United States Patent [19]

McWilliams et al.

[11] **3,797,140**

[45] **Mar. 19, 1974**

[54] **FLUID SUSPENSION SYSTEM**

[75] Inventors: **Orcenith D. McWilliams**, Morris; **Roger A. Rice**, Joliet, both of Ill.

[73] Assignee: **Caterpillar Tractor Co.**, Peoria, Ill.

[22] Filed: **Sept. 5, 1972**

[21] Appl. No.: **286,025**

[52] **U.S. Cl.** ..... **37/129**, 267/65 D, 267/126, 91/461, 137/102, 137/624.27, 137/625.68, 172/307, 280/489, 137/625.6

[51] **Int. Cl.** **B60d 1/00**

[58] **Field of Search** ..... 172/307, 4, 4.5; 37/124, 37/126 R, 129; 280/488, 489, 124, 423; 180/14 R; 267/64, 65 D, 124, 126; 137/102, 106, 596.12, 624.27, 625.6, 625.68; 60/52 HE; 91/461

[56] **References Cited**

UNITED STATES PATENTS

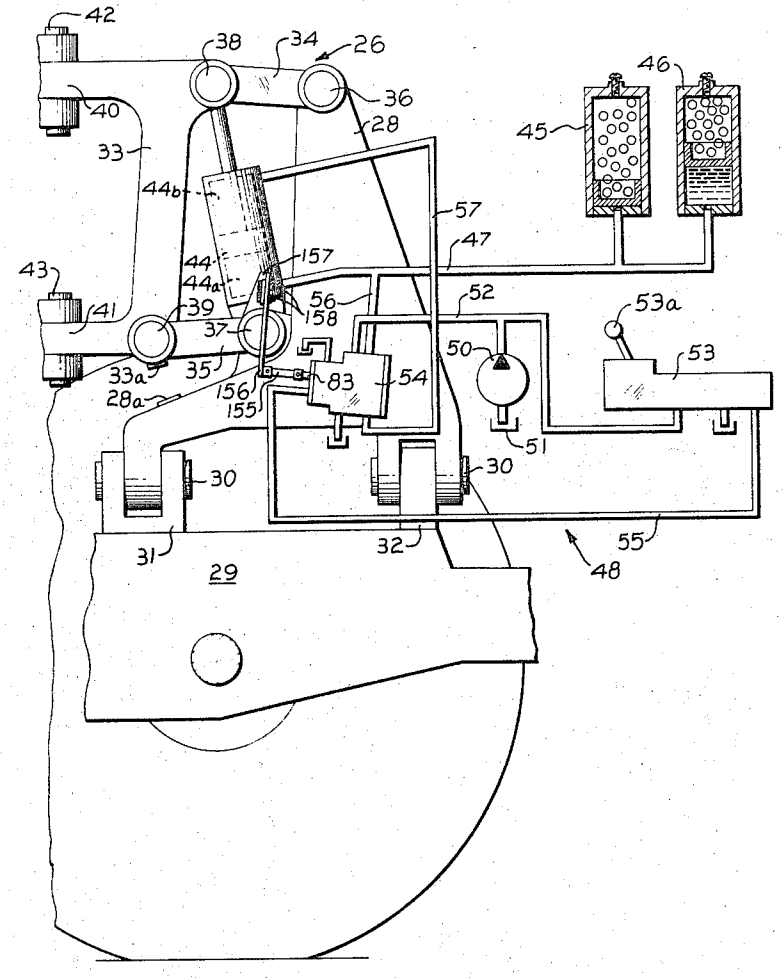
2,965,372	12/1960	Cavanaugh	267/65 R X
2,974,946	3/1961	Tuczek	267/64 R
3,689,103	9/1972	Meulendyk	267/65 R
3,311,389	3/1967	Barton et al.	37/129 X
3,449,845	6/1969	Jessen et al.	37/129
3,321,216	5/1967	Carter	37/126 R
3,177,599	4/1965	Rood	37/129
3,450,418	6/1969	Rice	37/126 R
3,618,984	11/1971	Cook et al.	280/489
3,118,686	7/1964	McAdams	37/129 X
3,135,529	6/1964	Conrad	37/129 X

Primary Examiner—Robert E. Pulfrey
Assistant Examiner—Eugene H. Eickholt
Attorney, Agent, or Firm—Ralph E. Walters

[57] **ABSTRACT**

A fluid suspension system for a sprung mass includes a fluid motor having a cushioning end and an opposite end disposed in elevational supporting relation between the sprung mass and an unsprung mass. A resiliently biased fluid pressure system is in constant communication with the cushioning end of the fluid motor normally to resiliently support the sprung mass at substantially a predetermined elevated cushioning position relative to the unsprung mass. A lockout valve affords selective communication of the opposite end of the fluid motor with the fluid pressure system to equalize pressure in both ends of the motor and permit the sprung mass temporarily to move to a lower predetermined fixed position.

