached to the load support member and a second end portion coupled to the at least one link member at a location between the load support member and the other one of the body and the shaft.

60. The assembly of claim 39 wherein the at least one link member is fixedly attached to the other one of the body and the shaft, and pivotably attached to the load support member, and the at least one link member is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

61. The assembly of claim 55 further comprising a first member with a first end portion fixedly attached to the other one of the body and the shaft, and a second end portion positioned to support at least a portion of the load supported by the load support member against movement in the selected direction, and wherein the load sensor is attached to the first member to detect the portion of the load supported by the load support member which is on the first member in the selected direction.

62. The assembly of claim 61 wherein the at least one link member is fixedly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

63. The assembly of claim 61 wherein the at least one link member is fixedly attached to the other one of the body and the shaft, and pivotably attached to the load support member, and the at least one link member is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

64. The assembly of claim 61 wherein the first member is flexible and resilient to allow resilient flexure in the selected direction.

65. The assembly of claim 61 wherein the load sensor includes a strain gauge attached to the first member.

66. The assembly of claim 61 further comprising a second member with a first end portion fixedly attached to the load support member and a second end portion coupled to the first member at a location between the load support member and the other one of the body and the shaft.

67. The assembly of claim 61 wherein the at least one link member is fixedly attached to the other one of the body and the shaft, and pivotably attached to the load support member, and the at least one link member is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

68. The assembly of claim 55 further comprising a load transmission member coupled between the load support member and other one of the body and shaft, the load transmission member being configured to support at least a portion of the load

supported by the load support member against movement in the selected direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

69. The assembly of claim 68 wherein the at least one link member is pivotably attached to the other one of the body and the shaft, and pivotably attached to the load support member.

70. The assembly of claim 68 wherein the load transmission member is fixedly attached to the load support member.

71. The assembly of claim 70 wherein the load transmission member is flexible and resilient to allow resilient flexure in the selected direction.

72. The assembly of claim 71 wherein the load sensor includes a strain gauge attached to the load transmission member.

73. The assembly of claim 68 wherein the load transmission member is fixedly attached to the other one of the body and shaft.

74. The assembly of claim 55 wherein the at least one link member is coupled between the shaft and the load support member, and the body is coupled to the assembly support platform, and further comprising a load transmission member fixedly attached to the shaft and coupled to the load support member to support at least a portion of the load supported by the load support member against movement in the selected direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

75. The assembly of claim 74, further comprising:

a spring positioned between the load support member and the load transmission member, the spring biasing the load support member in a direction away from the selected direction.

76. The assembly of claim 75 wherein the load sensor is positioned between the at least one link member and the load transmission member.

77. A fluid-powered rotatable support member assembly usable with a assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform in a rotational plane;

a rotation transmission member coupled between the load support member and the other one of the body and shaft, the rotation transmission member being configured to transmit the rotary drive of the other of the body and the shaft to the load support member to selectively rotate the load support member about the longitudinal axis relative to the assembly support platform in a rotational plane as one of the shaft and the body rotates relative to the other;

at least one link member coupled between the other one of the body and the shaft and the load support member to permit movement of the load support member in a selected direction out of alignment with the rotational plane while restricting movement in directions out of alignment with the selected direction except rotation of the lead support member in the rotational plane in response to the rotary drive transmitted thereto by the rotation transmission member; and

a load sensor positioned to detect a load on the load support member in the selected direction.

78. The assembly of claim 77 wherein the rotation transmission member is further configured to support at least a portion of the load supported by the load support member against movement in the selected direction, and the load sensor is positioned to detect the portion of the load supported by the rotation transmission member.

79. The assembly of claim 78 wherein the load sensor is positioned between the rotation transmission member and the load support member.

80. The assembly of claim 77 wherein the rotation transmission member is further configured to support at least a portion of the load supported by the load support member against movement in the selected direction, and wherein the rotation transmission member is fixedly attached to the other one of the body and the shaft, and is flexible and resilient to allow resilient flexure in the selected direction.

81. The assembly of claim 80 further comprising a first member with a first end portion fixedly attached to the load support member and a second end portion coupled to the rotation transmission member at a location between the load support member and the other one of the body and the shaft.

82. The assembly of claim 81, further comprising:

a spring positioned between the second end portion of the first member and the rotation transmission member, the spring biasing the load support member in a direction away from the selected direction.

83. The assembly of claim 71 wherein the at least one link member is pivotably attached to the other one of the body and the shaft, and pivotably attached to the load support member, and wherein the rotation transmission member is further configured to support at least a portion of the load supported by the load support member against movement in the selected direction and is sufficiently flexible to permit at least limited downward movement of the load support member under the load supported by the load support member.

84. A fluid-powered rotatable support platform assembly usable with an assembly support configured to selectively position the support platform assembly, the support platform assembly comprising;

a load support platform having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support and the other one of the body and the shaft being configured to provide rotary drive to the load support platform;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support platform about the longitudinal axis relative to the assembly support in a rotational plane in clockwise and counterclockwise rotational directions;

a load sensor positioned to detect a load on the load support platform in a load direction out of alignment with the rotational plane; and

a platform connector member coupled between the load support platform and the other one of the body and shaft, the platform connector member being configured to permit movement of the load support platform in the load direction while restricting movement in directions out of alignment with the load direction except rotation of the load support platform in the rotational plane in response to the rotary drive.

85. The assembly of claim 84 wherein the platform connection member is further configured to provide rotary drive to the load support platform by transmitting the rotational force to the load support platform and thereby selectively rotate the load support platform relative to the assembly support in the rotational plane.

86. The assembly of claim 84 further including a rotation transmission member coupled between the load support platform and the other one of body and the shaft configured to transmit the rotary drive to the load support platform, the rotation transmission member being configured to apply the rotational force to the load support platform and thereby selectively rotate the load support platform relative to the assembly support in the rotational plane.

87. The assembly of claim 86 wherein the rotation transmission member is further configured to support at least a portion of the load supported by the load support platform against movement in the load direction, and the load sensor is positioned to detect the portion of the load supported by the rotation transmission member.

88. The assembly of claim 87 wherein the rotation transmission member is fixedly attached to the other one of body and the shaft configured to provide rotary drive to the load support platform and bears on a portion of the load support platform to transmit the rotational force to the load support platform.

89. The assembly of claim 88 wherein the rotation transmission member is flexible to bend in the load direction.

90. The assembly of claim 84 wherein the longitudinal axis of the body is oriented in a generally vertical direction, the rotational plane is oriented transverse to the longitudinal axis of the body, and the load sensor is positioned to detect loads in an approximately vertical direction.

91. The assembly of claim 84 wherein the platform support member is the first of at least two link members coupled between the load support platform and the one of the body and the shaft configured to provide rotary drive to the load support platform.

92. The assembly of claim 84 wherein the platform connector member is pivotably attached to the load support platform to permit rotation of the load support platform in the load direction.

93. The assembly of claim 92 wherein the platform connector member is further pivotably attached to the other one of the body and the shaft configured to provide rotary drive to the load support platform, to permit rotation of the load support platform in the load direction.

94. The assembly of claim 84 wherein the platform connector member is pivotably attached to the other one of the body and the shaft configured to

provide rotary drive to the load support platform, to permit rotation of the load support platform in the load direction.

95. The assembly of claim 84 wherein the platform connector member is fixedly attached to the other one of the body and the shaft configured to provide rotary drive to the load support platform, and is flexible to flex in the load direction.

96. The assembly of claim 95 wherein the load sensor includes a strain gauge attached to the platform connector member.

97. The assembly of claim 95, further comprising a first member with a first end portion attached to the load support platform and a second end portion coupled to the platform connector member at a location between the load support platform and the other one of the body and the shaft configured to provide rotary drive to the load support platform.

98. The assembly of claim 84, further comprising a load transmission member coupled between the load support platform and other one of the body and the shaft, the load transmission member being configured to support at least a portion of the load supported by the load support platform against movement in the load direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

99. The assembly of claim 98 wherein the load transmission member is fixedly attached to the load support platform.

100. The assembly of claim 99 wherein the load transmission member is flexible and resilient to allow resilient flexure in the load direction.

101. The assembly of claim 100 wherein the load sensor includes a strain gauge attached to the load transmission member.

102. The assembly of claim 98 wherein the load transmission member is fixedly attached to the other one of the body and shaft configured to provide rotary drive to the load support platform.

103. The assembly of claim 84 wherein the platform connector member is coupled between the shaft and the load support platform, and the body is coupled to the assembly support, and further comprising a load transmission member fixedly attached to the shaft and coupled to the load support platform to support at least a portion of the load supported by the load support platform against movement in the load direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

104. The assembly of claim 103, further comprising:

a spring positioned between the load support platform and the load transmission member, the spring biasing the load support platform in a direction away from the load direction.

105. The assembly of claim 104 wherein the load sensor is positioned between the platform connector member and the load transmission member.

106. The assembly of claim 84 wherein the platform connector member is coupled between the load support platform and the shaft, and the body is coupled to the assembly support, and wherein the platform connector member has a first end portion and a second end portion opposite the first end portion, the platform connector member being pivotably attached toward the first end portion to the load support platform to be pivotable relative to the load support platform in upward and downward directions, the platform connector member being pivotably attached toward

the second end portion to the shaft to be pivotable relative to the shaft in upward and downward directions.

