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(54) **CONTROL VALVE ASSEMBLY**

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(58) **Field of Classification Search**
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USPC .... 91/189 A, 526; 60/424, 420, 422, 459, 60/468
See application file for complete search history.

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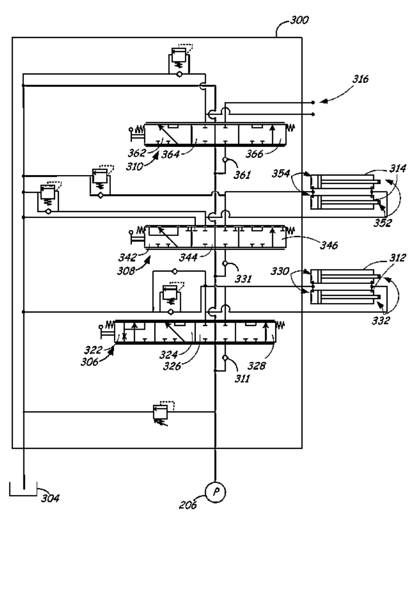
(57) **ABSTRACT**

A power machine and a power conversion system for a power machine are disclosed. In an exemplary embodiment, the power conversion system includes a pump configured to provide a source of pressurized hydraulic fluid and a control valve assembly to receive the hydraulic fluid. The control valve assembly includes a first valve element configured to direct hydraulic fluid to an actuator when the first valve element is in first and second actuated positions. The control valve assembly also includes a second valve element downstream of the first spool. The first valve element is moveable between an unactuated position and the first and second actuated positions and is configured to direct hydraulic fluid received from the actuator through the second actuated position to the second valve element and to direct hydraulic fluid received from the actuator through the first actuated position to bypass the second valve element.

19 Claims, 7 Drawing Sheets



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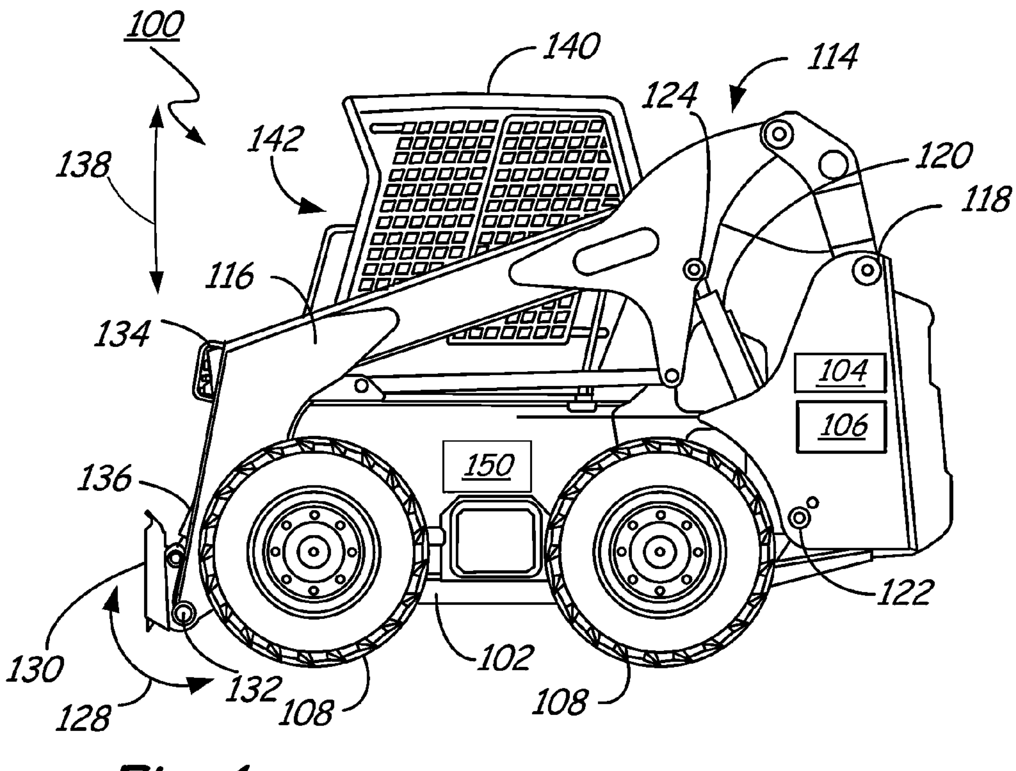
100
140
114
124
142
120
138
118
116
134
104
106
150
136
122
130
102
132
108
108
128

Fig. 1

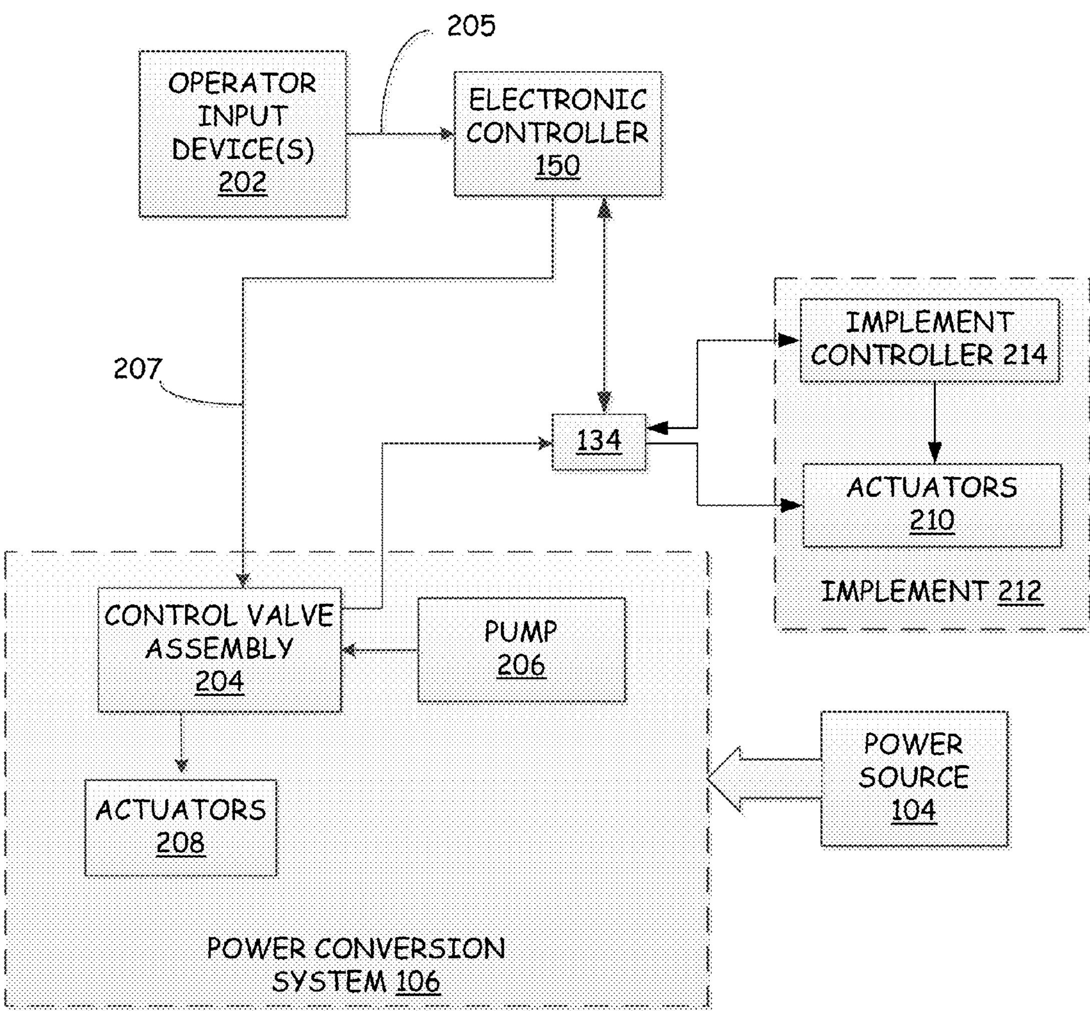
205
OPERATOR INPUT DEVICE(S) 202
ELECTRONIC CONTROLLER 150
207
IMPLEMENT CONTROLLER 214
134
ACTUATORS 210
IMPLEMENT 212
CONTROL VALVE ASSEMBLY 204
PUMP 206
POWER SOURCE 104
ACTUATORS 208
POWER CONVERSION SYSTEM 106