22 Claims, 6 Drawing Figures



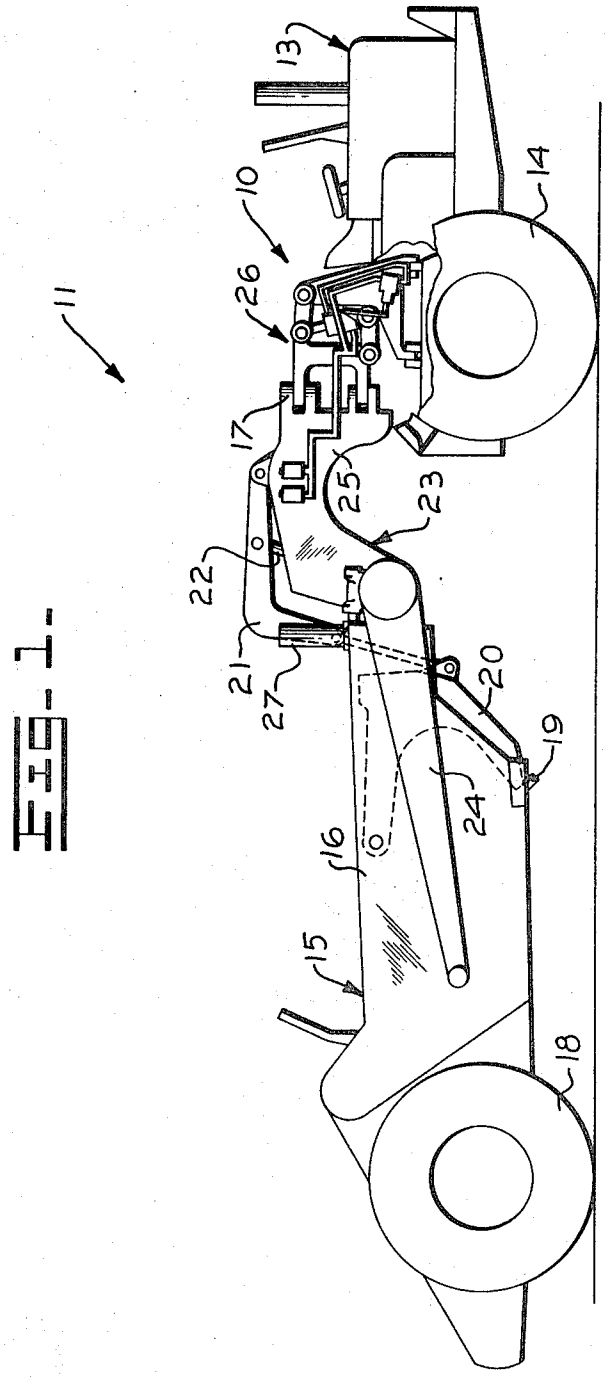


FIG. 1.