107. The assembly of claim 106, further comprising a load transmission member fixedly attached the load support platform and to support at least a portion of the load supported by the load support platform against movement in the load direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

108. The assembly of claim 106, further comprising a load transmission member fixedly attached to the load support platform and coupled to the one of the body and shaft to support at least a portion of the load supported by the load support platform against movement in the load direction, and wherein the load sensor is positioned to detect the portion of the load supported by the load transmission member.

109. The assembly of claim 108 wherein the load transmission member is flexible and resilient to allow resilient flexure in the load direction.

110. The assembly of claim 84 wherein the body is configured to be coupled to the assembly support, further wherein the shaft has a first end and a second end opposite the first end, the shaft including a first shaft connection portion positioned toward the first end of the shaft and a second shaft connection portioned toward the second end of the shaft, the connector support member being a first link member pivotably coupled between the load support platform and the first shaft connection portion, and wherein the assembly further includes a second link member pivotably coupled between the load support platform and the second shaft connection portion and extending generally parallel to the first link member.

111. The assembly of claim 84, further comprising:

an endcap sealing an end of the cavity of the body and connected to the shaft, the endcap having a shoulder and a projection extending away from the shoulder, further wherein the platform connector member has an aperture that receives the projection of the endcap;

a retainer connected to the projection of the endcap and spaced apart from the shoulder of the projection so that the aperture of the platform connector member fits around the projection between the shoulder and the retainer;

a first compressible member positioned between the retainer and the platform connector member; and

a second compressible member positioned between the platform connector member and the shoulder of the endcap, the first and second compressible members being compressible to permit pivotal motion of the platform connector member relative to the endcap and the shaft.

112. The assembly of claim 111 wherein at least one of the first and second compressible members includes an O-ring.

113. The assembly of claim 84, further comprising:

a spring support coupled to one of the body and the shaft; and

a spring positioned between the spring support and the load support platform, the spring biasing the load support platform in a direction away from the load direction.

114. The assembly of claim 113, further comprising a retainer configured to retain the spring in position and restrict separation between the spring and the spring support.

115. The assembly of claim 113 wherein the spring is pre-loaded.

116. The assembly of claim 84, further comprising:

a spring support coupled to the shaft;

a bracket extending from the load support platform; and

a spring positioned between the spring support and the bracket, the spring biasing the load support platform in a direction away from the load direction.

117. The assembly of claim 84, further comprising:

a load transmission member fixedly attached to the load support platform and coupled to the shaft to support at least a portion of the load supported by the load support platform against movement in the load direction

a spring support coupled to the shaft toward an end thereof; and

a spring positioned between the spring support and the load transmission member, the spring biasing the load support platform in a direction away from the load direction.

118. The assembly of claim 84 wherein the body has internal grooves, the shaft has external grooves and the force transmitting member has external grooves engaged with the internal grooves of the body and internal grooves engaged with the external grooves of the shaft, at least the external grooves of the force transmitting member and the internal grooves of the body, or the internal grooves of the force transmitter and the external grooves of the shaft being helical to rotate at least one of the shaft and the body relative to the other as the force transmitting member moves axially relative to the body.

119. A fluid-powered rotatable support member assembly usable with a support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the support platform;

a load sensor; and

a load transmission member configured to isolate the load sensor from loading of the load support member in directions other than a selected direction and to transmit only a load on the support member loads in the selected direction to the load sensor.

120. The assembly of claim 119 wherein the load transmission member is coupled to the load support member and the other one of the body and the shaft configured to provide rotary drive to the load support member, to transmit the rotational force to the load support member and thereby selectively rotate the load support member relative to the support platform.

121. The assembly of claim 119 further including a rotating arm coupled to the load supporting member and the other one of body and the output shaft configured to provide the rotary drive to the load supporting member, to transmit the

rotational force to the load support member and thereby selectively rotate the load support member relative to the support platform.

122. A fluid-powered rotatable support member assembly usable with an assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a body having a first end, a second end, a longitudinal axis extending between the first and second ends and a cavity extending along the longitudinal axis at least part way between the first and second ends;

a shaft rotatably disposed within the body and having a shaft axis generally aligned with the longitudinal axis of the body, one of the body and the shaft configured to be coupled to the assembly support platform and the other one of the body and the shaft being configured to provide rotary drive to the load support member;

a linear-to-rotary force transmitting member positioned within the cavity of the body and mounted for longitudinal movement within the body generally aligned with the longitudinal axis in response to selective application of pressurized fluid thereto, the force transmitting member engaging the body and the shaft to translate longitudinal motion of the force transmitting member to rotational movement between the shaft and the body with a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform in a rotational plane;

first and second link members in spaced apart relation, the first and second link members each being coupled between the load support member and the other one of the body and the shaft, the first and second link members each having a first end portion attached to the load support member and a second end portion attached the other one of the body and the shaft to transmit the rotary drive of the other one of the body and the shaft to the load support member to selectively rotate the load support member about the longitudinal axis relative to the assembly support platform in the rotational plane as one of the shaft and the body rotates relative to the other, and to permit movement of the load support member in a selected direction out of alignment with the rotational plane while restricting movement in directions out of alignment with the selected direction except rotation of the load support member in the rotational plane in response to the rotary drive transmitted thereto by the first and second link members, the first and second link members each being arranged in a plane out of alignment with the selected direction and sufficiently flexible and resilient to permit flexure thereof in the selected direction under the load supported by the load support member and return movement in a direction opposite the selected direction when the load is removed, at least one of the first and second link members having sufficient rigidity to transmit at least a portion of the load supported by the load support member to the other one of the body and the shaft; and

a load sensor positioned to detect a load on the load support member in the selected direction.

123. The assembly of claim 122 wherein the first and second link members each have a generally planar portion arranged in the plane out of alignment with the selected direction, the planar portions providing the flexibility and resilience to permit flexure in the selected direction.

124. The assembly of claim 122 wherein at least one of the first and second link members has its first end portion rigidly attached to the load support member and its second end portion rigidly attached to the other one of the body and the shaft.

125. The assembly of claim 124 wherein the at least one of the first and second link members with its first end portion rigidly attached to the load support member is attached by a weld.

126. The assembly of claim 122 wherein the load sensor is attached to the first link member to detect the portion of the load supported by the load support member which is transmitted by the first link member in the selected direction.

127. The assembly of claim 126 wherein the load sensor includes a strain gauge.

128. The assembly of claim 122, further comprising an overload member with an attachment portion rigidly attached to the load support member and extending between the first and second link members, the overload member further having an engagement portion positioned toward the second end portion of the first link member at a location adjacent to the other one of the body and the shaft so as to be engaged by the first link member when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

129. The assembly of claim 128 wherein the overload member has another engagement portion positioned toward the second end portion of the second link member at a location adjacent to the other one of the body and the shaft so as to be engaged by the second link member when the second link member flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

130. The assembly of claim 122, further comprising an overload member with an attachment portion rigidly attached to the load support member and extending toward the other one of the body and the shaft, the overload member further having an engagement portion positioned toward the second end portion of the first link member at a location adjacent to the other one of the body and the shaft so as to be engaged by the first link member when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

131. The assembly of claim 130 wherein the overload member has another engagement portion positioned toward the second end portion of the second link

member at a location adjacent to the other one of the body and the shaft so as to be engaged by the second link member when the second link member flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

132. The assembly of claim 122, further comprising an engagement member positioned toward the second end portion of the first link member at a location adjacent to the other one of the body and the shaft so as to be engaged by the first link member and limit movement thereof in the selected direction when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

133. The assembly of claim 132 further comprising another engagement member positioned toward the second end portion of one of the first and second link members at a location adjacent to the other one of the body and the shaft so as to be engaged by the one of the first and second link members and limit movement thereof in the direction opposite the selected direction when the one of the first and second link members flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

134 The assembly of claim 133 wherein the engagement member has a support rigidly attached to the load support member, and the another engagement member has a support rigidly attached to the load support member.

135. The assembly of claim 122 wherein the first link member is more rigid than the second link member to transmit more of the load supported by the load support member to the other one of the body and the shaft than the second link member.

136. The assembly of claim 122 wherein the first and second link members have substantially the same rigidity and thereby transmit substantially the same amount of the load supported by the load support member to the other one of the body and the shaft.

137. A powered rotatable support member assembly usable with an assembly support platform configured to position the support member assembly, the support member assembly comprising;

a load support member having a support surface for supporting a load;

a pivot member configured to be coupled to the assembly support platform for rotation of the load support member about a rotation axis;

a force transmitting member operable to apply a rotational force sufficient to selectively rotate the load support member relative to the assembly support platform about the rotation axis in a rotational plane;

first and second link members in spaced apart relation, the first and second link members each being coupled between the load support member and the pivot member, the first and second link members each having a first end portion attached to the load support member and a second end portion attached the pivot member to allow rotation of the load support member about the rotation axis in the rotational plane in response to the rotational force applied by the force transmitting member, and to permit movement of the load support member in a selected direction out of alignment with the rotational plane while restricting movement in directions out of alignment with the selected direction except rotation of the load support member in the rotational plane in response to the rotational force applied by the force transmitting member, the first and second link members each being arranged in a plane out of alignment with the selected direction and sufficiently flexible and resilient to permit flexure thereof in the selected direction under the load supported by the load support member and return movement in a direction opposite the selected direction when the load is removed, at least one of the first and second link members having sufficient rigidity to transmit at least a portion of the load supported by the load support member to the pivot member; and

a load sensor positioned to detect a load on the load support member in the selected direction.

