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(54) MINIMAL TILL MANURE APPLICATION UNITS

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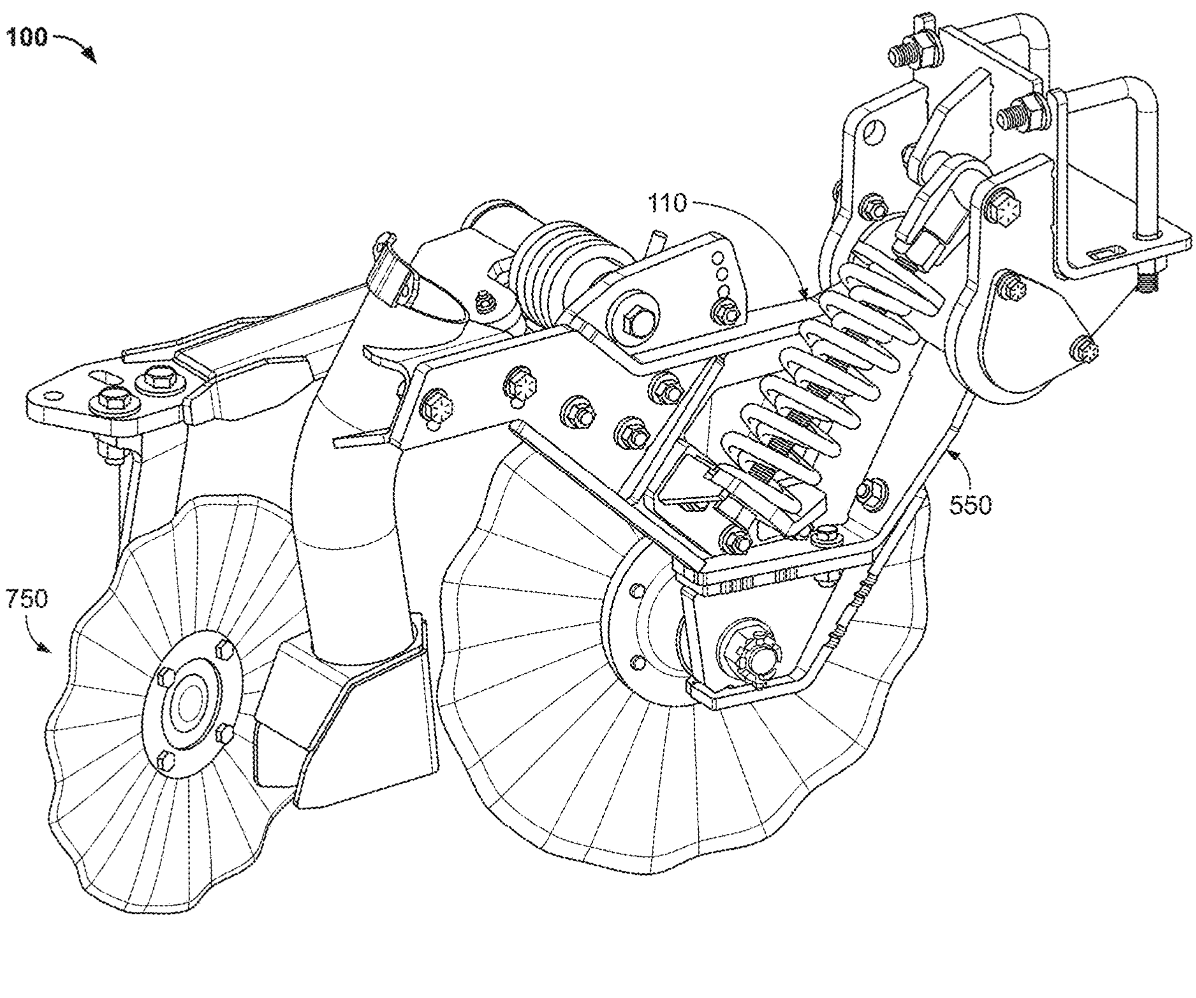
CPC *A01C 15/001* (2013.01)

(57) **ABSTRACT**

An example manure application unit can include: a main arm pivotally mounted to a toolbar mount tube; a coulter blade operatively connected to the main arm; a closure arm pivotally mounted to the main arm; a closure blade mounted to the closure arm; a main arm downforce assembly, operatively connected between the toolbar mount tube and the main arm, to provide an adjustable downforce force to maintain the coulter blade engaged with ground; and a closure arm torsion spring, operatively connected to the closure arm, to provide varying downforce forces on the closure blade to maintain the closure blade engaged with the ground during operation.