Fig. 2

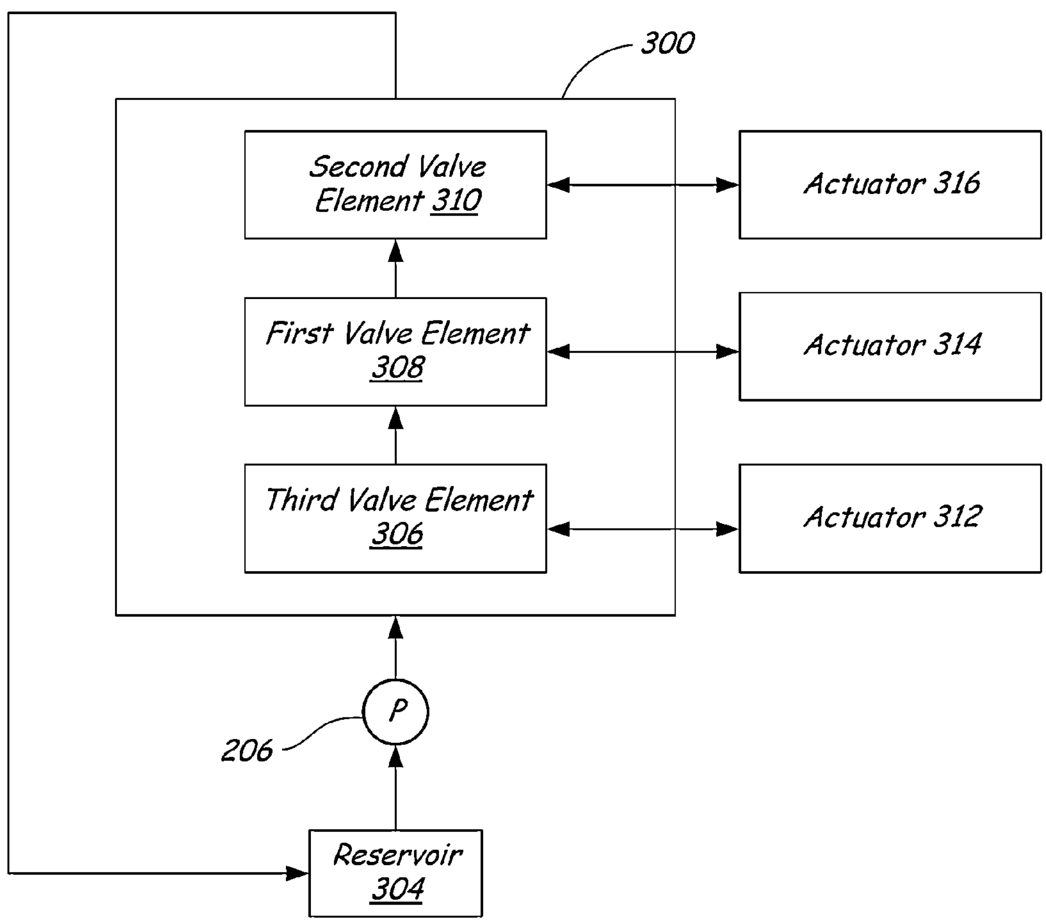
300
Second Valve Element 310
Actuator 316
First Valve Element 308
Actuator 314
Third Valve Element 306
Actuator 312
P
206
Reservoir 304

Fig. 3

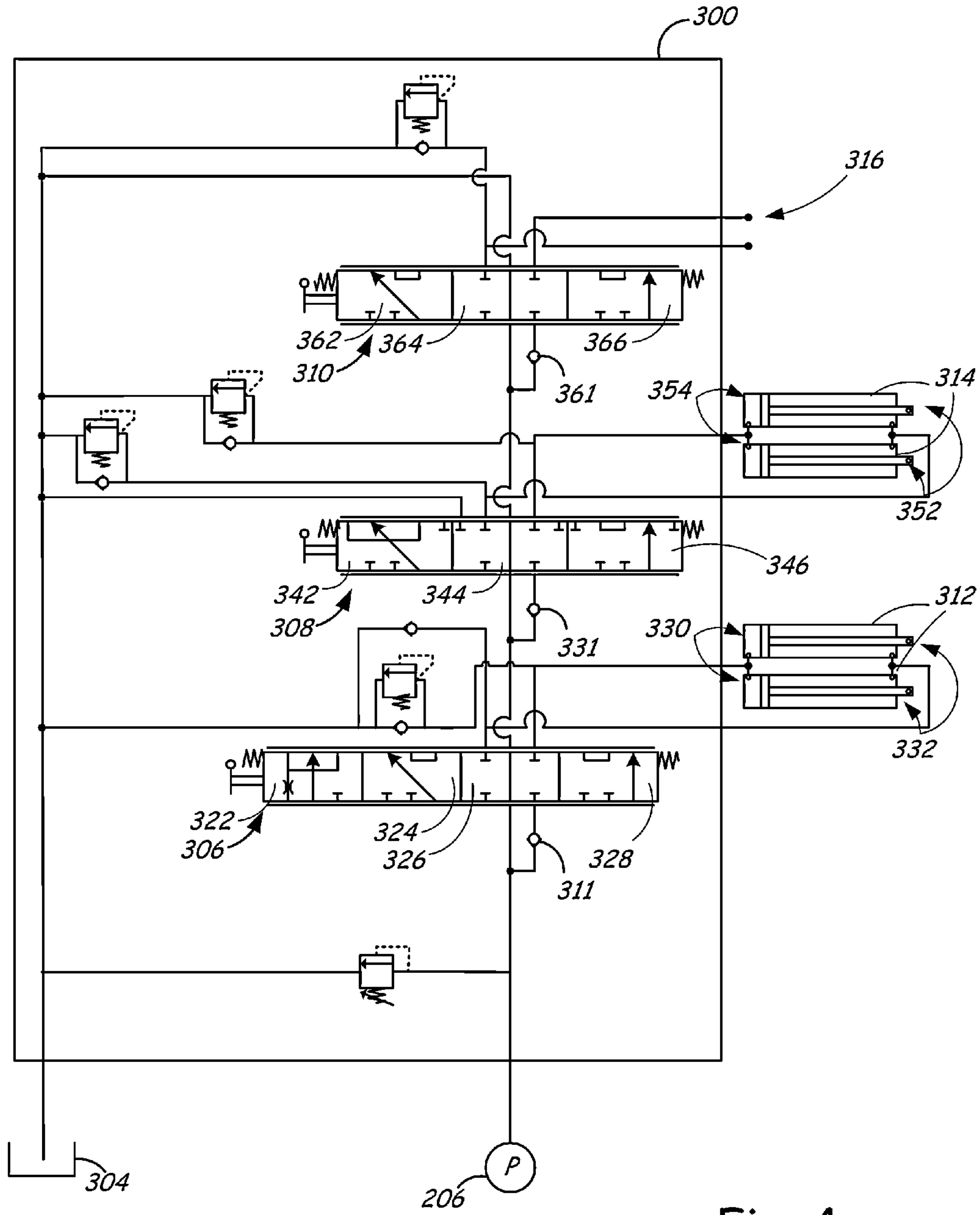
300
316
362
364
366
310
361
354
314
352
342
344
346
308
331
330
312
332
322
306
324
326
328
311
304
P
206

