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(54) FLUID SUSPENSION SYSTEM

(71) We, CATERPILLAR TRACTOR CO., a Corporation organised and existing under the laws of the State of California, United States of America, of 100 N.E. Adams Street, Peoria, State of Illinois 61602, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a fluid suspension system.

Hydropneumatic suspension hitches for coupling a two wheel tractor with a scraper unit or the like have met with increasing acceptance because of their ability to control pitch and bounce in such vehicles in both the loaded and unloaded condition. United States Patents Nos. 3,311,389 and 3,449,845 are illustrative of hydropneumatic suspension hitches of this type. The theory and operation of such hydropneumatic suspension hitches are described in United States Patent No. 3,311,389.

Improved riding qualities are obtained in tractor-scraper combinations with the hydropneumatic suspension systems described in the above patents. However, the control valves of such systems must be highly sophisticated and precision manufactured in order for the hitches to operate properly under all field operating conditions. For example, actuating a particular system for a temporarily fixed lockout condition to permit lowering of the hitch to a mechanical stop at a desired controlled rate required precise dual rate metering of flow at both ends of the fluid suspension motor of the system. To accomplish this control it is necessary to meter flow out of the lower or cushioning end of the fluid suspension motor to allow the hitch to lower. Simultaneously, pressure fluid from the suspension system must be metered into the upper end of the fluid

suspension motor at a slower rate than fluid is metered from the lower end of the suspension motor. This dual rate metering is necessary to prevent pressure fluid in the upper end of the suspension motor from driving the hitch downward to mechanical stops which could result in excessive stresses in the hitch structure.

Additionally, complex and costly pilot controlled leveling valves with double-acting fluid damping capabilities have been employed by the prior art to prevent operation of the leveling valve during normal dynamic motion of the machine when traveling over rough terrain. Such unnecessary repetitive energizing or "hunting" of the leveling valve adversely affects the life of the system's components and is also detrimental to the function of the suspension system as a tuned and damped vibration absorber.

According to the invention, there is provided a fluid suspension system including a fluid suspension element disposed in elevational supporting relation between a sprung mass and an unsprung mass, said fluid suspension element comprising a piston movable in a cylinder having a rod end and a cushioning end and a rod connected to the piston and one of the masses and extending through the rod end of the cylinder, means for venting the rod end, resiliently biased fluid pressure means in continuous unrestricted communication with the cushioning end for resiliently supporting said sprung mass at substantially a predetermined elevated cushioning position relative to said unsprung mass when the rod end is vented, and

lockout valve means in communication with said cushioning end and operable selectively to communicate said rod end with said cushioning end so as to equalize pressure in said ends of the cylinder and reduce the support of the sprung mass relative to the unsprung mass, whereby to

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permit the sprung mass to move to a lower position.

Certain embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:—

Fig. 1 is an elevation of a two wheel tractor and an earthmoving scraper combination connected through a hydropneumatic suspension hitch and incorporating a fluid suspension system according to the invention;

Fig. 2 is an enlarged broken-away elevation of the hydropneumatic suspension hitch of Fig. 1 with parts of its hydraulic circuit schematically illustrated;

Fig. 3 is a section through the control valve of the fluid suspension system of Fig. 1 to an enlarged scale,

Fig. 4 is a graph illustrating the dead-band area where a leveling valve section of the control valve of Fig. 3 remains in its neutral position;

Fig. 5 is a view similar to Fig. 2 showing an alternative and differently oriented control valve; and

Fig. 6 is a section through the control valve of Fig. 5.

Referring to the drawing, a fluid suspension system according to the invention is generally indicated by the reference numeral 10 and is illustrated in Fig. 1 as operatively associated with an articulated vehicle 11. The forward portion of the vehicle is depicted as a two-wheel tractor generally indicated at 13 which is mounted on a pair of rubber tyred wheels 14. The rear portion of the vehicle is illustrated as an earthmoving scraper generally indicated at 15 and has a bowl 16 which is supported for oscillation about the axis of rotation of a pair of rubber tired wheels 18.

The bowl 16 is a box-like forwardly opening material carrying receptacle having a cutting edge 19 disposed transversely along the lower leading edge thereof. An apron 20 is pivotally supported on the bowl for closing and opening the forward end thereof to control the entry and exit of dirt or other material over the cutting edge. A suitable linkage system 21 under control of a hydraulic jack, a portion of which is shown at 22, is provided for elevational adjustment of the apron between open and closed positions.

A draft frame 23 includes a pair of laterally spaced draft arms 24 pivotally connected to opposite sides of the bowl 16, and a forwardly extending centrally disposed arched goose-neck 25 articulately connected to the tractor 13 by means of a hydropneumatic suspension hitch 26. A pair of bowl lift jacks, one of which is shown at 27, are pivotally supported on the draft

frame for elevationally adjustable support of the forward end of the bowl.