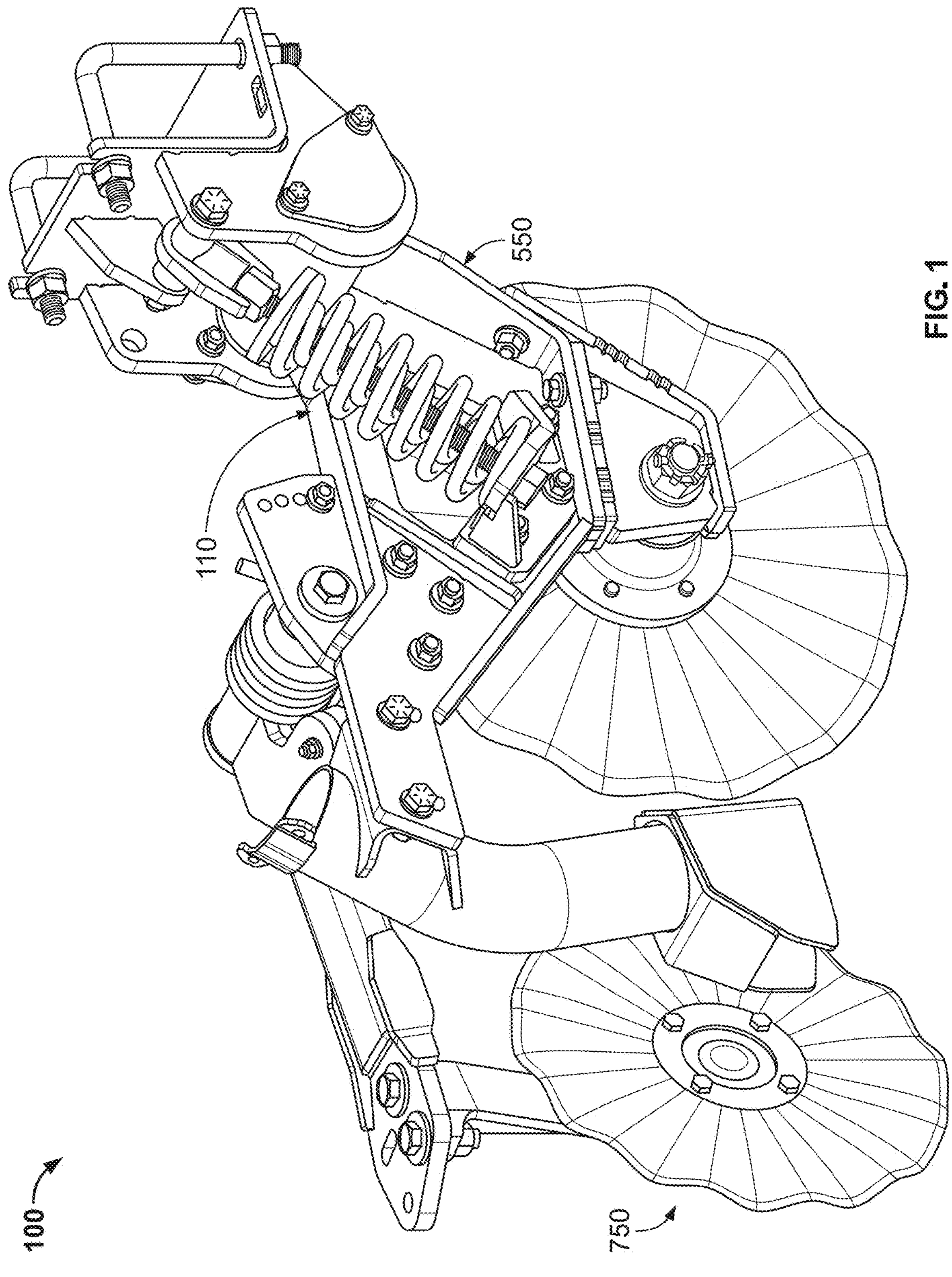


FIG. 1

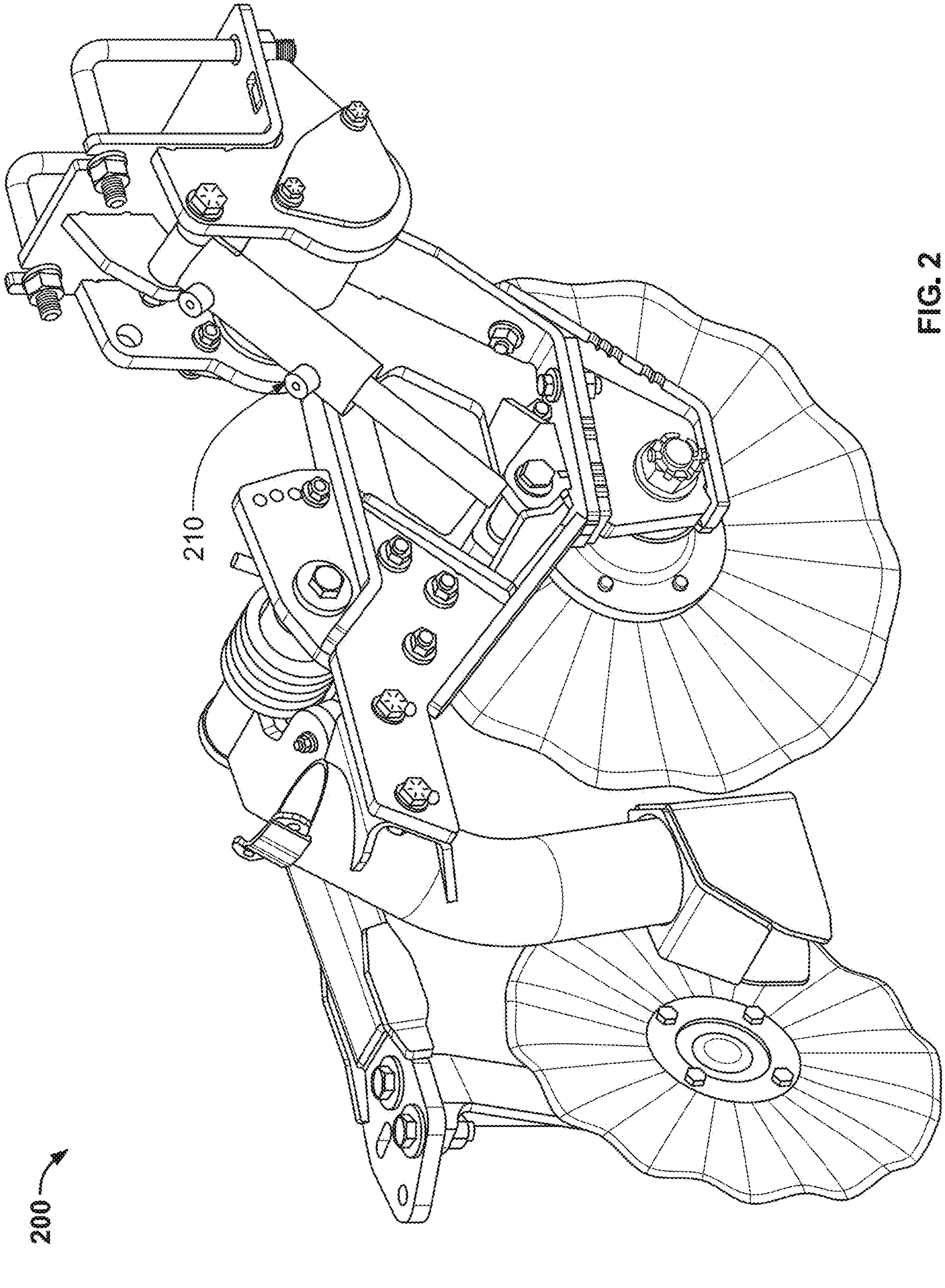


FIG. 2

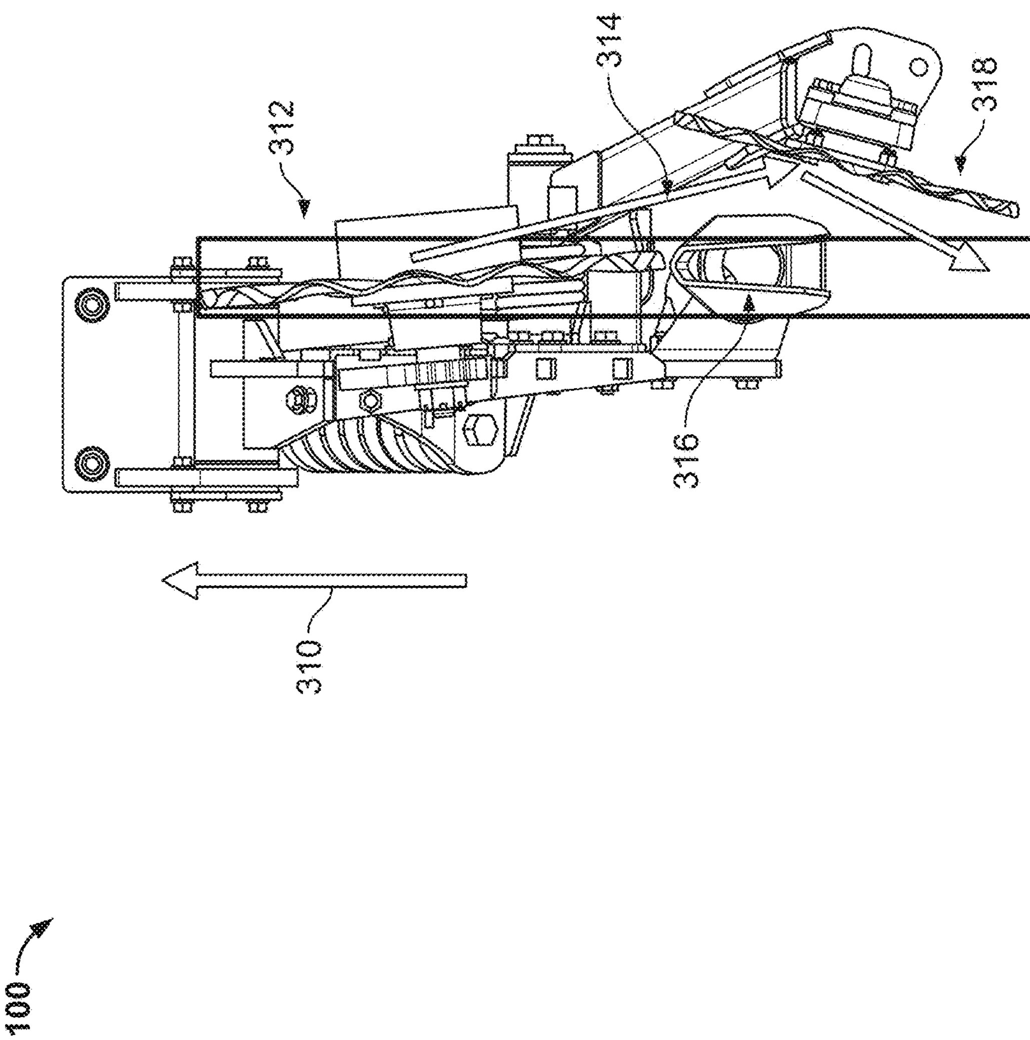


FIG. 3

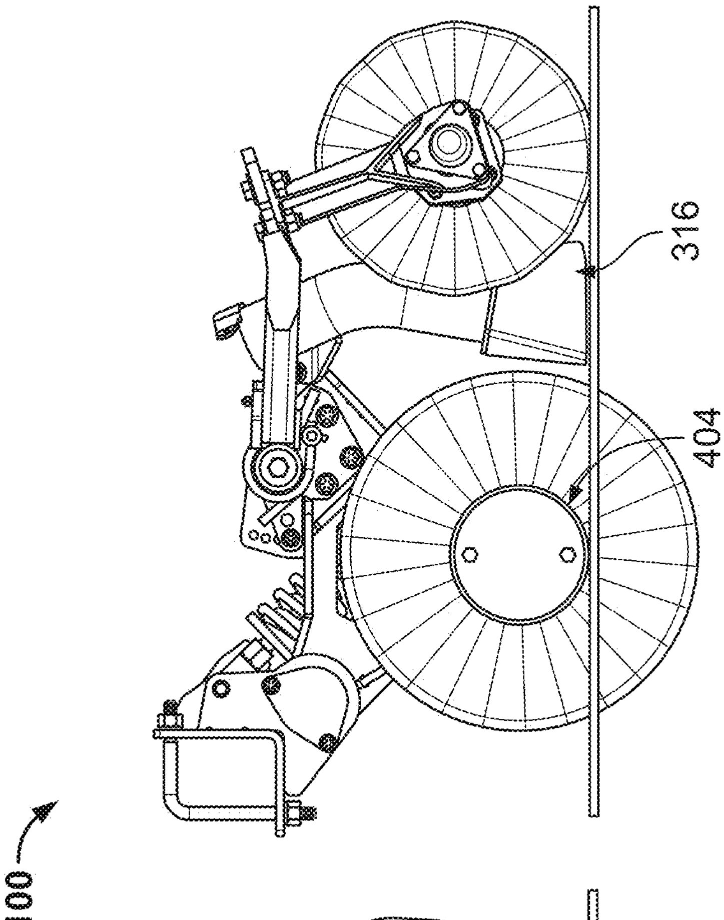


FIG. 4B

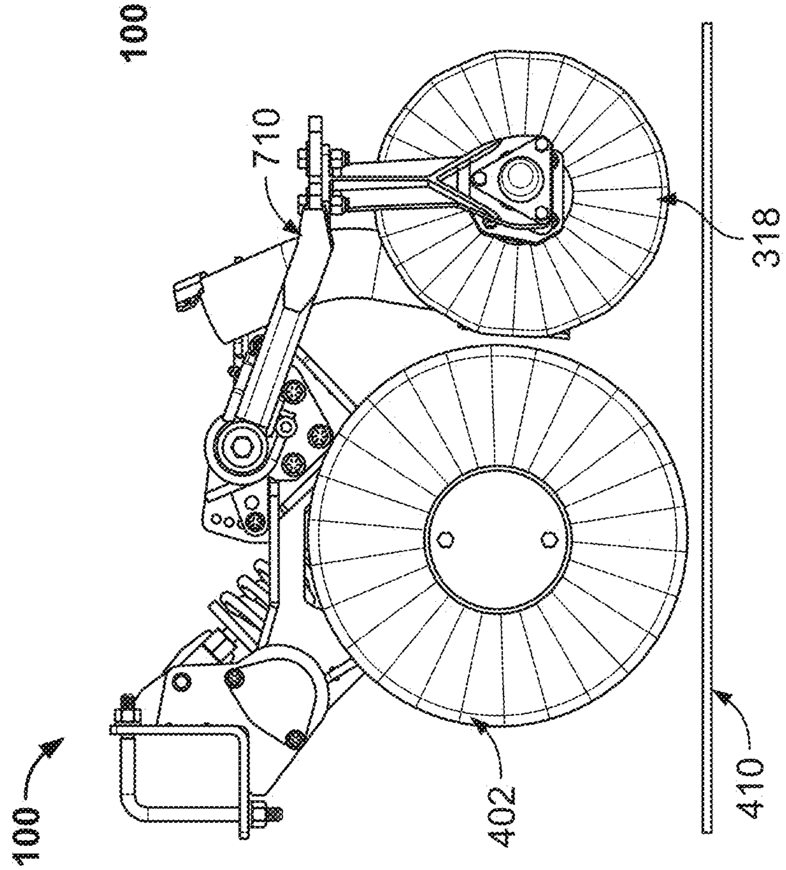


FIG. 4A

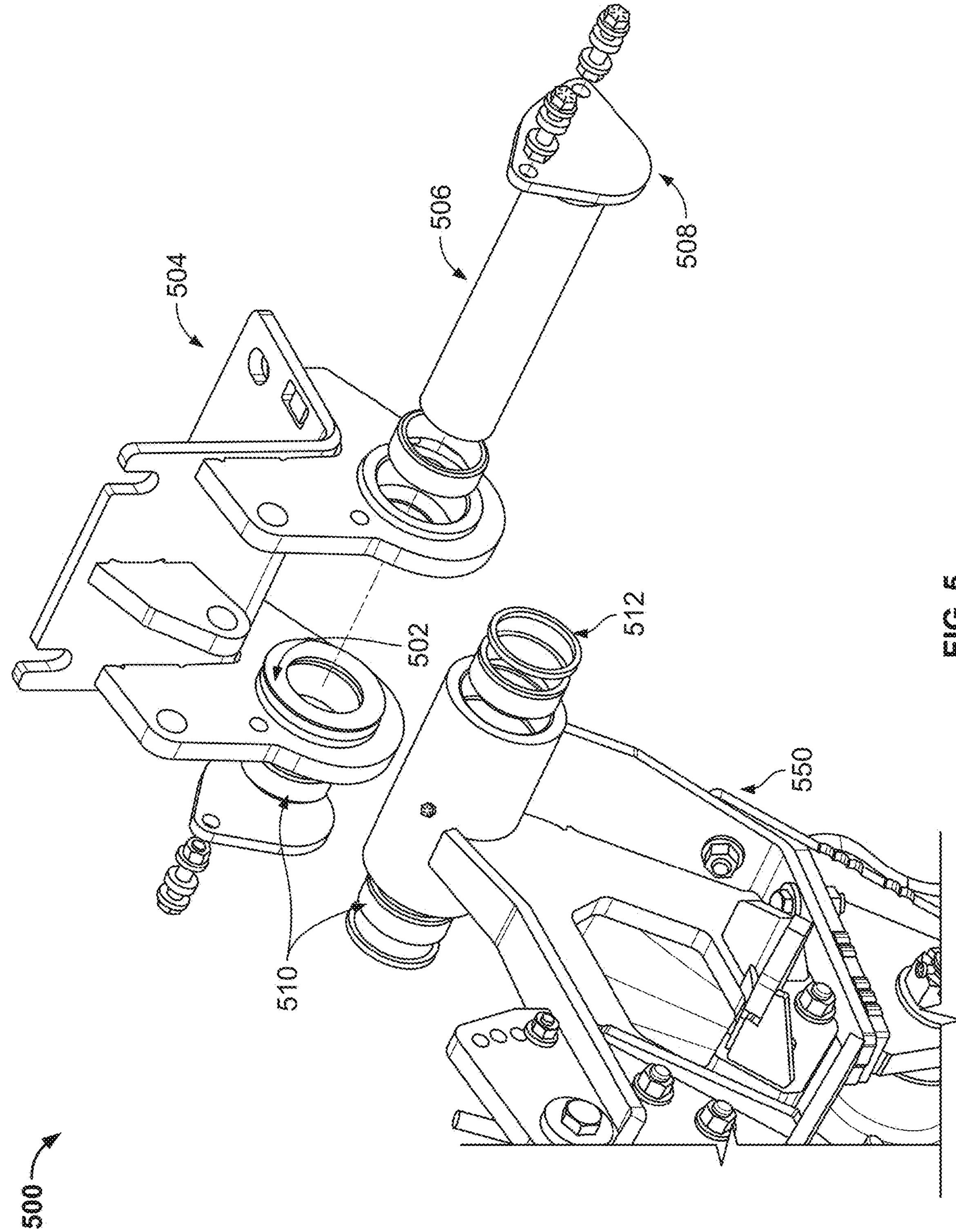


FIG. 5

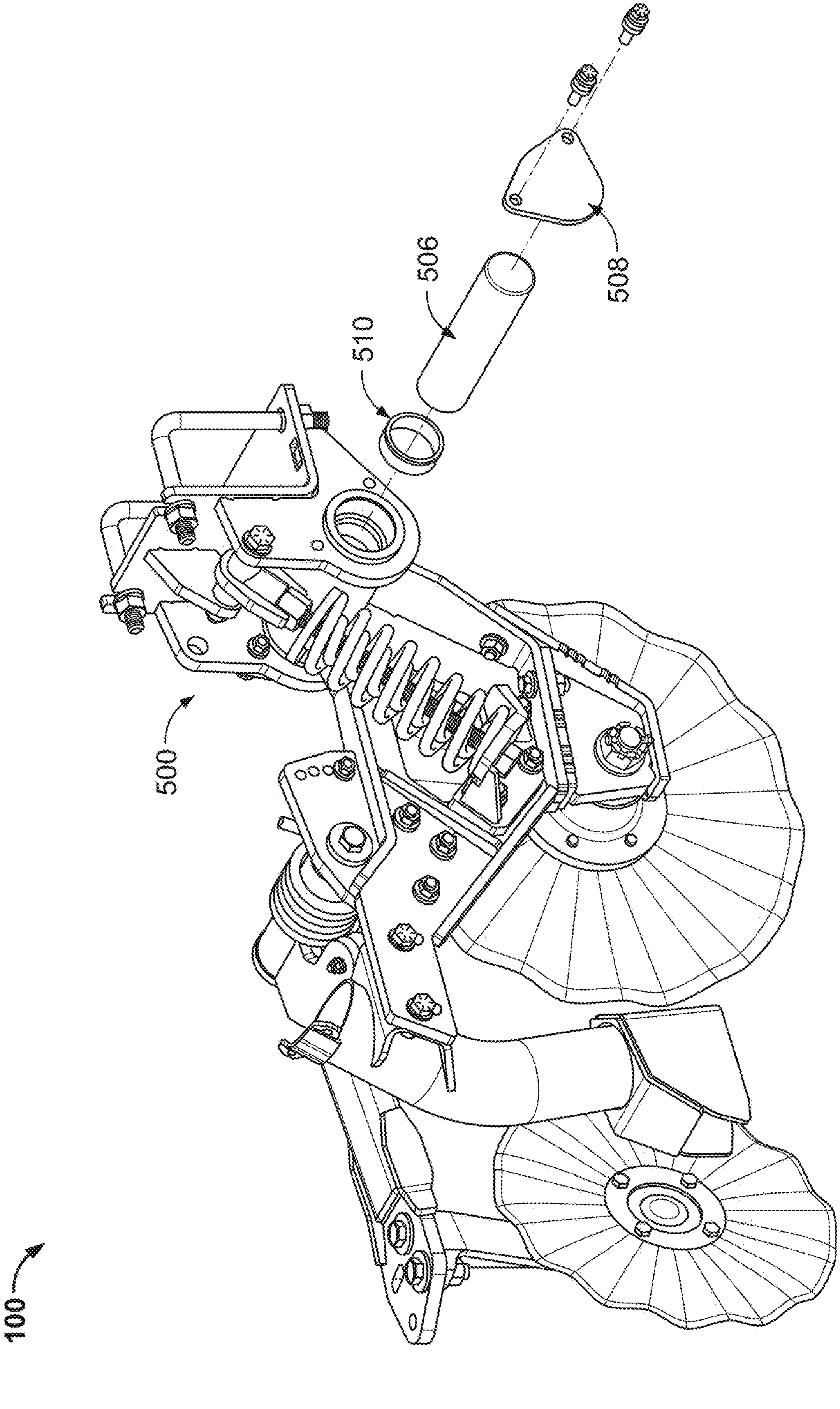


FIG. 6

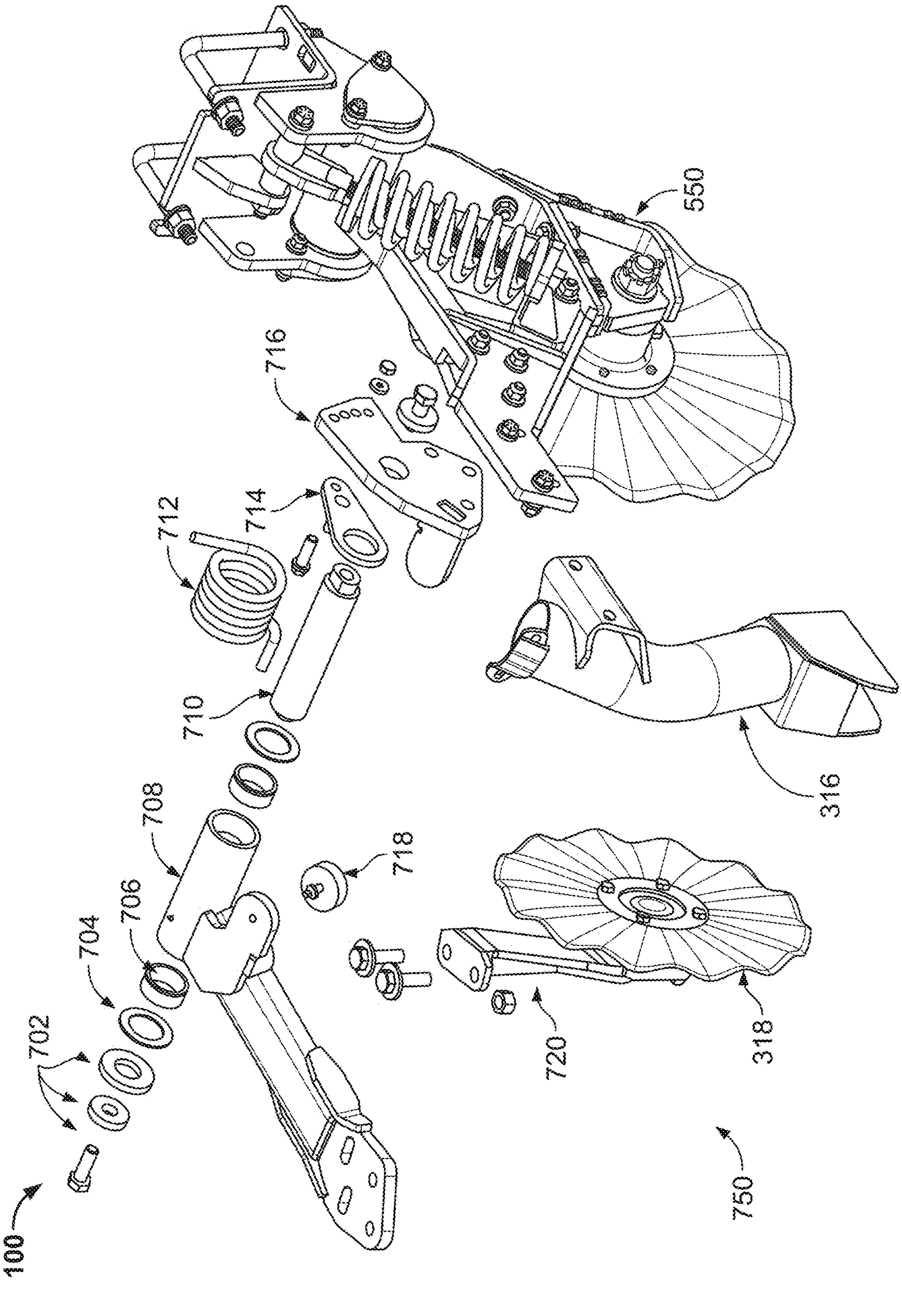


FIG. 7

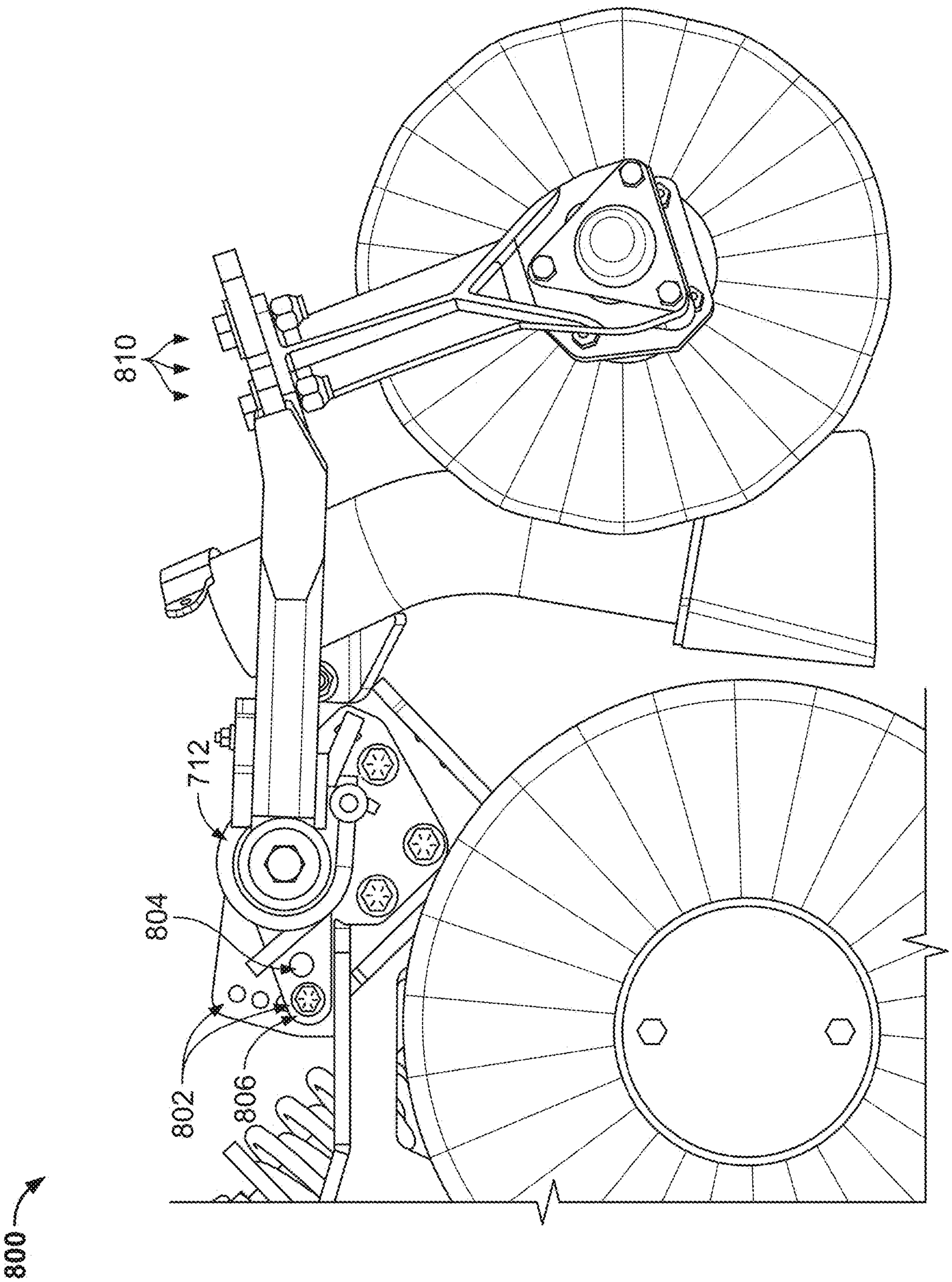


FIG. 8

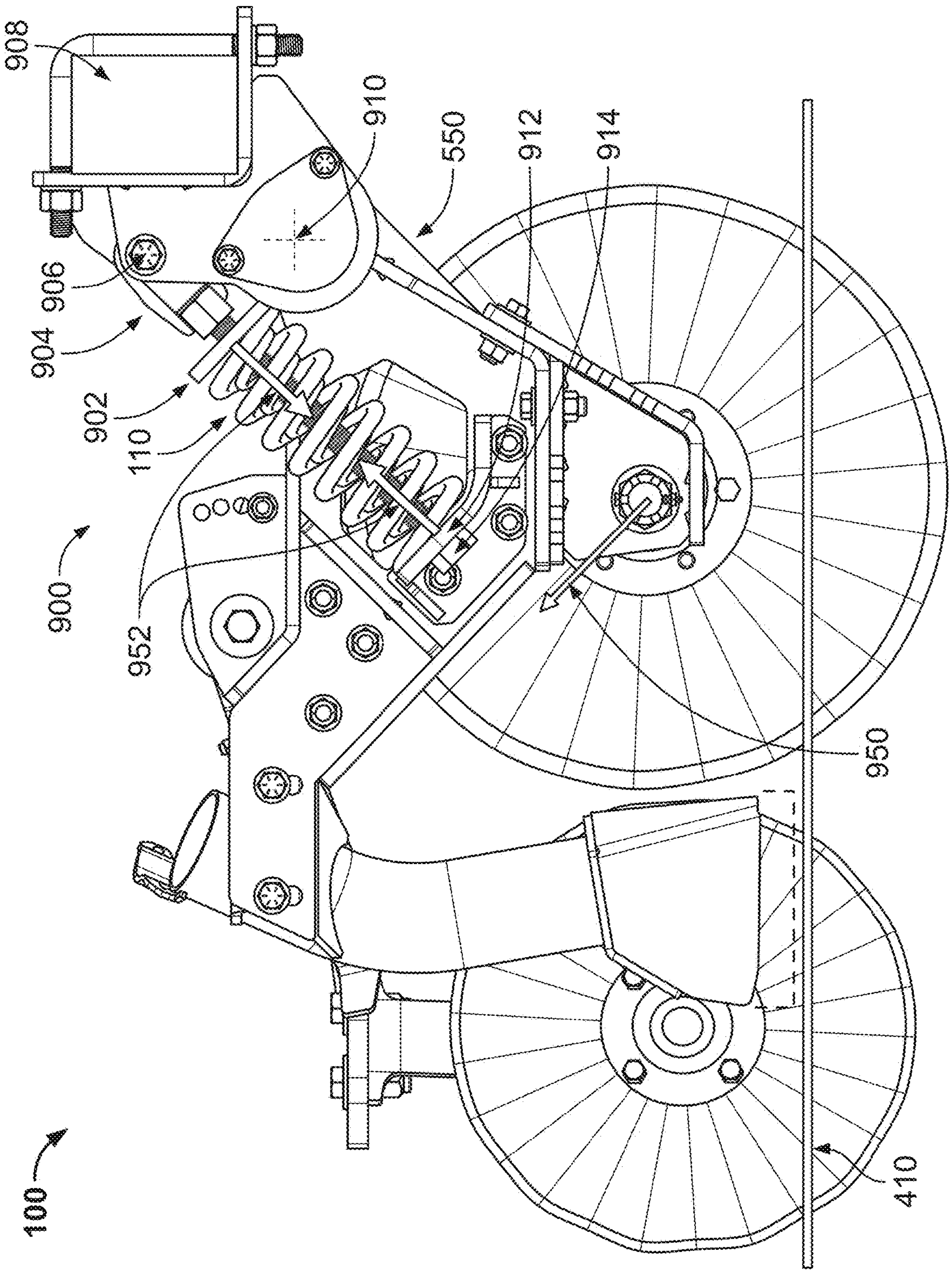


FIG. 9

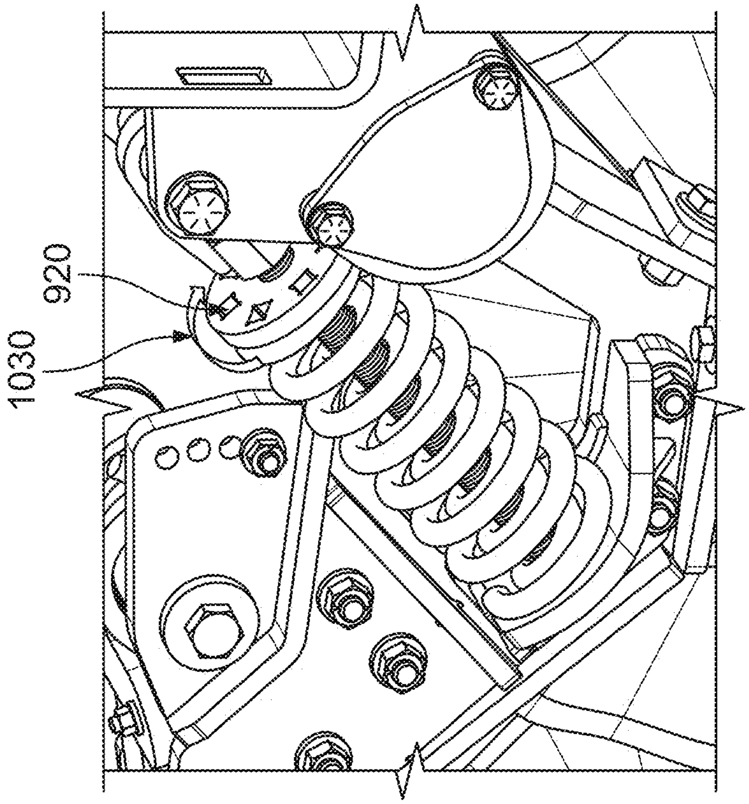


FIG. 10B

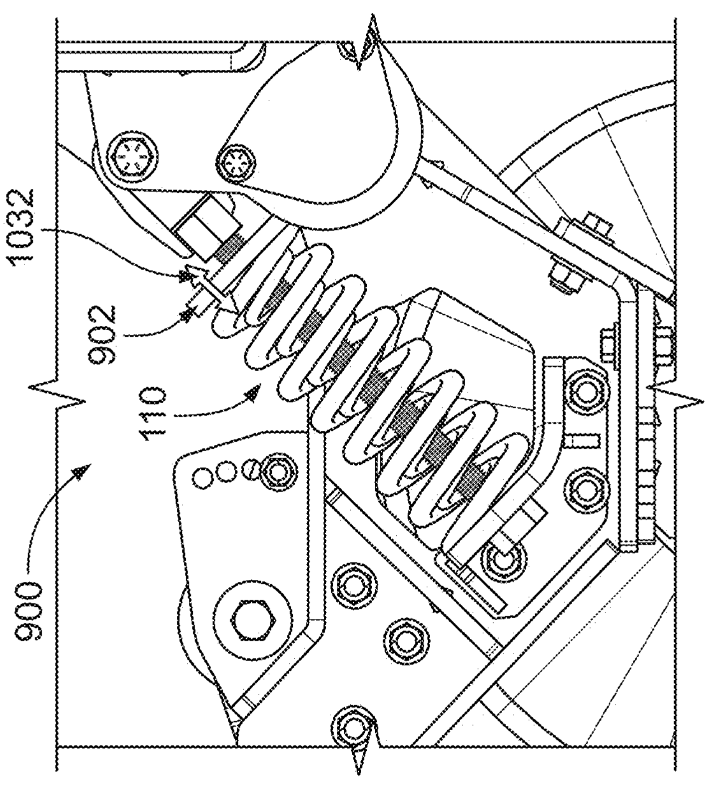


FIG. 10A

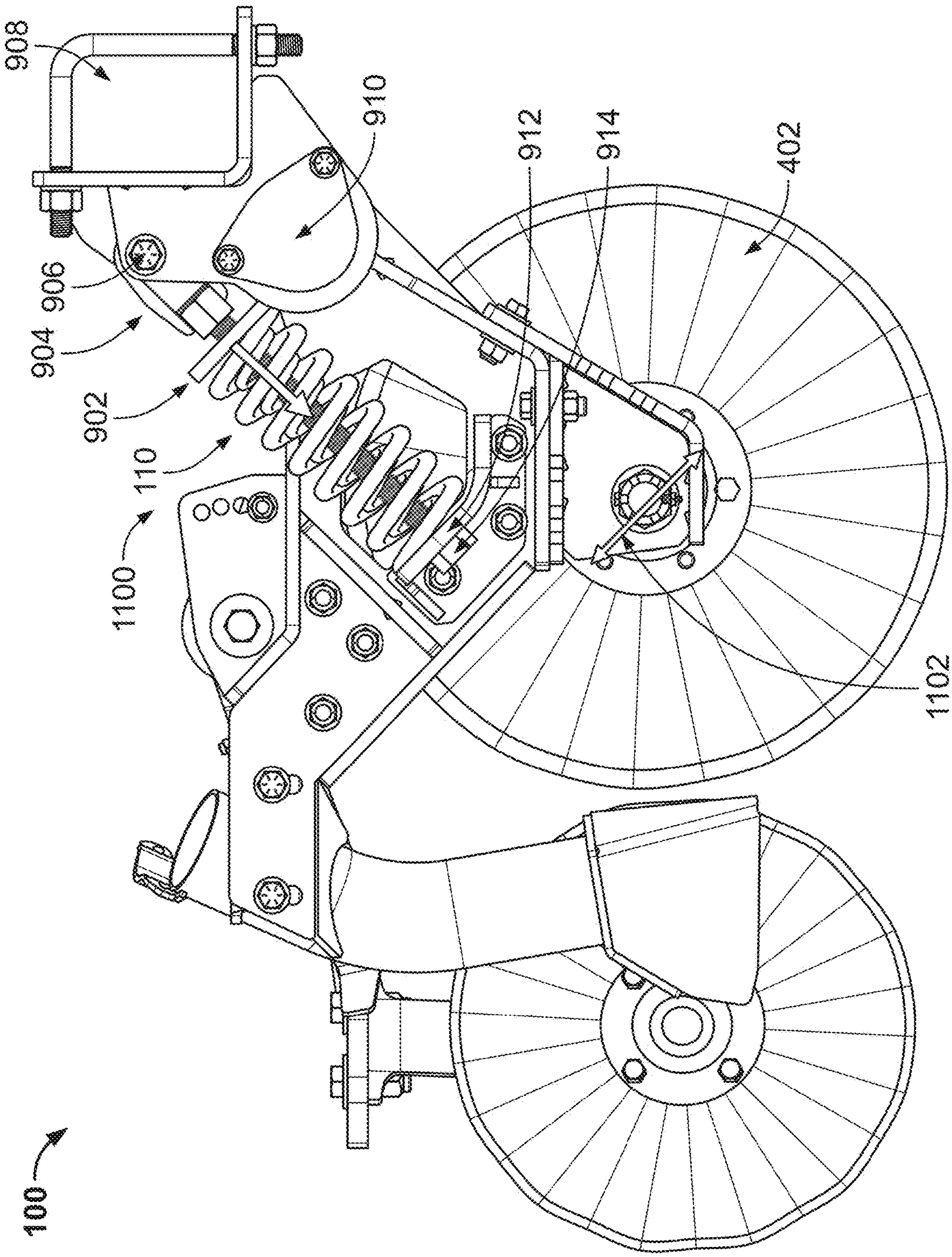


FIG. 11

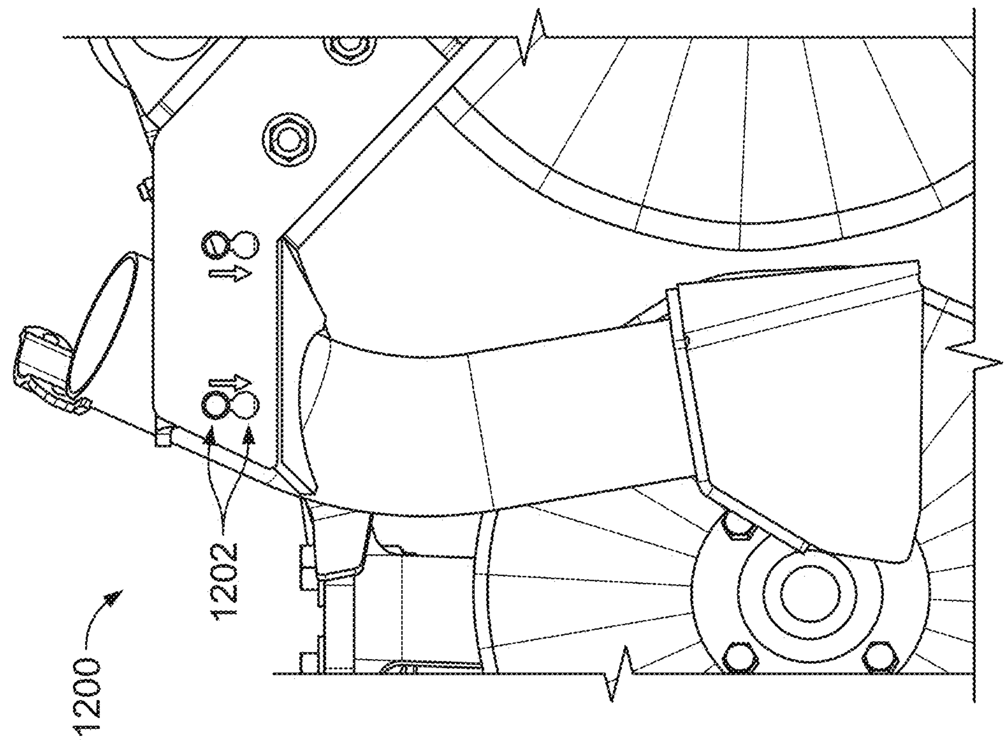


FIG. 12B

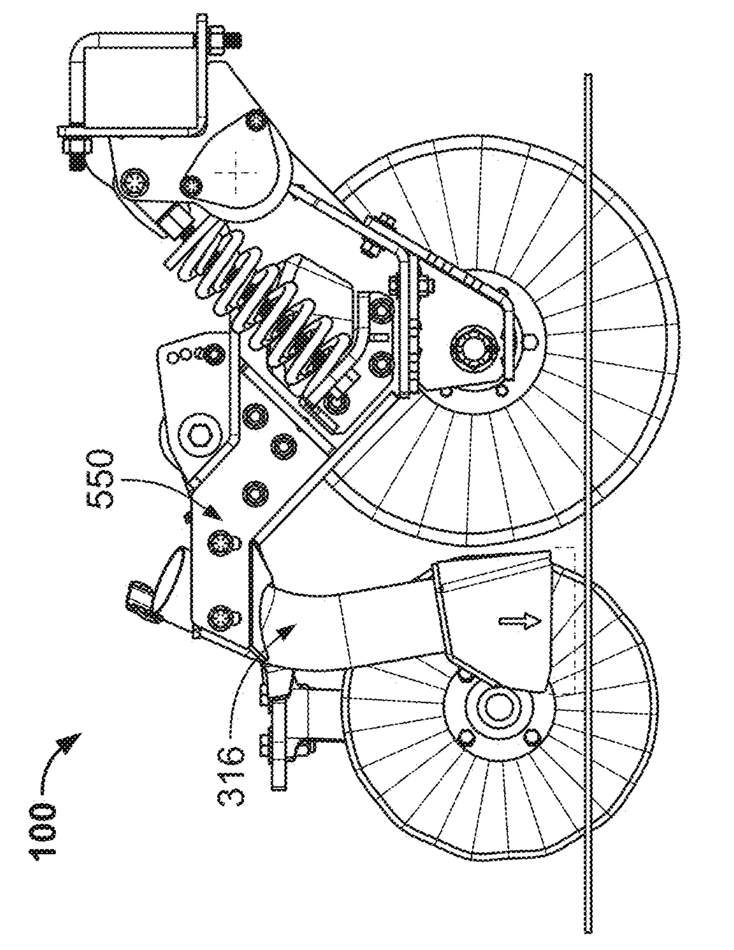


FIG. 12A

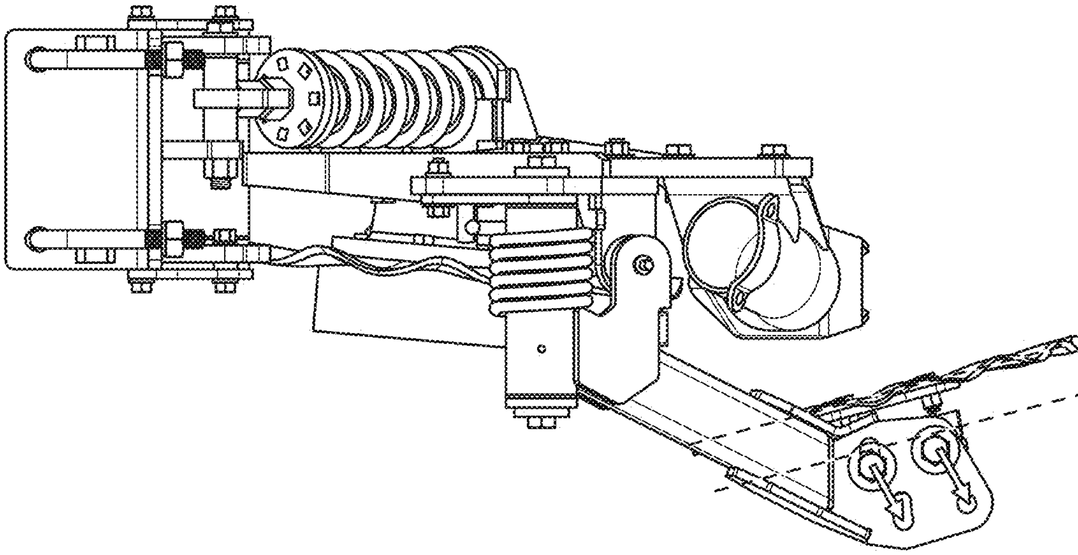


FIG. 13B

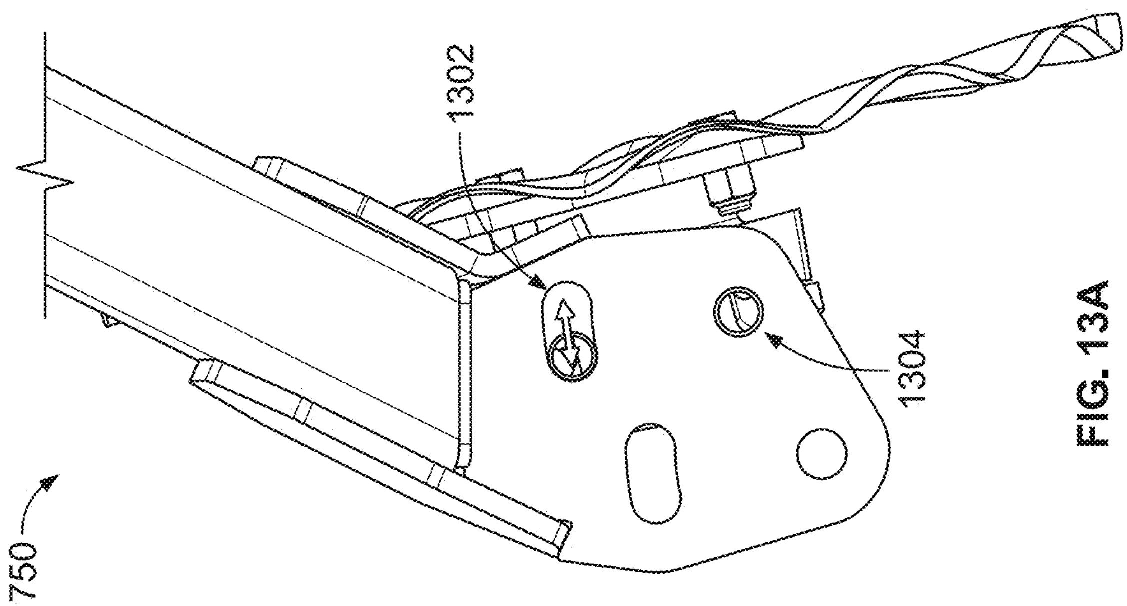


FIG. 13A

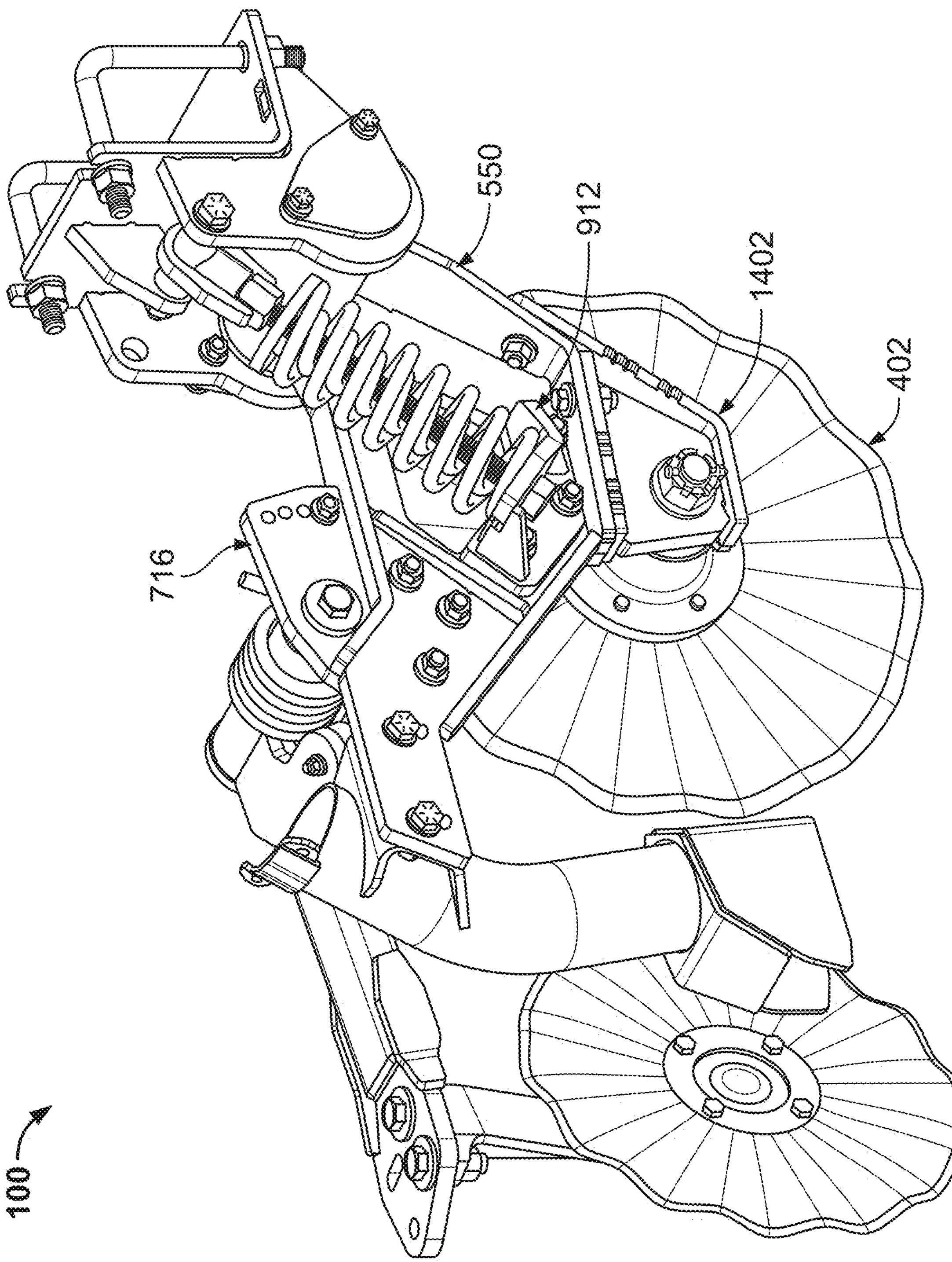


FIG. 14

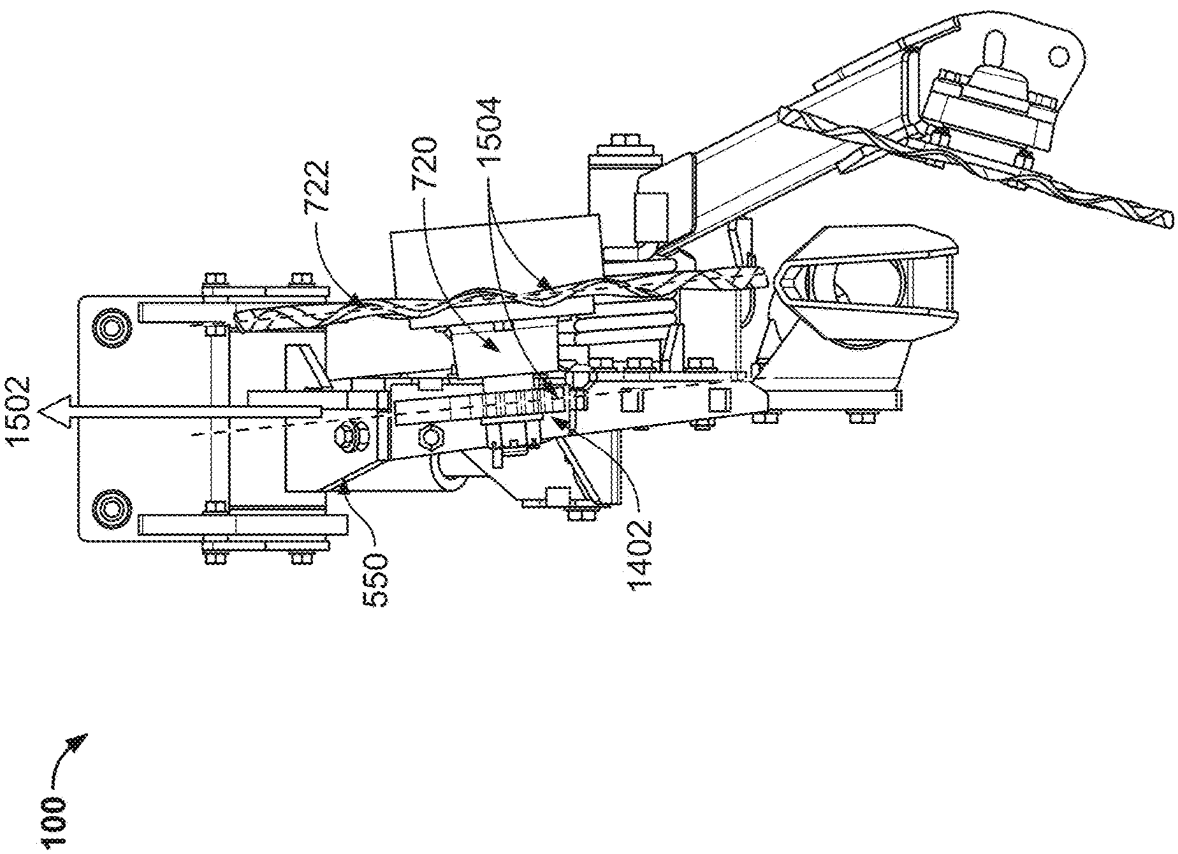


FIG. 15

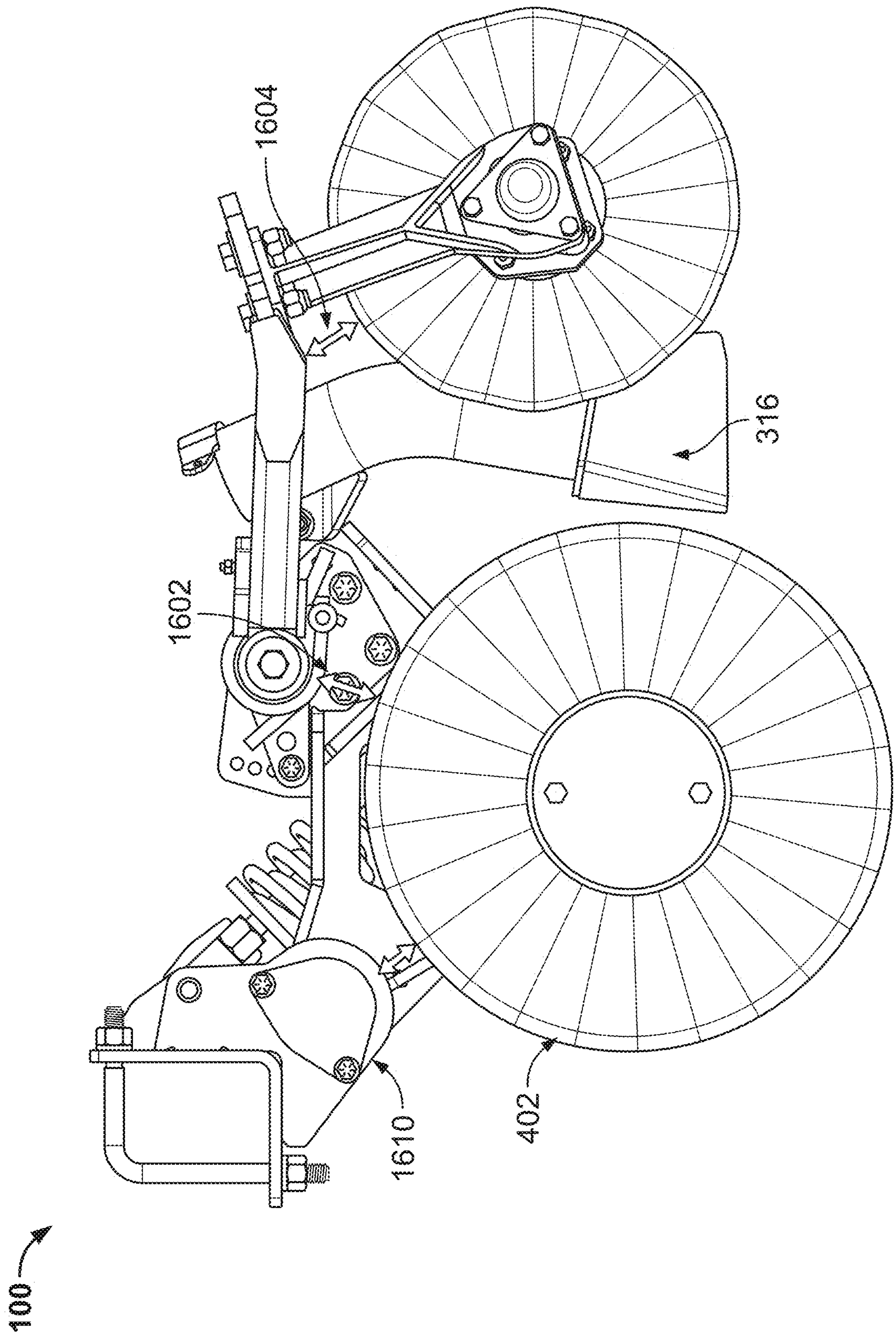


FIG. 16

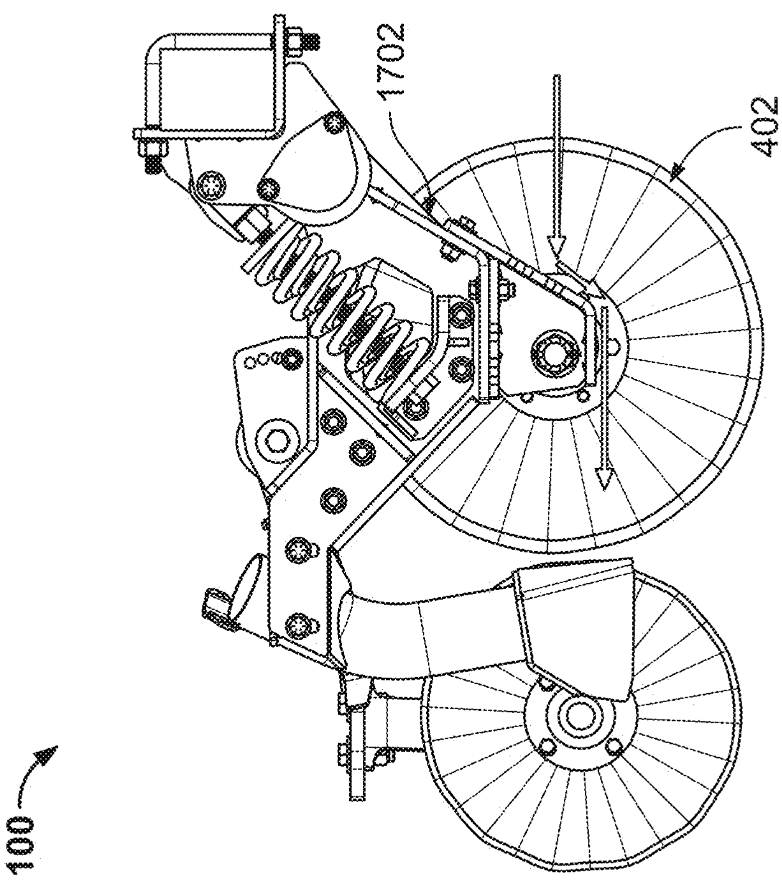


FIG. 17A

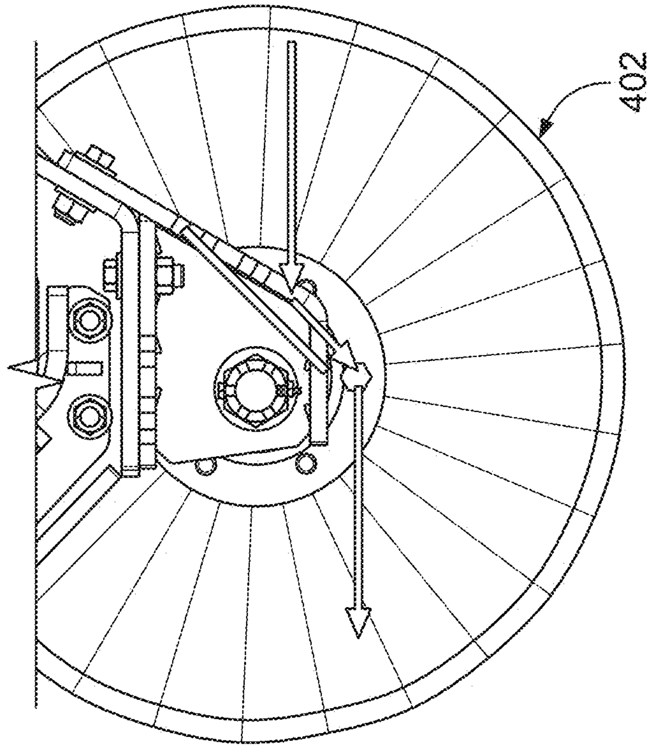


FIG. 17B

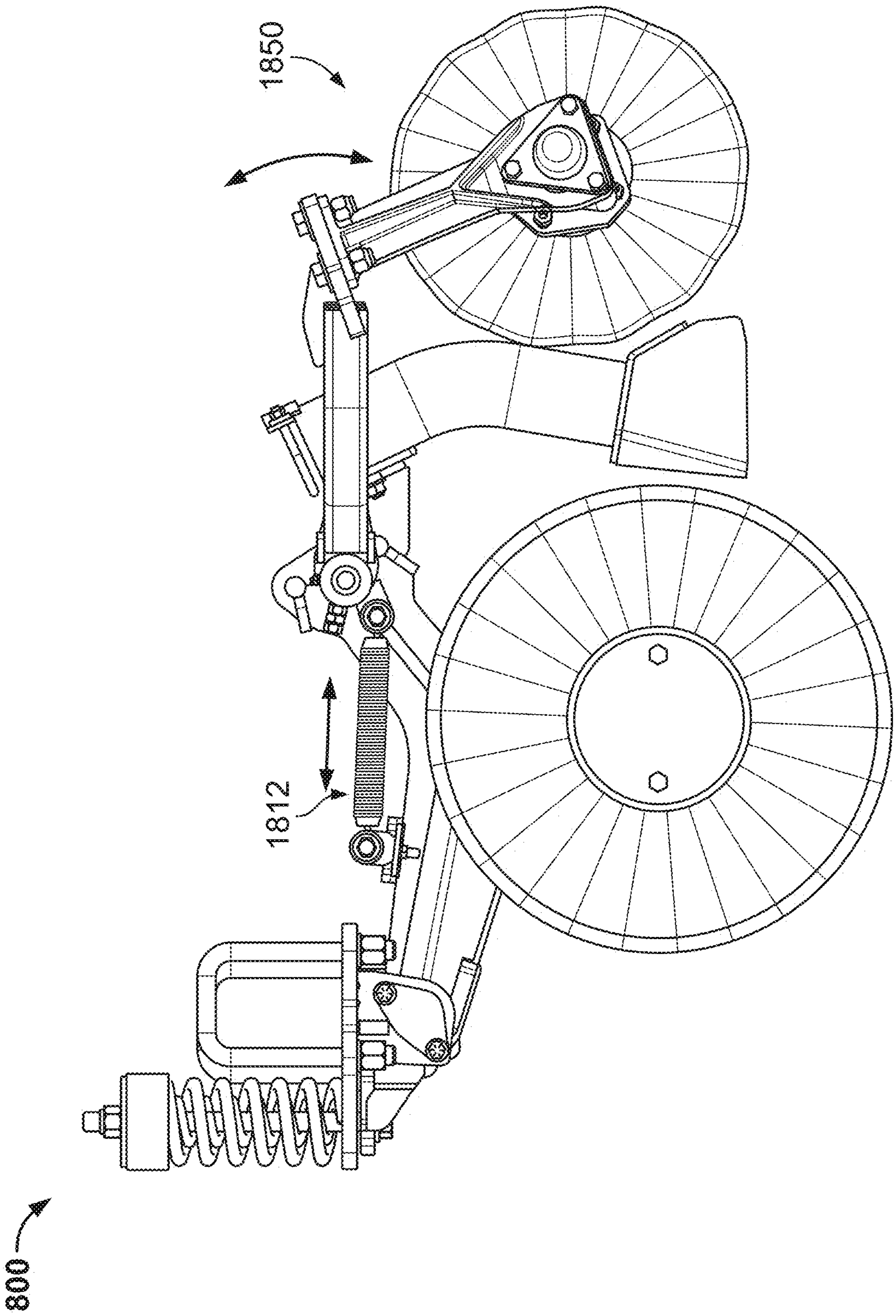


FIG. 18

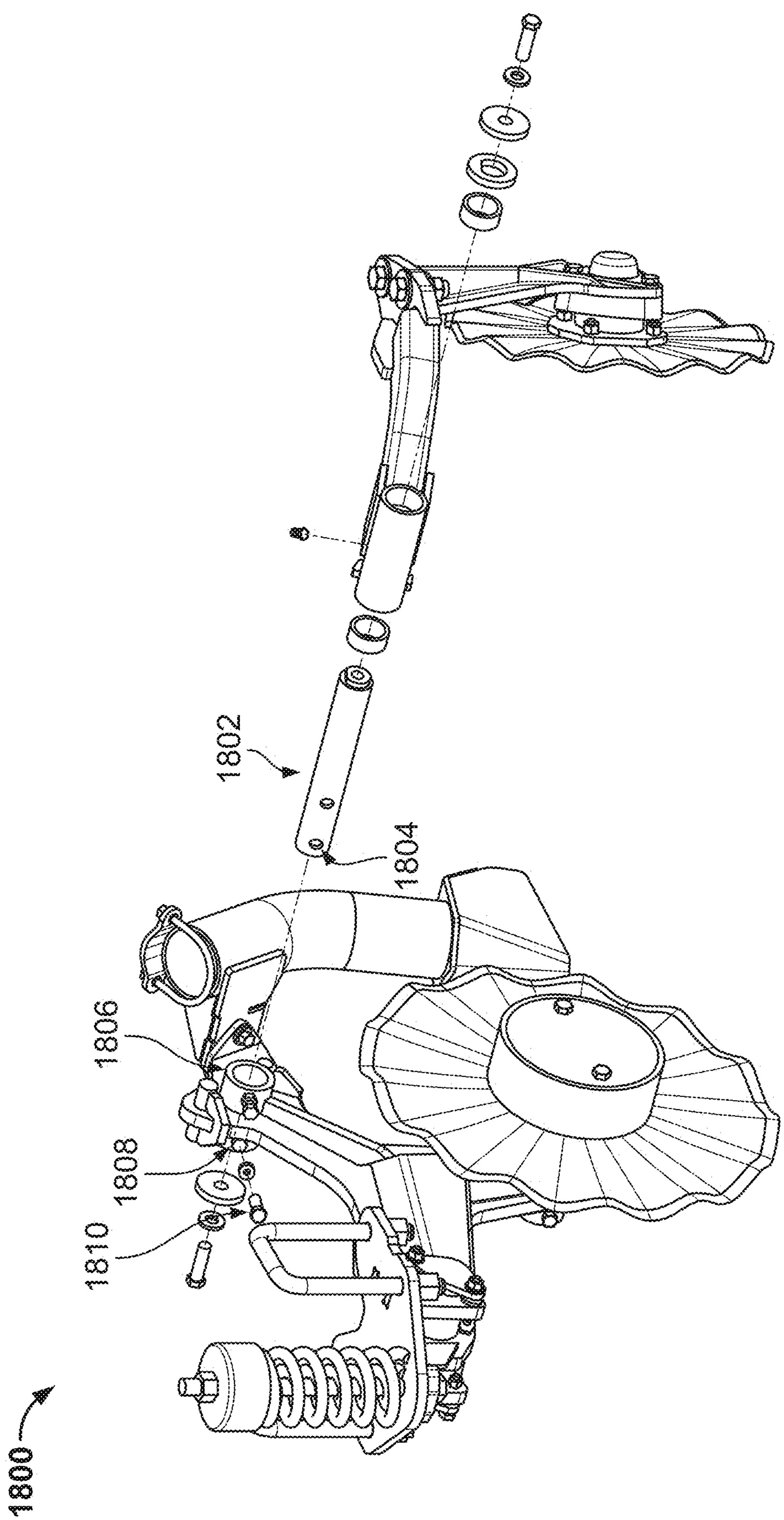


FIG. 19

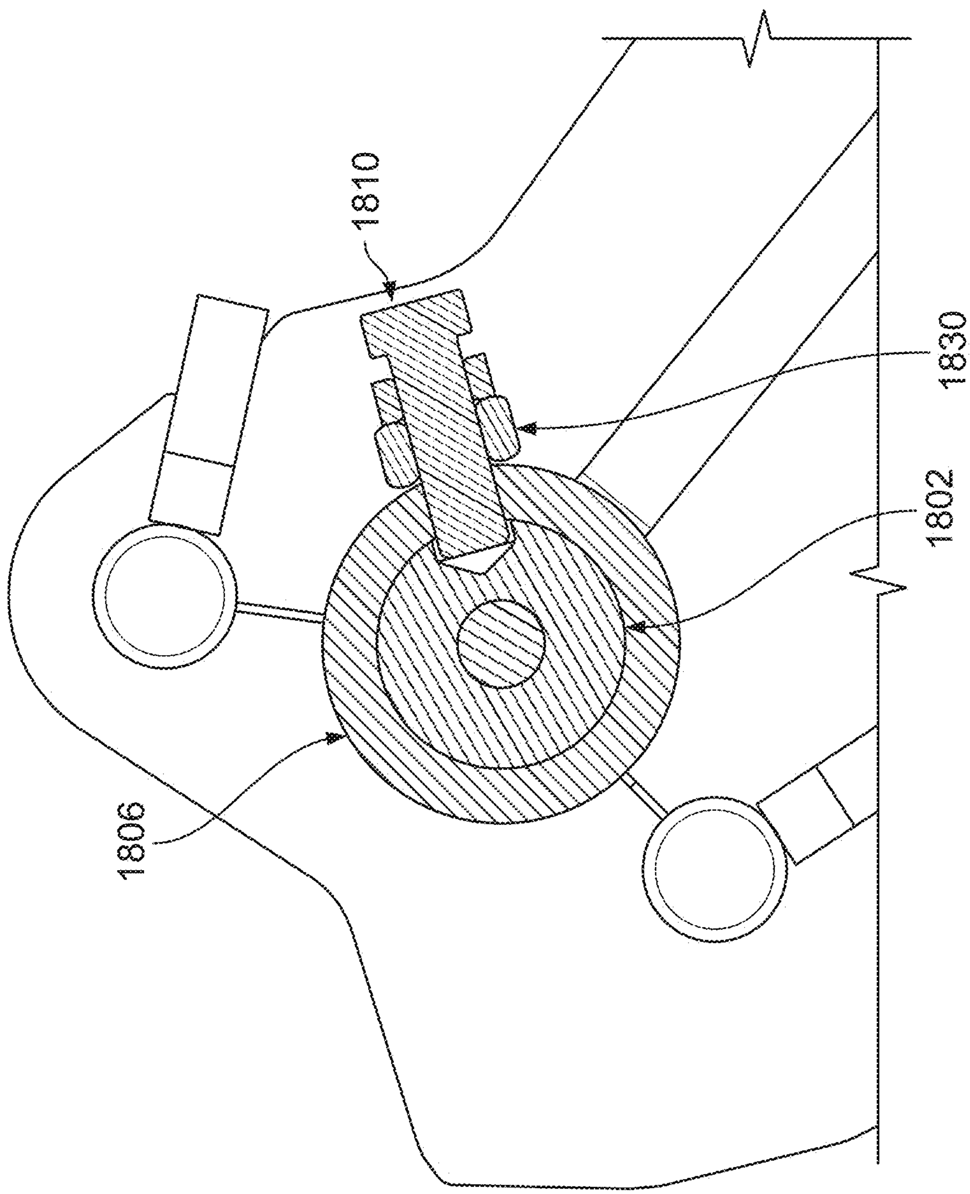


FIG. 20

MINIMAL TILL MANURE APPLICATION UNITS

RELATED APPLICATION(S)

[0001] This patent application incorporates U.S. Patent Application No. 63/555,342 filed on Feb. 19, 2024 in its entirety.

BACKGROUND