Fig. 4

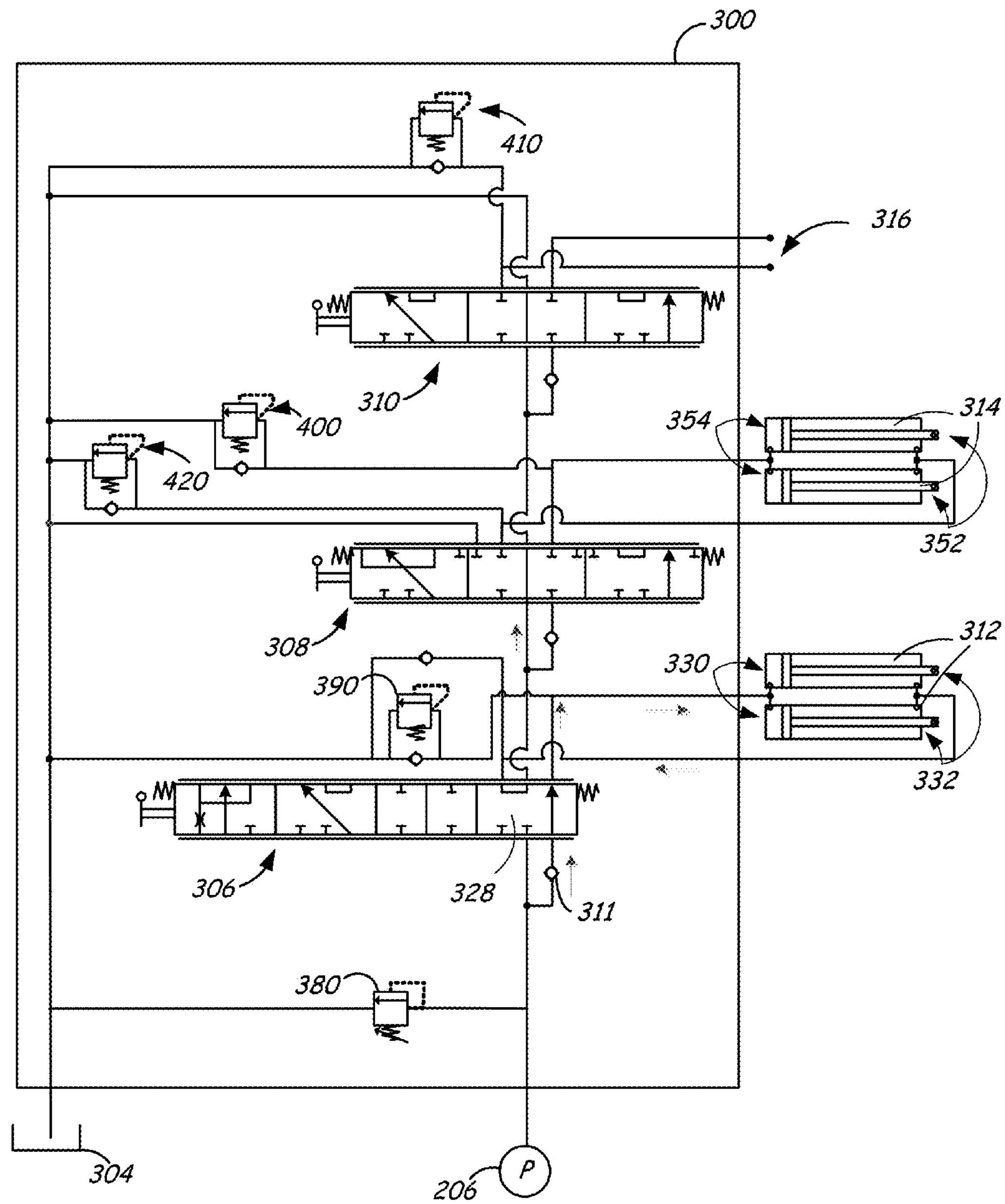
300
410
316
310
400
420
354
314
352
308
390
330
312
332
306
328
311
380
304
206
P