The hydropneumatic suspension hitch 26 is more clearly illustrated in Fig. 2 and includes an A-frame 28 centrally mounted on a main frame 29 of the tractor 13 in substantially upright aligned relation with the longitudinal axis of the tractor. The A-frame is pivotally secured on the frame with pins 30 through lugs 31 and 32 which allow the A-frame to swing about a generally horizontal pivot axis through the pins. A stop 28a is provided on the A-frame to limit downward movement of the hitch. A suspension bracket 33 is connected to the A-frame by a pair of vertically spaced generally horizontally disposed links 34 and 35. The bracket 33 includes a stop 33a for engagement with the stop 28a. The links have their respective forward ends pivotally connected to the A-frame 28 by pins 36 and 37 respectively and their rearward ends are pivotally connected to the suspension bracket by a pair of pins 38 and 39, respectively.

Suspension bracket 33 includes a pair of upper and lower rearwardly extending mounting ears 40 and 41 for a pivotal connection with lugs 17 at the forward end of the gooseneck 25 by a pair of vertically disposed pivot pins 42 and 43 forming an articulation joint about which the vehicle is steered.

Since the suspension bracket 33 can move vertically with respect to the tractor 13 and the A-frame 28 due to the pivotal connection therebetween through links 34 and 35, a fluid suspension element in the form of a cushioning jack 44 is diagonally coupled between the pivots 37 and 38. Cushioning jack 44 is of the normal piston-cylinder type defining therein a head end or cushioning chamber 44a and a rod or opposite end chamber 44b and forms a part of the fluid suspension system 10. The head end chamber of the cushioning jack is in continuous unrestricted communication with resiliently biased fluid pressure means in the form of a pair of hydro-pneumatic accumulators 45 and 46 by way of a line 47 during all modes of operation.

The provision of different gas pressure preloads in the accumulators 45 and 46 provides the proper cushioning conditions for either a loaded or empty scraper condition. Since the load in the scraper 15 will vary and hence the vertical position of the suspension bracket 33 will vary accordingly, it is desirable to permit the admission to or venting of liquid from the suspension system to maintain a preselected vertical relationship between the tractor 13 and the scraper.

Control of the fluid suspension system 10 is accomplished by a control circuit in-

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5 dicated generally at 48. The control circuit includes a pump 50 adapted to draw fluid from a reservoir 51 for supply through a line 52 to a manual selector valve 53 and a control valve 54. The manual selector valve has two positions for alternately and selectively establishing a cushion ride condition or lockout condition of the suspension system by controlling communication of pilot pressure through a line 10 55 to the control valve 54. In the cushion ride condition, the scraper 15 is resiliently supported at an elevated cushioning position relative to the tractor 13 and in the lockout condition the scraper 15 is permitted to move to a lower position.

The internal components of the selector valve 53 are identical with the selector valve illustrated in U. S. Patent No. 3,511,276 and it needs no further amplification other than to indicate that it connects line 55 either to pump pressure or drain as dictated by the position of a control lever 53a.

Valve 54 communicates with the cushioning chamber 44a of the jack 44 and the accumulators 45 and 46 by way of a line 56 and the line 47. The valve also communicates by way of a line 57 with the opposite end chamber 44b of the jack.

Referring more particularly to Fig. 3, the valve 54 includes a body 60 having a safety valve section 61, a leveling valve section 62, lockout valve means in the form of a lockout valve section 63, and a vent valve section 64.

35 The safety valve 61 includes a spool 66 disposed for reciprocation in a bore 67 to control communication between a cushioning port 68 and a passage 69 which communicates with a reservoir return port 70 by way of a passage 72, a check valve 73, an orifice 74 and a return chamber 75. One end of bore 67 communicates with a pump inlet port 77 so that an end 78 of the spool 66 is exposed to the pressure in the pump line 45 52 in opposition to the bias of a spring 80. A drilled passage 81 in spool 66 provides communication between the cushioning port 68 and the passage 69 when the spool 66 is in the position shown. The chamber of spring 80 is vented to the passage 69 and hence to the reservoir by way of a slot 82 in the spool 66. The safety valve 61 operates to vent the cushioning port 68 when the pump pressure is below a predetermined minimum.

55 The leveling valve section 62 includes a leveling spool 83 disposed for reciprocation in a bore 84 defined by the housing 60. The spool 83 includes a pair of grooves 85 and 86 which in cooperation with a plurality of metering slots, 88, 89 and 90 selectively control fluid communication between the pump inlet port 77, the cushioning port 68, the passage 69 and an annulus 92 communicating with the check valve 73.

One end of spool 83 projects into a chamber 95 formed at one end of the bore 84 with the other end of the spool projecting outwardly of body 60 for connection through an appropriate linkage with the suspension hitch 26, as will hereinafter be described. The bore 94 further includes an annulus 96 which communicates by way of passage 69 with the bore 67 of the safety vent valve 61, and an annulus 97 which communicates with the bore 67 and cushioning port 68 by way of a passage 98 and also communicates by way of a passage 99 with a bore 100 in the lockout valve section 63. An annulus 102 communicates by way of a passage 103 with the bore 67 and pump inlet port 77 and also communicates through a low pressure relief valve 104 and an orifice 105 with the reservoir return chamber 75. The annulus 102 further communicates through a passage 107 with the bore 100 at a point axially spaced from the passage 99. The bore 100 also communicates by way of a passage 110 with the chamber 95 which further communicates through a passage 111, an orifice 112 and a passage 113 to the reservoir 51.