[0002] The application of manure to a field during tilling can be a complex process. It can require a consistent application of manure at a desired depth to be effective. This requires an applicator that is flexible in terms of operation and adaptable to the specific environment. Further, maintenance of such applicators can be cost-prohibitive and time-consuming.

SUMMARY

[0003] In one aspect, an example manure application unit can include: a main arm pivotally mounted to a toolbar mount tube; a coulter blade operatively connected to the main arm; a closure arm pivotally mounted to the main arm; a closure blade mounted to the closure arm; a main arm downforce assembly, operatively connected between the toolbar mount tube and the main arm, to provide an adjustable downforce force to maintain the coulter blade engaged with ground; and a closure arm torsion spring, operatively connected to the closure arm, to provide varying downforce forces on the closure blade to maintain the closure blade engaged with the ground during operation.

[0004] In another aspect, an example method for manure application can include: pivotally mounting a main arm to a toolbar mount tube; operatively connecting a coulter blade to the main arm; pivotally mounting a closure arm to the main arm; mounting a closure blade to the closure arm; providing an adjustable downforce force by a main arm downforce assembly, operatively connected between the toolbar mount tube and the main arm, to maintain the coulter blade engaged with ground; and providing varying downforce forces by a closure arm torsion spring, operatively connected to the closure arm, to maintain the closure blade engaged with the ground during operation.