Fig . 5

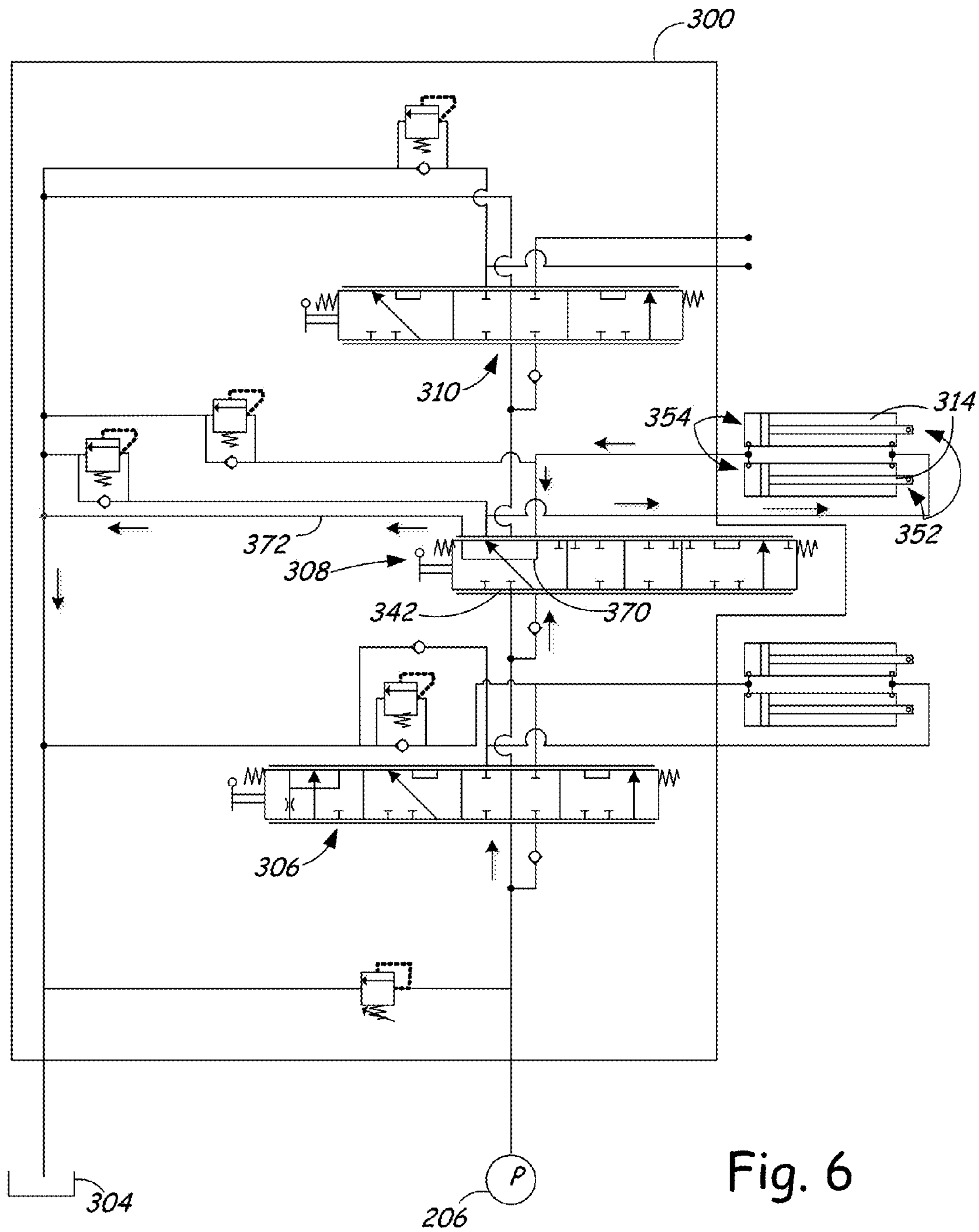

Fig. 6

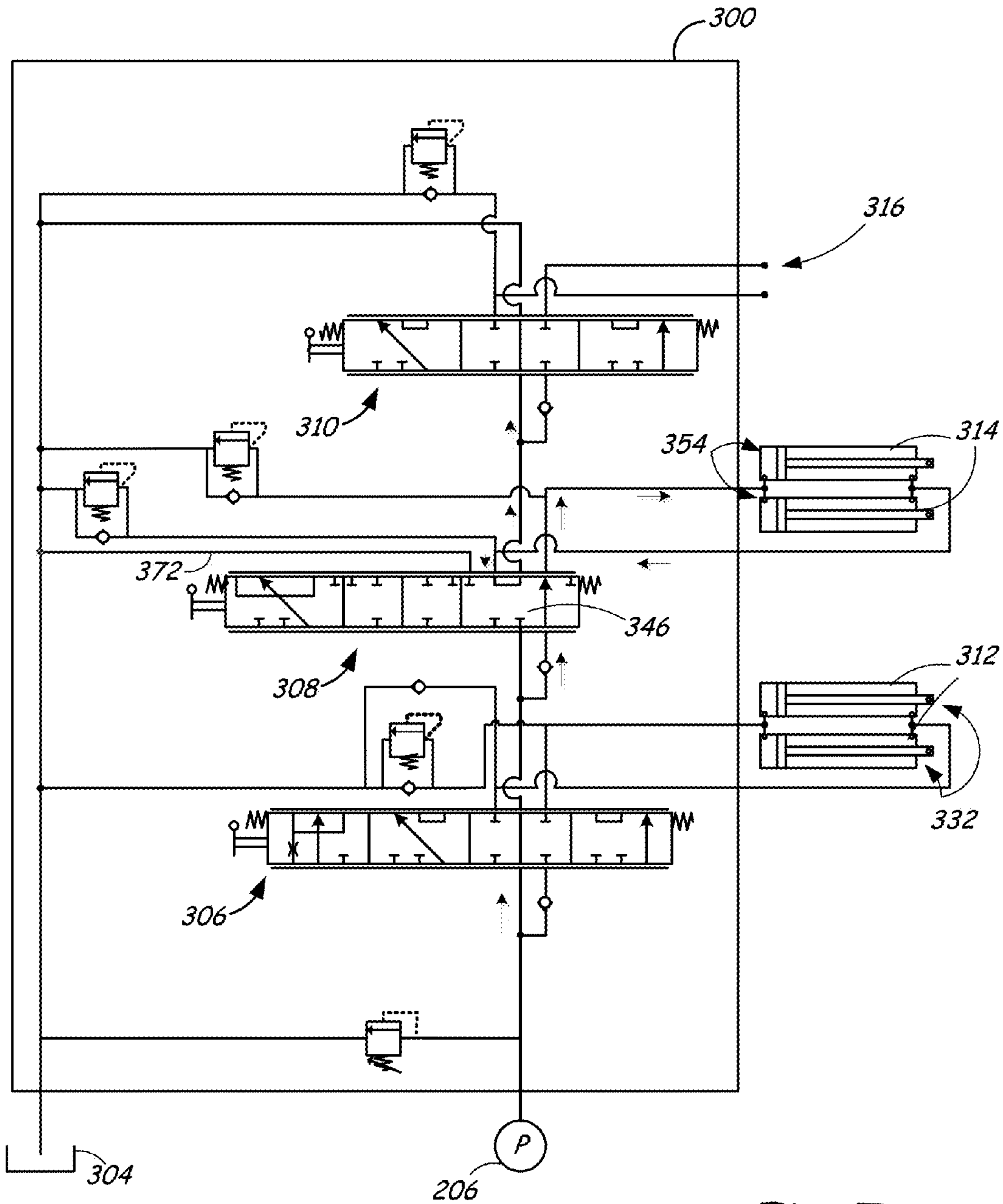

Fig. 7

CONTROL VALVE ASSEMBLY

FIELD

Disclosed embodiments relate to power machines that employ a control valve assembly for controlling hydraulic fluid flow provided to various actuators that are operably coupled to the control valve assembly.