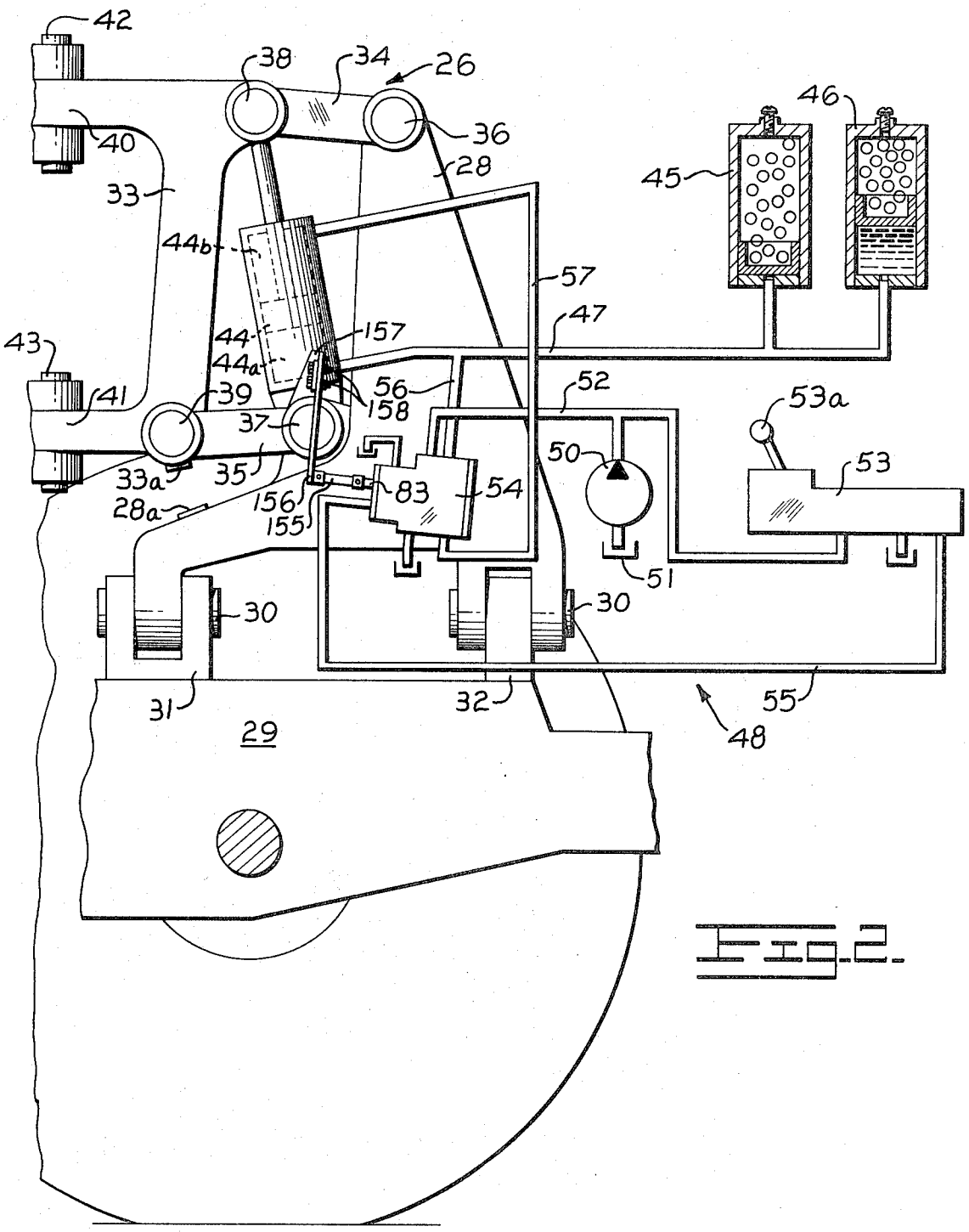

42
38
34
26
40
36
28
33
46
45
44b
57
47
43
44
44a
157
41
39
56
158
52
53a
37
50
53
33a
35
156
155
83
54
28a
30
30
51
31
32
55
48
29

Fig. 2

Fig. 3

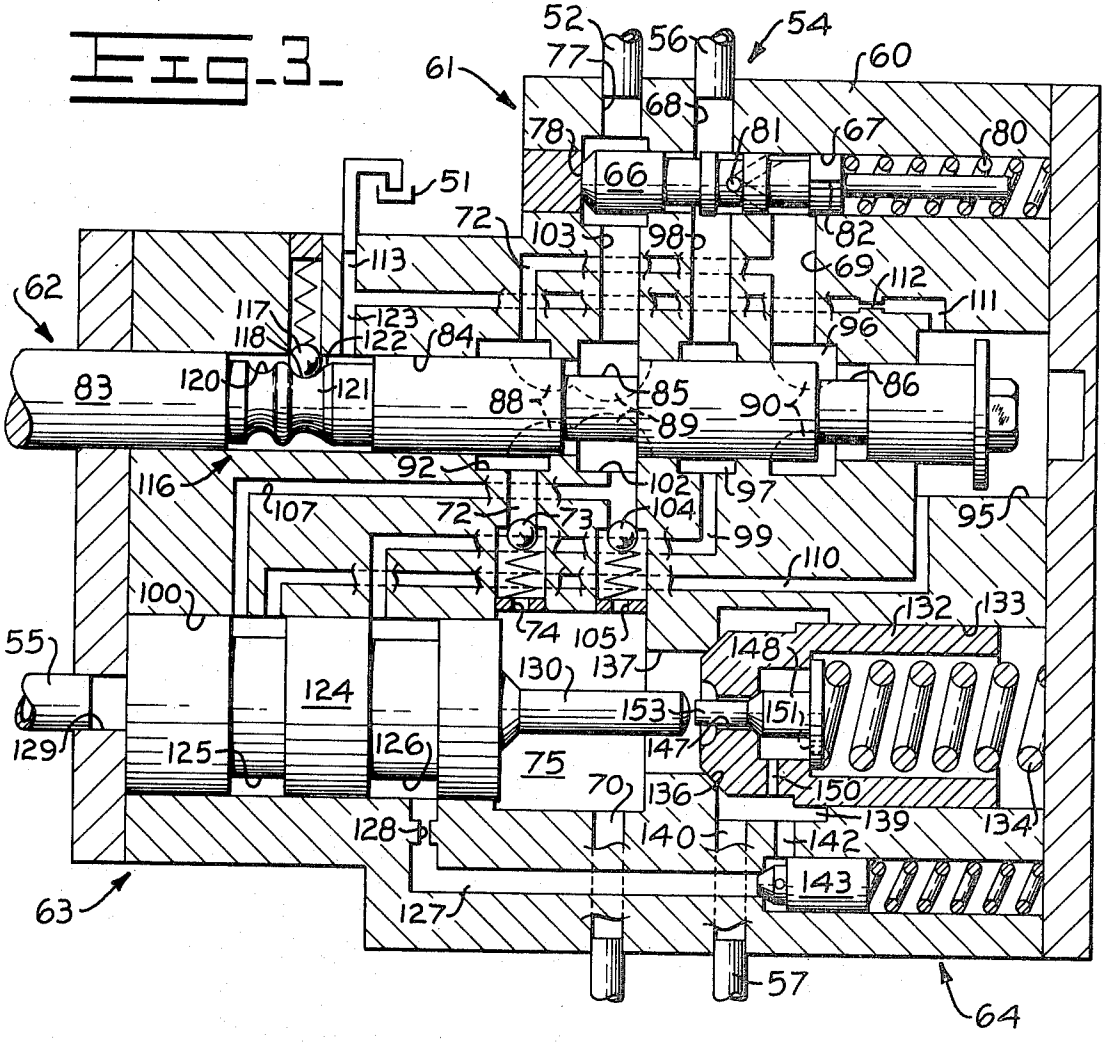

52
56
54
77
61
60
68
78
81
67
80
66
51
72
103
98
82
69
112
111
62
113
117
123
118
122
84
96
83
120
121
88
85
90
86
89
92
102
97
116
107
72
73
104
99
95
110
100
74
105
132
133
55
148
130
137
124
153
151
129
125
126
147
75
70
136
150
139
134
128
140
142
143
63
127
57
64

