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(54) **TASK-SPECIFIC RIDE-HEIGHT CONTROL OF AN AGRICULTURAL PRODUCT APPLICATOR WITH AIR STRUT SUSPENSION**

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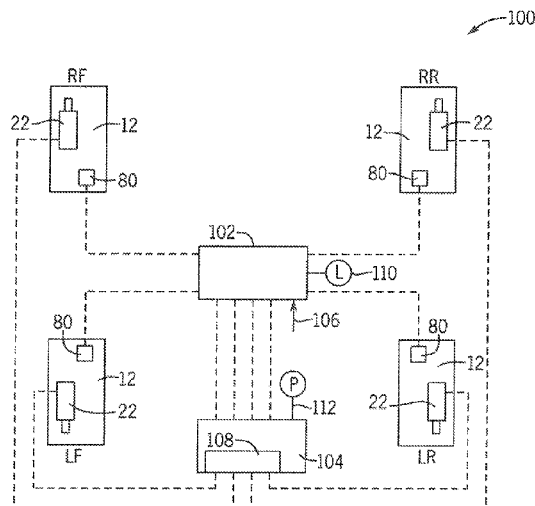
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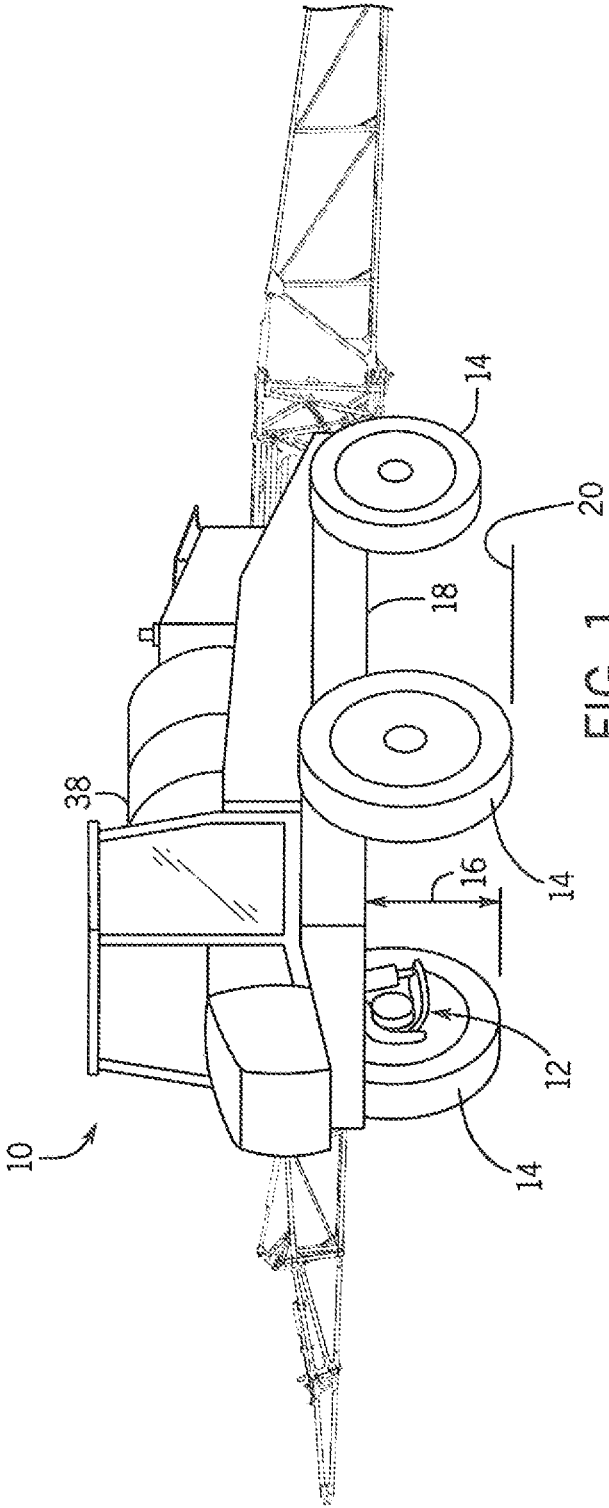
(57) **ABSTRACT**

A system, apparatus and method for providing task-specific ride-height control in a self-propelled agricultural product applicator utilize a controllable ride-height trailing arm suspension system for independently joining each wheel to a frame of the applicator. Each trailing arm suspension system includes upper and lower suspension arms, an extensible air strut, and an angular position sensor operatively interconnected to one another and disposed between a rolling axis of the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame, such that the position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut. An electronic control unit utilizes the angular positions detected by the sensors, in conjunction with a desired task input, to control the air struts in a manner providing a ride-height corresponding to the desired task input.

20 Claims, 7 Drawing Sheets



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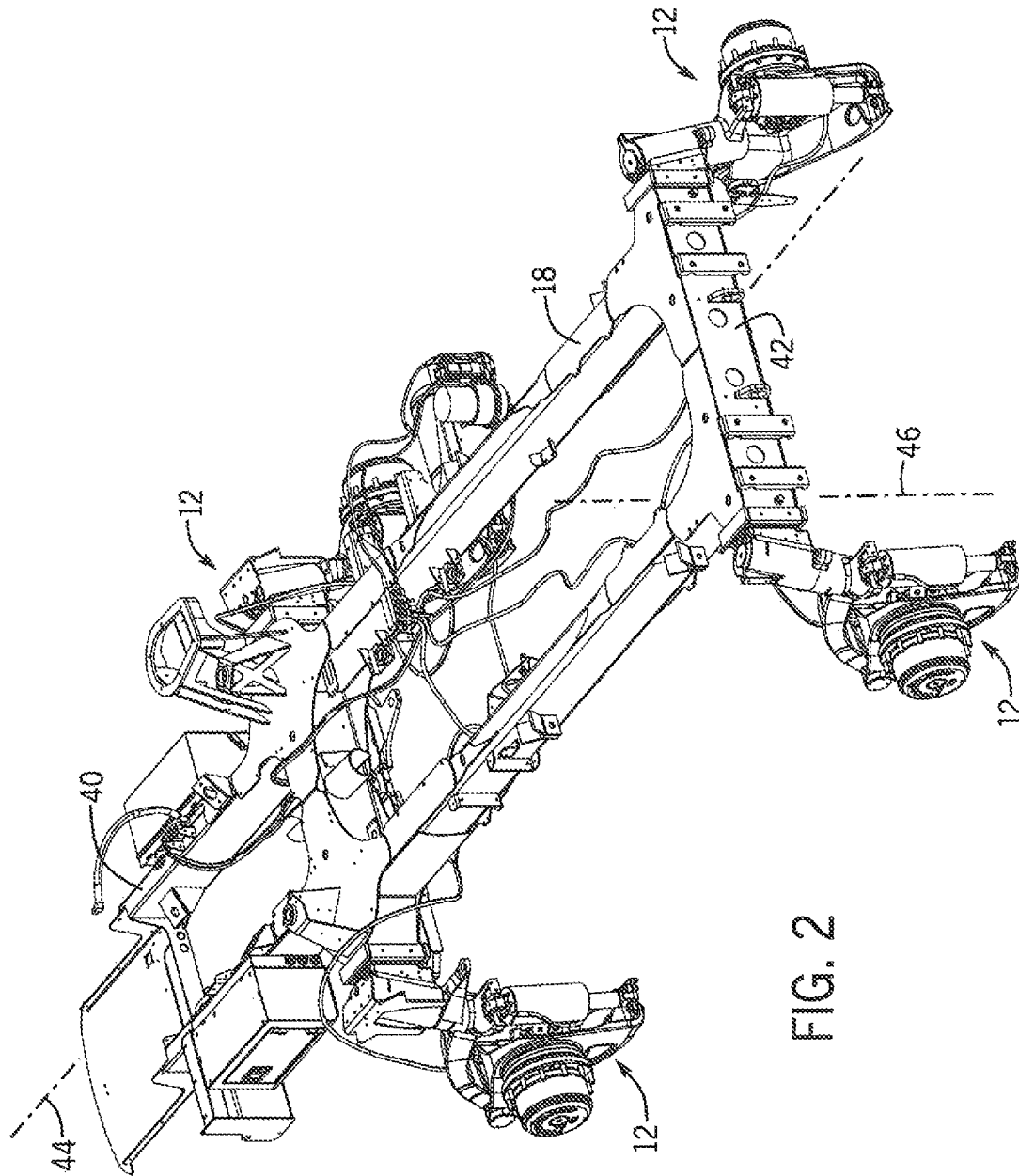