BACKGROUND

Some power machines including skid steer loaders, tracked loaders, steerable axle loaders, excavators, telehandlers, walk behind loaders, trenchers, and the like, employ engine powered hydraulic power conversion systems. In some power machines, the hydraulic power conversion systems utilize an open center series control valve assembly that receives pressurized fluid from a pump. This control valve assembly typically has multiple valve elements to port hydraulic fluid to different work functions on the power machine. For example, on a work machine with a lift cylinder that raises and lowers a lift arm, a tilt cylinder that controls a tilt position of an implement carrier and thus an attached implement with respect to the lift arm, and one or more implement work actuators, the control valve assembly may have three (although any number can be used) valve elements, often in the form of linear spools, to port hydraulic fluid to the different actuators on the power machine and/or implement. The term open center refers to a feature in a valve assembly such that when a valve element is in an unactuated position (such as the center position on a typical spool valve) or a partially actuated position (such as in a proportional spool valve), at least some hydraulic fluid is allowed to flow through the unactuated position to a downstream valve element.

The valve elements in an open center control valve assembly are arranged such that the first valve element that receives hydraulic fluid from a pump has priority over subsequent downstream valve elements. A traditional priority in a power machine such as a skid steer loader is that the hydraulic fluid is provided first to a lift valve element, which is used to selectively control the lift cylinder to raise and lower the lift arm. Subsequently hydraulic fluid is provided to the tilt valve element, which is used to control the tilt cylinder and then to the auxiliary or implement valve element and then out of the valve.

It is known that in certain open center hydraulic control valve assemblies, when downstream valve elements are actuated to provide fluid to a downstream actuator, back pressures can be raised to a point where functionality of upstream elements can be limited or compromised.

The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

SUMMARY

Disclosed embodiments include a power machine and a power conversion system for a power machine. In an exemplary embodiment, the power conversion system includes a pump configured to provide a source of pressurized hydraulic fluid. A control valve assembly is coupled to the pump to receive the hydraulic fluid. The control valve assembly includes a first valve element configured to direct pressurized hydraulic fluid to and receive pressurized hydraulic fluid from an actuator when the first valve element is in first and second actuated positions. The control valve assembly also includes a second valve element downstream of the first valve element.

The first valve element is moveable between an unactuated position and the first and second actuated positions. The control valve assembly is configured to direct hydraulic fluid received from the actuator through the second actuated position to the second valve element and direct hydraulic fluid received from the actuator through the first actuated position to bypass the second valve element.

This Summary and the Abstract are provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view of a power machine having a power conversion system with a control valve assembly in accordance with exemplary embodiments.

FIG. **2** is a block diagram illustrating components of the power machine and power conversion system of FIG. **1**.

FIG. **3** is a block diagram illustrating a power conversion system according to one illustrative embodiment.

FIGS. **4-7** are hydraulic circuit diagrams illustrating an exemplary embodiment of a control valve assembly of FIG. **3** configured to implement disclosed embodiments and concepts.

DETAILED DESCRIPTION

The concepts disclosed herein are not limited in their application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. That is, the embodiments disclosed herein are illustrative in nature. The concepts illustrated in these embodiments are capable of being practiced or being carried out in various ways. The phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. Words such as “including,” “comprising,” and “having” and variations thereof as used herein are meant to encompass the items listed thereafter, equivalents thereof, as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

FIG. **1** is a side elevation view of a representative power machine **100** upon which the disclosed embodiments can be employed. FIG. **2** is a block diagram illustrating certain features and arrangements of the power machine. The power machine **100** illustrated in FIG. **1** is a skid loader, but other types of power machines such as tracked loaders, steerable wheeled loaders, including all-wheel steer loaders, excavators, telehandlers, walk behind loaders, trenchers, and utility vehicles, to name but a few examples, may employ the disclosed embodiments. The power machine **100** includes a supporting frame or main frame **102**, which supports a power source **104**, which in some embodiments is an internal combustion engine. A power conversion system **106** is operably coupled to the power source **104**. Power conversion system **106** illustratively receives power from the power source **104** and operator inputs to convert the received power to power signals in a form that is provided to and utilized by functional components of the power machine. In some embodiments, such as with the power machine **100** in FIG. **1**, the power conversion system **106** includes hydraulic components such as one or more hydraulic pumps and various actuators and valve components that are illustratively employed to receive and selectively provide power signals in the form of pressurized hydraulic fluid to some or all of the actuators used to control functional components of the power machine **100**. For example, a control valve assembly **204** (shown in FIG. **2**) can be used to selectively provide pressurized hydraulic fluid from a hydraulic pump **206** (shown in FIG. **2**) to actuators **208** (shown in FIG. **2**) such as hydraulic cylinders that are positioned on the power machine. In some embodiments, control valve assembly **204** also selectively provides pressurized hydraulic fluid to actuators **210** located on an implement **212** attached to the power machine. Other types of control systems are contemplated. For example, the power conversion system **106** can include electric generators or the like to generate electrical control signals to power electric actuators. For the sake of simplicity, the actuators discussed in the disclosed embodiments herein are referred to as hydraulic or electrohydraulic actuators, but other types of actuators can be employed in some embodiments.

Among the functional components that are capable of receiving power signals from the power conversion system **106** are tractive elements **108**, illustratively shown as wheels, which are configured to rotatably engage a support surface to cause the power machine to travel. Other examples of power machines can have tracks or other tractive elements instead of wheels. In an example embodiment, a pair of hydraulic motors (not shown in FIG. **1**), are provided to convert a hydraulic power signal into a rotational output. In power machines such as skid steer loaders, a single hydraulic motor can be operatively coupled to both of the wheels on one side of the power machine. Alternatively, a hydraulic motor can be provided for each tractive element in a machine. In a skid steer loader, steering is accomplished by providing unequal rotational outputs to the tractive element or elements on one side of the machine as opposed to the other side. In some power machines, steering is accomplished through other means, such as, for example, steerable axles.

The power machine **100** also includes a lift arm structure **114** that is capable of being raised and lowered with respect to the frame **102**. The lift arm structure **114** illustratively includes a lift arm **116** that is pivotally attached to the frame **102** at attachment point **118**. An actuator **120**, which in some embodiments is a hydraulic cylinder configured to receive pressurized fluid from power conversion system **106**, is pivotally attached to both the frame **102** and the lift arm **116** at attachment points **122** and **124**, respectively. Actuator **120** is sometimes referred to as a lift cylinder, and is a representative example of one type of actuator **208** shown in FIG. **2**. Extension and retraction of the actuator **120** causes the lift arm **116** to pivot about attachment point **118** and thereby be raised and lowered along a generally vertical path indicated approximately by arrow **138**. The lift arm **116** is representative of the type of lift arm that may be attached to the power machine **100**. The lift arm structure **114** shown in FIG. **1** includes a second lift arm and actuator disposed on an opposite side of the of the power machine **100**, although neither is shown in FIG. **1**. Other lift arm structures, with different geometries, components, and arrangements can be coupled to the power machine **100** or other power machines upon which the embodiments discussed herein can be practiced without departing from the scope of the present discussion.