Fig. 4

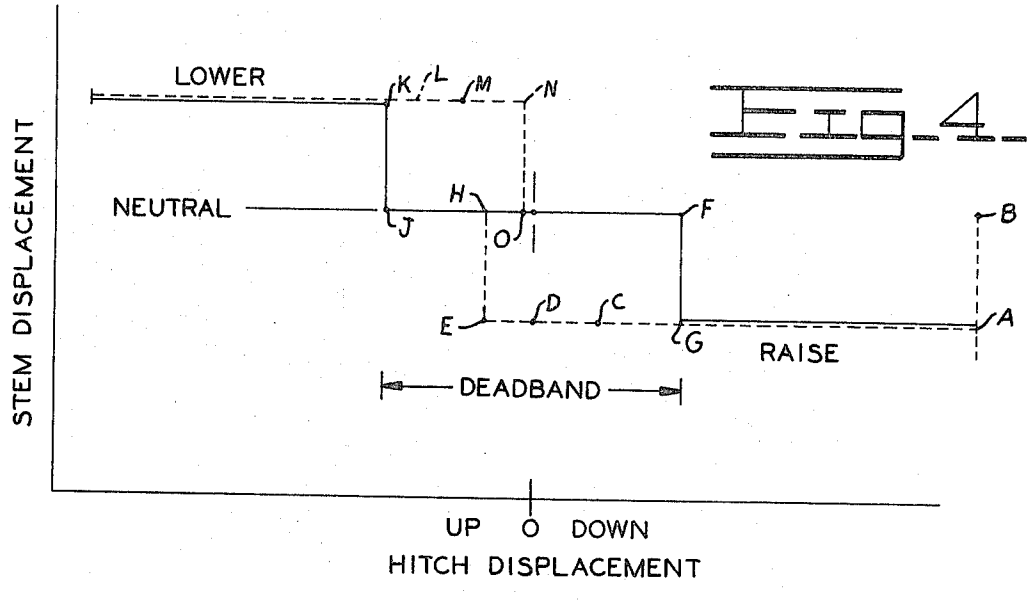

LOWER
K
L
M
N
NEUTRAL
H
J
O
F
B
E
D
C
A
G
RAISE
DEADBAND
STEM DISPLACEMENT
UP
O
DOWN
HITCH DISPLACEMENT

FIG. 5

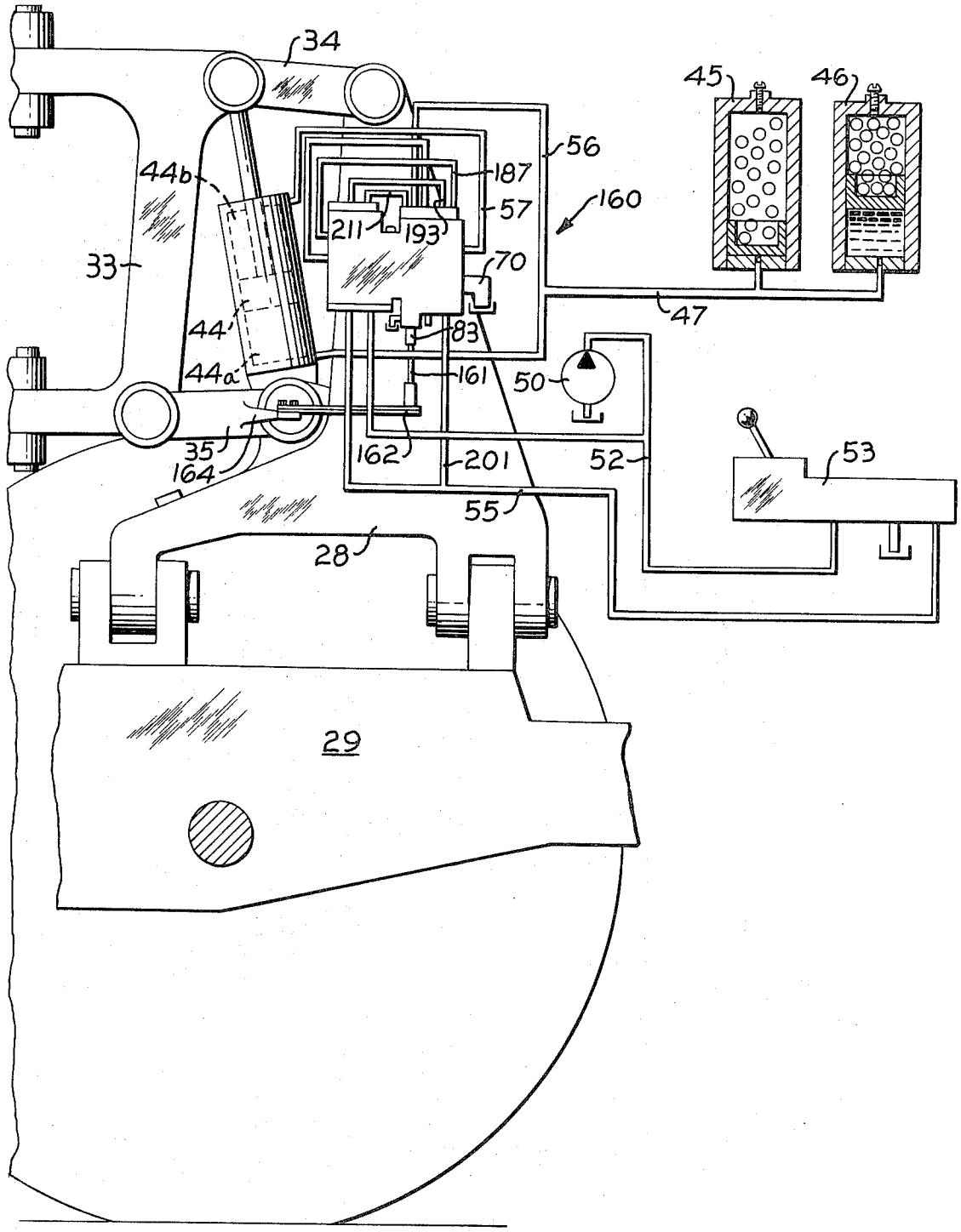
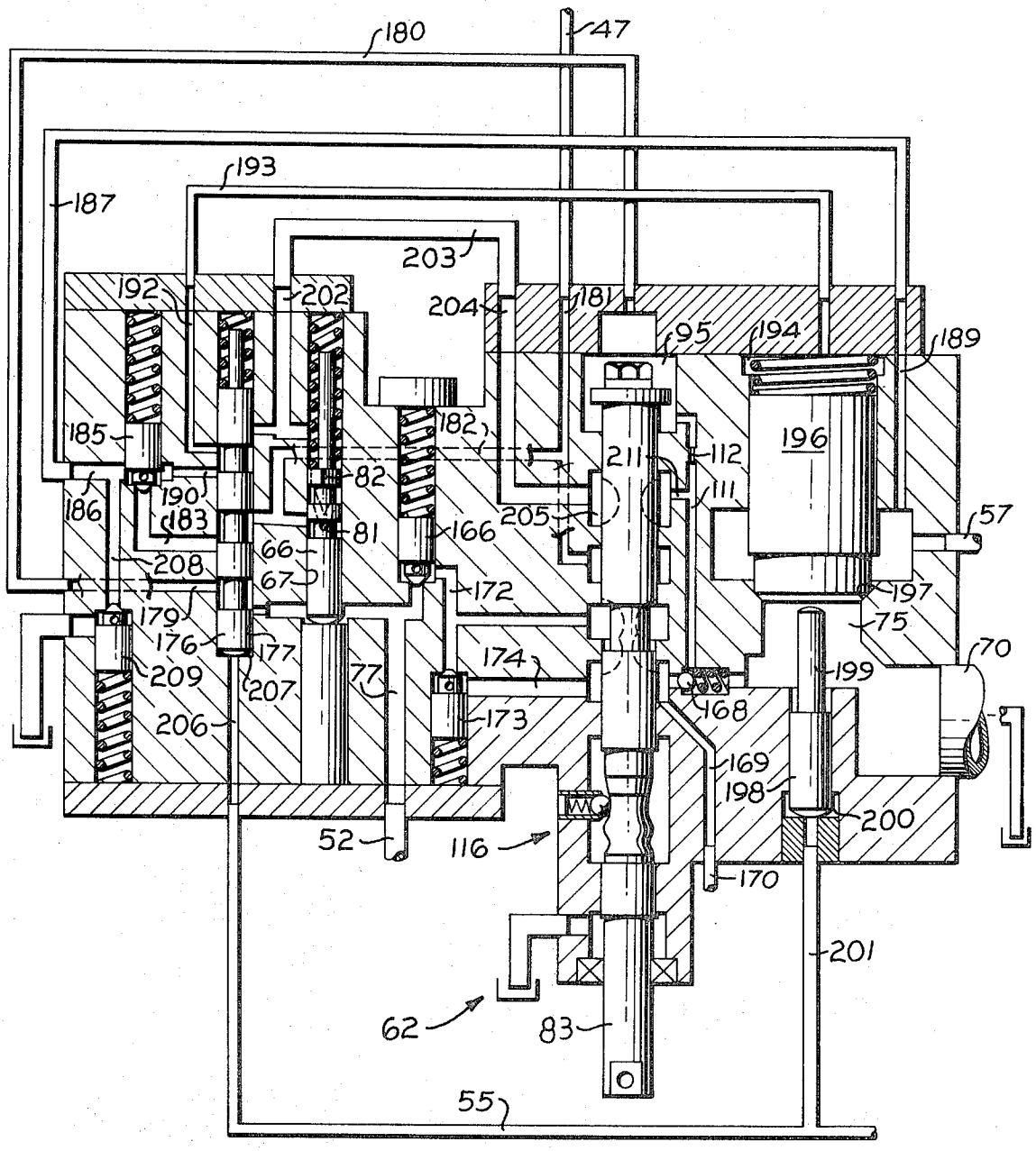

34
45
46
56
187
57
160
44b
211
193
33
70
47
44'
83
44a
161
50
35
164
162
201
52
53
55
28
29

Fig. 6


180
47
193
187
203
192
202
204
181
95
194
189
185
182
211
112
196
186
190
82
111
183
81
205
57
66
166
208
67
172
197
179
75
176
177
174
70
209
207
77
199
206
173
168
169
198
200
52
116
170
201
62
83
55

FLUID SUSPENSION SYSTEM

BACKGROUND OF THE INVENTION

Hydropneumatic suspension hitches for coupling a two wheel tractor with a scraper unit or the like have met with increasing acceptance because of the ability to control pitch and bounce in such vehicles in both the loaded and unloaded condition. U.S. Pat. No. 3,311,389, issued to Barton et al, and U.S. Pat. No. 3,449,845, issued to Jessen et al, are illustrative of hydropneumatic suspension hitches of this type. The theory and operation of such hydropneumatic suspension hitches are best described in U.S. Pat. No. 3,311,389 which is hereby incorporated by reference for a complete understanding of this invention.