FIG. 2

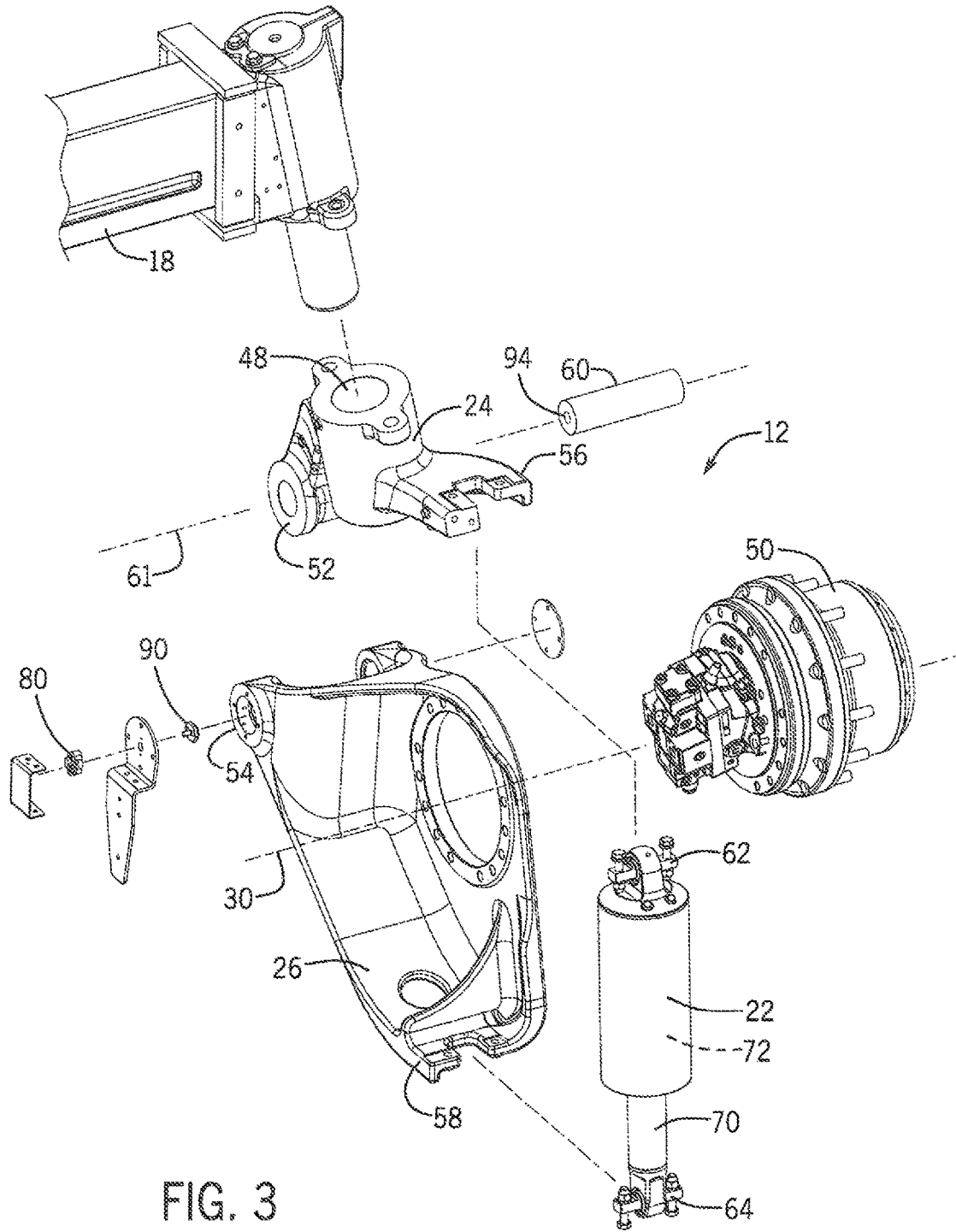


FIG. 3

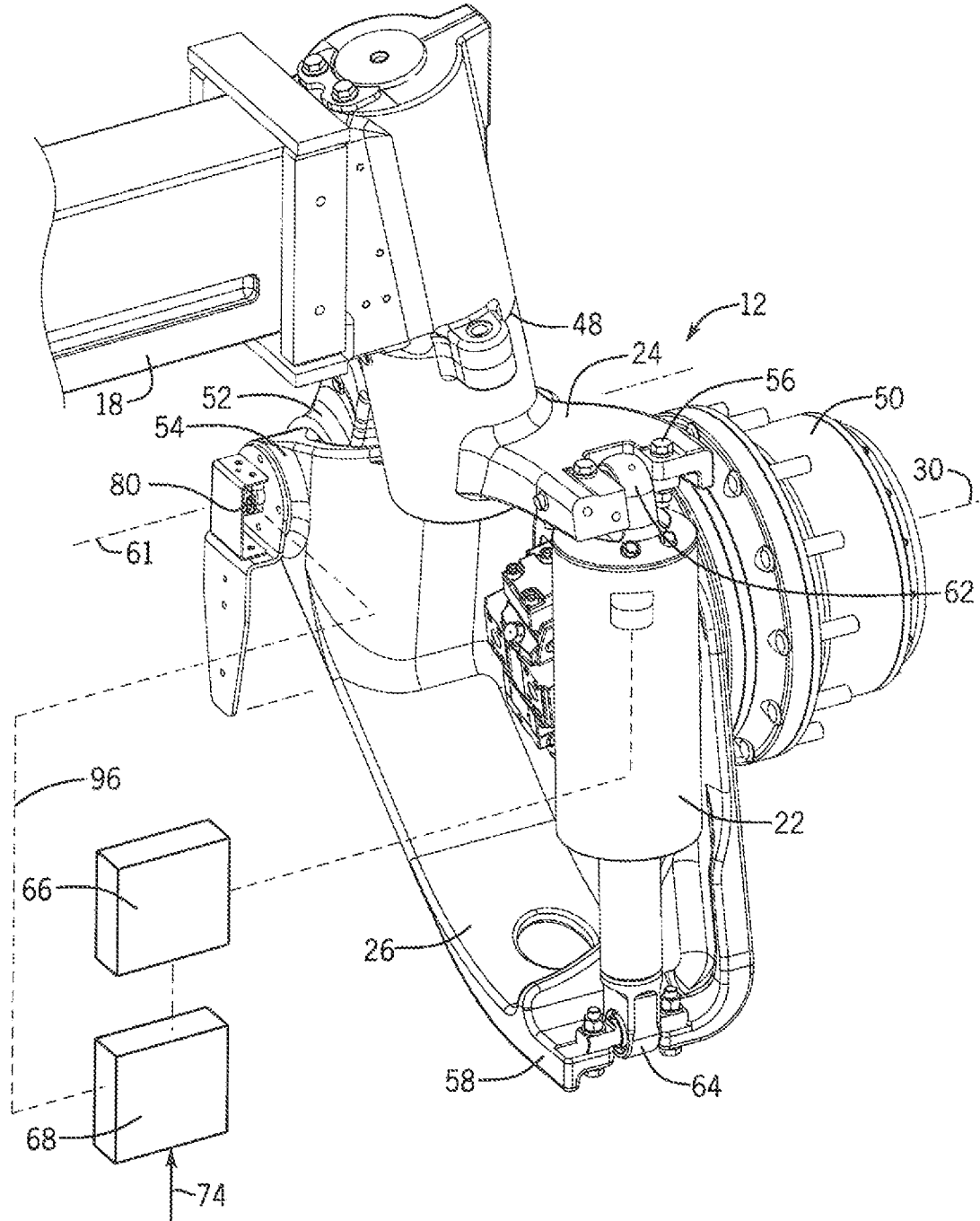


FIG. 4

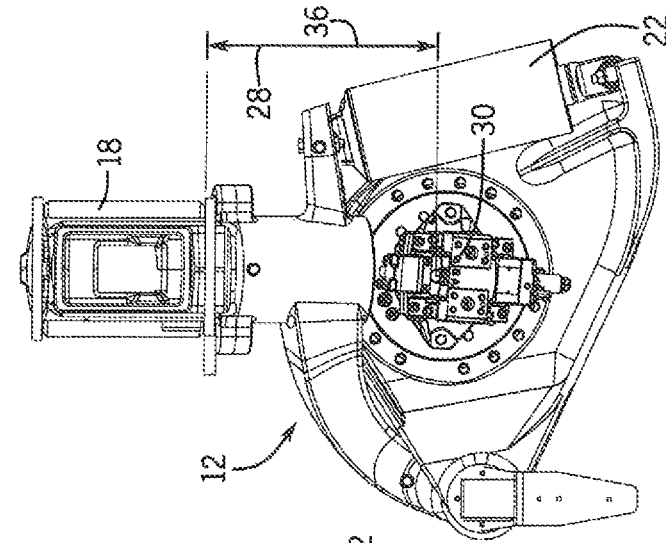


FIG. 5

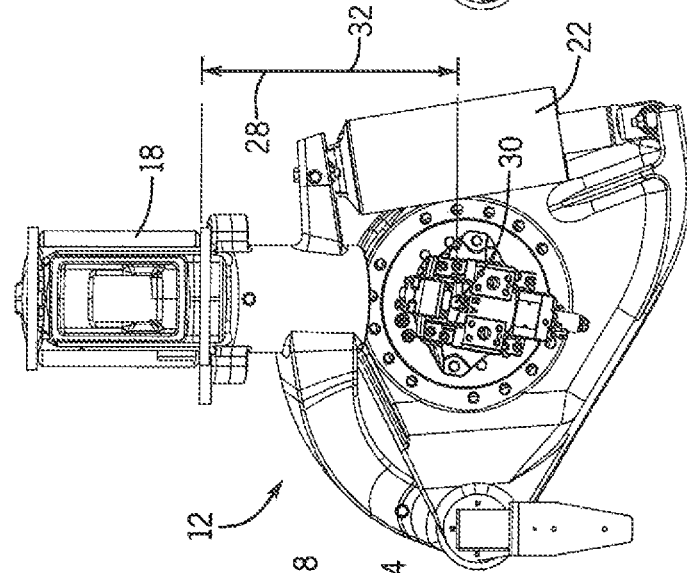


FIG. 6

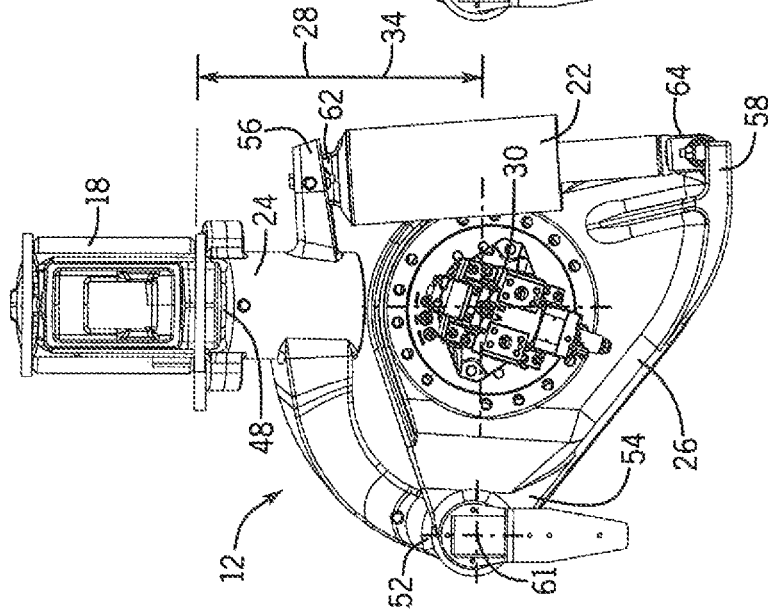


FIG. 7

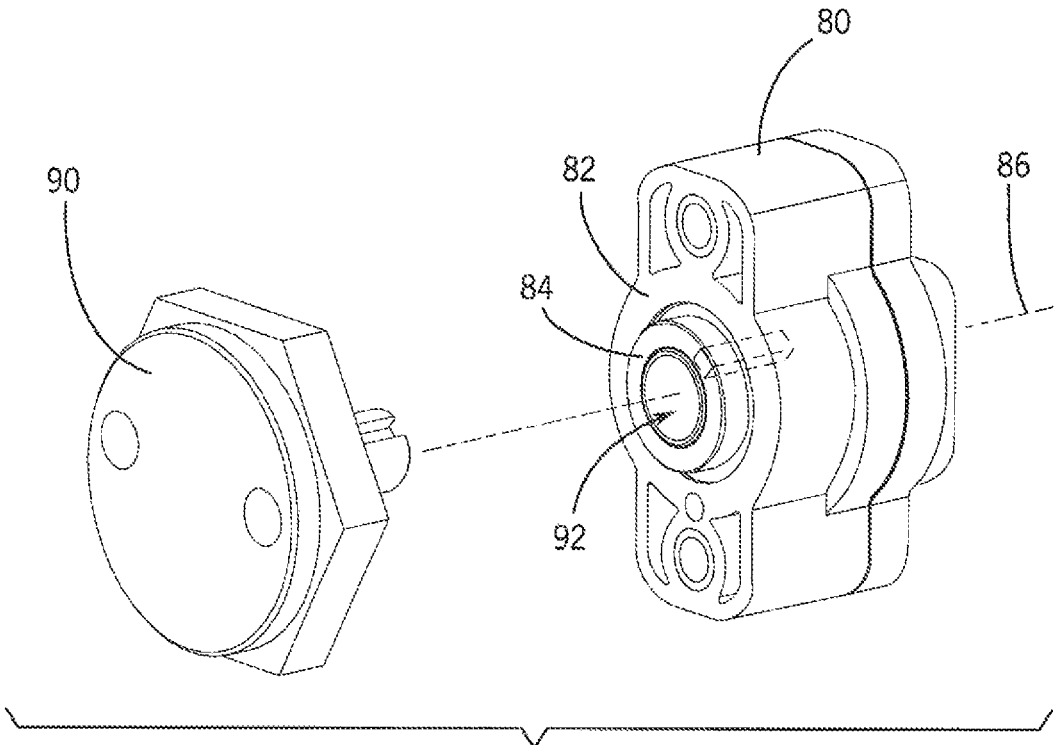


FIG. 8

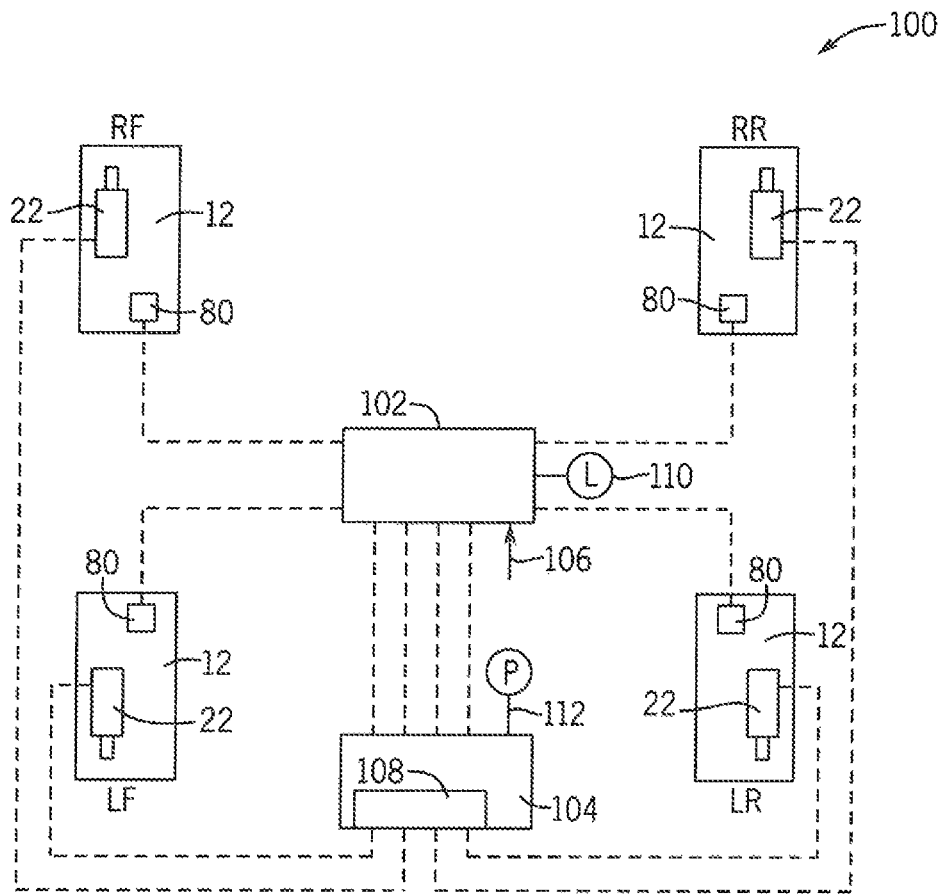


FIG. 9

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**TASK-SPECIFIC RIDE-HEIGHT CONTROL
OF AN AGRICULTURAL PRODUCT
APPLICATOR WITH AIR STRUT
SUSPENSION**

FIELD OF THE INVENTION

This invention relates generally to self-propelled agricultural product application implements, such as a high-clearance sprayer and/or spreader, and more particularly to a suspension system for such implements.