An implement carrier **130** is pivotally attached to the lift arm **116** at attachment point **132**. One or more actuators such as hydraulic cylinder **136** are pivotally attached to the implement carrier and the lift arm structure **114** to cause the implement carrier to rotate under power about an axis that extends through the attachment point **132** in an arc approximated by arrow **128** in response to operator input. In some embodiments, the one or more actuators pivotally attached to the implement carrier and the lift arm assembly are hydraulic cylinders capable of receiving pressurized hydraulic fluid from the power conversion system **106**. In these embodiments, the one or more hydraulic cylinders **136**, which are sometimes referred to as tilt cylinders, and are further representative examples of actuators **208** shown in FIG. **2**. Although no implements are shown as being attached to the power machine **100** in FIG. **1**, the implement carrier **130** is configured to accept and secure any one of a number of different implements (e.g., implement **212** shown in FIG. **2**) to the power machine **100** as may be desired to accomplish a particular work task.

In some applications, a simple bucket can be attached to the implement carrier **130** to accomplish a variety of tasks. However, many other attachments that include various actuators such as cylinders and motors, to name two examples, can also be attached to the implement carrier **130** to accomplish a variety of tasks. A partial list of the types of implements that can be attached to the implement carrier **130** includes augers, planers, graders, combination buckets, wheel saws, and the like. These are only a few examples of the many different types of implements that can be attached to power machine **100**. The power machine **100** provides a source, accessible at connection point **134**, of power and control signals that can be coupled to an implement to control various functions on such an implement, in response to operator inputs. In one embodiment, connection point **134** includes hydraulic couplers that are connectable to the implement **212** for providing power signals in the form of pressurized fluid provided by the power conversion system **106** for use by an implement that is operably coupled to the power machine **100**. Alternatively or in addition, connection point **134** includes electrical connectors that can provide power signals and control signals to an implement to control and enable actuators of the type described above to control operation of functional components on an implement. Actuation devices **210** located on an implement are controllable using control valve assembly **204** of power system **106**.

Power machine **100** also illustratively includes a cab **140** that is supported by the frame **102** and defines, at least in part, an operator compartment **142**. Operator compartment **142** typically includes an operator seat (not shown in FIG. **1**) and operator input devices **202** (shown schematically in FIG. **2**) and display devices accessible and viewable from a sitting position in the seat. When an operator is seated properly within the operator compartment **142**, the operator can manipulate operator input devices **202** to control such functions as driving the power machine **100**, raising and lowering the lift arm structure **114**, rotating the implement carrier **130** about the lift arm structure **114** and make power and control signals available to implement **212** via the sources available at connection point **134**.

In some embodiments, an electronic controller **150** (shown in FIGS. **1** and **2**) is configured to receive input signals from at least some of the operator input devices **202** and provide control signals to the power conversion system **106** and to implements via connection point **134**. It should be appreciated that electronic controller **150** can be a single electronic control device with instructions stored in a memory device and a processor that reads and executes the instructions to receive input signals and provide output signals all contained within a single enclosure. Alternatively, the electronic controller **150** can be implemented as a plurality of electronic devices coupled on a network. The disclosed embodiments are not limited to any single implementation of an electronic control device or devices. The electronic device or devices such as electronic controller **150** are programmed and configured by the stored instructions to function and operate as described.

Referring now more particularly to FIG. **2**, further features of power machine **100** are shown in block diagram form in accordance with exemplary embodiments. As shown, the one or more operator input devices **202** are operatively coupled to electronic controller **150** via a network **205** or other hard wired or wireless connection. The operator input devices **202** are manipulable by an operator to provide control signals to the electronic controller **150** via network **205** to communicate control intentions of the operator. The operator input devices **202** are to provide control signals for controlling some or all of the functions on the machine such as the speed and direction of travel, raising and lowering the lift arm structure **114**, rotating the implement carrier **130** relative to the lift arm structure, and providing power and control signals to an implement to name a few examples. Operator input devices **202** can take the form of joystick controllers, levers, foot pedals, switches, actuable devices on a hand grip, pressure sensitive electronic display panels, and the like.

In response to control signals generated by operator input devices **202**, electronic controller **150** controls operation of control valve assembly **204** and actuators **208**. In addition, electronic controller **150** can control actuators **210** on implement **212** or alternatively provide signals to an implement controller **214** that can, in turn, directly control one or more actuators **210** or provide control signals back to the electronic controller **150** to signal that control valve assembly **204** be actuated to provide hydraulic fluid to one or more of the actuators **210**. Control of actuators **208** and **210** is, in at least some respects, performed using electrical signals on control lines or network **207** to control spool valves of control valve assembly **204** to selectively direct the flow of hydraulic fluid from pump **206** to those actuators. Flow of hydraulic fluid to actuators **210** on implement **212** is through hydraulic lines connected to the implement at connection point **134**. Disclosed embodiments are described with reference to control of a control valve assembly **204** for selectively providing pressurized hydraulic fluid to actuators **208** on power machine **100**, which can include lift cylinders **120** and tilt cylinders **136**, and actuators **210** on implement **212** attached to implement carrier **130**.

FIG. **3** illustrates a simple block diagram of one embodiment of a series control valve assembly **300** of the type that might be employed as control valve assembly **204** in the power machine **100** discussed above. Embodiments discussed in more detail below show and describe an open center series control valve assembly, but some of the concepts discussed herein can be applied to other types of control valves and need not be limited to an open center series control valve. Generally, the series control valve assembly **300** receives pressurized hydraulic fluid from pump **206**, which draws fluid from a reservoir **304**, which may or may not be pressurized. The series control valve assembly **300** includes a plurality of valve elements **306**, **308**, and **310** in a priority arrangement, i.e. valve element **306** receives pressurized fluid from the pump **206** first, and then fluid is provided next to valve element **308**, and then to valve element **310**. While three valve elements are shown, in alternative embodiments, an series control valve assembly can include a different number of valve elements. As shown, each of the valve elements **306**, **308**, and **310** is connected to and controls an actuator **312**, **314**, and **316** in a corresponding circuit. For the purposes of discussing the embodiments below, valve element **308** will be referred to as a first valve element, valve element **310** will be referred to as a second valve element, and valve element **306** will be referred to as a third valve element. As shown, the third valve element **306** has priority over both the first and second valve elements **308** and **310**. First valve element **308** likewise has priority over the second valve element **310**. After the pressurized fluid has passed through the control valve assembly **300**, it is returned from the control valve assembly **300** to the reservoir **304**. How oil passes through the control valve assembly **300** will be discussed in more detail below.

Referring now to FIGS. **4-7**, series control valve assembly **300** is shown in more detail. Series control valve assembly **300** includes features that allow an upstream circuit that controls a machine function, such as the tilt function, to be controlled in either direction regardless of whether a high load exists on a downstream circuit, such as the implement circuit, that might otherwise prevent the upstream function from being actuated. The series control valve assembly **300** is described below with respect to the control of specific functions of a power machine, but it should be appreciated that concepts discussed below need not be incorporated only on the functions with which they are shown. More particularly, a bypass feature described below associated with a valve element that controls a tilt function can be incorporated on any spool or other applicable valve element to realize the advantages provided by such a feature. Series control valve assembly **300** is illustratively a spool valve assembly with three spools (although any number can be used). As illustrated, the third valve element **306** selectively provides hydraulic fluid to one or more lift arm actuators **312**, the first valve element **308** selectively provides hydraulic fluid to one or more tilt actuators **314** and the second valve element **310** selectively provides hydraulic fluid to an auxiliary hydraulic port **316**. Although other types of actuators may be employed, in the illustrated embodiment, the lift arm actuators **312** and tilt actuators **314** are hydraulic cylinders and will be described as such. In some embodiments, at least the first valve element **310** is a proportional spool that allows for metered flow as the spool moves from an unactuated position to a fully actuated position. By metering flow, partial actuation of a spool valve, in response to an operator input, for example, allows the operator to advantageously control the rate at which an actuator controlled by a proportional spool is operated. Thus, the rate at which a lift arm is raised or lowered or an implement carrier is rotated can be controlled. Any of the other valve elements in the series control valve assembly **300** can also be proportional spools.