A mechanical detent generally indicated by the reference numeral 116 has a spring biased ball 117 cooperating with a groove 118 to establish a neutral centered position for spool 83. A second groove 120 in the spool cooperates with the ball to releasably lock the spool in a raise position communicating the pump inlet port 77 with the cushioning port 68. A pair of contiguous cam surfaces 121 and 122 on the right hand side of groove 118 cooperate with ball 117 when the spool 83 is moving toward or returning from a leftward or "lower" position to provide essentially a snap action of the valve spool. The cam surfaces are conical with the outer cam 122 remote from the groove being less oblique to the longitudinal axis of spool 83 than the inner cam 121 which is contiguous to the groove, in order to increase the valve spool centering forces as the spool approaches its centered neutral position. The detent area around the spool is vented to the reservoir 51 by way of a passage 123 and the passage 113.

The lockout valve section 63 provides a spool 124 movably disposed in the bore 100 and includes a pair of grooves 125 and 126. The groove 125 selectively controls communication between the passages 107 and 110, depending upon the positioning of the spool. The groove 126 controls communication between the passage 99 and a passage 127 which communicates between the bore 100 and the vent valve section 64. The passage 127 includes an orifice 128 to control the rate of fluid flow to the vent valve as will later be more fully explained.

A pilot actuating chamber 129 formed at one end of spool 124 communicates with the line 55 which may be selectively pressurized or vented by the selector valve 52 to control the position of the spool 124. The spool further includes an actuating extension 130 extending axially toward the vent valve section 64.

The vent valve section 64 includes a poppet type check valve 132 disposed for reciprocation in a bore 133 and biased by a spring 134 into sealing engagement with a conical seat 136. The conical seat defines the juncture between a passage 137 communicating between the reservoir return chamber 75 and an annulus 139 provided in the bore 133. The annulus 139 is in open communication with a lockout port 140 and communicates via a passage 142 and a check valve 143 with the passage 137 and through the orifice 128 with the bore 100 of the lockout valve 63. The check valve 143 is spring biased to a closed position, as shown in Fig. 3, to normally block flow from the annulus 139 toward bore 100 and yet permit relatively free flow from the orifice 128 toward the annulus 139, i.e. from the cushioning port 68 to the lockout port 140 when the spool 124 is in its lockout (leftward) position shown in Fig. 3.

A central passage 147 formed in one end of the check valve 132 is normally closed by a spring biased poppet 148 to permit equalization of pressure between the lockout port 140 and the chamber of the spring 134 behind the check valve 132 by way of an orifice 150 and a passage 151. The poppet includes an actuating stem 153 which extends outwardly of the check valve 132 in engagable coaxially aligned relation to the actuating extension 130 of the spool 124.

As is best shown in Fig. 2, the outwardly extending end of the leveling spool 83 is pivotally connected by a link 155 to the free end of a leaf spring 156 which has its other end secured to a bracket 157 by a plurality of bolts 158. The bracket 157 is rigidly secured to the link 35 so that as the bracket 33 moves vertically by pivotal movement of the links the spring exerts an actuating force on the spool 83 depending on the direction of hitch movement. This resilient linkage in cooperation with mechanical detent 116 permits limited hitch movement without actuation of the leveling spool 83 to minimize the frequency at which the leveling circuit is energized. As a result, pressure loading of the pump and other circuit components due to dynamic bouncing of the hitch during travel operations of the vehicle is minimized.

A second embodiment of the present invention is illustrated in Figs. 5 and 6 wherein a modified form of control valve indicated generally at 160 is supported for

connection through a link 161 to the free end of a generally horizontally disposed leaf spring 162. The opposite end of the leaf spring is secured to a bracket 164 integrally formed with the lower link 35. With this arrangement vertical movement of the bracket 33 by pivotal swinging of the links 34 and 35 imparts an actuating force through the spring 162 to the leveling valve spool 83 of the control valve 160 which is fixedly mounted with respect to the A-frame 28.

The fluid connection of control valve 160 to the cushioning jack 44, accumulators 45 and 46, pump 50, and selector valve 52 is substantially the same as in the previously described embodiment.

The internal design of the control valve 160, as is best disclosed in Fig. 6, has been modified as compared with the design of the control valve 54 disclosed in Fig. 3. As best shown in Fig. 6, pump line 52 communicates with the pump inlet 77 which in turn communicates with one end of the bore 67 so that the safety valve spool 66 is responsive to pump pressure in the pump inlet 77. The drilled passages 81 and the slots 82 in safety valve spool 66 serve to vent the accumulators 45 and 46 when the system is inactive, via port 181, line 182, passages 81, slots 82, port 202, line 203, port 204, annulus 205, line 111, reservoir return chamber 75 and return port 70.