BACKGROUND OF THE INVENTION

Modern agricultural practices rely heavily on precise and timely applications of fertilizers, herbicides, pesticides and other chemicals. In situations where the applications must be made to standing row crops, such as corn or beans, liquid or granular materials are often applied using a high ground clearance, self-propelled applicator.

In order to provide maximum ground clearance, such applicators utilize highly specialized suspension systems for connecting the ground engaging wheels of the applicator to a frame of the applicator. Typically, separate hydraulic drive motors are provided as part of the suspension, for each drive wheel, to thereby further, enhance ground clearance by minimizing the encroachment of drive line or typical suspension components into the space between the wheels under the applicator.

In the past, suspension systems for high ground clearance, self-propelled applicators utilized suspension components, including compression springs and hydraulic shock absorbers, that were essentially the same as those used in automotive and commercial vehicle suspensions. While these components have generally worked well in the specialized suspension systems of high ground clearance, self-propelled applicators, they are not ideal and further improvement is desirable.

One problem with prior high clearance applicator suspension systems, is that the ground clearance tends to vary depending upon how heavily the applicator is loaded. Initially, as it pulls away from a tender with a full load, an applicator is typically carrying several thousand pounds of a product, to be applied. As the product is dispensed onto the field by the applicator, the weight of the remaining product being carried by the applicator gradually decreases to zero. With prior suspensions that rely on compression springs for supporting the load carried by the applicator, ground clearance starts out at a minimum when the applicator is initially fully loaded, with the springs compressed to their lowest working height. As product is dispensed and load on the applicator decreases, the compression springs extend from their initially compressed state, and raise the applicator higher above the ground surface.

Having ground clearance vary is undesirable for at least two reasons. First, the effectiveness of the product being applied is highly dependent upon precise application. As ground clearance changes, spray or granular spreading patterns may be adversely affected, requiring continual compensating adjustments to be made by an operator of the applicator, in order to maintain optimal product application. Second, ride quality and handling characteristics of the applicator are typically affected by ground clearance, and the state of extension of the compression springs. The springs, and hence the suspension, is considerably stiffer when the springs are more fully compressed than when they are extended.

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Prior suspension systems using compression springs are also typically optimized for one type of operating mode. This results in compromising suspension performance in other operating modes that are typically necessary in practical utilization of the applicator. For example, it is necessary to drive the applicator across the field in an unloaded state, to and from the tender, in addition to driving the vehicle across the field in a fully or partially loaded state while applying product to the field. It will likely be necessary for the applicator to travel on public roads, at times, in moving between fields. Differences in handling characteristics inherent in spring-based suspension systems, from loaded to unloaded states of the applicator, may make such on-road transit more difficult. It may be necessary to transport the applicator on a truck or trailer between fields. This can present additional problems for high ground clearance applicators, in that the overall combined height of the applicator and the bed of the trailer or vehicle carrying the applicator may exceed applicable limits for transport on public roads.

It is desirable, therefore, to provide an improved suspension system for self-propelled, high around clearance, agricultural product applicators. It is particularly desirable to provide such an improved suspension system that can set and maintain a desired ground clearance, and provide desirable ride and handling characteristics in a self-propelled, high ground clearance, agricultural product applicator throughout a wide range of operating modes and conditions.

SUMMARY OF THE INVENTION

The invention provides task-specific ride-height control in a self-propelled agricultural product applicator, by utilizing a controllable ride-height trailing arm suspension system for independently joining each wheel to a frame of the applicator. Each trailing arm suspension system includes upper and lower suspension arms, an extensible air strut, and an angular position sensor operatively interconnected to one another and disposed between a rolling axis of the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame, such that the position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut. An electronic control unit utilizes the angular positions detected by the sensors, in conjunction with a desired task input, to control the air struts in a manner providing a ride-height corresponding to the desired task input.

In one form of the invention, a task-specific ride-height control system is provided for a self-propelled agricultural product applicator having three or more ground engaging wheels operatively joined to a frame. The frame is adapted for supporting at least one agricultural product container and defines forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame.

The task-specific ride-height system may include, a controllable ride-height trailing arm suspension system having an air strut and an angular position sensor at each wheel, an air power source, and an electronic control unit.

In some forms of the invention, each controllable ride-height trailing arm suspension system independently joins one of the wheels to the frame. Each trailing arm suspension system includes an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor. The suspension arms, air strut and sensor are operatively interconnected to one another, and disposed between

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a rolling axis the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame, in such a manner that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut.

The air power source may provide a controlled flow of pressurized air to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts.

The electronic control unit may be operatively connected to the angular position sensors and the air power source, and be configured for receiving a desired task input and signals from the angular position sensors indicative of a present relative angular position of the upper and lower suspension arms of each suspension system. The electronic control unit may be further configured for commanding the air power source to control the air struts at an extension of the struts that provides a ride-height corresponding to the desired task input.

In some forms of a task-specific ride-height control system, according to the invention, for each trailing-arm suspension system for connecting one of the ground engaging wheels to the frame, the upper suspension arm defines a frame attachment point thereof, adapted for fixed attachment to the frame. The lower suspension arm defines a rolling axis of the ground engaging wheel and is adapted for supportive attachment to the lower suspension arm of the ground engaging wheel, for rotation of the ground engaging wheel about the rolling axis of the wheel. The upper and lower suspension arms also define respective forward and aft ends thereof, with the forward ends being adapted for operative pivoting connection to one another through an angular rotation about the suspension pivot axis extending generally parallel to the rolling axis of the wheel and disposed forward of the rolling axis of the wheel. The aft ends of the upper and lower suspension arms are disposed respectively aft of the frame attachment point and rolling axis, with the aft ends of the upper and lower suspension arms being respectively adapted for operative attachment thereto of the air strut. And, the angular position sensor is operatively connected between the upper and lower suspension arms for detecting the angular rotation of the upper and lower arms with respect to each other about the pivot axis. The angular rotation detected by the sensor is indicative of a distance between the rolling axis of the wheel and the frame attachment point, and is thereby also indicative of a ride height of the frame above the ground.

In some forms of a task-specific ride-height control system according to the invention, the angular position sensor may be a rotary position sensor. The rotary position sensor may have a first element thereof fixedly attached to the lower suspension arm for rotation therewith, and may also have a second element thereof that is rotatable relative to the first element. The second element may be fixedly attached to the upper suspension arm for rotation therewith, in such a manner that angular rotation of the upper and lower suspension arms relative to one another about the suspension pivot axis rotates the first and second elements of the rotary position sensor relative to one another, to thereby cause the rotary position sensor to detect the angular rotation.

In some forms of a task-specific ride-height control system, according to the invention, in the suspension system of each wheel, the air strut may be configured for receiving a flow of pressurized air from an air power source, and for extending and retracting in response to the flow of pressur-

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ized air, to thereby respectively lower and raise the rolling axis of the wheel with respect to the frame attachment point.

In a task-specific ride-height control system, according to the invention, the desired task input may indicate a selected desired task of one or more predetermined desired tasks, and the electronic control unit may be configured to control the air struts at an extension thereof providing a ride-height corresponding to the selected desired task input. In some forms of the invention, the one or more predetermined desired tasks may include a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height. In some forms of the invention, the at least one additional desired task input and its corresponding ride-height is selected from the group of desired task inputs and corresponding ride-heights consisting of: tendering, at a maximum ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

Some forms of a task-specific ride-height control system, according to the invention, may further include a load sensor for detecting a weight of the applicator and agricultural product in the product container, and the electronic control unit may be further configured to modify one or more of the desired task inputs in accordance with a predetermined protocol corresponding to the detected weight.

The invention may also take the form of a self-propelled agricultural product applicator having three or more ground engaging wheels operatively joined to a frame of the applicator, where the frame is adapted for supporting at least one agricultural product container and defining forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame. The wheels may be joined to the frame of the applicator by a task-specific ride-height control system, in accordance with the invention.