138. The assembly of claim 137 wherein the first and second link members each have a generally planar portion arranged in the plane out of alignment with the selected direction, the planar portions providing the flexibility and resiliency to permit flexure in the selected direction.

139. The assembly of claim 137 wherein the pivot member has a first portion configured to be coupled to the assembly support platform and a second portion rotatable relative to the first pivot member portion, and at least one of the first and second link members has its first end portion rigidly attached to the load support member and its second end portion rigidly attached to the second pivot member portion.

140. The assembly of claim 139 wherein the at least one of the first and second link members with its first end portion rigidly attached to the load support member is attached by a weld.

141. The assembly of claim 137 wherein the load sensor is attached to the first link member to detect the portion of the load supported by the load support member which is transmitted by the first link member in the selected direction.

142. The assembly of claim 141 wherein the load sensor includes a strain gauge.

143. The assembly of claim 137, further comprising an overload member with an attachment portion rigidly attached to the load support member and extending between the first and second link members, the overload member further

having an engagement portion positioned toward the second end portion of the first link member at a location adjacent to the pivot member so as to be engaged by the first link member when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

144. The assembly of claim 143 wherein the overload member has another engagement portion positioned toward the second end portion of the second link member at a location adjacent to the pivot member so as to be engaged by the second link member when the second link member flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

145. The assembly of claim 137, further comprising an overload member with an attachment portion rigidly attached to the load support member and extending toward the pivot member, the overload member further having an engagement portion positioned toward the second end portion of the first link member at a location adjacent to the pivot member so as to be engaged by the first link member when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

146. The assembly of claim 145 wherein the overload member has another engagement portion positioned toward the second end portion of the second link member at a location adjacent to the pivot member so as to be engaged by the second link member when the second link member flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

147. The assembly of claim 137, further comprising an engagement member positioned toward the second end portion of the first link member at a location adjacent to the pivot member so as to be engaged by the first link member and limit

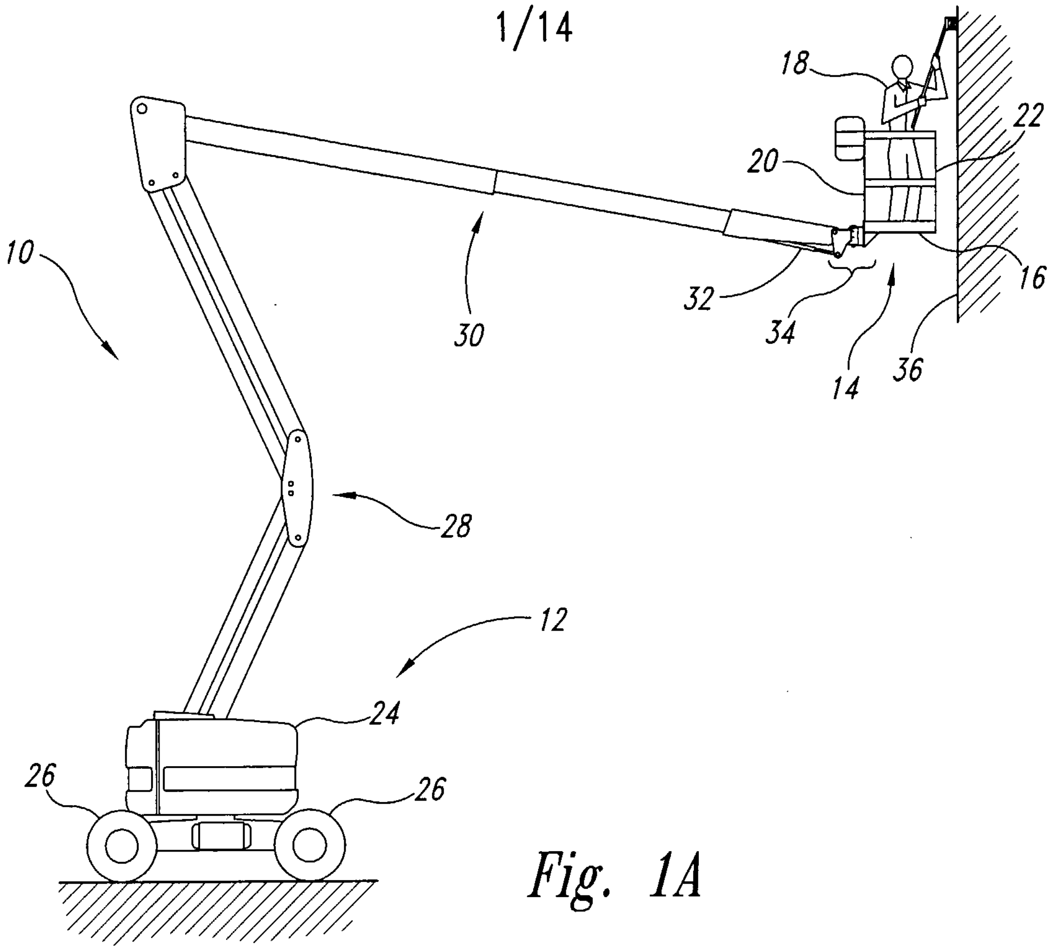
movement thereof in the selected direction when the first link member flexes in the selected direction under the load supported by the load support member exceeding a selected amount.

148. The assembly of claim 147 further comprising another engagement member positioned toward the second end portion of one of the first and second link members at a location adjacent to the pivot member so as to be engaged by the one of the first and second link members and limit movement thereof in the direction opposite the selected direction when the one of the first and second link members flexes in the direction opposite the selected direction when a force is applied to the load support member in the direction opposite the selected direction exceeding a selected amount.

149. The assembly of claim 148 wherein the engagement member has a support rigidly attached to the load support member, and the another engagement member has a support rigidly attached to the load support member.

150. The assembly of claim 137 wherein the first link member is more rigid than the second link member to transmit more of the load supported by the load support member to the pivot member than the second link member.

151. The assembly of claim 137 wherein the first and second link members have substantially the same rigidity and thereby transmit substantially the same amount of the load supported by the load support member to the pivot member.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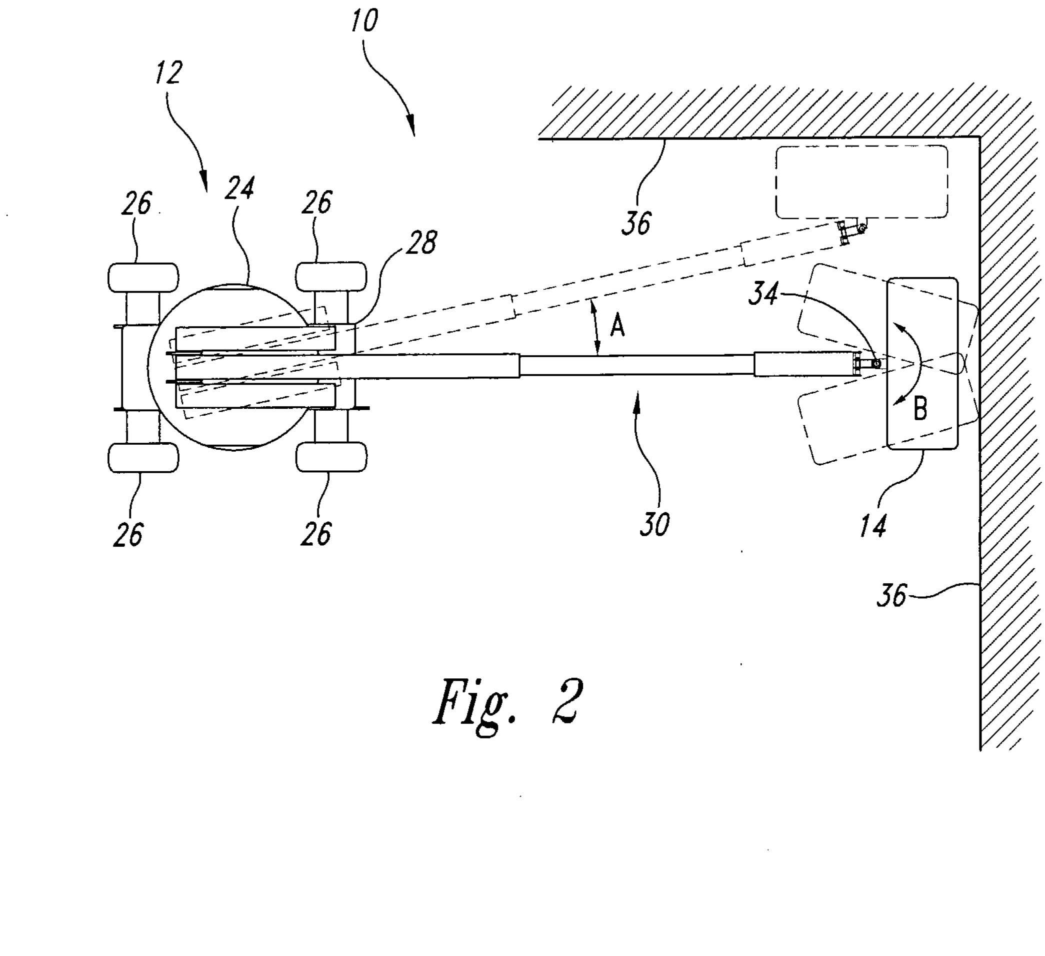
26