The inlet port 77 also communicates with a relatively low pressure restrictor valve 166 which is disposed in series with a second low pressure restrictor valve 168 when the leveling spool 83 is in the neutral position as illustrated. The series arrangement of the restrictor valves maintains the pilot pressure required in the inlet 77 for actuation of the safety valve 66 and pilot positioning of the leveling valve 83 by pressurization of chamber 95. This series arrangement of two restrictor valves permits a second pilot or control pressure somewhat lower than that required in inlet port 77 to be provided by the restrictor valve 168 for supply through a passage 169 and a line 170 for use external of the control valve 160. The valve 166 also prevents the reverse flow from line 47 to passage 172, which would pressurize the end of stem 66. This could happen when the engine is shut down, as pressure in the chamber 95 decreases, allowing the spool 83 to shift upward, connecting the accumulators to the pump, thus pressurizing inlet port 77 via port 181 and line 172. Under these conditions, the spool 66 would not return to the vent position shown and the accumulators would not be prevented.

The pump inlet port 77 also communicates through passage 172, a relief valve 173, a passage 174, and the restrictor valve 168 to the reservoir return chamber 75

from where fluid is returned to the reservoir by way of return port 70.

The leveling valve section 62, including the spool 83, is substantially identical to that previously described with respect to Fig. 3. The mechanical detent mechanism 116 is associated with spool 83 for controlling positioning of the spool in response to vertical movement of the bracket 33 and a resultant spool actuating force transmitted through the leaf spring 162.

A lockout valve spool 176 is reciprocally disposed in bore 177 and is spring biased to the position shown to communicate pump inlet port 77 to the chamber 95 by way of a passage 179 and a line 180. The chamber 95 communicates via an orifice 112 and passage 111 to the spring chamber of restrictor valve 163 which communicates with return chamber 75. The cushioning pressure from the accumulators 45 and 46 and the cushioning chamber 44a of the cushioning jack 44 is communicated by way of the line 47, passage 181, passage 182, the lockout spool 176, a passage 183, a non-return check valve 185, a passage 186, a line 187, a passage 189 and the line 57 to the rod end of the cushioning jack. The passage 186 and hence the accumulator or cushioning pressure is also communicated by way of a passage 190, the lock-out spool 176, a passage 192 and a line 193 to the spring chamber 194 of a vent valve 196. The vent valve 196 is a poppet-type valve, somewhat similar to the vent valve 132 of Fig. 3, which is spring biased for closing engagement with a conical seat 197 to block communication between the rod end chamber 44b of the cushioning jack and the return chamber 75. A vent valve actuating piston 198, including an actuating extension 199, is disposed in coaxial alignment with the vent valve 196 for axially urging the vent valve to an open position under the influence of pilot pressure in an actuating chamber 200. The actuating chamber 200 is in communication with the pilot line 55 from selector valve 53 by way of a line 201.

When the system is conditioned for cushion ride, line 55 is pressurised and the chamber 194 is vented to tank by way of line 193, passage 192, lockout spool 176, a passage 202, a line 203, a passage 204, an annulus 205, passage 211, return chamber 75 and return port 70. The line 55 communicates by way of a passage 206 with an actuating chamber 207, operatively associated with the lockout valve spool 176 for selectively moving the spool to a cushioning position.

The passage 186 also communicates by way of a passage 208 with a high-pressure relief valve 209 to prevent damage from an over pressure condition due to initiation of a lockout condition. When the cushioning

jack 44 is allowed to collapse due to a lockout signal, there is an increase in system volume as the piston-rod assembly retracts. If the gas volume of the accumulators 45-46 is insufficient to handle this additional volume, the pressure will become excessive, causing the valve 209 to vent.

The operation of the foregoing embodiments will now be described. With the vehicle parked and the engine not running, pressure is not available in the circuit and the safety spool 66 is urged by the spring 80 to the position shown in Fig. 3. This vents the accumulators 45 and 46 and the head end of cushioning jack 44 by way of the passage 81, passages 69 and 72 and the check valve 73 to the tank return chamber 75 from where it is communicated to the tank by way of return port 70. In the absence of pressure in the accumulators and the cushioning jack, bracket 33 is permitted to lower until the stop 33a engages the stop 28a on the hitch A-frame 28. Downward movement of the bracket 33 through pivotal action of the links 34 and 35 imparts a force through the leaf spring 156 to move the spool 83 of the leveling valve to the right as viewed in Fig. 3 to a position communicating pump inlet port 77 with the cushioning port 68 by way of passage 103, slots 89 and passage 98. Since the pump is not running and pressure is not available, the hitch will remain in the lowered position.

Under these conditions, the selector valve 52 is disposed in a lockout position as may be more clearly understood with reference to the description in U.S. Patent 3,511,276 mentioned above so that line 55 is vented to the reservoir and line 52 is blocked from communication with the line 55. Under these conditions, the lockout spool 124 assumes the position shown so that vent valve 132 is urged by its spring 134 to the closed position.