The task-specific ride-height control system, in an applicator according to the invention, may include, a controllable ride-height trailing arm suspension system having an air strut and an angular position sensor at each wheel, an air power source, and an electronic control unit.

In some forms of an applicator according to the invention, each controllable ride-height trailing arm suspension system independently joins one of the wheels to the frame. Each trailing arm suspension system includes an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor. The suspension arms, air strut and sensor are operatively interconnected to one another, and disposed between a rolling axis the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame, in such a manner that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut.

The air power source of the applicator may provide a controlled flow of pressurized air to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts.

The electronic control unit of the applicator may be operatively connected to the angular position sensors and the air power source, and be configured for receiving a desired task input and signals from the angular position sensors indicative of a present relative angular position of the upper

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and lower suspension arms of each suspension system. The electronic control unit may be further configured for commanding the air power source to control the air struts at an extension of the struts that provides a ride-height corresponding to the desired task input.

In some forms of a task-specific ride-height control system of an applicator, according to the invention, for each trailing-arm suspension system for connecting one of the ground engaging wheels to the frame, the upper suspension arm defines a frame attachment point thereof, adapted for fixed attachment to the frame. The lower suspension arm defines a rolling axis of the ground engaging wheel and is adapted for supportive attachment to the lower suspension arm of the ground engaging wheel, for rotation of the ground engaging wheel about the rolling axis of the wheel. The upper and lower suspension arms also define respective forward and aft ends thereof, with the forward ends being adapted for operative pivoting connection to one another through an angular rotation about the suspension pivot axis extending generally parallel to the rolling axis of the wheel and disposed forward of the rolling axis of the wheel. The aft ends of the upper and lower suspension arms are disposed respectively aft of the frame attachment point and rolling axis, with the aft ends of the upper and lower suspension arms being respectively adapted for operative attachment thereto of the air strut. And, the angular position sensor is operatively connected between the upper and lower suspension arms for detecting the angular rotation of the upper and lower arms with respect to each other about the pivot axis. The angular rotation detected by the sensor is indicative of a distance between the rolling axis of the wheel and the frame attachment point, and is thereby also indicative of a ride height of the frame above the ground.

In some forms of a task-specific ride-height control system in an applicator according to the invention, the angular position sensor may be a rotary position sensor. The rotary position sensor may have a first element thereof fixedly attached to the lower suspension arm for rotation therewith, and may also have a second element thereof that is rotatable relative to the first element. The second element may be fixedly attached to the upper suspension arm for rotation therewith, in such a manner that angular rotation of the upper and lower suspension arms relative to one another about the suspension pivot axis rotates the first and second elements of the rotary position sensor relative to one another, to thereby cause the rotary position sensor to detect the angular rotation.

In some forms of a task-specific ride-height control system, in an applicator according to the invention, in the suspension system of each wheel, the air strut may be configured for receiving a flow of pressurized air from an air power source, and for extending and retracting in response to the flow of pressurized air, to thereby respectively lower and raise the rolling axis of the wheel with respect to the frame attachment point.

In a task-specific ride-height control system, of an applicator according to the invention, the desired task input may indicate a selected desired task of one or more predetermined desired tasks, and the electronic control unit may be configured to control the air struts at an extension thereof providing a ride-height corresponding to the selected desired task input. In some forms of the invention, the one or more predetermined desired tasks may include a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height. In some forms of the invention, the at least one additional

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desired task input and its corresponding ride-height is selected from the group of desired task inputs and corresponding ride-heights consisting of: tendering, at a maximum ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

Some forms of a task-specific ride-height control system, in an applicator according to the invention, may further include a load sensor for detecting a weight of the applicator and agricultural product in the product container, and the electronic control unit may be further configured to modify one or more of the desired task inputs in accordance with a predetermined protocol corresponding to the detected weight.

The invention may also take the form of a method for providing task-specific ride-height control for a self-propelled agricultural product applicator. The applicator may have three or more ground engaging wheels operatively joined to a frame adapted for supporting at least one agricultural product container and defining forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame.

A method for providing task-specific ride-height control, according to the invention, may include the step of independently joining each wheel to the frame with a controllable ride-height trailing arm suspension system. Each trailing arm suspension system may include an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor operatively interconnected to one another and disposed between a rolling axis the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame such that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut.

The method may also include the step of providing a controlled flow of pressurized air from an air power source to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts.

The method may further include the steps of: operatively connecting an electronic control unit to the angular position sensors and the air power source; receiving, a desired task input and signals from the angular position sensors, at the electronic control unit, the signals from the angular position sensor being indicative of a present relative angular position of the upper and lower suspension arms of each suspension system; and utilizing the electronic control unit for commanding the air power source to control the air struts at an extension thereof providing a ride-height corresponding to the desired task input.

In a method, according to the invention, the desired task input may indicate a selected desired task of one or more predetermined desired tasks, and the electronic control unit may be configured to control the air struts at an extension thereof providing, a ride-height corresponding to the selected desired task input. In some forms of a method, according to the invention, the one or more predetermined desired tasks may include a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height. The at least one additional desired task input and its corresponding ride-

height may be selected from the group of desired task inputs and corresponding ride-heights consisting of: tendering, at a maximum ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

Other aspects, objects and advantages of the invention will be apparent from the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIG. 1 is an isometric illustration of an exemplary embodiment of a self-propelled, high ground clearance, agricultural applicator, according to the invention;

FIG. 2 is an isometric illustration of a frame and suspension systems of the exemplary embodiment of the applicator of FIG. 1;

FIG. 3 is an exploded isometric illustration of a suspension system of the exemplary embodiment of the applicator shown in FIG. 1;

FIG. 4 is an assembled isometric illustration of the suspension system shown in FIG. 3;

FIGS. 5-7 are orthographic illustrations of the suspension system of FIG. 4, showing the suspension system respectively in maximum height, working height, and minimum height positions;

FIG. 8 is an isometric illustration of an exemplary embodiment of an angular position sensor according to the invention; and

FIG. 9 is a schematic representation of a task-specific ride-height control system, according to the invention, as applied in the self-propelled agricultural product applicator of FIG. 1.

While the invention will be described in connection with certain preferred embodiments, there is no intent to limit it to those embodiments. On the contrary, the intent is to cover all alternatives, modifications and equivalents as included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

FIG. 1 shows an exemplary embodiment of the invention in the form of a high ground clearance, self-propelled, agricultural product applicator 10, that includes improved suspension systems 12, according to the invention, for each of the four ground engaging wheels 14 of the applicator 10.

As shown in FIGS. 1-4, and described in more detail below, the invention provides a system, apparatus and method for controlling the height 16 of a frame 18 of a self-propelled agricultural product applicator 10 above a ground surface 20, by using a trailing link suspension system 12 that has an extensible air strut 22, for connecting each of the four ground engaging wheels 14 of the applicator 10 to the frame 18 of the applicator 10. The trailing arm suspension systems 12 each include an upper suspension arm 24 attached to the frame 18, and a lower suspension arm 26 that provides sole support of a ground engaging wheel 14 attached to the lower arm 26, in a manner described in more detail below.

As illustrated in FIGS. 4-7, the extensible air strut 22 is interconnected between the upper and lower arms 24, 26 in such a manner that the height 16 of the applicator 10 above the ground surface 20 may be controlled by regulating a flow of pressurized air to the air strut 22, to thereby control extension of the air strut 22 and a vertical distance 28 between a rolling axis 30 of the wheel 14 and the frame 18 of the applicator 10. As shown in FIGS. 5-7, by controlling the flow of pressurized air to the strut 22, the suspension can be positioned and held at desired working height position 32, as shown in FIG. 6, or any other height position between a highest position 34, shown in FIG. 5, and a lowest height position 36, as shown in FIG. 7. Specifically, to raise the applicator frame 18 to a maximum height 16 above the ground surface 20, a flow of pressurized air is supplied the air strut 22 that is sufficient to cause the air strut 22 to extend to its maximum length 34 as illustrated in FIG. 5. To lower the applicator frame 18 to its minimum height 16 above the ground surface 20, pressurized air is allowed to flow out of the air strut 22, so that the air strut 22 can retract to its minimum length 36, as shown in FIG. 7. By regulating the flow of pressurized air to the air strut 22, the suspension 12 can adjust the length of the air strut 22, and hold the frame 18 of the applicator at any desired, working height 16 by holding extension of the air strut 22 at a corresponding length within the operative stroke length of the air strut 22.