Fig. 1A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A
B
30
14
26
26
36

Fig. 2

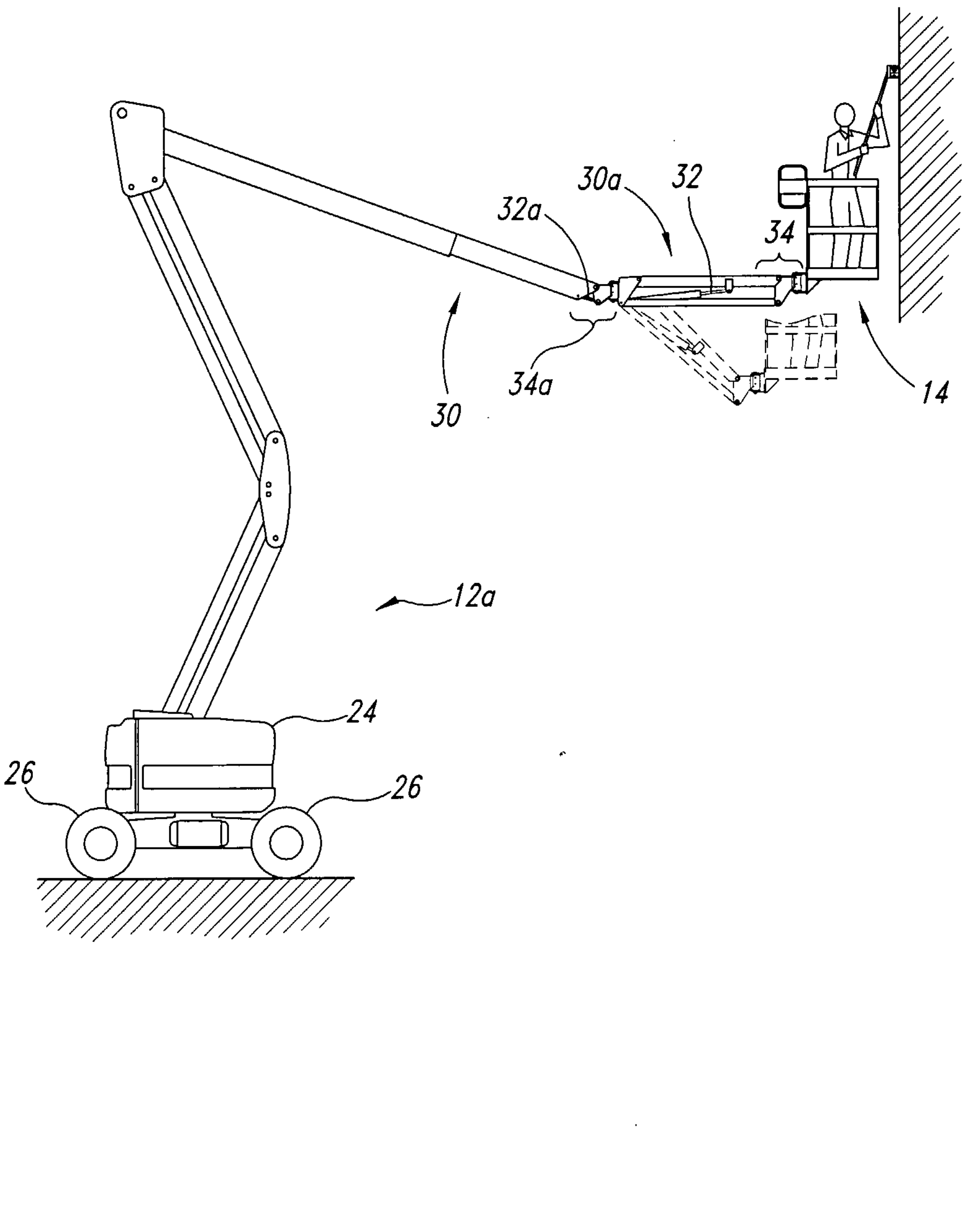
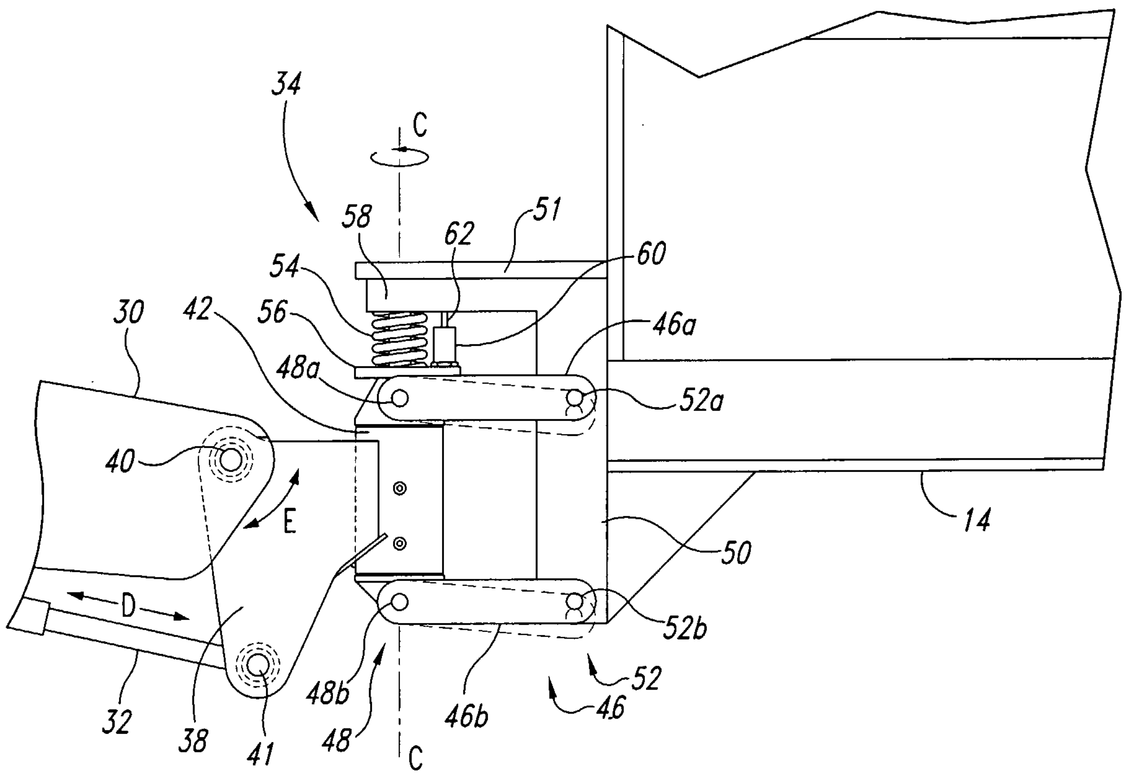


Fig. 1B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46a
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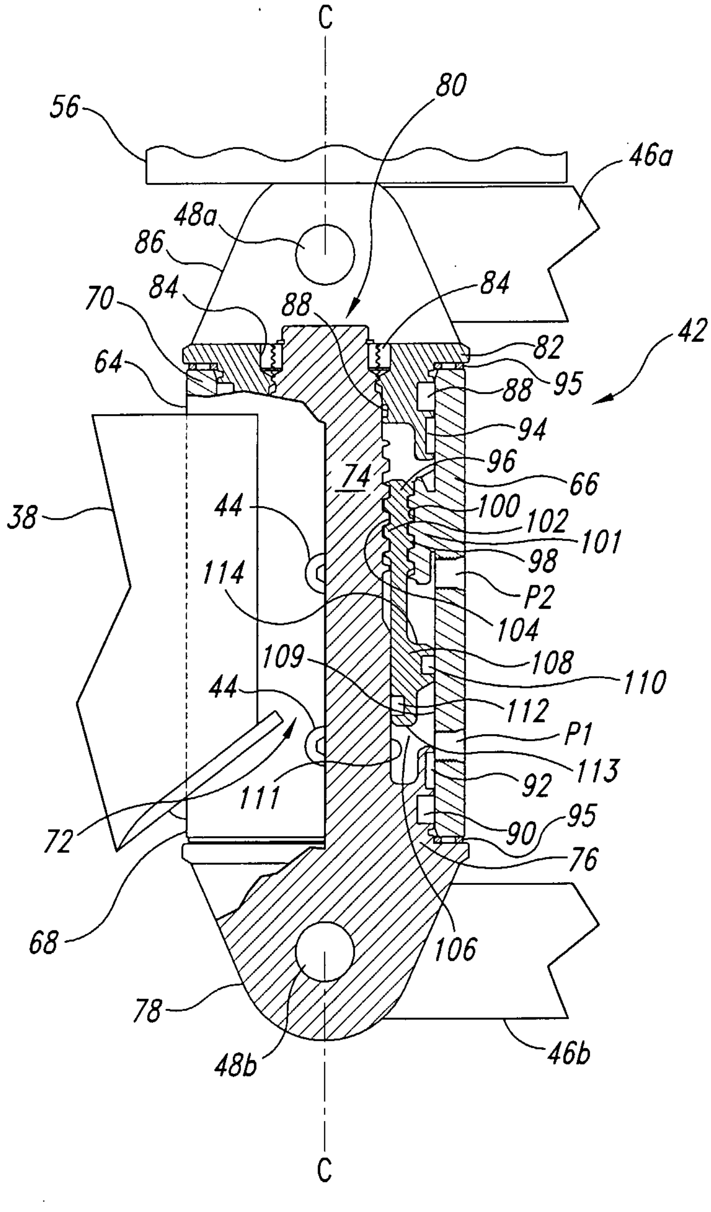
46
52
C