When the tractor engine is started, the pump 50 supplies pressure to the line 52 and the safety valve 61 operates to stop the venting of cushioning port 68. Even though leveling spool 83 is at that point in a position which would raise the hitch, the pump pressure is immediately communicated by way of passage 107, groove 125 of the lockout spool and passage 110 to the chamber 95. The restriction of orifice 112 provides sufficient pressure in that chamber to overcome the bias of the leaf spring 156 and return spool 83 to the neutral position illustrated to vent the pump to the reservoir by way slots 88, annulus 92 and check valve 73. This establishes a lockout condition wherein the bracket 33 remains in the lowered position until such time as the operator actuates the selector valve 53 to a cushion ride position by manipulation of lever 53a.

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6 Movement of the valve 53 to the cushion
ride position communicates pump line 52
with the pilot line 55 to pressurize the
lockout valve actuating chamber 129 to urge
5 spool 124 to the right as viewed in Fig. 3.
Such movement of the lockout spool blocks
communication of the pump pressure to the
chamber 95 so that pressure in that chamber
is bled to the reservoir at a controlled rate
10 through the passage 111, orifice 112, and
passage 113 to permit leaf spring 156 to
return the leveling valve to a raise position
wherein detent ball 117 engages detent
15 groove 120 in the spool. Movement of
lockout spool 124 to the right also engages
actuating extension 130 with stem 153 of the
poppet valve 148 to open that valve and vent
the pressure from the chamber of spring
20 134. Continued movement of the spool 124
causes the extension 130 to engage the front
face of the check valve 132 to urge it to an
open position communicating the rod end of
the cushioning jack with the reservoir by
25 way of port 140, passage 137, return
chamber 75 and return port 70. Com-
munication of the accumulator pressure
from line 47 to the rod end of the jack is also
blocked as the spool 124 blocks com-
30 munication between the passage 99 and the
passage 127.

Under these conditions and with the
leveling spool 83 in a raise detented position
as previously described, the pump pressure
from line 52 is communicated to the head
35 end of the cushioning jack 44 and the ac-
cumulators 45 and 46 to pressurize the
cushioning system and hence raise the
bracket 33 and the forward end of the
scraper 15 toward a centered or "level"
40 position within its total range of movement.
As the bracket 33 raises, the pivotal
movement of link 35 relaxes the actuating
force in leaf spring 156.

The above described action is best ex-
45 plained with reference to Fig. 4 wherein
leveling spool displacement relative to hitch
displacement is plotted in solid line for
movement of the hitch away from a cen-
tered or level position toward either ex-
50 treme of movement with the action of the
system as the hitch is returned toward a level
position being plotted in dashed lines. For
example, with the vehicle engine running
and the system in a hitch lowering lockout
55 condition, the leveling stem is disposed at
point A in Fig. 4. Since the chamber 95 is
pressurized, the leveling spool is displaced
to a neutral condition in opposition to the
force of spring 156 as depicted at point B.
60 When the selector valve 53 is shifted to a
cushion ride position, the leveling spool is
returned to a fully actuated position, point
A on the graph, so that the hitch will begin
to rise as last described. At this point, the
65 spring is deflected and is exerting ap-

proximately 75 pounds of force to hold the
leveling spool in a raise position for com-
municating pump pressure to the cushioning
circuit. As the hitch reaches approximately
point C on the curve, the force of the spring
is zero; however, since the spool 83 is held
70 in a raise position by detent 116, the hitch
continues to rise. As the hitch reaches a
level condition, point D, the force exerted
by the spring is approximately 20 pounds
75 and acting in a direction to urge spool 83
toward a neutral position. Since ap-
proximately 30 pounds is required to
disengage detent ball 117 from the groove
120, the hitch continues to rise to point E at
80 which point the spring force reaches 30
pounds and returns the spool 83 to the
neutral position.

The over-leveled condition resulting from
the detented raise position of the leveling
85 spool 83 increases the leak-down time or
load required to depress the hitch suf-
ficiently to actuate the leveling spool to a
raise position. This minimizes cycling of the
system and reduces wear and stress on the
90 pump and other hydraulic components.

As load is added to the scraper bowl or
the hitch settles due to internal fluid leakage
after an extended period of machine
operation, the engagement of the ball 117
95 with the neutral groove 118 is effective to
resist movement of the leveling valve until
the force in spring 156 reaches ap-
proximately 30 pounds. This condition is
achieved at one point F in the downward
100 direction at which point the spool 83 snaps
to the "raise" position represented at point
G. This communicates the pump inlet port 77
by way of passage 103, slots 89 and passage
98 with the cushioning port 68. Such ad-
105 mission of fluid to the cushioning jack and
accumulators raises or returns the hitch to
the over-leveled condition as previously
described and as indicated by point H in Fig.
4.