Returning to FIGS. 1 and 2, the frame 18 of the applicator 10 is adapted for supporting at least one product container 38 and defines forward and rear ends 40, 42 of the frame 18, a longitudinally extending central axis 44 of the frame extending from the rear end 42 to the front end 40 of the frame 18, in a direction of travel of the applicator 10, and a vertical axis 46 of the frame 18.

FIGS. 3 and 4, illustrate the manner in which the lower suspension arm 26, the upper suspension arm 24, and the air strut 22, of the suspension system 12, are operatively interconnected to one another and disposed between the rolling axis 30 of the ground engaging wheel 14 and the frame 18, for supporting the applicator 10 above the ground surface 20.

The upper suspension arm 24 defines a frame attachment point 48 of the upper suspension arm 24, that is adapted for attachment to the frame 18. FIGS. 3 and 4 illustrate the suspension system 12 for the right rear wheel 12 of the applicator 10. In the exemplary embodiment of the applicator 10, the rear wheels 12 are not steerable, so the attachment points 48 of the rear suspension systems 12 are fixedly attached in a non-rotatable manner to the frame 18. Because the front wheels of the exemplary embodiment of the applicator 10 are steerable, the frame attachment points 48 for the front suspension systems 12 are attached to the frame in a manner that allows the upper suspension arms 22 of the front wheels to pivot about generally vertically extending steering axes (not shown) with respect to the frame 18, as part of a steering mechanism (not shown) of the applicator 10.

The lower suspension arm 26 defines the rolling axis 30 of the ground engaging wheel 12 and is adapted for supportive attachment, to the lower suspension arm 26, of the ground engaging wheel 12, for rotation of the ground engaging wheel 12 about the rolling axis 30 of the wheel 12. In the exemplary embodiment of the applicator 10, each of the four wheels of the applicator 12 is independently powered by a hydraulic motor unit 50 that is mounted on, and solely supported by the lower arm 26 of the suspension, for driving the wheel 12 about the rolling axis 30.

As further illustrated in FIGS. 3-5, the upper and lower suspension arms **24**, **26** also each define respective forward **52**, **54** and aft **56**, **58** ends of the suspension arms **24**, **26**. The forward ends **52**, **54** of the upper and lower suspension arms **24**, **26** are joined to one another by a knee pin **60**, best seen in FIG. 3, to form a pivoting connection, that allows for pivoting movement of the lower arm **26** with respect to the upper arm **24** about a suspension pivot axis **61** that extends generally parallel to the rolling axis **30** of the wheel **12** and is located forward of the rolling axis **30** of the wheel **12**. The aft ends **56**, **58** of the upper and lower suspension arms **24**, **26** are located respectively aft of the frame attachment point **48** and rolling axis **30**, and are respectively adapted for connection to upper and lower ends **62**, **64** of the air strut **22**.

As shown schematically in FIG. 4, each of the air struts **22** in the suspension systems of the exemplary embodiment of the applicator **10** is configured for receiving a flow of pressurized air from an air power source **66**, and for extending and retracting in response to the flow of pressurized air, to thereby respectively lower and raise the rolling axis **30** of the wheel **12** with respect to the frame attachment point **48**, in the manner described above in relation to FIGS. 5-7.

The air struts **22** of the exemplary embodiments are air cylinders, each having an internal movable air piston, contained within a rigid cylinder, and connected to a piston rod of the cylinder. The movable piston and rigid walls of the cylinder form an internal air chamber **72** for receipt of the flow of pressurized air from the air power source **66**. As pressurized air enters the internal air chamber, the air strut is urged to extend. And, conversely as pressurized air exits the internal chamber, the air strut retracts. Because the cylinder has rigid walls, it provides a substantially solid support at any extended length, and can be pressurized to hold a wide range of weights at the desired extended length. In essence, it will be understood that the air struts **22** of the exemplary embodiment of the invention have operating characteristics in which an effective spring rate of the air strut is remotely adjustable to provide a wide variety of desired operating heights, ride characteristics, and operating modes. This provides significant advantages in a trailing arm suspension system **12**, according to the invention, over prior approaches that used compression springs with fixed spring rates, and over prior systems that utilized air springs with flexible side walls which were limited to lower operating pressures.

As indicated in FIG. 3, the air struts **22** of the exemplary embodiment of the applicator **10** also include an integral hydraulic shock absorber **70**, disposed in a linear relationship to the internal air chamber and piston arrangement **72**. Other embodiments of the invention may not utilize such a shock absorber.

As will be understood from the forgoing description, the upper suspension arms **24** of the suspension systems **12** of the exemplary embodiment of the applicator **10**, are rigid, and configured to not articulate vertically with respect to the frame **18**. Furthermore, the forward end **52** of each of the upper suspension arms **24** is located both forward of and below the frame attachment point **48** for that upper suspension arm **24**.

As illustrated in FIG. 4, a trailing-link suspension system **12**, according to the invention, may further include an electronic control unit **68** that is operatively connected and configured for controlling the flow of pressurized air to the air strut **22** from the air power source **66**, to thereby control extension and retraction of the air strut **22**. An electronic control unit **68**, according to the invention, may also be configured to receive an input signal **74** that is indicative of

a desired height **16** of the frame **18** of the applicator **10** above the ground surface **16** beneath the applicator, and for controlling the air power source **66** in a manner causing the air strut **22** and suspension to support the frame **18** at the desired height **16**. In the exemplary embodiment of the applicator **10**, the air struts **22** in the suspension systems **12** of all four wheels **14** are controlled by one or more pressurized air sources **66**, and one or more controllers **68**, that may be cross linked or combined into a common air power source **66** and controller **68** for controlling the height of the frame **18**.

The exemplary embodiment of the applicator **10** is operated using a method, in accordance with the invention, for controlling the height **16** of the frame **18** of the self-propelled agricultural product applicator **10** above a ground surface **20**, by connecting the frame **18** to the four ground supporting wheels **14** of the applicator **12**, using a trailing link suspension system **12** according to the invention at each wheel **14**, and controlling a flow of pressurized air to the air struts **22** of the suspension systems **12**, to thereby control extension of the air struts **22** and height **16** of the applicator frame **18** above the ground surface **20**.

As shown in FIGS. 3, 4 and 8, the exemplary embodiment of the applicator **10** also includes angular position sensors **80** in the suspension systems **12** for all four wheels **14** of the applicator **10**. In the exemplary embodiment of the applicator **10**, the angular position sensors **80** are rotary position sensors, having first and second elements **82**, **84** thereof, in the form of a body **82** and a shaft **84** mounted within the body **82**, that are rotatable relative to one another about a common axis of rotation **86**. In the exemplary embodiment, the sensors **80** are each mounted with their rotational axis **86** in alignment with the suspension pivot axis **61** of the suspension system **12** for their respective wheel **14**.

More specifically, the first element **82** of each sensor **80** is fixedly attached to the lower suspension arm **26** for rotation with the lower arm **26**. The second element **84** is connected via a quill shaft **90** that provides a keyed, driving connection between an internal keyway **92** in the end of the second element **84** of the position sensor **80**, and a second internal keyway **94** in the end of the knee pin **60**. In the exemplary embodiments, the knee pins **60** are pinned to the upper suspension arms **24**, and thus do not rotate relative to the upper arms **24**. As a result of the keyed connection between the second elements **84** of the sensors **80** and the knee pins **60**, the second elements **84** of the sensors **80** are fixedly attached to the upper suspension arms **24**. By virtue of this arrangement angular rotation of the lower suspension arms **26** relative to the upper suspension arms **24** about the suspension pivot axis **61** rotates the first elements **82** of the rotary position sensors **80** relative to the second elements **84** of the sensors **80**, to thereby cause the rotary position sensors **80** to detect the degree of angular rotation between the first and second suspension arms **24**, **26** supporting each of the wheels **14** of the applicator **10**.

In the exemplary embodiment of the applicator **10**, the rotary position sensors **80** are Hall-effect sensors, but it is contemplated that in other embodiments of the invention, rotary potentiometers, or other types of suitable sensors may be utilized for detecting angular position of the upper and lower suspension arms **24**, **26** with respect to one another.