Fig. 3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100
102
101
98
114
P2
104
108
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76
68
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48b
46b
C

Fig. 4

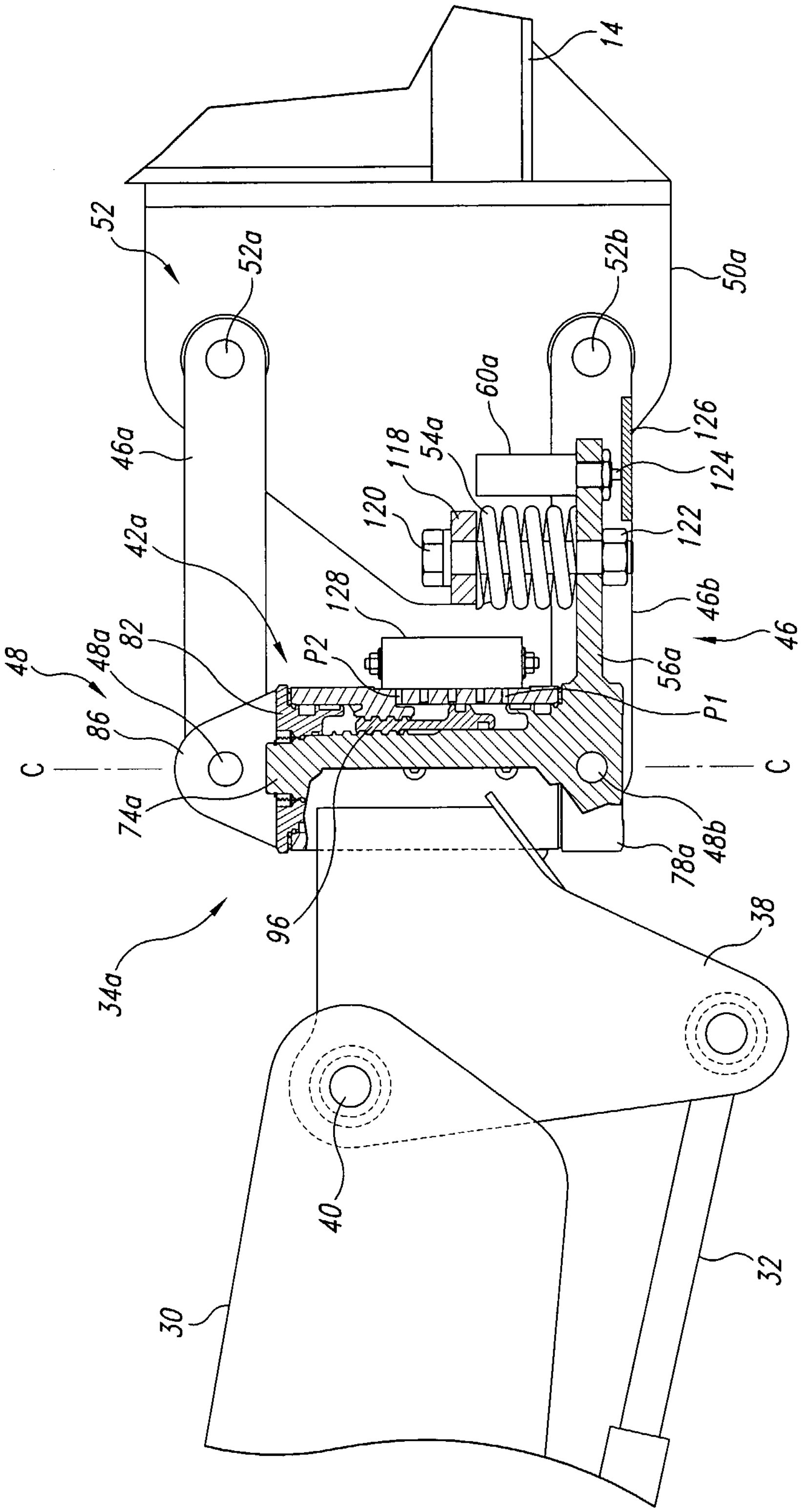
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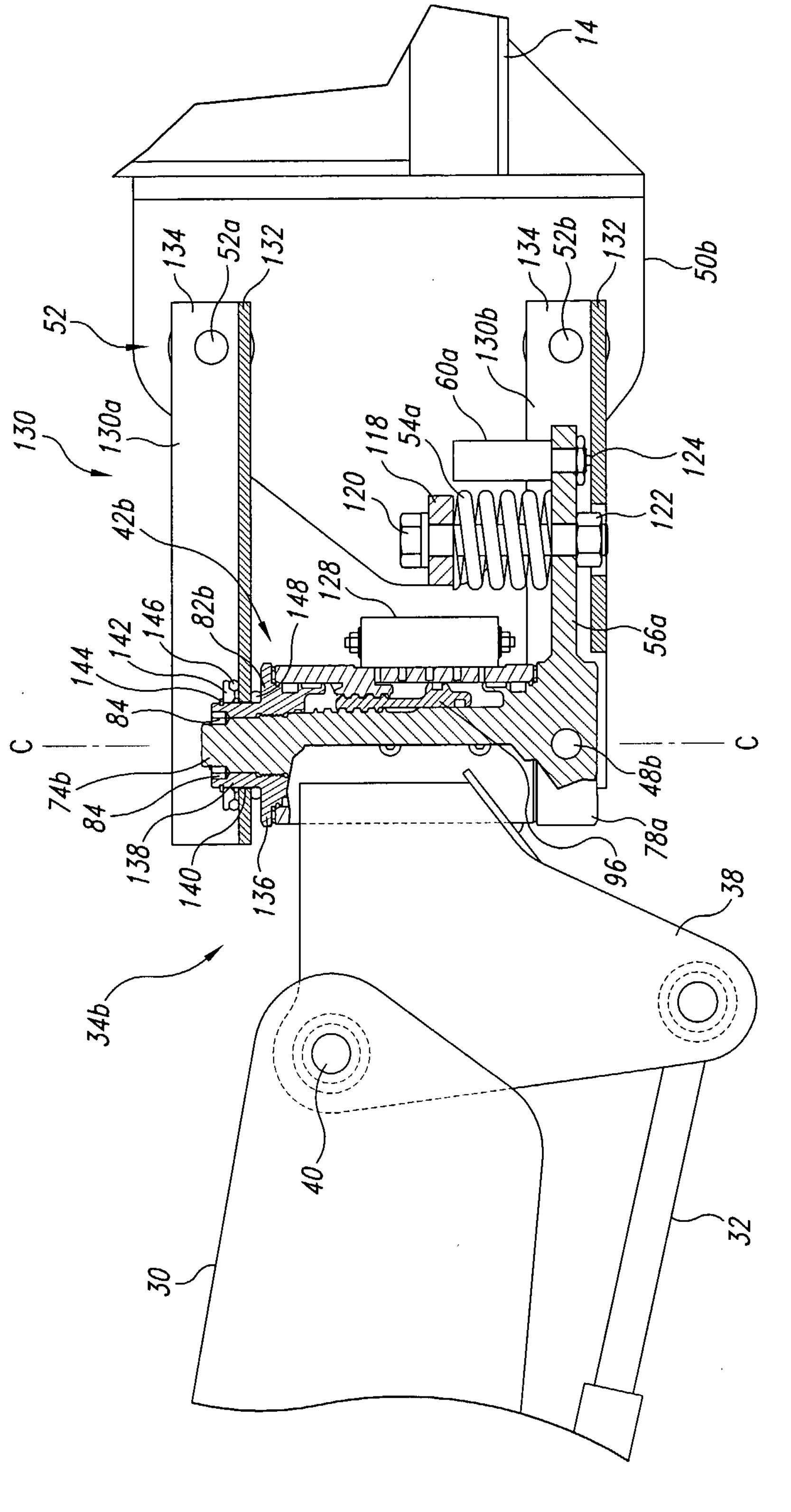
Fig. 5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144
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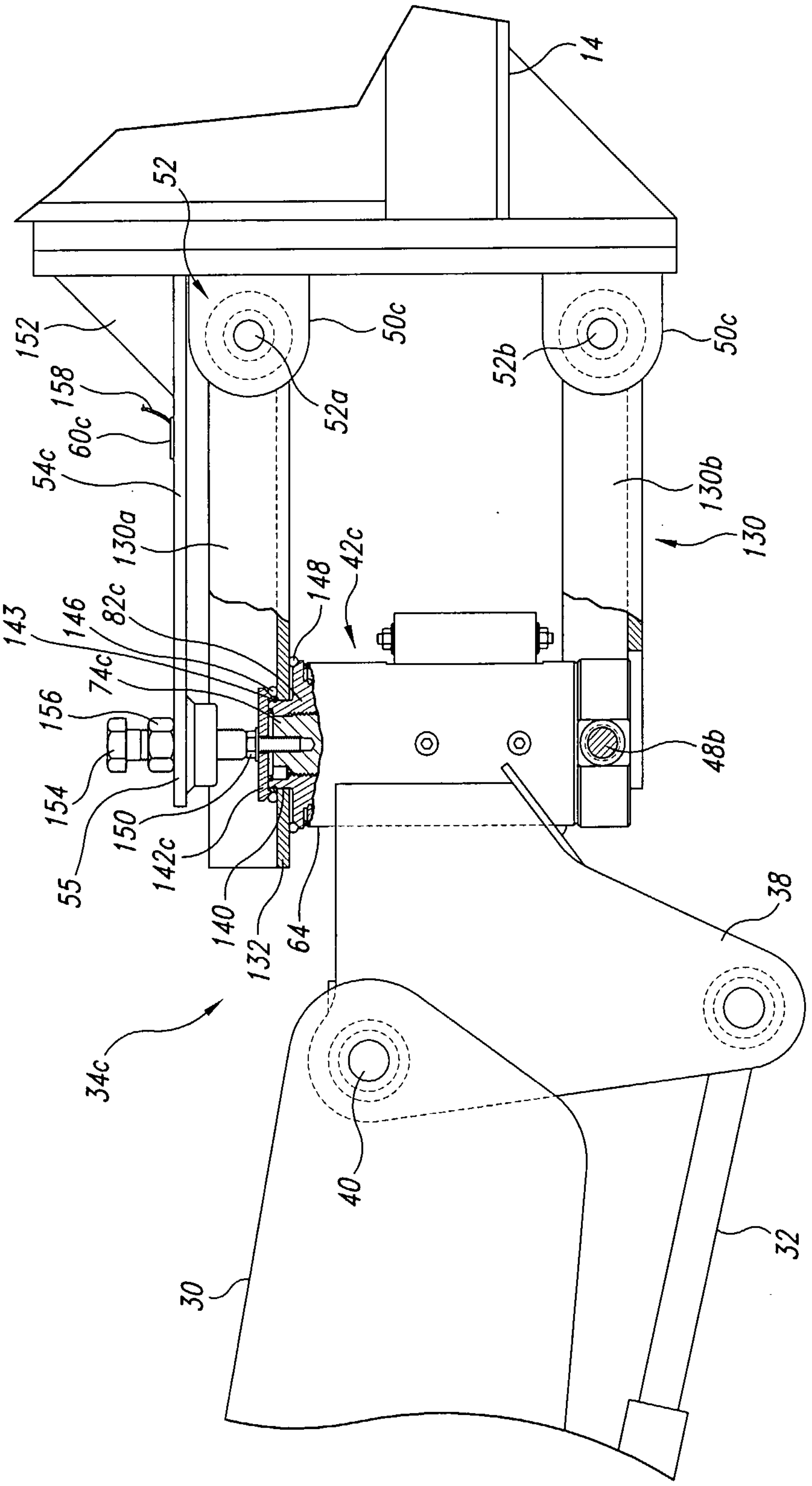
Fig. 6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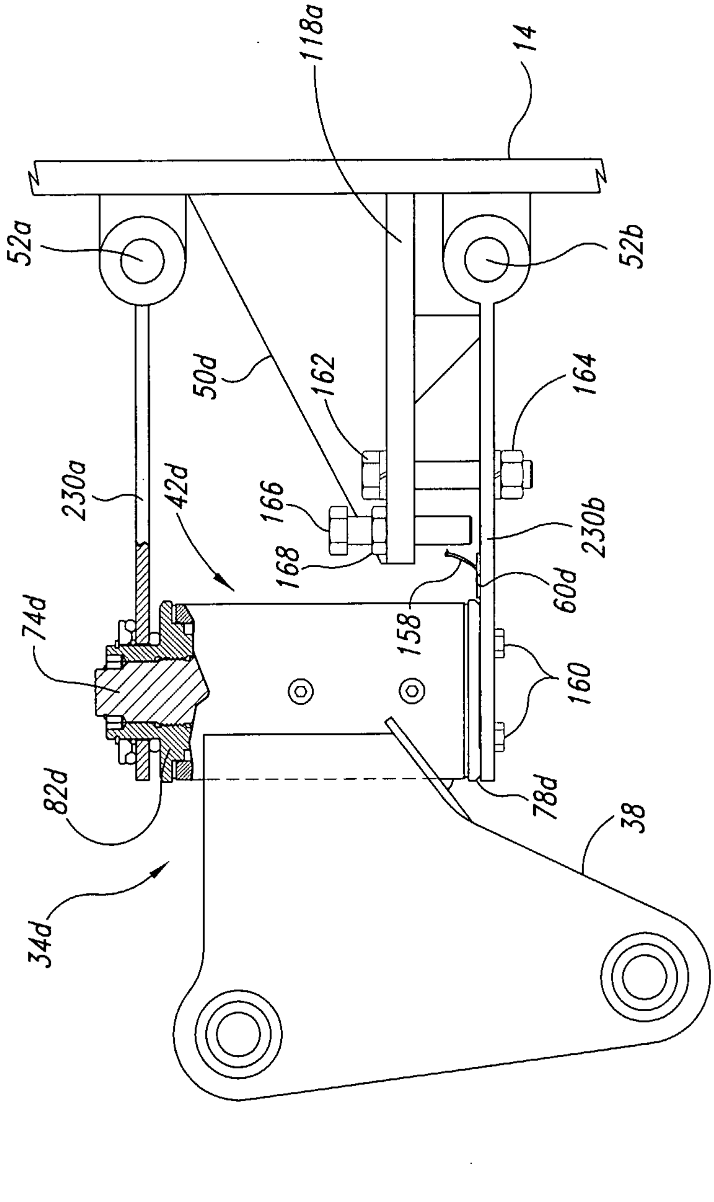
32