DESCRIPTION OF DRAWINGS

[0005] FIG. **1** shows an example manure application unit with a spring.

[0006] FIG. **2** shows another example manure application unit with a hydraulic cylinder.

[0007] FIG. **3** shows example functionality of the manure application unit of FIG. **1**.

[0008] FIGS. **4**A and **4**B show example rest and working positions of the manure application unit of FIG. **1**.

[0009] FIG. **5** shows an example main arm pin assembly of the manure application unit of FIG. **1**.

[0010] FIG. **6** shows an alternate view of the main arm pin assembly of FIG. **5**.

[0011] FIG. **7** shows an example closure arm assembly components of the manure application unit of FIG. **1**.

[0012] FIG. **8** shows an example closure adjustable tension torsion spring system of the manure application unit of FIG. **1**.

[0013] FIG. **9** shows an example main spring adjustment mechanism of the manure application unit of FIG. **1**.

[0014] FIGS. **10**A and **10**B show adjustment of the main spring of the manure application unit of FIG. **1**.

[0015] FIG. **11** shows an example main spring unit height adjustment system of the manure application unit of FIG. **1**.

[0016] FIGS. **12**A and **12**B show example drop tube height adjustment of the manure application unit of FIG. **1**.

[0017] FIGS. **13**A and **13**B show example adjustable closure blade positions of the manure application unit of FIG. **1**.

[0018] FIG. **14** shows example modular design components of the manure application unit of FIG. **1**.

[0019] FIG. **15** shows an example main blade angle mount of the manure application unit of FIG. **1**.

[0020] FIG. **16** shows example anti-clog features of the manure application unit of FIG. **1**.

[0021] FIGS. **17**A and **17**B show additional anti-clog features of the manure application unit of FIG. **1**.

[0022] FIG. **18** shows another example manure application unit.

[0023] FIG. **19** shows additional details of the manure application unit of FIG. **18**.

[0024] FIG. **20** shows a portion of the manure application unit of FIG. **19**.

DETAILED DESCRIPTION

[0025] Referring now to FIGS. **1-2**, example embodiments of manure application units **100**, **200** are shown.

[0026] In these examples, each of the manure application units **100**, **200** is configured to cut a trench in the ground while moving forward, with the main blade engaging at a consistent depth controlled by the depth gauge ring. As the trench is formed, manure flows continuously through the drop tube into the trench. The closure blade then moves the loose dirt back over the trench to bury the manure, maximizing nutrient uptake by crops and minimizing nutrient loss through volatilization or runoff.

[0027] Various coverage improvements can be exhibited by the manure application units described herein. Manure can be buried better and stay in the ground for maximum crop nutrient uptake. The closure arm downforce of the manure application units can stay engaged with the ground to constantly move dirt over the trench without missing areas. The manure application units can include tight fitting, low clearance bushings on all pivots, which have a long wear life. This ensures the blade angles stay consistent, meaning trench size and dirt movement is consistent over the life of the equipment.

[0028] In one example, the manure application unit **100** is configured to provide a spring **110** that is configured to create downforce. Further, some of the manure application units, such as the manure application unit **200**, provide a hydraulic cylinder **210** to create downforce option to ensure the unit stays engaged fully with the ground at a consistent cutting depth in varying hardness of dirt. Downforce is adjustable by controlling the maximum hydraulic pressure allowed into the cylinder.

[0029] Further, the manure application units **100**, **200** can include an adjustable closure blade angle and position for varying speeds which ensures the dirt moved by the trench opening main blade is captured and returned overtop the trench once the manure is in the trench. This can include the capability of working with various coulter blade options, which can be changed depending on hard or soft ground, the need for a larger or fully cleaned out trench, wet or dry conditions, or fields with the need to cut or move more crop residue left after harvest.