In this example, third valve element **306** is a four-position lift spool, with position **322** being a float position in which each of a base end **330** and a rod end **332** of the one or more lift cylinders **312** ported to the reservoir **304** so that the lift arm is allowed to float while the power machine is traveling over terrain. Position **324** of the third valve element **306** is a commanded lowering position in which hydraulic fluid is ported to the rod ends **332** of the lift arm actuators **312** to lower the lift arm. Position **326** is a centered or unactuated position in which no command is provided to the lift cylinders **312**, which causes the lift cylinders to remain in their current position. Position **328** is a raising position in which hydraulic fluid is ported to the base end **330** of actuator **312** to raise the lift arm.

The first valve element **308** is illustratively a three-position tilt spool. A first position **342** is illustratively a roll back position in which hydraulic fluid is ported to the rod ends **352** of tilt actuators **314** to cause the implement carrier **130** and any attached implement to pivot, or roll back, toward the lift arm structure **114**. Position **344** is an centered or unactuated position in which no command is provided to the tilt cylinders **314**, which causes the lift cylinders to remain in their current position. Position **346** being a roll out position in which hydraulic fluid is ported to base end **354** of actuator **314**, which causes the implement carrier and any attached implement to pivot, or roll out, away from the lift arm structure **114**. The second valve element **310** is also a three-position spool, with position **362** being a first actuated position configured to providing hydraulic fluid to a first line of the auxiliary port **134**, position **364** being an unactuated centered position, and position **366** being a second actuated position for providing hydraulic fluid to a second line of auxiliary port **134**. Check valves **311**, **331** and **361** precede inlets to third, second, and third valve elements **306**, **308** and **310**, respectively, to prevent the flow of hydraulic fluid back through the spools when each of the spools is being actuated.

FIG. **4** illustrates each of the first **308**, second **310**, and third **306** valve elements in a centered or unactuated position. Hydraulic fluid is allowed to flow through each of the first, second, and third valve elements and back to reservoir **304**. Referring now for the moment more specifically to FIG. **5**, shown is control valve assembly **300** with lift spool **306** shifted to the raising position **328** to provide hydraulic fluid to the lift arm actuators **312** to raise the lift arm. In this position, hydraulic fluid from pump **206** passes through check valve **311** and into base end **330** of actuators **312**, thus extending the actuator. The fluid path is illustrated with arrows in FIG. **5**. As discussed above, at least the first element is a proportional spool. In an open center valve assembly, shifting the spools in either direction toward an actuated position may allow some fluid to continue to flow through the unactuated position toward downstream circuits unless and until the spool is fully shifted to the actuated position. FIG. **5**, as well as FIGS. **6** and **7** illustrate the spools being shifted into a fully actuated position and arrows showing fluid flow do not indicate that any fluid flow is provided downstream via the unactuated positions, even though when the spools are not fully actuated, some fluid flow can be provided through the unactuated positions downstream. Hydraulic fluid forced from rod end **332** of actuator **312** is routed back through third valve element **306** and directed toward first valve element **308**. This fluid path is also illustrated with arrows. When the lift arm actuators **312** are fully extended, porting fluid to the base end **330** of the cylinder will not force any more fluid out of the lift cylinders and into the downstream circuit. Furthermore, continuing to provide fluid to the base end of the lift cylinders could result in an extremely high pressure buildup on the base end. A relief valve **380** coupling the outlet of the relief valve to reservoir relieves high pressure port fluid away from the base end of the lift cylinder in this instance out of the control valve assembly **300** and eventually to the inlet of the reservoir **304**.

In exemplary embodiments, each of valve elements **306**, **308** and **310** of control valve assembly **300** has a port relief/anti-cavitation valve for relieving pressures across the corresponding actuator when the spool is in a centered position and/or the corresponding actuator is subject to cavitation. As such, relief valve **390** is shown coupled between base ends **330** of lift actuators **312** and reservoir **304**. Relief valve **400** is shown coupled between base ends **354** of tilt actuators **314** and reservoir **304**. Relief valve **420** is shown coupled between rod ends **352** of tilt actuators **314** and reservoir **304**. Finally, relief valve **410** is shown coupled between a first auxiliary port and reservoir **304**.

As mentioned, relief valve **380** acts to relieve pressure in the system when an actuator is deadheaded by dumping hydraulic fluid to reservoir **304** when a relief pressure of the valve **380** is reached or exceeded. In conventional designs, the use of downstream functions is severely compromised or effectively eliminated when fluid is run over the relief valve **380**. Also, under conventional designs, when downstream pressures are high (such as near relief), functionality of upstream circuits are limited or compromised. Due to cylinder differential areas in upstream circuits, upstream circuits can be activated in one direction with high downstream pressure. That is, the lower cylinder area end (i.e. the rod end) can be relieved to reservoir over port relief valves so that a cylinder can be extended. However, it is not the case that an upstream cylinder can be retracted in such a situation in conventional designs. In fact, in many conventional open center valve configurations, the pressure conditions present when a downstream circuit is at high or even at relief pressure is that any attempt to retract an upstream cylinder will result in no retraction or even slight extension. In certain implement operating conditions, the ability to retract the tilt cylinder **314** (i.e., roll back the implement carrier) is desirable. While this is not possible under some conventional control valve designs, disclosed embodiments include features which allow the tilt cylinder to be retracted under a broader range of conditions.

Features of control valve assembly **300** that overcome the above-described limitations of some conventional control valve designs are now discussed with reference to FIGS. **6** and **7**. FIG. **6** illustrates first valve element **308** in the form of a tilt spool moved to the second actuated position **342** in which hydraulic fluid is ported to the rod end **352** of actuator **314** through a path illustrated with arrows, to roll back the implement carrier **130** and any attached implement **212**. FIG. **7** illustrates first valve element **308** in a first actuated position **346** in which hydraulic fluid is ported to base end **354** of actuator **314** to roll out the implement carrier and any attached implement.