Fig. 7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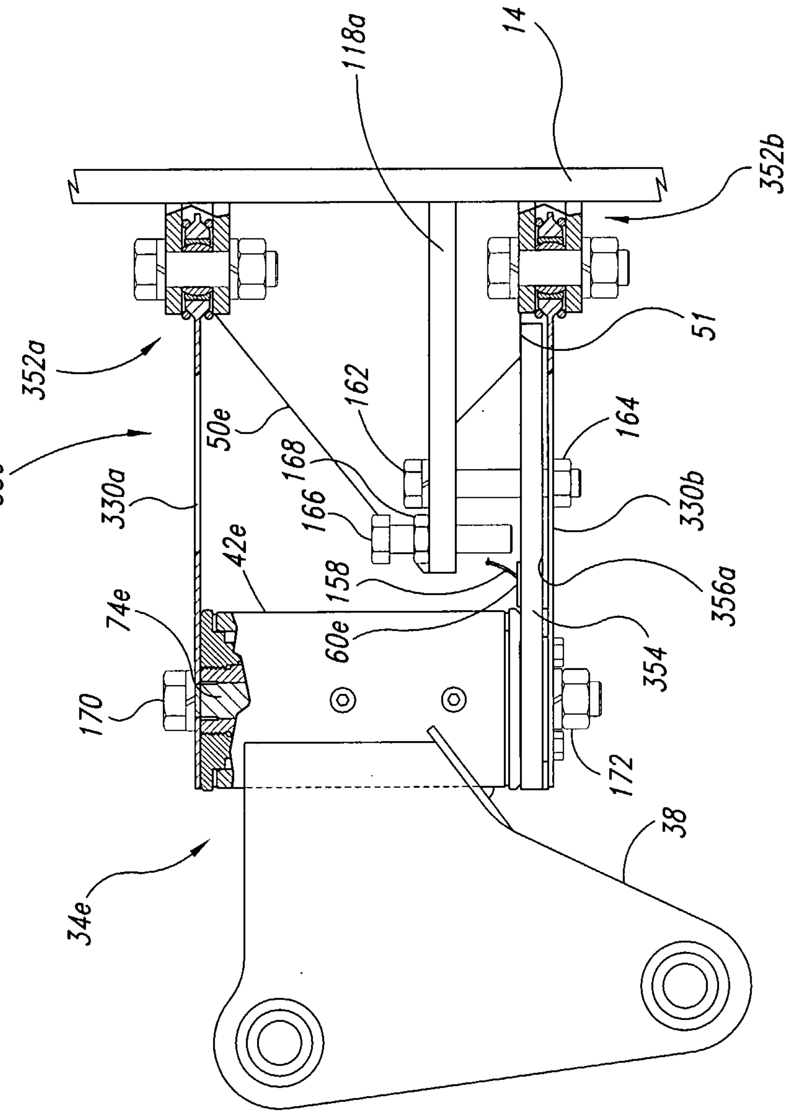
34d