[0030] Referring now to FIGS. **3-17**B, additional details on the manure application unit **100** including the spring **110** are shown. The manure application unit **200** can be similarly configured.

[0031] FIG. **3** illustrates example operation of the manure application unit **100**. This includes the key components and their interaction during field operation. The unit travels in a direction **310** while the main blade engages with the ground to cut a trench **312** (schematically referenced) approximately 6 inches deep. As the main blade creates the trench **312**, it generates a specific dirt flow path **314** where soil is displaced from the trench and temporarily positioned on top of the ground surface.

[0032] The manure delivery system operates continuously during this process, with manure flowing through a drop tube **316** directly into the freshly cut trench **312**. This consistent flow ensures uniform manure application throughout the field operation. A closure blade **318**, which follows behind the main blade and manure delivery system, moves the previously displaced loose dirt back over the trench **312** containing the manure.

[0033] This coordinated sequence of operations—trench cutting, manure application, and trench closure—is designed to optimize nutrient delivery and retention by the manure application unit **100**. The process ensures manure is buried properly and remains in the ground, maximizing crop nutrient uptake while minimizing potential nutrient loss. A closure arm assembly **750** (see FIG. **7**) maintains consistent downforce engagement with the ground to ensure complete coverage of the trench without missing areas, which is important for proper manure incorporation.

[0034] The design allows for various coverage improvements, including better manure burial and consistent trench formation. The blade angles maintain consistency throughout operation, ensuring uniform trench size and dirt movement over the life of the equipment. This systematic approach helps prevent manure exposure to sun and rain, which could otherwise lead to nutrient volatilization or field runoff.

[0035] In some examples, the manure application unit **100** provides adjustability for different needs and setups. The downforce spring adjustment mechanism can separately adjust the spring force versus the unit's height or position between the toolbar and ground level **410**. See FIGS. **1** and **4**A-**4**B.

[0036] More specification, the manure application unit **100** includes both a rest position (FIG. **4**A) and a working position (FIG. **4**B). In the rest position, when the manure application unit **100** is out of the ground **410**, the closure arm assembly **750** rests in a low position against a urethane cushioned down-stop bumper **718**. See FIG. **7**.

[0037] In the working position of FIG. **4**B, the manure application unit **100** operates with multiple coordinated components: the main blade **402** engages with the ground **410** to cut the trench, while the closure arm assembly **750** maintains its working position running along the ground surface **410** to push loose dirt back over the trench. During operation, the manure drop tube **316** continuously flows manure into the trench for burial by the closure arm assembly **750**.

[0038] An example depth control mechanism **404**, illustrated as a gauge ring, serves a control function by setting the depth of the trench and preventing the main blade **402** from digging too deep into the soil. This depth control mechanism **404** helps ensure consistent application depth, which is essential for effective manure incorporation and nutrient uptake.

[0039] The working position of FIG. **4**B demonstrates how the manure application unit **100** maintains consistent engagement with the ground **410** through its downforce system, allowing for proper trench formation and manure application even in varying ground conditions. This design ensures the blade angles stay consistent, resulting in uniform trench size and dirt movement throughout the operational life of the manure application unit **100**.

[0040] Further, the manure application unit **100** can include fewer wear parts, with each pivot having an option for greaseless maintenance free bushings and simple to manufacture, one piece pins that can be easily replaced. See FIGS. **5-6**.

[0041] For instance, a detailed illustration of a main arm pin assembly **500** of the manure application unit **100** and its key components designed for maintenance-free operation are shown in FIG. **5**. The main arm pin assembly **500** utilizes thrust washers **502** that serve a critical function by preventing direct steel-on-steel contact between a main arm **550** and mount plate, making the thrust washer the primary wear component which is more cost-effective to replace over time.

[0042] The design incorporates maintenance-free pin bushings **510** that ensure proper rotation of the main arm relative to both the pin and mount plate without requiring grease. These bushings **510** are engineered to be easily replaceable if wear occurs over time, while preventing any direct contact between steel components that could cause friction and wear to components that are more difficult and costly to replace.

[0043] The main arm pin assembly **500** features a floating pin design where the pin can rotate freely while being contained axially between the keeper plates **508**. Notably, the pin keeper plates **508** are not directly attached to a pin **506**. The main arm rotation pin **506** utilizes a seal system on a mount plate **504** that activates once the pin **506** is inserted through the main arm **50**, effectively preventing dirt and moisture from entering the main arm **550** and causing rust over time.

[0044] This design focuses on minimizing wear parts, with each pivot having greaseless maintenance-free bushings and simple pins that can be easily replaced. Components that do not pivot utilize bolted joint engagement to minimize the possibility of vibration-induced wear due to inadequate connections.

[0045] FIG. **7** illustrates the example closure arm assembly **750** of the manure application unit **100**, which functions to control manure application and trench closure. The closure arm assembly **750** is anchored by a closure arm pivot pin **710**, which works in conjunction with bushings **706** and thrust washers **704** to enable smooth rotational movement.

[0046] A closure arm weldment **708** serves as the main structural component, connecting to a closure arm hub **720** including a closure blade **318**. This assembly interfaces with a closure arm spring **712**, which provides the necessary downforce for ground engagement. The tension of the closure arm spring **712** is managed through a closure arm tension adjustment plate **714**, allowing for variable pressure control, as described further below.

[0047] The closure arm weldment **708** incorporates the down-stop bumper **718**, which provides a cushioned rest position for the closure arm assembly **750** against a closure mount/down-stop weldment **716** when not engaged with the ground. This component works in concert with the closure keeper washers and bolt to maintain proper assembly alignment and security.

[0048] The manure drop tube **316** is positioned near the closure arm assembly **750** to deliver manure directly into the trench. This positioning works in coordination with the closure arm hub **720** and closure blade **318** (formed as a coulter blade) to ensure proper manure placement and subsequent coverage. The closure arm assembly **750** maintains consistent engagement with the ground to constantly move dirt over the trench without missing areas, while the closure arm downforce stays engaged to ensure proper burial of the manure for maximum crop nutrient uptake.

[0049] More specifically, as shown in FIG. **8**, a closure adjustable tension torsion spring system **800** provides controlled downforce for the closure arm operation. The closure arm torsion spring **712** is designed to engage with a spring stop pin **804** located on the closure tension adjustment plate when the closure arm angle increases above ground level.

[0050] In its default position, the spring **712** applies minimal down pressure to the closure arm **750** as it floats freely above the pin. However, if the closure arm **750** bounces upward during operation, the spring **712** functions as a catch mechanism, preventing the closure from pivoting too high before returning to its working position.

[0051] The closure adjustable tension torsion spring system **800** features four distinct tension adjustment positions **802** that can be selected using a tension adjustment bolt **806**. These positions engage the torsion spring at different closure arm angles, resulting in varying levels of downforce **810** on the closure blade **318**. This adjustable downforce capability serves two critical functions: it helps maintain consistent blade engagement with the ground at any operating speed, and it assists with soil displacement in hard ground conditions.

[0052] The adjustable downforce feature is particularly important in hard ground conditions where the main blade's soil displacement may be limited due to minimal "shattering" of dirt around the trench. In these situations, the ability to increase closure blade downforce **810** helps displace more dirt over the trench, representing a significant improvement in manure application effectiveness. The spring also acts as an "up stop" catch when the entire unit and closure arm encounters obstacles like rocks, preventing excessive upward movement.

[0053] The design incorporates tension adjustment positions **802** clearly marked on the assembly, allowing for precise control of the spring's engagement point. This adjustability ensures the closure blade maintains proper ground contact while effectively moving displaced soil back over the manure-filled trench.

[0054] FIGS. **9**-**10**B illustrate a main spring system **900** and its operation. The downforce spring system **900** that maintains prescribed force to keep the main opener blade **402** engaged with the ground **410**. The spring **110** of the downforce spring system **900** employs a nested coil spring (one spring inside another to maximize spring loads for the size), though this could be alternatively configured with a hydraulic cylinder, airbag, or equivalent mechanisms.

[0055] The system's operation involves several interconnected components: spring mount clevis **904**; a spring mount pivot bolt **906**; a toolbar mount tube **908**; a spring pre-load plate **902**; a main arm/main pin axis of rotation **910**; a spring lower mount plate **912**; and a spring bolt **914**.

[0056] When the main arm rotates upward in a direction **950** around the main pin axis **910** due to encountering obstacles like hard ground or rocks, it decreases the distance between the spring lower mount plate **912** and the spring pre-load plate **902**, compressing the spring **110** in directions **952**. During this action, the spring bolt **914** maintains its position while extending out of the spring lower mount plate **912** as the spring compresses.

[0057] The spring mount clevis **904** rotates around the spring mount pivot bolt **906** to accommodate the rotating main arm **550**. The different rotation points between the spring **110** and the main arm **550** enable the distance reduction between the spring lower mount plate **912** and spring pre-load plate **902** during upward rotation of the main arm **550**.

[0058] As shown in FIGS. **10**A-**10**B, the spring force can be adjusted by engaging cutouts **920** in the spring pre-load plate **902** with a ½" ratchet or breaker bar. Rotating the plate **902** around the bolt **906** in directions **1030** moves it up or down in directions **1032**, which compresses or decompresses the spring **110** to adjust the force applied to the main arm **550**.

[0059] A notable design feature is a location of the spring **110** behind the toolbar mount tube **908**, which provides greater flexibility for unit spacing options when mounted to a toolbar. The configuration, where only bolts wrap around the front side of the tube, reduces potential interference with toolbar cross tubes.

[0060] In addition to adjusting the spring tension using the main spring system **900**, FIG. **11** illustrates a main spring unit height adjustment system **1100**, which operates independently from the main spring system **900**. The main spring unit height adjustment system **1100** allows a main arm position (height) relative to the toolbar mount tube **908** to be adjusted separately from the main spring system **900**.

[0061] This main spring unit height adjustment system **1100** is achieved through the spring bolt **914**, which can be tightened or loosened to thread further into or out of the spring mount clevis **904**. This action causes the resting position of the main arm **550** to rotate upward or downward in directions **1102** around the main pin axis of rotation **910**, effectively changing the height of the main blade **402** relative to the toolbar mount tube **908**.

[0062] This main spring unit height adjustment system **1100** provides significant benefits for implementing multiple manure injection units across a toolbar. For example, when using 30 individual injection units, this main spring unit height adjustment system **1100** capability helps eliminate variability in manufacturing tolerances that could otherwise result in inconsistent injection depths across units.

[0063] A crucial advantage of this design is that the spring tension remains independent of spring height, ensuring that performance of the manure application unit **100** remains consistent regardless of mounting adjustments. This separation of height adjustment from spring tension control allows for precise calibration of both the operating height and downforce pressure, enabling optimal performance across varying field conditions.

[0064] FIGS. **12A-12B** illustrate an example drop tube height adjustment system **1200**, which addresses the challenge of manure application in varying ground conditions. When encountering hard ground, the main blade **402** may not achieve sufficient depth penetration, causing the manure application unit **100** and associated drop tube **316** to operate higher above ground **410** than desired. This can result in manure splashing out of the trench in the gap between the drop tube **316** and ground level.

[0065] The design provides at least two distinct manure drop tube mounting positions **1202** that allow for height adjustment of the drop tube **316** relative to the main arm **550**. This adjustability brings the manure outlet closer to the trench, which helps minimize spillage and splashing of manure on top of the ground.

[0066] This adjustable drop tube height adjustment system **1200** aligns with the overall purpose of ensuring manure is properly buried in the ground for maximum crop nutrient uptake. The ability to adjust the height of the drop tube **316** helps maintain consistent manure placement even when ground conditions vary, contributing to the system's effectiveness in minimizing nutrient loss through volatilization or runoff.

[0067] The drop tube height adjustment system **1200** works in conjunction with other system components of the manure application unit **100** to ensure proper manure application, particularly when the unit encounters varying field conditions that might affect trench depth and manure placement. This adaptability helps maintain the effectiveness of the manure application process across different operating conditions

[0068] FIGS. **13A-13B** illustrate an example adjustable closure blade mount system **1300**, which is designed to optimize manure coverage and trench closure through multiple position and angle adjustments. The mount position of the closure blade **318** can be adjusted between at least two different positions and various degrees of rotation, allowing for quick adjustments to properly catch and position loose dirt moved by the main blade back over the manure-filled trench.

[0069] The adjustability of the adjustable closure blade mount system **1300** is achieved through two key mechanisms: rotational adjustment using one bolted position that acts as an axis of rotation **1304**, while another bolt operates within a slot **1302**; and/or position adjustment that allows the closure to be moved outward and bolted in place for a wider operating position

[0070] This adaptable design serves several functions. For example, it enables proper coverage of liquid manure in the ground to maximize nutrient uptake by crops. It can also minimize nutrient volatilization from sun exposure and reduce the risk of nutrient runoff from rainfall. The adjustable features are particularly valuable because different operating conditions can affect how soil is displaced during trench formation. These variables include: different main blade options being used; varying operating speeds in the field; and/or different operating angles of the main blade forming the trench.

[0071] Since the dirt moved while cleaning the trench may not be thrown to a predictable location relative to the closure, the adjustable angle and position of the closure blade mount allows operators to optimize the closure position based on specific setup requirements. This adjustability ensures maximum performance of the manure injection unit across varying field conditions. The closure blade can be positioned further out and back to catch more dirt during high-speed operation and when using main blades that move more dirt outward to better open the trench

[0072] Referring now to FIG. **14**, the manure application unit **100** can employ a modular design approach that offers advantages. At the heart of the design is the main arm **550**, which serves as the foundation for three critical sub-weldments that can be easily replaced or reconfigured.

[0073] The first key component is the closure mount/down-stop weldment **716**, which integrates multiple functions into a single replaceable unit. This closure mount/down-stop weldment **716** houses the spring tension adjustment positions and the closure arm down-stop or rest position. Due to its role in mounting the closure arm pin, it experiences significant wear from repeated loading and rotational forces during operation.

[0074] The second major component is the spring lower mount plate **912**, which plays a crucial role in managing the forces encountered during operation. This spring lower mount plate **912** must withstand substantial loads, particularly when the manure application unit **100** encounters obstacles like rocks that force rapid upward movement. Its modular design allows users to switch between different down-pressure methods without replacing the entire main arm assembly.

[0075] The third component is the main blade angle mount **1402**, which controls the engagement angle of the main blade **402** with the ground **410**. This main blade angle mount **1402** can be manufactured with varying degrees of angle based on specific operating conditions and speeds. In its current configuration, it offers both 3-degree and 5-degree angles from straight, allowing the same main arms to be used across different angle configurations.