As load is removed from the scraper the
higher pressure which was required to
support the load causes the hitch to rise
until the force in spring 156 reaches ap-
110 proximately 30 pounds at point J of Fig. 4.
This overcomes the detent and moves spool
83 to the left, as viewed in Fig. 3, to a
"lower" position at point K of Fig. 4. This
communicates the cushioning end of the
115 jack 44 and the accumulators 45 and 46 to
the reservoir by way of the cushioning port
68, passage 98, slots 90, passages 69 and 72,
check valve 73, return chamber 75 and
return port 70. This is effective to vent fluid
from the cushioning system so that the hitch
120 will lower as indicated by broken line L. The
spring force is approximately zero at point
M. As the hitch continues to lower to point
N the spool is urged toward a neutral
125 condition by the spring 156. At this point the
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ball engages the ramps 122 and 121 to snap the spool 83 back to a neutral condition just prior to a leveled condition so that the hitch will remain slightly above level at point O of Fig. 4, for the same reason as previously described with respect to point H.

The distance between points F and J of Fig. 4 represents the hitch displacement or "deadband" which can occur without shifting the leveling valve spool 83. This "deadband" absorbs most of the normal dynamic motion of the hitch to minimize actuation of the leveling spool.

When leveling spool 83 is in a neutral condition, the fluid displaced by pump 50 must open restrictor valve 104 to return to the reservoir. This maintains sufficient pressure in the system to overcome the spring 156 and return the leveling spool to a neutral condition when spool 124 is moved to the lockout position for communicating the pump pressure to the chamber 95.

Movement of spool 124 to the lockout position, i.e. to the left in Fig. 3, also communicates the accumulators with the rod end of the cushioning jack 44 via passage 99, orifice 128 and check valve 143 as previously described. Since the head or cushioning end of the jack is in constant communication with the accumulators, control of the hitch lowering is accomplished solely by the fixed orifice 128.

The second embodiment disclosed in Figs. 5 and 6 functions in a manner very similar to that previously described for Figs. 2 and 3. However, a brief summary of the operation of that embodiment will be provided to clarify the function of the modified valve of Fig. 6.

With the engine running and the selector valve 53 in a cushion ride position, pilot pressure is available by way of lines 55 and 201 to the actuating chambers 200 and 207 of the vent valve actuating piston 198 and the lockout spool 176. The lockout spool is shifted upwardly as viewed in Fig. 6 to block communication between pump inlet 77 and chamber 95 by way of line 180. This is also effective to block communication between the cushioning end and the rod end of cushioning jack 44 by way of line 47, passage 181, lockout spool 176, passage 183, check valve 185, passage 186, line 187, passage 189 and the line 57. Spring chamber 194 communicates by way of the line 193, the passage 192, the lockout spool 176, the passage 202, the line 203, the passage 204, the annulus 205, and the passage 211 to the return chamber 75 from where it is directed to the reservoir by way of the return port 70. This allows upward movement of the actuating piston 198 to urge the vent valve 196 to an open position by contact of the actuating extension 199 with the face of the check valve. This vents the rod end of the

cushioning jack 44 to the reservoir by way of return chamber 75 and return port 70.

Pressure in chamber 95 is metered at a controlled rate to the reservoir by way of an orifice 112 and passage 111 to permit the force of spring 162 to return spool 83 to a "raise" position, upwardly as viewed in Fig. 6. This communicates the pump 50 with the cushioning jack chamber 44a and accumulators 45 and 46 by way of restrictor valve 166, leveling spool 83, passage 181 and line 47 to raise the hitch toward the over-leveled condition as disclosed in Fig. 4.

The mechanical deadband and over-leveled condition previously described with respect to Fig. 4 also applies to the embodiment of Figs. 5 and 6 since the detent 116 cooperates with the spool 83 in exactly the same manner to provide those described conditions.

In view of the foregoing, it is readily apparent that the described structure provides an improved fluid suspension system to achieve a greatly improved and simplified control for the descent rate of the hitch from a cushion ride to a lockout condition.

Application No. 19598/76 (Serial No. 1 451 330) has been divided from this application and describes the systems disclosed herein and claims a hitch assembly including a leveling valve provided with detent/release means and a lost motion linkage.

WHAT WE CLAIM IS:—

1. A fluid suspension system including a fluid suspension element disposed in elevational supporting relation between a sprung mass and an unsprung mass, said fluid suspension element comprising a piston movable in a cylinder having a rod end and a cushioning end and a rod connected to the piston and one of the masses and extending through the rod end of the cylinder, means for venting the rod end, resiliently biased fluid pressure means in continuous unrestricted communication with the cushioning end for resiliently supporting said sprung mass at substantially a predetermined elevated cushioning position relative to said unsprung mass when the rod end is vented, and lockout valve means in communication with said cushioning end and operable selectively to communicate said rod end with said cushioning end so as to equalize pressure in said ends of the cylinder and reduce the support of the sprung mass relative to the unsprung mass, whereby to permit the sprung mass to move to a lower position.

2. A fluid suspension system as claimed in claim 1 including fluid flow restricting means disposed between said cushioning end and said rod end for controlling the rate of relative movement of the sprung and

ball engages the ramps 122 and 121 to snap the spool 83 back to a neutral condition just prior to a leveled condition so that the hitch will remain slightly above level at point O of Fig. 4, for the same reason as previously described with respect to point H.