As compared to conventional designs, the tilt circuit is modified such that when the first valve element **308** is shifted to the second actuated position **342** as shown in FIG. **6**, the base ends **354** of the tilt cylinders **314** are ported (drained) to reservoir **304** through a fluid path **370** within the first valve element **308** and a drain line **372**, as opposed to being connected to the inlet of the second valve element **310** as would be conventionally done. This fluid path **370** and drain line **372** can be considered to be parallel with the downstream function, from a perspective of the inlet to first valve element **308**, in that both the second valve element **310** and the drain line **372** are connected to the outlet side of the first valve element **308**. The drain line **372** is not actually in parallel with the downstream function from a perspective of the outlet of first valve element **308**, though, as they do not share a common node at the outlet side of the first valve element **308**. Rather, the drain line **372** is an alternative path such that the implement circuit is bypassed with no hydraulic fluid being provided to the inlet of the second valve element **310** via the second actuated position **342**, although if the spool is not fully actuated into the second actuated position **342**, some fluid may be provided to the inlet of the second valve element **310** via the unactuated position of the first valve element **308**. When the first valve element **308** is in the first actuated position **346** to port hydraulic fluid to the base ends **354** of the tilt cylinders **314** so as to extend the cylinder, hydraulic fluid is provided to the inlet of the second valve element **310** and not to the drain **372** as shown in FIG. **7**. This arrangement allows the first work function, in this embodiment, the tilt function, to be controlled in either direction whether or not a high load exists on the downstream circuit, in this embodiment, the implement circuit. This also allows the implement circuit to be controlled, except when the tilt cylinder is being retracted at full spool stroke. This arrangement advantageously allows for control of the actuator coupled to the first valve element in either direction, regardless of whether there is a high pressure load downstream of the first valve element. In addition, in embodiments where proportional valves are employed, any actuator in communication with the second valve element can still be controlled if the first valve element is not in one of the fully actuated positions. In the embodiment described above, if a tilt cylinder is slowly retracted from a position when an implement is operating a cutting function, such as a planer, the implement is still actuated when the tilt cylinder is retracted.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims. For example, in various embodiments, different types of power machines can be configured to implement the control valve assembly and power conversion systems and methods. Further, while particular control valve assembly configurations and work functions are illustrated, other valve configurations and types of work functions can also be used. Other examples of modifications of the disclosed concepts are also possible, without departing from the scope of the disclosed concepts.

What is claimed is:

1. A power conversion system for a power machine, comprising:
- a pump configured to provide a source of pressurized hydraulic fluid;
- a control valve assembly coupled to the pump to receive the pressurized hydraulic fluid from the pump, the control valve assembly including:
  - a first valve element having an unactuated position and first and second actuated positions, the first valve element configured to direct pressurized hydraulic fluid to and receive pressurized hydraulic fluid from an actuator when the first valve element is in the first and second actuated positions; and
  - a second valve element downstream of and in series with the first valve element when the first valve element is in the unactuated position, the second valve element having first and second actuated positions; and
- wherein the first valve element is moveable between the unactuated position and the first and second actuated positions, and wherein the control valve assembly is configured to direct hydraulic fluid received from the actuator through the second actuated position to the second valve element, and direct hydraulic fluid received from the actuator through the first actuated position to bypass the second valve element.

2. The power conversion system of claim **1**, wherein the first and second valve elements are spool valves.

3. The power conversion system of claim **1**, wherein the actuator is a tilt cylinder, and wherein the second valve element is configured to control implement actuator functions.

4. The power conversion system of claim **3**, wherein in the first actuated position, hydraulic fluid received from a base end of the tilt cylinder is directed to a reservoir through a fluid path in the first actuated position.

5. The power conversion system of claim **3**, wherein the second actuated position of the first valve element is configured to direct pressurized hydraulic fluid to a base end of the tilt cylinder.

6. The power conversion system of claim **1**, wherein the control valve assembly further comprises a third valve element upstream of the first valve element.

7. A power conversion system for a power machine, comprising:
- a pump configured to provide a source of pressurized hydraulic fluid;
- a work actuator for controlling a work function; and
- a control valve assembly in communication with the pump to receive the pressurized hydraulic fluid, including:
  - a first spool having an unactuated position and first and second actuated positions configured to direct pressurized hydraulic fluid to the work actuator and receive pressurized hydraulic fluid returned from the work actuator;
  - a second spool downstream of and in series with the first spool when the first spool is in the unactuated position, the second spool having first and second actuated positions; and
  - wherein the first spool is configured to direct hydraulic fluid returned from the work actuator through the second actuated position to the second spool and direct hydraulic fluid returned from the work actuator through the first actuated position to bypass the second spool.

8. The power conversion system of claim **7**, wherein the control valve assembly further comprises a third spool upstream of the first spool.

9. A power machine including the power conversion system of claim **7**, wherein the work actuator is configured to selectively position an implement carrier on the power machine.

10. The power machine of claim **9**, wherein the second spool is configured to provide a source of pressurized hydraulic fluid connectable to an implement coupled to the implement carrier.

11. The power machine of claim **9**, wherein hydraulic fluid provided to the work actuator through the second actuated position of the first spool causes the implement carrier to roll out relative to the power machine.

12. The power machine of claim **9**, wherein hydraulic fluid provided to the work actuator through the second actuated position of the first spool causes the implement carrier to roll back relative to the power machine.

13. The power conversion system of claim **7**, wherein the control valve assembly is an open center control valve assembly.

14. The power conversion system of claim **7**, wherein the first spool is a proportional spool having an unactuated position between the first actuated position and the second actuated position and wherein when the spool is moved from the unactuated position toward the first actuated position, hydraulic fluid is provided to the second spool via the unactuated position until the spool is fully moved to the first actuated position.

15. A power machine having a frame, a lift arm pivotally coupled to the frame, and an implement carrier pivotally coupled to the lift arm, and further comprising:
- a power source;
- an operator input device configured to provide control signals; and
- a power conversion system coupled to and receiving power from the power source, the power conversion system including:
  - a pump configured to provide a source of pressurized hydraulic fluid;
  - a work actuator; and

an open center control valve assembly in fluid communication with the pump and including first and second spools, the first spool configured to direct pressurized hydraulic fluid and receive pressurized hydraulic fluid from the work actuator in response to the control signals via first and second actuated positions, the first spool being configured to direct hydraulic fluid received from the work actuator available to the second spool via the second actuated position and to direct hydraulic fluid received from the first work actuator via the first actuated position to bypass the second spool;

wherein the power machine further comprises at least one hydraulic line in communication with the second spool connectable to an external actuator and wherein the second spool is configured to direct pressurized hydraulic fluid to the at least one hydraulic line in response to the control signals.

16. The power machine of claim **15**, wherein the first spool is a proportional spool having an unactuated position between the first actuated position and the second actuated position and wherein when the spool is moved from the unactuated position toward one of the first and second actuated positions, hydraulic fluid is provided to the second spool via the unactuated position until the spool is fully moved to one of the first and second actuated positions.

17. The power machine of claim **15**, wherein hydraulic fluid received from the work actuator via the first actuated position is directed to a low pressure outlet.

18. The power machine of claim **15**, wherein the work actuator is a hydraulic cylinder pivotally coupled to the lift arm and the implement carrier and actuable to rotate the implement carrier relative to the lift arm.

19. The power machine of claim **15**, wherein the open center control valve assembly further includes a third spool upstream of the first spool.

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