Fig. 8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172
38
34e

Fig. 9

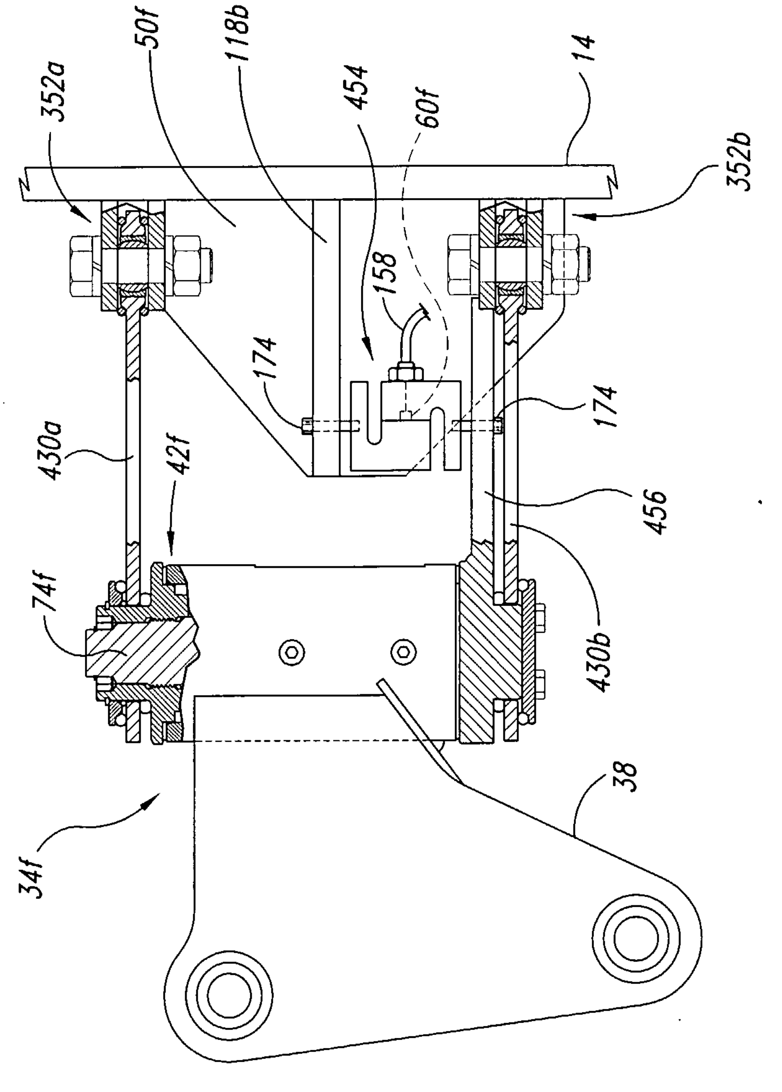
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Fig. 10