The distance between points F and J of Fig. 4 represents the hitch displacement or "deadband" which can occur without shifting the leveling valve spool 83. This "deadband" absorbs most of the normal dynamic motion of the hitch to minimize actuation of the leveling spool.

When leveling spool 83 is in a neutral condition, the fluid displaced by pump 50 must open restrictor valve 104 to return to the reservoir. This maintains sufficient pressure in the system to overcome the spring 156 and return the leveling spool to a neutral condition when spool 124 is moved to the lockout position for communicating the pump pressure to the chamber 95.

Movement of spool 124 to the lockout position, i.e. to the left in Fig. 3, also communicates the accumulators with the rod end of the cushioning jack 44 via passage 99, orifice 128 and check valve 143 as previously described. Since the head or cushioning end of the jack is in constant communication with the accumulators, control of the hitch lowering is accomplished solely by the fixed orifice 128.

The second embodiment disclosed in Figs. 5 and 6 functions in a manner very similar to that previously described for Figs. 2 and 3. However, a brief summary of the operation of that embodiment will be provided to clarify the function of the modified valve of Fig. 6.

With the engine running and the selector valve 53 in a cushion ride position, pilot pressure is available by way of lines 55 and 201 to the actuating chambers 200 and 207 of the vent valve actuating piston 198 and the lockout spool 176. The lockout spool is shifted upwardly as viewed in Fig. 6 to block communication between pump inlet 77 and chamber 95 by way of line 180. This is also effective to block communication between the cushioning end and the rod end of cushioning jack 44 by way of line 47, passage 181, lockout spool 176, passage 183, check valve 185, passage 186, line 187, passage 189 and the line 57. Spring chamber 194 communicates by way of the line 193, the passage 192, the lockout spool 176, the passage 202, the line 203, the passage 204, the annulus 205, and the passage 211 to the return chamber 75 from where it is directed to the reservoir by way of the return port 70. This allows upward movement of the actuating piston 198 to urge the vent valve 196 to an open position by contact of the actuating extension 199 with the face of the check valve. This vents the rod end of the

cushioning jack 44 to the reservoir by way of return chamber 75 and return port 70.

Pressure in chamber 95 is metered at a controlled rate to the reservoir by way of an orifice 112 and passage 111 to permit the force of spring 162 to return spool 83 to a "raise" position, upwardly as viewed in Fig. 6. This communicates the pump 50 with the cushioning jack chamber 44a and accumulators 45 and 46 by way of restrictor valve 166, leveling spool 83, passage 181 and line 47 to raise the hitch toward the over-leveled condition as disclosed in Fig. 4.

The mechanical deadband and over-leveled condition previously described with respect to Fig. 4 also applies to the embodiment of Figs. 5 and 6 since the detent 116 cooperates with the spool 83 in exactly the same manner to provide those described conditions.

In view of the foregoing, it is readily apparent that the described structure provides an improved fluid suspension system to achieve a greatly improved and simplified control for the descent rate of the hitch from a cushion ride to a lockout condition.

Application No. 19598/76 (Serial No. 1 451 330) has been divided from this application and describes the systems disclosed herein and claims a hitch assembly including a leveling valve provided with detent/release means and a lost motion linkage.

WHAT WE CLAIM IS:—

1. A fluid suspension system including a fluid suspension element disposed in elevational supporting relation between a sprung mass and an unsprung mass, said fluid suspension element comprising a piston movable in a cylinder having a rod end and a cushioning end and a rod connected to the piston and one of the masses and extending through the rod end of the cylinder, means for venting the rod end, resiliently biased fluid pressure means in continuous unrestricted communication with the cushioning end for resiliently supporting said sprung mass at substantially a predetermined elevated cushioning position relative to said unsprung mass when the rod end is vented, and lockout valve means in communication with said cushioning end and operable selectively to communicate said rod end with said cushioning end so as to equalize pressure in said ends of the cylinder and reduce the support of the sprung mass relative to the unsprung mass, whereby to permit the sprung mass to move to a lower position.

2. A fluid suspension system as claimed in claim 1 including fluid flow restricting means disposed between said cushioning end and said rod end for controlling the rate of relative movement of the sprung and

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unsprung masses when said lockout valve means is operated to communicate said rod end with said cushioning end.

3. A fluid suspension system as claimed in claim 1 or 2 including a non-return valve disposed between said cushioning end and said rod end to selectively prevent flow of fluid from said rod end toward said cushioning end.

4. A fluid suspension system as claimed in any preceding claim including a reservoir and wherein the means for venting the rod end comprise a separate valve means for controlling communication between said rod end and said reservoir and operative to move to its open position to vent said rod end to said reservoir in response to said lockout valve means blocking communication of said rod end with said cushioning end, whereby to enable said sprung mass to return to said predetermined cushioning position.