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 requires 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 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.

SUMMARY AND OBJECTS OF THE INVENTION

Accordingly, it is an object of this invention to provide an improved fluid suspension system of greatly simplified construction and which is capable of more efficient operation than presently available suspension systems.

Another object of this invention is to provide a fluid suspension system wherein simplified fluid metering is accomplished by a single orifice to control lowering of the hitch to a temporarily fixed lockout condition.

Another object of this invention is to provide a fluid suspension system which utilizes a double acting fluid suspension motor wherein the cushioning end is constantly pressurized in both of its operating conditions.

Other objects and advantages of the present invention will become more readily apparent upon reference

to the accompanying drawings and following description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevation of a two wheel tractor and an earthmoving scraper combination connected through a hydropneumatic suspension hitch with the instant fluid suspension system incoporated therein.

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

FIG. **3** is a section through the low-cost control valve illustrated in FIG. **1.**

FIG. **4** is a graph illustrating the dead-band area where the control valve remains in its neutral position even though minor up and down relative movements between the tractor and trailer occur in the hitch members.

FIG. **5** is an enlarged broken away section of the suspension hitch with an alternate control valve oriented differently on the A-frame; and

FIG. **6** is a section through the alternate low-cost control valve shown in FIG. **5.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring more particularly to the drawings, a fluid suspension system embodying the principles of the present invention is generally indicated by the reference numeral **10** and is illustrated in FIG. **1** thereof 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 tired 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 **28***a* 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 **33***a* for engagement with the stop **28***a*. 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 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 cushioning jack or double acting fluid suspension motor **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 **44***a* and a rod or opposite end chamber **44***b* and forms a part of the fluid suspension system **10.** The head end chamber of the cushioning jack is in constant fluid communication with a pair of 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 fluid from the fluid 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 indicated 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 simplified relatively low cost control valve **54.** The manual selector valve has two positions for alternately and selectively establishing a cushion ride condition or a lockout condition of the suspension system by controlling communication of pilot pressure through a line **55** to the control valve **54.**

The internal components of the selector valve **53** are identical with the selector valve illustrated in U.S. Pat. No. 3,511,276 and 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 **53**a.

Valve **54** communicates with the cushioning chamber **44**a 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 **44***b* 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,** a lockout valve section **63,** and a vent valve section **64.**

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 tank return port **70** by way of a passage **72,** a restrictor 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 **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 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 appropriate linkage with the suspension hitch **26,** as will hereinafter be described. The bore **84** further includes an annulus **96** which communicates by way of passage **69** with the bore **67** of the safety vent valve **61,** 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 lock-out 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 high pressure relief valve **104** and an orifice **105** with the tank 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 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 tank **114** 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 **53** 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 is 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 tank 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 **127** 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.**

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.

SECOND FORM

An alternate 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 pivotal 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 **53** 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 spool **66** is responsive to pump pressure in the pump inlet. The drilled passages **81** and the slots **82** in safety spool **66** serve to vent the accumulators when the system is inactive.

The inlet port **77** also communicates through 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,** pressurizing 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 accumulator to pump, thus pressurizing passage **77.** Under these conditions, the spool **66** will not return to the vent position shown and the accumulators will not be vented.

The pump inlet port **77** also communicates through a passage **172,** a relief valve **173,** a passage **174,** and the restrictor valve **168** to the tank return chamber **75** from where it is returned to the reservoir by way of a tank 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 throug the leaf spring **162.**

A lockout valve spool **176** is reciprocably disposed in a 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 a passage **111** to the spring chamber of restrictor valve **168** which communicates with tank 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,** a passage **181,** a 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 by way of line **57** and the tank 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 is in communication with the pilot line **55** from selector valve **53** by way of line **201**.

When the system is conditioned for cushion ride, 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** also 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 overpressure 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.

OPERATION

While the operation of the present invention is believed clearly apparent from the foregoing description, further amplification will subsequently be made in the following brief summary of such operation. 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 **35** is permitted to lower until the stop **35***a* engages the stop **26***a* on the hitch A-frame **28**. Downward movement of the bracket **35** 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 **53** is disposed in a lockout position as may be more clearly understood with reference to the description in U.S. Pat. No. 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 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 of 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 **53***a*.

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 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 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 groove **120** in the spool. Movement of lockout spool 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 **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 way of port **140**, passage **137**, return chamber **75** and return port **70**. Communication of the accumulator pressure from line **47** to the rod end of the jack is also blocked as the spool **124** blocks communication 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 end of the cushioning jack **44** and the accumulators **45** and **46** to pressurize the cushioning system. That pressure acting on the full area of the piston is effective to raise the bracket **33** and the forward end of the scraper **15** toward a centered or "level" position within its total range of movement wherein the spring force and the weight of the scraper is balanced. As the bracket **33** raises, the pivotal movement of line **35** relaxes the actuating force inleaf spring **156**.