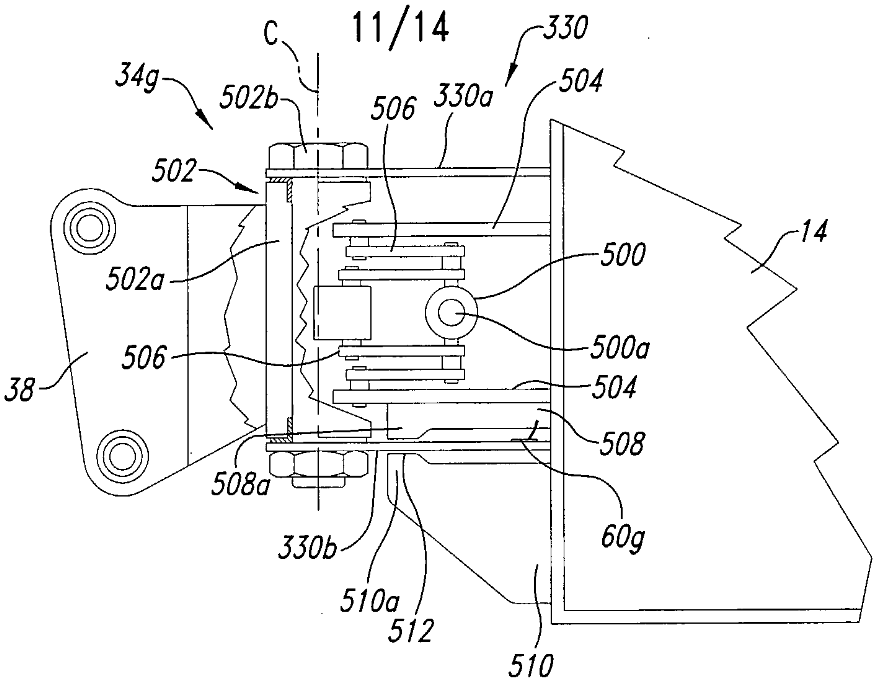

Fig. 11A

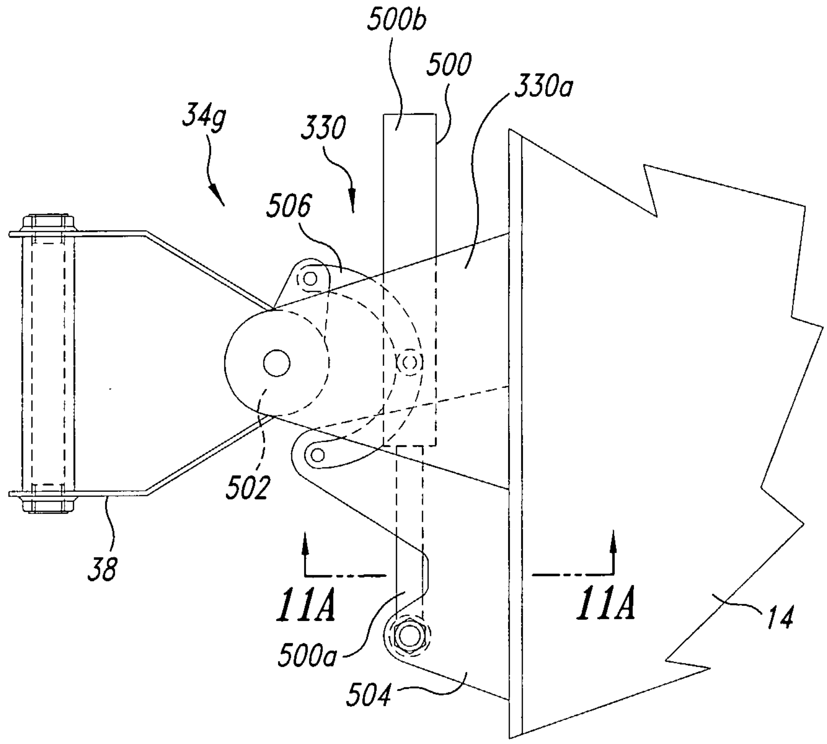

Fig. 11B

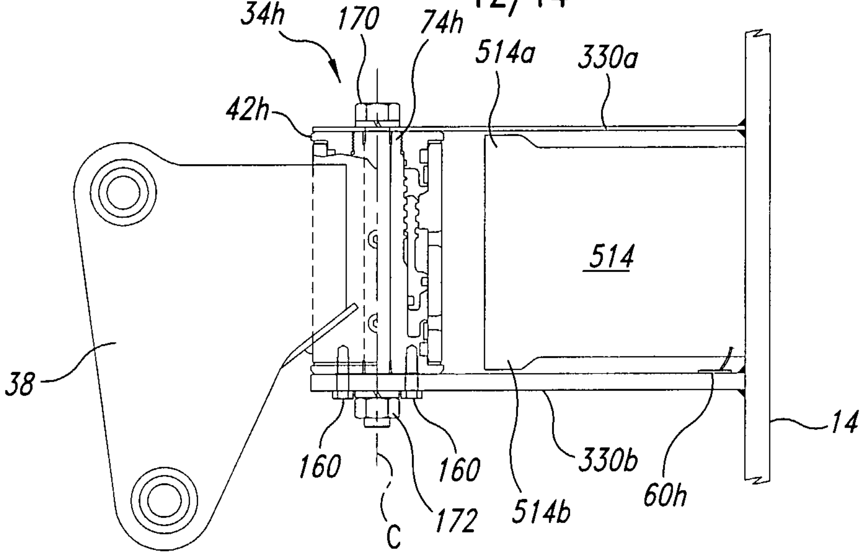

Fig. 12A

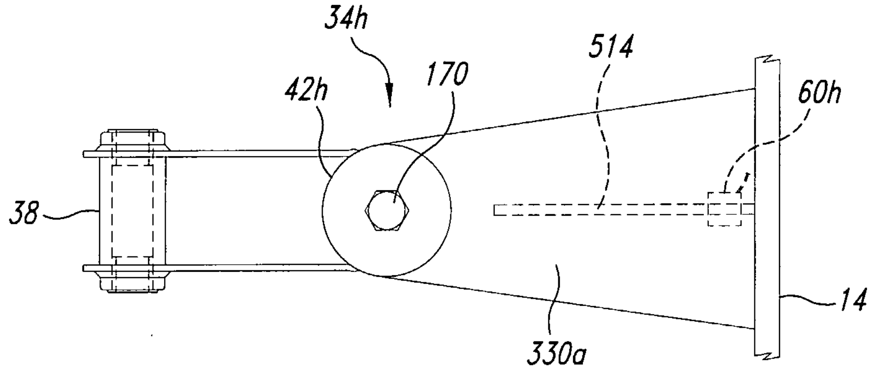

Fig. 12B

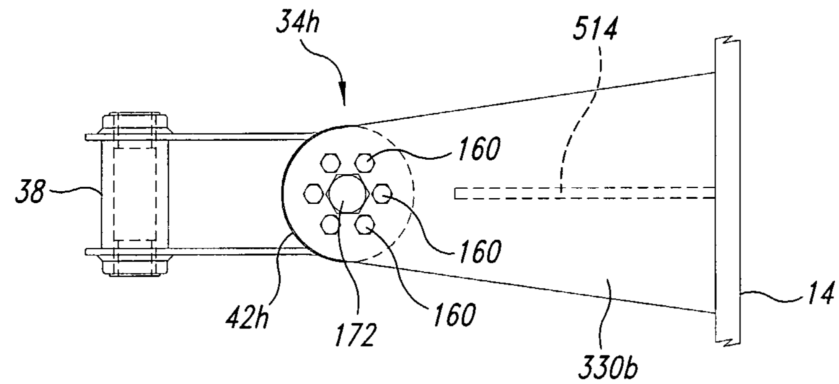

Fig. 12C

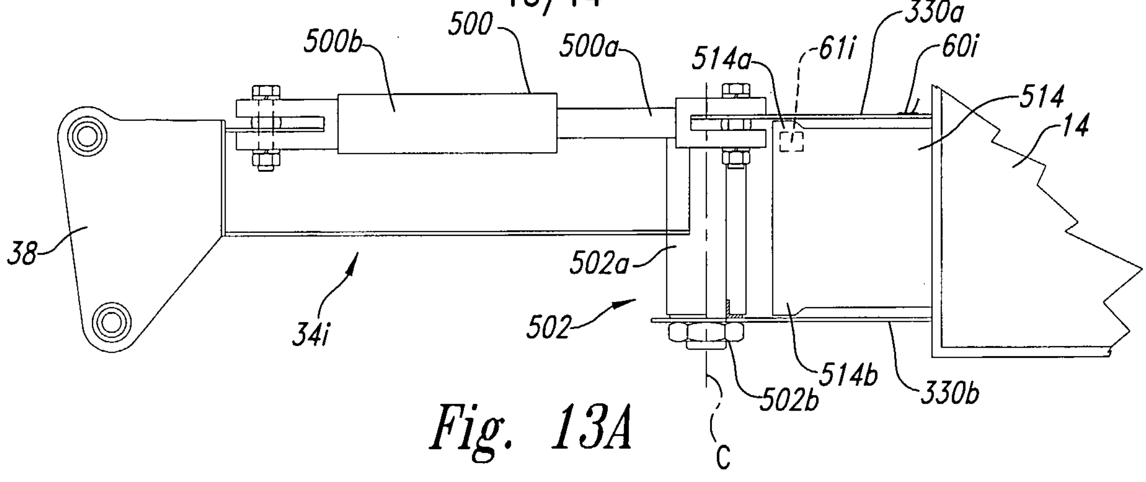

Fig. 13A

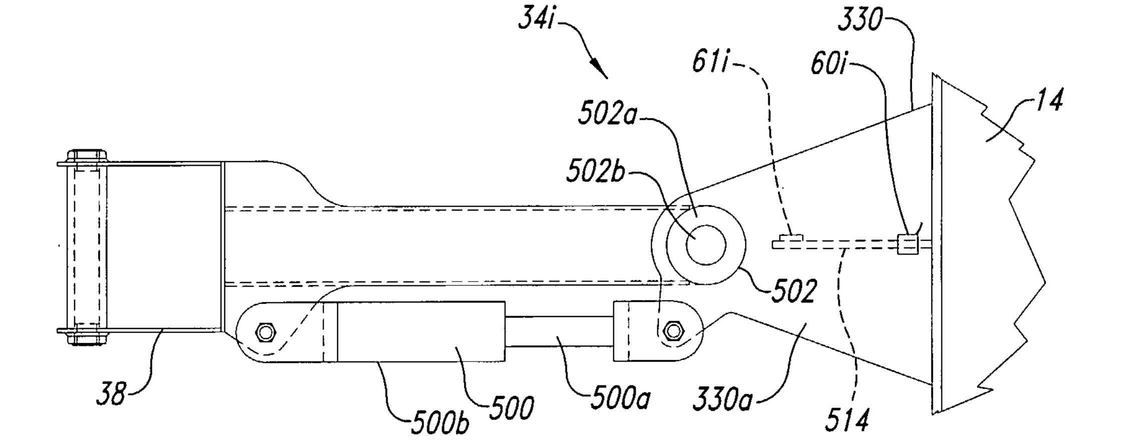

Fig. 13B

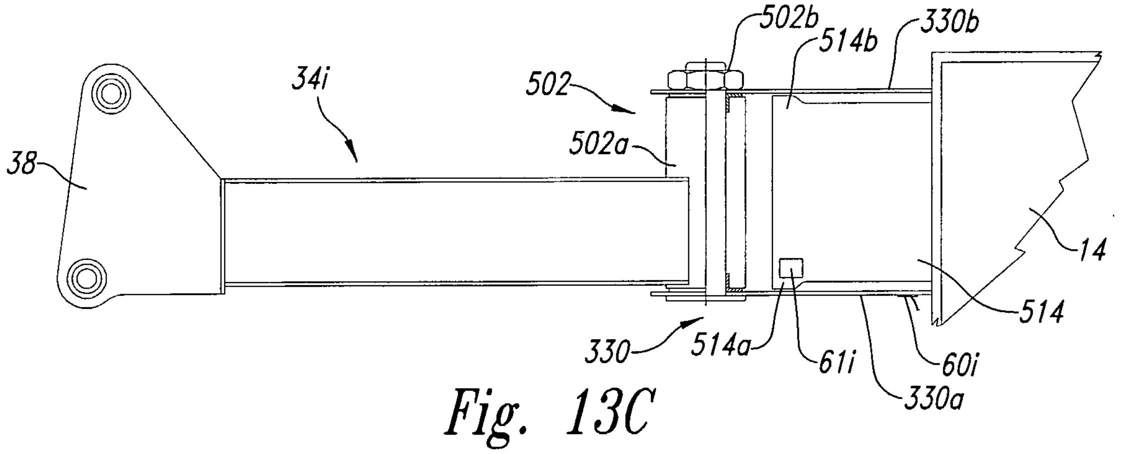

Fig. 13C

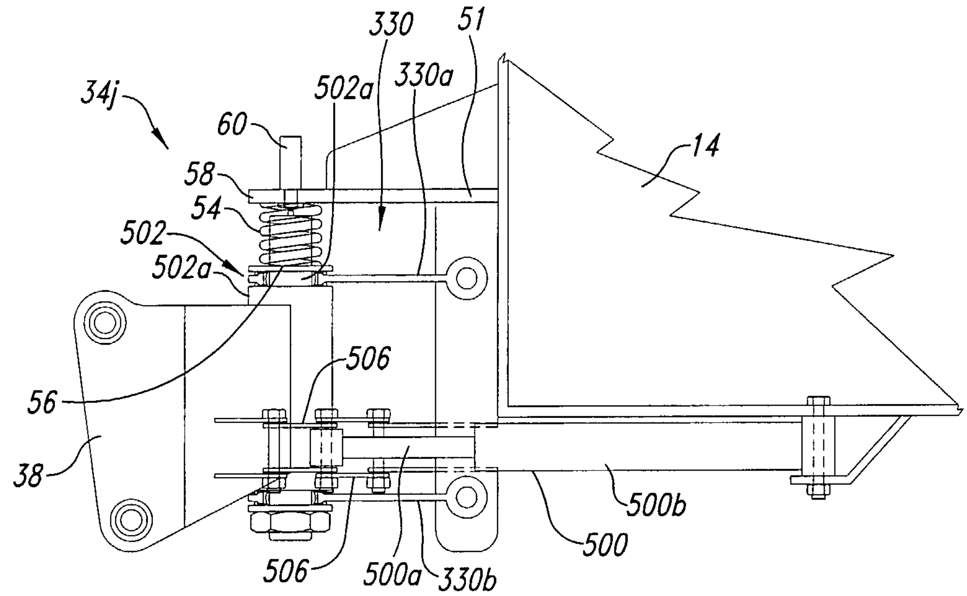

Fig. 14A

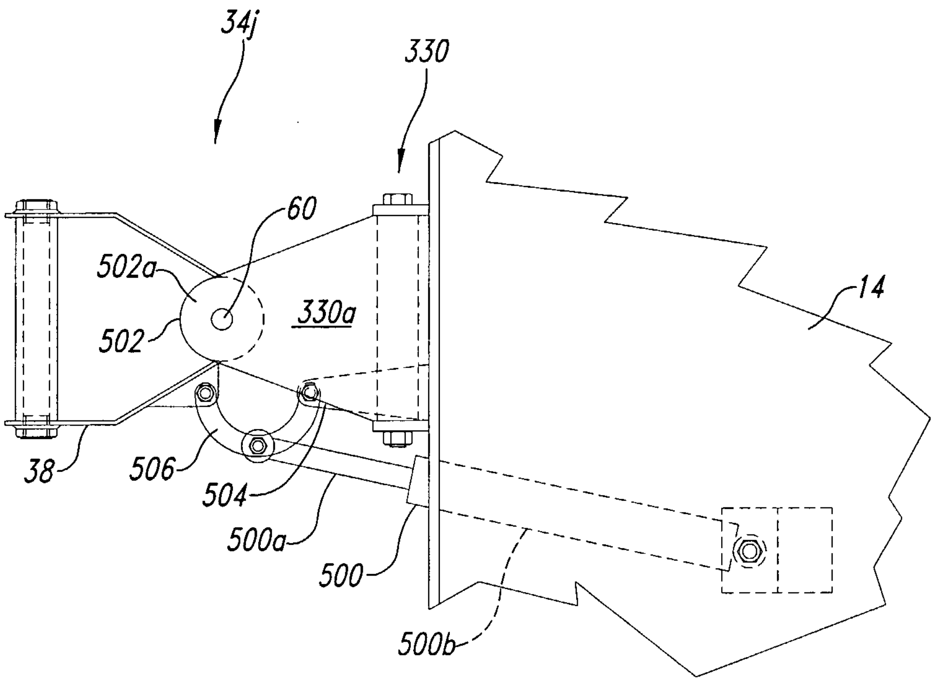

Fig. 14B