As shown in FIG. 4, each of the angular position sensors **80** provides an electrical output signal **96** that is indicative of the present angular position of the upper and lower suspension arms **24**, **26**, to which the sensor **80** is attached, relative to one another about the suspension pivot axis **61**. The electronic control unit **68** may be operatively connected

for receiving the signal 96 from one or more of the angular position sensors 80, and for controlling the flow of pressurized air to the air struts 22 from the air power source 66, to thereby control extension and retraction of the air struts 22 in response to signals 96 from one or more of the angular position sensors 80. The electronic control unit 68 may be configured to: receive the input signal 74 indicative of a desired height 16 of the frame 18 above the ground surface 20 engaged by the wheels 14; compare the desired height 74 to the current angular position of the upper and lower arms 24, 26 as indicated by the signals 96 received from one or more of the position sensors 80; and control the air power source 66 in a manner causing the air struts 22 to support the frame 18 at the desired height 16 by driving the air struts 22 to an extended position whereat one or more of the angular position sensors 80 indicate that the angular position of the upper and lower arms 24, 26 corresponds to the desired height 16.

It will be appreciated that the invention allows the air strut 22 of the suspension system 12 for each of the wheels 14 to be independently controlled, in response to the signal provided by the angular position sensor 80 attached to the suspension system 12 connecting that wheel 14 to the frame 18. Those skilled in the art will recognize that this degree of control has not been available in most prior approaches to providing suspension systems in agricultural product applicators, particularly in such an elegantly simple and compact manner.

It will be further appreciated that, the invention allows all the air struts 22 at all four wheels 14 of an applicator 10 to be controlled with a single position sensor 80 mounted in the suspension system 12 of one of the wheels 14, if it were deemed desirable to do so by one practicing the invention. It is also contemplated that, in some embodiments, a user of the, invention might choose to practice the invention only on the front wheels, or only on the rear wheels of an applicator.

From the foregoing description, it will be apparent that the invention provides significant advantages over previous suspension systems, apparatuses and methods for high ground clearance, self-propelled, agricultural product applicators. The incorporation of the air strut and the angular position sensor into the suspension system allows the height of the applicator above the ground to be continuously controlled at a desired height, through monitoring of height by the angular position sensor, and regulation of the flow of pressurized air to the strut as the agricultural product is dispensed.

In contrast to prior systems that utilized compression springs, the struts can be actively controlled to maintain a constant height, independent of the load that the applicator may be carrying at any given moment in time. In addition, the ride height may be selected and held for a given load, in a manner that was not possible with prior suspension systems that utilized compression springs or flexible-sided air springs.

Use of the angular position sensor in the suspension system for monitoring ride height is a far simpler solution than prior approaches that relied upon complex linkages to operate other types of sensors.

A suspension system, according to the invention, also allows for height of the applicator to be selectively adjusted for special situations, such as transporting the applicator on a trailer or truck. By controlling the air struts to retract to their lowest position (see FIG. 7) even an unloaded applicator can be made to "kneel" in a lowered position, to

thereby reduce the overall height of the applicator and trailer or truck to facilitate movement of the applicator on public roadways.

As illustrated in FIG. 9, in some embodiments of the invention, various components and functionalities described above may be combined to provide a task-specific ride-height control system 100 in a self-propelled agricultural product applicator 10. The task-specific ride height control system 100 utilizes a controllable ride-height trailing arm suspension system 12, at each of the four corners LF, RF, LR, RR of the applicator 10, for independently joining each of the four wheels 14 to the frame 18 of the applicator 10. In the manner discussed in more detail above, each trailing arm suspension system 12 includes upper and lower suspension arms 24, 26, an extensible air strut 22, and an angular position sensor 80 operatively interconnected to one another and disposed between the rolling axis 30 of the ground engaging wheel 14 independently supported by that suspension system 12, and a point of attachment 48 of the suspension system 12 to the frame 18, such that the position sensor 80 detects a relative angular position between the upper and lower suspension arms 24, 26 at a present extension of the air strut 22.

A common electronic control unit 102 utilizes the angular positions detected by the sensors 80 at all four wheels 14, in conjunction with a desired task input 106, to control the air struts 22 of the four suspension systems 12 through a common air power source 104, in a manner substantially as described above, for automatically providing and maintaining a ride-height 16 corresponding to a desired task input 106.

In such a task-specific ride-height control system 100, according to the invention, the air power source 104 may take any appropriate form. It is contemplated, however, that an air power source 104 for use in practicing the invention might, among other things, include a solenoid operated, pressurized air supply manifold arrangement 108, that is operatively connected to and controlled by the common electronic control unit 102, for providing individually controlled flows of pressurized air to the air strut 22 of each of the suspension systems 12, to thereby control ride-height 16 by independently controlling extension of each of the air struts 22.

The desired task input 106 indicates a specific desired task, selected by the operator of the applicator 10 from a predetermined list of one or more predetermined desired tasks, and the electronic control unit 102 is internally configured to automatically control the air struts 22 at an extension thereof providing a ride-height 16 corresponding to the desired task input 106 selected by the operator. In various forms of the invention, the one or more predetermined desired tasks may include a product application task corresponding to a standard APPLICATION ride-height, as illustrated in FIG. 6, for applying the agricultural product, and at least one additional desired task input 106 corresponding to an additional ride height 16 that is different from the standard ride-height 16, (as illustrated in FIG. 6), used for applying the agricultural product.

In various forms of the invention, the at least one additional desired task input 106 and its corresponding ride-height 16 may be selected from the group of desired task inputs 106 and corresponding ride-heights 16 including: TENDERING, at a maximum ride-height 16 of the applicator 10, as shown in FIG. 5; TRANSIT, at a selected servicing ride-height 16 of the applicator 10 in the range of ride-heights between the maximum and minimum heights shown in FIGS. 5 and 7 respectively; TRANSPORT, at a

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minimum ride-height **16** of the applicator **10**, as shown in FIG. 7; SERVICING, at a selected servicing ride-height **16** of the applicator **10** in the range of ride-heights between the maximum and minimum heights shown in FIGS. 5 and 7 respectively; and PARKED, wherein the air struts **22** of the suspension systems **12** are locked against movement at a present ride-height, i.e. at whatever ride-height **16** the applicator **10** was operating at when the operator of the applicator **10** entered the PARKED desired task mode.

As further illustrated in FIG. 9, some forms of a task-specific ride-height control system **100**, according to the invention, may further include a load sensing arrangement **110** for detecting a weight of the applicator **10** and/or the agricultural product in the product container **38**, and the common electronic control unit **102** may be further configured to modify one or more of the desired task inputs **106** in accordance with a predetermined protocol corresponding to the detected weight. For example, the electronic control unit **106** may be configured to provide a different standard APPLICATION ride height when the applicator **10** is configured for applying a dry product than when the applicator **10** is configured for applying a liquid product. It is contemplated that a load sensing arrangement **108** utilized in practicing the invention may take any appropriate form, and include components such as a load cell (not shown), or an air pressure sensor **112** in the air power source **104**.

In practicing the invention with some form of load sensing arrangement **110** or **112**, it is contemplated that the common electronic control unit **102** may be configured to utilize inputs from the load sensing arrangement **110** or **112**, in combination with signals from the angular position sensors **80** at the four corners LF, RF, LR, RR of the applicator in the configured protocols that the electronic control unit **102** utilizes for controlling ride-height **16** at one or more of the desired task-specific ride heights provided in the configuration of the task-specific ride-height control system **100**.

Those having skill in the art will readily appreciate that through practice of a task-specific ride-height control system **100**, according to the invention, operating case and functionality of the applicator **10** is substantially enhanced. By automating control of ride-height **16** as a function of a desired task input **106**, the operator is freed from manual manipulation of ride-height to concentrate more on driving the applicator **10** in a manner resulting in optimal application efficiency and effectiveness. It will also be appreciated that practice of the invention in its various forms provides substantially greater freedom for automated task-specific ride-control that could be achieved in prior approaches to providing suspension systems in self-propelled agricultural product applicators.

The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) is to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use

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of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. It is anticipated that skilled artisans may employ such variations as appropriate, and further anticipated that the invention may be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

We claim:

1. A task-specific ride-height control system for a self-propelled agricultural product applicator having three or more ground engaging wheels operatively joined to a frame adapted for supporting at least one agricultural product container and defining forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame, the task-specific ride-height system comprising:

a controllable ride-height trailing arm suspension system independently joining each wheel to the frame, with each trailing arm suspension system including an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor operatively interconnected to one another and disposed between a rolling axis of the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame such that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut;

an air power source for providing a controlled flow of pressurized air to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts; and

an electronic control unit operatively connected to the angular position sensors and the air power source;

the electronic control unit being configured for receiving a desired task input from an operator and signals from the angular position sensors indicative of a present relative angular position of the upper and lower suspension arms of each suspension system, and commanding the air power source to control the air struts at an extension thereof providing a ride-height corresponding to the desired task input.