The above described action is best explained 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 centered or level position toward either extreme 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 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. 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. As this point, the spring is deflected and is exerting approximately 75 pounds of force to hold the leveling spool in a raise position for communicating 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 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 and acting in a direction to urge spool **83** toward a neutral position. Since approximately 30 pounds is required to disengage detent ball **117** from the groove **120**, the hitch continues to rise to point E at 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 spool **83** increases the leak-down time or load required to depress the hitch sufficiently to actuate the leveling spool to a raise position. This minimizes cycling of the system and reduces wear and stress on the 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** with the neutral groove **118** is effective to resist movement of the leveling valve until the force in spring **156** reaches approximately **30** pounds. This condition is achieved at point F in the downward direction at which point the spool **83** snaps to a full open 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 admission 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 approximately 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 full open or lower position at point K of FIG. **4**. This communicates the cushioning end of the 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 will lower as indicated by broken line L. The spring force is approximately 0 at point M. As the hitch continues to lower to point N the spool is urged toward a neutral condition by the spring **156**. At this point the 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 0 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 **73** 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 also communicates the accumulators with the rod end of the cushioning jack **44** as previously described to equalize the pressure in the opposite ends of the jack. Although the differential area of the piston provides an unbalanced upward force, the weight of the scraper **15** and the bracket **33** is sufficient to move the piston downwardly until the stop **33***a* engages the stop **28***a*. 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**.

OPERATION OF SECOND FORM

The alternate 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 valve 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 suspension system and the rod end of cushioning jack **44** by way of line **47**, passage **181**, lockout spool **176**, passage **83**, 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 raised position, as viewed in FIG. **6**. This communicates the pump **50** with the cushioning jack chamber **44***a* and accumulators **45** and **46** by way of restrictor valve **166**, leveling spool **83**, passage **181** and line **47** to raise the latch 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 alternate 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 structure of the present invention provides an improved fluid suspension system and simplified leveling valve to achieve a greatly improved and simplified control for the descent rate of the hitch from a cushion ride to a lockout condition. It further provides direct mechanical actuation of the leveling spool in conjunction with individual spools for each of the other hitch functions and/or modes of operation to permit the use of a greatly simplified valve construction with improved control of the hitch position. It further provides a mechanical spring directly connected to the leveling spool in combination with a mechanical detent to eliminate

the need for expensive complicated pilot systems and hydraulic damping devices to provide the deadband desired to avoid excessive energizing of the fluid suspension circuit. This combination also permits the use of an extremely simplified valve to materially reduce costs and yet achieve superior performance of the fluid suspension system.

While the invention has been described and shown with particular reference to the preferred embodiments, it will be apparent that variations might be possible that would fall within the scope of the present invention which is not intended to be limited except as defined in the following claims.

What is claimed is:

1. A fluid suspension system in which a fluid motor having a cushioning end and a normally vented opposite end is disposed in elevational supporting relation between a sprung mass and an unsprung mass, said fluid suspension system comprising;

resiliently biased fluid pressure means in constant communication with said cushioning end of said fluid motor to resiliently support said sprung mass at substantially a predetermined elevated cushioning position relative to said unsprung mass when said opposite end is vented; and

lockout valve means operative selectively to communicate said opposite end of said fluid motor with said fluid pressure means and simultaneously to block the venting thereof to equalize pressure in said ends of the motor and minimize said resilient supprt whereby the weight of the sprung mass is operative temporarily to move the sprung mass to a lower predetermined fixed position.

2. The fluid suspension system of claim **1** including fluid flow restricting means disposed between said fluid pressure means and said opposite end of said fluid motor to control the lowering rate of the sprung mass.

3. The fluid suspension system of claim **1** including a non-return valve disposed between said fluid pressure means and said opposite end of said fluid motor to prevent flow of fluid from said opposite end toward said fluid pressure means temporarily to lock said sprung mass in said predetermined fixed position.

4. The fluid suspension system of claim **1** including;

a reservoir; and

separate valve means having open and closed positions for controlling communication between said opposite end and said reservoir and operative to move to said open position communicating said opposite end with said reservoir responsive to operation of said lockout valve means to block communication of said opposite end with said fluid pressure means and return said sprung mass to said predetermined cushioning position.

5. A fluid suspension system in which a fluid motor having a cushioning end and a normally vented opposite end is disposed in elevational supporting relation between a sprung mass and an unsprung mass, said fluid suspension system comprising;

resiliently biased fluid pressure means in constant communication with said cushioning end of said fluid motor to resiliently support said sprung mass at substantially a predetermined elevated cushioning position relative to said unsprung mass when said opposite end is vented;

lockout valve means operative selectively to communicate said opposite end of said fluid motor with said fluid pressure means and simultaneously to block the venting thereof to equalize pressure in said ends of the motor whereby the weight of the sprung mass is operative temporarily to move the sprung mass to a lower predetermined fixed position;

a reservoir;

separate valve means having open and closed positions for controlling communication between said opposite end and said reservoir and operative to move to said open position communicating said opposite end with said reservoir responsive to operation of said lockout valve means to block communication of said opposite end with said fluid pressure means and return said sprung mass to said predetermined cushioning position;

a source of fluid pressure; and

leveling valve means, having a neutral position normally blocking communication of said cushioning end of said fluid motor with said source of fluid pressure and said reservoir and being responsive to predetermined variations in the relative position of said sprung mass to said unsprung mass to control communciation of said cushioning end with said source of fluid pressure and said reservoir to maintain said sprung mass substantially in said predetermined cushioning position.