5. A fluid suspension system as claimed in claim 4 including a source of fluid pressure and leveling valve means having a neutral position in which it serves in use to block communication of said cushioning end with said source of fluid pressure and said reservoir and being connected to respond to predetermined variations in the relative position of said sprung mass to said unsprung mass to control communication of said cushioning end with said source of fluid pressure or said reservoir to maintain said sprung mass substantially in said predetermined cushioning position.

6. A fluid suspension system as claimed in claim 5 including a valve spool movably disposed in said leveling valve means for controlling the communication of said cushioning end with said source or said reservoir to maintain said sprung mass in said predetermined cushioning position, detent/release means in said leveling valve means engaging said valve spool in a neutral blocking position and requiring a selected minimum break-out force for moving said valve spool, and a resilient lost motion linkage adapted to exert an increasing actuating force on said valve spool in response to relative vertical movement of said sprung mass and said unsprung mass so that limited relative movement of said sprung mass from said predetermined cushioning position can occur without exceeding said selected minimum break-out force required to move said valve spool from said neutral blocking position.

7. A fluid suspension system as claimed in claim 6 wherein said resilient lost motion linkage is adapted to respond to movement of said sprung mass toward said lower position to move said valve spool to a position communicating said source of fluid pressure with said cushioning end, and

including fluid actuation means operatively associated with said valve spool and selectively communicable with said source of fluid pressure in dependence on the position of said lockout valve means to act in opposition to said resilient lost motion linkage for returning said valve spool to said neutral position.

8. A fluid suspension system as claimed in claim 6 or 7 further comprising a pilot circuit including a source of pilot fluid pressure, actuation means responsive to pilot fluid pressure for actuating said lockout valve means and said separate valve means, and a pilot selector valve means interposed between said source of pilot fluid pressure and said actuation means for selectively conditioning said lockout valve means and said separate valve means to establish said predetermined elevational cushioning position of said sprung mass or to condition said lockout valve means and said separate valve means to permit said sprung mass to move to said lower position.

9. A fluid suspension system as claimed in claim 8 wherein said separate valve means comprises a poppet type check valve and is coaxially aligned with said lockout valve means, and actuating means integral with said lockout valve means are arranged to move said separate valve means to its open position when said lockout valve is conditioned to block communication between said rod end and said cushioning end.

10. A fluid suspension system as claimed in claim 8 including actuation means responsive to pilot fluid pressure for actuating said lockout valve means, and separate actuation means responsive to said pilot fluid pressure for actuating said separate valve means simultaneously with said lockout valve means.

11. A fluid suspension system as claimed in any preceding claim wherein said unsprung mass is a tractor and said sprung mass is a trailer, and said fluid suspension system comprises a cushion hitch coupling said trailer to said tractor for relative vertical movement therebetween.

12. A fluid suspension system as claimed in claim 11 wherein said cushion hitch includes a pair of links pivotally coupling said trailer and tractor and said fluid suspension element is connected between said links.

13. A fluid suspension system as claimed in claim 1 including a valve body having an inlet port connectable to a source of fluid pressure, first and second outlet ports communicating with the cushioning and rod ends respectively, and a return port, a first valve element movably disposed in said valve body for selectively communicating said inlet port with said first outlet port or said return port, said lockout valve means in the form of a second valve element movably



disposed in said valve body for selectively controlling communication between said first and second outlet ports, and said means for venting the rod end in the form of a third valve element movably disposed in said valve body for selectively controlling communication of said second outlet port with said return port when communication between said outlet ports is blocked.

14. A fluid suspension system as claimed in claim 13 including a non-return valve disposed between said first and second outlet ports to prevent flow of fluid from said second outlet port toward said first outlet port.

15. A fluid suspension system as claimed in claim 13 or 14 including fluid flow restricting means disposed between said first and second outlet ports to control the rate of fluid flow from said first outlet port toward said second outlet port.

16. A fluid suspension system as claimed in any of claims 12 to 15 wherein said second and third valve elements are coaxially arranged, and said second valve element includes an actuating extension means for engagement with said third valve element so that movement of said second valve element is mechanically transmitted to said third valve element for selectively controlling communication between said second outlet port and said return port.

17. A fluid suspension system as claimed in any of claims 13 to 15 including first fluid pilot actuating means operatively associated with said second valve element; second fluid

pilot actuating means operatively associated with said third valve element, and a fluid passage interconnecting said first and second fluid pilot actuating means so that said second and third valve elements are simultaneously actuated in response to pilot fluid pressure in said first and second fluid pilot actuating means.

18. A fluid suspension system as claimed in claim 16 or 17 wherein said first valve element has a neutral position blocking communication of said first outlet port from said inlet and second outlet ports, a first operative position communicating said first outlet port to said inlet port, a second operative position in which said first outlet port communicates with said second outlet port, and including resilient linkage means operatively associated with said first valve element for selectively applying a variable force urging said first valve element toward said first or second operative positions and detent/release means for releasable locking said first valve element in said neutral position until said variable force exceeds a predetermined minimum value.

19. Fluid suspension systems substantially as herein-before described with reference to the accompanying drawings.

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