2. The task-specific ride-height control system of claim 1, wherein, for each trailing-arm suspension system for connecting one of the ground engaging wheels to the frame:

the upper suspension arm defines a frame attachment point thereof, adapted for fixed attachment to the frame;

the lower suspension arm defines a rolling axis of the ground engaging wheel and adapted for supportive

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attachment thereto of the ground engaging wheel for rotation of the ground engaging wheel about the rolling axis of the wheel;

the upper and lower suspension arms also define respective forward and aft ends thereof, with the forward ends being adapted for operative pivoting connection to one another through an angular rotation about the suspension pivot axis extending generally parallel to the rolling axis of the wheel and disposed forward of the rolling axis of the wheel, and the aft ends of the upper and lower suspension arms are disposed respectively aft of the frame attachment point and rolling axis, with the aft ends of the upper and lower suspension arms being respectively adapted for operative attachment thereto of the air strut; and

the angular position sensor is operatively connected between the upper and lower suspension arms for detecting the angular rotation of the upper and lower arms with respect to each other about the pivot axis, the angular rotation detected being indicative of a distance between the rolling axis of the wheel and the frame attachment point, and thereby also indicative of a ride height of the frame above the ground.

3. The task-specific ride-height control system of claim 2, wherein the angular position sensor is a rotary position sensor, having a first element thereof fixedly attached to the lower suspension arm for rotation therewith, and also having a second element thereof that is rotatable relative to the first element, with the second element being fixedly attached to the upper suspension arm for rotation therewith, in such a manner that angular rotation of the upper and lower suspension arms relative to one another about the suspension pivot axis rotates the first and second elements of the rotary position sensor relative to one another, to thereby cause the rotary position sensor to detect the angular rotation.

4. The task-specific ride-height control system of claim 1, wherein, for the suspension system of each wheel, the air strut is configured for receiving a flow of pressurized air from an air power source, and for extending and retracting in response to the flow of pressurized air, to thereby respectively lower and raise the rolling axis of the wheel with respect to the frame attachment point.

5. The task-specific ride-height control system of claim 1, wherein the desired task input indicates a selected desired task of one or more predetermined desired tasks, and the electronic control unit is configured to control the air struts at an extension thereof providing a ride-height corresponding to the selected desired task input.

6. The task-specific ride-height control system of claim 5, wherein the one or more predetermined desired tasks includes a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height.

7. The task-specific ride-height control system of claim 6, wherein the at least one additional desired task input and its corresponding ride-height is selected from the group of desired task inputs and corresponding ride-heights consisting of: tending, at a maximum ride-height of the applicator; transit, at a transit ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

8. The task-specific ride-height control system of claim 7, wherein the system further comprises a load sensor for

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detecting a weight of the applicator and agricultural product in the product container, and the electronic control unit is further configured to modify one or more of the desired task inputs in accordance with a predetermined protocol corresponding to the detected weight.

9. A self-propelled agricultural product applicator having three or more ground engaging wheels operatively joined to a frame of the applicator, with the frame being adapted for supporting at least one agricultural product container and defining forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame, the wheels each being joined to the frame by a task-specific ride-height system comprising:

a controllable ride-height trailing arm suspension system independently joining each wheel to the frame, with each trailing arm suspension system including an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor operatively interconnected to one another and disposed between a rolling axis of the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame such that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut;

an air power source for providing a controlled flow of pressurized air to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts; and

an electronic control unit operatively connected to the angular position sensors and the air power source;

the electronic control unit being configured for receiving a desired task input from an operator and signals from the angular position sensors indicative of a present relative angular position of the upper and lower suspension arms of each suspension system, and commanding the air power source to control the air struts at an extension thereof providing a ride-height corresponding to the desired task input.

10. The applicator of claim 9, wherein, for each trailing-arm suspension system for connecting one of the ground engaging wheels to the frame:

the upper suspension arm defines a frame attachment point thereof, adapted for fixed attachment to the frame;

the lower suspension arm defines a rolling axis of the ground engaging wheel and adapted for supportive attachment thereto of the ground engaging wheel for rotation of the ground engaging wheel about the rolling axis of the wheel;

the upper and lower suspension arms also define respective forward and aft ends thereof, with the forward ends being adapted for operative pivoting connection to one another through an angular rotation about the suspension pivot axis extending generally parallel to the rolling axis of the wheel and disposed forward of the rolling axis of the wheel, and the aft ends of the upper and lower suspension arms are disposed respectively aft of the frame attachment point and rolling axis, with the aft ends of the upper and lower suspension arms being respectively adapted for operative attachment thereto of the air strut; and

the angular position sensor is operatively connected between the upper and lower suspension arms for detecting the angular rotation of the upper and lower

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arms with respect to each other about the pivot axis, the angular rotation detected being indicative of a distance between the rolling axis of the wheel and the frame attachment point, and thereby also indicative of a ride height of the frame above the ground.

11. The applicator of claim 10, wherein the angular position sensor is a rotary position sensor, having a first element thereof fixedly attached to the lower suspension arm for rotation therewith, and also having a second element thereof that is rotatable relative to the first element, with the second element being fixedly attached to the upper suspension arm for rotation therewith, in such a manner that angular rotation of the upper and lower suspension arms relative to one another about the suspension pivot axis rotates the first and second elements of the rotary position sensor relative to one another, to thereby cause the rotary position sensor to detect the angular rotation.

12. The applicator of claim 9, wherein, for the suspension system of each wheel, the air strut is configured for receiving a flow of pressurized air from an air power source, and for extending and retracting in response to the flow of pressurized air, to thereby respectively lower and raise the rolling axis of the wheel with respect to the frame attachment point.

13. The applicator of claim 9, wherein the desired task input indicates a selected desired task of one or more predetermined desired tasks, and the electronic control unit is configured to control the air struts at an extension thereof providing a ride-height corresponding to the selected desired task input.

14. The applicator of claim 13, wherein the one or more predetermined desired tasks includes a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height.

15. The applicator of claim 14, wherein the at least one additional desired task input and its corresponding ride-height is selected from the group of desired task inputs and corresponding ride-heights consisting of: tendering, at a maximum ride-height of the applicator; transit, at a transit ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

16. The applicator of claim 15, wherein the task-specific ride-height control system further comprises a load sensor for detecting a weight of the applicator and agricultural product in the product container, and the electronic control unit is further configured to modify one or more of the desired task inputs in accordance with a predetermined protocol corresponding to the detected weight.

17. A method for providing task-specific ride-height control for a self-propelled agricultural product applicator having three or more ground engaging wheels operatively joined to a frame adapted for supporting at least one agri-

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cultural product container and defining forward and rear ends of the frame, a longitudinally extending central axis of the frame extending from the rear to the front of the frame in a direction of travel of the applicator, and a vertical axis of the frame, the method for providing task-specific ride-height control comprising:

independently joining each wheel to the frame with a controllable ride-height trailing arm suspension system, with each trailing arm suspension system including an upper suspension arm, a lower suspension arm, an extensible air strut and an angular position sensor operatively interconnected to one another and disposed between a rolling axis of the ground engaging wheel independently supported by that suspension system and a point of attachment of the suspension system to the frame such that the angular position sensor detects a relative angular position between the upper and lower suspension arms at a present extension of the air strut;

providing a controlled flow of pressurized air from an air power source to the air strut of each of the suspension systems, to thereby control ride-height by controlling extension of each of the air struts; and

operatively connecting an electronic control unit to the angular position sensors and the air power source;

receiving, a desired task input from an operator and signals from the angular position sensors, at the electronic control unit, the signals from the angular position sensor being indicative of a present relative angular position of the upper and lower suspension arms of each suspension system; and

utilizing the electronic control unit for commanding the air power source to control the air struts at an extension thereof providing a ride-height corresponding to the desired task input.

18. The method of claim 17, wherein the desired task input indicates a selected desired task of one or more predetermined desired tasks, and the electronic control unit is configured to control the air struts at an extension thereof providing a ride-height corresponding to the selected desired task input.

19. The method of claim 18, wherein the one or more predetermined desired tasks includes a product application task corresponding to a standard ride-height for applying the agricultural product, and at least one additional desired task input corresponding to an additional ride height.

20. The method of claim 19, wherein the at least one additional desired task input and its corresponding ride-height is selected from the group of desired task inputs and corresponding ride-heights consisting of: tendering, at a maximum ride-height of the applicator; transport, at a minimum ride-height of the applicator; servicing, at a servicing ride-height of the applicator; and parked, wherein the suspension systems are locked against movement at a present ride-height when the applicator enters a parked task mode.

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