6. The fluid suspension system of claim **5** wherein said unsprung mass is a tractor and said sprung mass is a trailer, and said fluid suspension system is a cushion hitch which couples said trailer to said tractor for relative vertical movement therebetween, said cushion hitch being tuned and damped to generate out-of-phase vertical movement of said trailer relative to vertical movement of said tractor to suppress bounce of said tractor and said trailer as a unit.

7. The fluid suspension system of claim **6** including link means pivotally coupling said trailer and said tractor for vertical relative movement therebetween with said fluid motor connected between said link means;

a valve spool movably disposed in said leveling valve means for controlling said communication of said cushioning end of said fluid motor with said source and said reservoir to maintain a preselected elevational relationship between said trailer and said tractor;

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

resilient lost motion linkage means for connecting said valve spool to said link means to exert an increasing actuating force on said valve spool in response to relative vertical movement of said tractor and trailer so that limited relative movement of said trailer from said preselected elevational relationship can occur without exceeding said selected minimum break-out force required to move said valve spool from said neutral blocking position.

8. The fluid suspension system of claim **5** further comprising;

pilot circuit means 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 preselected elevational position of said trailer and to condition said lockout valve means and said separate valve means to permit said trailer to move to said predetermined fixed position.

9. The fluid suspension means of claim **8** wherein said separate valve means comprises a poppet type check valve and is coaxially aligned with said lockout valve means;

actuating means on said lockout valve for moving said separate valve means to said open position when said lockout valve is conditioned to block communication between said opposite end of said fluid motor and said fluid pressure means.

10. The fluid suspension means of claim **8** wherein said lockout valve means includes pilot fluid pressure responsive actuating means;

separate actuation means, responsive to said pilot fluid pressure for actuating said separate valve means simultaneously with said lockout valve means.

11. The fluid suspension system of claim **8** wherein said leveling valve means includes a valve spool;

a resilient lost motion linkage connected to said spool and responsive to movement of said sprung mass toward said predetermined fixed position to move said valve spool to a position communicating said source of fluid pressure with said cushioning end of said fluid motor; and

fluid actuation means operatively associated with said valve spool and selectively communicable by said lockout valve means with said source of fluid pressure to act in opposition to said resilient lost motion linkage and return said valve spool to said neutral position.

12. In a hitch assembly coupling a tractor and a trailer through link members for vertical relative movement with a hydropneumatic support connected between the link members to improve the riding qualities by suppressing bounce, an improved, low-cost hitch control valve and linkage comprising:

a control valve mounted adjacent to said hitch assembly and connected to a source of pressurized fluid;

a suspension cushioning means connected to said control valve and connected across said link members of said hitch assembly allowing relative vertical movement between said tractor and said trailer, said suspension cushioning means having at least one pneumatic accumulator commonly connected thereto;

a valve spool movable in said control valve to admit pressurized fluid to said suspension cushioning means and vent fluid therefrom to maintain a preselected relationship between said tractor and said trailer;

a detent/release means in said valve engaging said valve spool and having a neutral engaged position requiring a selected mininum break-out force;

a lost motion linkage means connecting said valve spool and one of said link members of said hitch assembly moving relative to said control valve through which vertical movement of said hitch assembly is transmitted to said valve spool and whereby limited hitch movement relative to said preselected relationship of said tractor and said trailer can occur without actuation of said control valve and smooth fluid adjustment will be available once said break-out force of said valve spool has been exceeded by forces displacing it from said lost motion linkage means.

13. The improved control valve and linkage defined in claim **12** wherein the force generated by said lost motion linkage means is proportional to its absorbed motion and the break-out force of the valve spool is sufficient to cause said lost motion linkage means to absorb some motion before it exceeds said break-out force.

14. The improved control valve and linkage defined in claim **13** wherein the lost motion linkage means includes a displaceable spring member having a force generally linear relative to its absorbed displacement.

15. The improved control valve and linkage defined in claim **13** wherein several pneumatic accumulators are connected to the suspension cushioning means, each accumulator having a different preload to increase the load range of the trailer over which said cushioning means will effectively suppress bounce.

16. The improved control valve and linkage defined in claim **13** wherein the hitch assembly is a multipivoted unit connecting a tractor portion with a trailer portion of an articulated vehicle.

17. The improved control valve and linkage defined in claim **16** wherein the trailer portion is an earthmoving scraper.

18. The improved control valve and linkage defined in claim **16** wherein the hitch assembly is constructed with link members arranged to cause pitch to be suppressed along with bounce by the cushioning means.

19. The improved control valve and linkage defined in claim **13** wherein the source of pressurized fluid is a pump driven by an engine in the tractor and the control valve has a pressure controlled valve operable to bleed pressure from the suspension cushioning means when said engine is stopped.

20. The improved control valve and linkage defined in claim **13** wherein the detent/release means includes cammed surfaces on opposite sides of its neutral engaged position whereby the centering force on the valve spool is increased as the hitch assembly approaches the preselected relationship between said tractor and trailer.

21. The improved control valve and linkage defined in claim **13** wherein the control valve includes controllable piston means operable to activate and deactivate the cushion means of the hitch assembly.

22. The improved control valve and linkage defined in claim **13** wherein the cushioning means is a hydraulic cylinder.

* * * * *