[0076] This modular approach delivers several key benefits. It reduces customer costs by allowing replacement of individual worn components rather than entire assemblies. For manufacturers, it enables efficient inventory management and quick configuration changes without maintaining large stocks of complete weldments. Additionally, it facilitates future upgrades by allowing new technology or design improvements to be incorporated into smaller sub-components. The design also incorporates bolted joint engagement for non-pivoting components, which helps minimize wear from vibration. This versatility allows the unit to accommodate various tillage tools and fertilizer applicators for year-round use across different operating conditions and application requirements

[0077] FIG. **15** illustrates additional details of the main blade angle mount **1402**, which determines the angle at which the main blade **402** can engage with the ground **450**. In some embodiments, the main blade angle mount **1402** may position the main blade **402** at angles such as 3 degrees or 5 degrees relative to the direction of travel, though the main blade angle mount **1402** could potentially accommodate other angle configurations, including negative angles or straight alignment with a travel direction **1502**, depending on the specific performance requirements.

[0078] In this example, the blade angle could be configured to be parallel to and potentially constrained by the main blade angle mount **1402**, which may help provide ground engagement. See notation **1504**. This configuration may allow the closure blade **318** to operate across various ground conditions, speeds, and main coulter blade designs.

[0079] The spacing between the closure blade **318** and any stationary components may be an important design consideration. In some embodiments, the design could maintain clearance between the main blade **402** and stationary components, which may help allow dirt and crop residue to flow through and away from the application unit rather than potentially causing buildup. Such spacing considerations may align with anti-clog features that could help maintain performance during operation, as described further below.

[0080] The main blade angle mount **1402** could represent an element of a modular design approach, potentially allowing main arms to be used for different angle configurations of the manure application unit **100**. This adaptability may enable the system to accommodate various operating conditions without requiring complete unit replacement. The main blade angle feature could potentially be adjusted through mechanisms such as hydraulics or other systems, which may provide flexibility in operation and setup.

[0081] The manure application unit **100** can have anti-clog features as shown in FIGS. **16-17**B, including a front leading edge that is tapered to allow crop residue and dirt to flow under the unit to not get trapped and build up in front of the unit when ground engaging. The layout of components (pivot points, blades, and drop tubes) decreases chances for buildup and clogging. See FIGS. **16-17**B.

[0082] As shown in FIG. **16**, the anti-clog features of the manure application unit **100** may include strategic positioning of components that interact with the main blade **402**. Components that cross the path of the main blade **402** could be positioned either above at a distance, on the inside of the blade **402**, or in front of the main blade **402**, which may help minimize the chance for debris and dirt to accumulate and build up.

[0083] The design may incorporate specific spacing considerations, such as a gap **1602** between the main blade **402** and the closure pin that crosses above it, which could help prevent material from building up. The closure arm assembly **750** may be set a distance **1604** high above both blades **402**, **318**, potentially allowing material to flow out from between them, while a mount plate pin **1610** may be positioned in front of the main blade **402**.

[0084] A configuration of the drop tube **316** could also be designed to allow dirt and crop residue to flow alongside it without becoming pinched between its leading edge and the main blade **402**. This arrangement may align with the overall anti-clog features, including a front leading edge that could be tapered to allow crop residue and dirt to flow under the unit rather than potentially getting trapped and building up in front of the manure application unit **100** during ground engagement.

[0085] The layout of components, including pivot points, blades, and drop tubes, may be arranged to decrease chances for buildup and clogging. Positioning components behind and lower on the unit could potentially interrupt the flow of material and degrade performance, so the design may avoid such arrangements. This configuration could work in conjunction with other features to help maintain consistent performance during operation across various field conditions.

[0086] In FIG. **17**A, a leading edge **1702** of the main arm **550** and associated main blade angle mount **1402** are on a back-swept angle to allow crop residue to flow under the unit instead of building up in front of the manure application unit **100**. In other embodiments, that backswept angle of the main arm **550** and manure application unit **100** can be even greater, or the angle can vary at different heights to enhance this function even more.

[0087] FIG. **17**B illustrates another embodiment, in which the main blade angle mount **1402** has a varied angle to allow material to flow underneath the leading edge of the manure application unit **100** more easily. Many other configurations are possible.

[0088] Another embodiment of a manure application unit **1800** is shown in FIGS. **18-20**. The manure application unit **1800** is generally configured in a manner similar to the manure application units **100**, **300**, with the following noted distinctions.

[0089] In this example, a closure pivot pin **1802** is inserted into a main arm tube **1806** of the manure application unit **1800** and locked in place. The locking of the closure pivot pin **1802** in place could take on many alternatives, some of which are described herein.

[0090] In this embodiment, the closure pivot pin **1802** has at least one blind hole **1804** which, when oriented properly, aligns with a hole **1808** on a main arm tube **1806**. At least one set screw **1810** is threaded into a portion of the main arm tube **1806** and then aligns and engages with the blind hole **1804** of the closure pivot pin **1802**. In this example, a thread nut **1830** is welded to the main arm tube **1806** are shown in this embodiment as an alternative to drilling and tapping the main arm tube **1806**. When the set screw **1810** (or bolts) are tightened into the hole **1808**, they ensure the closure pivot pin **1802** can no longer slide side-to-side along the axial direction and keep it from rotating around that same axis. When the bolts are fully tightened, they engage the bottom of the pin's blind hole and clamp the pin against the opposing side of the main arm tube.

[0091] The closure pivot pin **1802** can be locked solidly in place to eliminate gaps and clearances between parts, to minimize movement or vibration between the pin and the main arm tube during use, thus eliminating the chances for wear over time. Using the set screw in blind holes, the closure pivot pin can easily be unlocked, disassembled, and replaced if wear or breakage occurs on any portion of the pin. It is desirable to replace a single pin instead of a larger weldment or more complex and expensive component.

[0092] The closure pivot pin **1802** can be temporarily locked into place and unable to rotate using alternative means, such as a keyway and key stock, any non-round shapes mate and interlock together to inhibit rotation, bolts acting directly on the pin clamping it in place in various orientations, a tab or flag welded onto the pin to attach to the main arm, etc. Another alternative would be simple cross bolts oriented perpendicular to the mounting tube and pin, locking it from sliding axially, or rotating around its axis. This embodiment may not clamp or lock the pin in a way that eliminates clearances between the pin and mounting tube and introduces the chance for relative movement and wear between the parts.

[0093] An example closure arm assembly **1850** of the manure application unit **1800** could use an alternative spring type to apply varying levels of down pressure to the closure blade as it engages the ground, such as an extension spring **1812**. Other types of springs, such as a compression spring, leaf spring, compliant joint, hydraulic cylinder, or other energy storage mechanisms can also be used. Spring mounting alternatives may include attachment plates with holes or slots, allowing adjustments to be made to the initial pre-loaded position of the spring to pre-tension it, or positions that allow leverage to vary in different ways throughout the closure arm rotation. This would allow for closure down-force options to be varied throughout the range of rotation to produce a desired result at certain points in the rotation of the arm.

[0094] The manure application units described herein can accommodate different tillage tools and fertilizer applicators for use at all times of year, in wet conditions, running many more acres per year, varying speeds and application requirements, varying ground conditions, alternative materials for decreased wear.

[0095] There are alternative embodiments to those shown herein for the manure application units. These can include one or more of (some of these components are discussed above):

- **[0096]** hydraulic closing arm with constant down pressure;
- **[0097]** adjustable main blade angle, on the fly with hydraulics or other mechanisms (see FIG. **15**);
- **[0098]** quick release assemblies rather than bolts, which latch into place;
- **[0099]** a grease system with automatic greasing of components, including grease reservoirs that could be independent on each individual row unit or combined from one reservoir and distributed to all row units;
- **[0100]** hydraulic/pneumatic/electromechanical down pressure for main disc and/or closure arm, the adjustment of which can be controlled manually on the implement's valving, by wired or wireless remote control in the tractor cab, user interface on a tablet computer or tractor ISOBUS system, or the like (see FIGS. **9-11**);
- **[0101]** down pressure can be changed through various mechanisms on each injection row unit independently, or in sections across the implement, or all having the same down pressure applied equally;
- **[0102]** depth control by hydraulic/pneumatic/electro-mechanical mechanism, which is typically controlled using down pressure but would be managed in such a way that it has position sensing to not go in beyond a certain depth;
- **[0103]** depth can be controlled through optical sensing of ground height, smart cylinders, rotary position sensors, or any mechanism known in the art to sense relative position of something;
- **[0104]** sensors and a controller to sense how much dirt is flowing past the closure and make position and angle adjustments as necessary to catch more dirt for covering the trench;
- **[0105]** sensors (optical, heat signature, etc. to see how much liquid manure is showing above ground after the unit has passed and make automatic adjustments to the injection unit to improve manure coverage and decrease the amount of manure on the ground;
- **[0106]** adjustments can be made to the main blade angle, down pressure, closure blade position/angle/down pressure;
- **[0107]** sensors to notify operator of maintenance issues, inferior performance issues, clogs in manure hose or clogs from crop chaff/cuttings catching and dragging in the unit;
- **[0108]** any pivoting component could incorporate dampening, resisting, and controlling the motion to affect the component's velocity, acceleration, deceleration, stop impact forces, or total travel; and
- **[0109]** mechanisms for controlling the motion of a component could be through any type of spring acting on the component, compliant material, hydraulic system, pneumatic system, electromechanical, torque converter, torque limiter, and the like.

[0110] It is considered that any bolt-on component of the manure application units could be attached through other mechanisms, whether to allow interchangeability or replacement, allow for prescribed movement, or to be permanently mounted through welding together or casting. Other non-limiting mechanisms of component attachment could include welding, pins and holes or slots, interlocking details, latches, slide engagement, or through any other locking component known in the art to fasten components to one another. Components may also be attached to one another to allow some flexibility rather than having a rigid connection. For instance, the component may be attached through a connecting piece of spring steel, rubber, or other compliant material to allow some movement or flexibility to the connection.

What is claimed is:

1. A manure application unit, comprising:

a main arm pivotally mounted to a toolbar mount tube;

a coulter blade operatively connected to the main arm;

a closure arm pivotally mounted to the main arm;

a closure blade mounted to the closure arm;

a main arm downforce assembly, operatively connected between the toolbar mount tube and the main arm, to provide an adjustable downforce force to maintain the coulter blade engaged with ground; and

a closure arm torsion spring, operatively connected to the closure arm, to provide varying downforce forces on the closure blade to maintain the closure blade engaged with the ground during operation.

2. The manure application unit of claim **1**, wherein the main arm downforce assembly includes a spring or a hydraulic unit.

3. The manure application unit of claim **2**, wherein the main arm downforce assembly comprises a nested coil spring system having an inner spring positioned within an outer spring to maximize spring loads.

4. The manure application unit of claim **3**, wherein the main arm downforce assembly further comprises a spring pre-load plate adjustably mounted on a spring bolt, wherein adjustment of the spring pre-load plate varies spring force independently from unit height.

5. The manure application unit of claim **1**, wherein the closure arm torsion spring engages with a spring stop pin mounted on a closure tension adjustment plate, the closure tension adjustment plate having multiple positions for the varying downforce on the closure blade.

6. The manure application unit of claim **5**, wherein the closure tension adjustment plate comprises four positions that engage the closure arm torsion spring at different angles of the closure arm to provide different levels of down-pressure on the closure blade.

7. The manure application unit of claim **1**, wherein the main arm comprises a modular design having separately attachable components including:

a closure pin mount plate;

a downforce assembly mount plate; and

a main blade angle mount.

8. The manure application unit of claim **7**, wherein the downforce assembly mount plate is configured to accommodate interchangeable down-pressure mechanisms including a spring assembly, a hydraulic cylinder, or an airbag.

9. The manure application unit of claim **1**, wherein the closure arm torsion spring is configured to act as a catch to stop the closure arm from pivoting beyond a predetermined height when encountering obstacles during operation.

10. The manure application unit of claim **1**, further comprising a closure arm pivot pin is insertable into a main arm tube and defines a blind hole, wherein the main arm tube includes a threaded hole aligned with the blind hole of the closure arm pivot pin, and wherein at least one set screw is threaded into the threaded hole to engage the blind hole and lock the closure arm pivot pin against rotation and axial movement.

11. A method for manure application, the method comprising:

pivotally mounting a main arm to a toolbar mount tube;

operatively connecting a coulter blade to the main arm;

pivotally mounting a closure arm to the main arm;

mounting a closure blade to the closure arm;

providing an adjustable downforce force by a main arm downforce assembly, operatively connected between the toolbar mount tube and the main arm, to maintain the coulter blade engaged with ground; and

providing varying downforce forces by a closure arm torsion spring, operatively connected to the closure arm, to maintain the closure blade engaged with the ground during operation.

12. The method of claim **11**, wherein the main arm downforce assembly includes a spring or a hydraulic unit.

13. The method of claim **12**, wherein the main arm downforce assembly comprises a nested coil spring system having an inner spring positioned within an outer spring to maximize spring loads.

14. The method of claim **13**, wherein the main arm downforce assembly further comprises a spring pre-load plate adjustably mounted on a spring bolt, wherein adjustment of the spring pre-load plate varies spring force independently from unit height.

15. The method of claim **11**, wherein the closure arm torsion spring engages with a spring stop pin mounted on a closure tension adjustment plate, the closure tension adjustment plate having multiple positions for the varying downforce on the closure blade.

16. The method of claim **15**, wherein the closure tension adjustment plate comprises four positions that engage the closure arm torsion spring at different angles of the closure arm to provide different levels of down-pressure on the closure blade.

17. The method of claim **11**, wherein the main arm comprises a modular design having separately attachable components including:

a closure pin mount plate;

a downforce assembly mount plate; and

a main blade angle mount.

18. The method of claim **17**, wherein the downforce assembly mount plate is configured to accommodate interchangeable down-pressure mechanisms including a spring assembly, a hydraulic cylinder, or an airbag.

19. The method of claim **11**, wherein the closure arm torsion spring is configured to act as a catch to stop the closure arm from pivoting beyond a predetermined height when encountering obstacles during operation.

20. The method of claim **11**, further comprising inserting a closure arm pivot pin into a main arm tube and defines a blind hole, wherein the main arm tube includes a threaded hole aligned with the blind hole of the closure arm pivot pin, and wherein at least one set screw is threaded into the threaded hole to engage the blind hole and lock the closure arm pivot pin against rotation and axial movement.

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