United States Patent

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[54] **HYDRAULIC SELF-LEVELING CONTROL FOR BOOM AND BUCKET**
21 Claims, 9 Drawing Figs.

[52] U.S. Cl. 91/414; 60/52; 214/763, 214/771; 137/596
[51] Int. Cl. F15b 11/16
[50] Field of Search .... 91/414; 214/763, 771, 140, (Inquired); 60/52 (HE); 37/596

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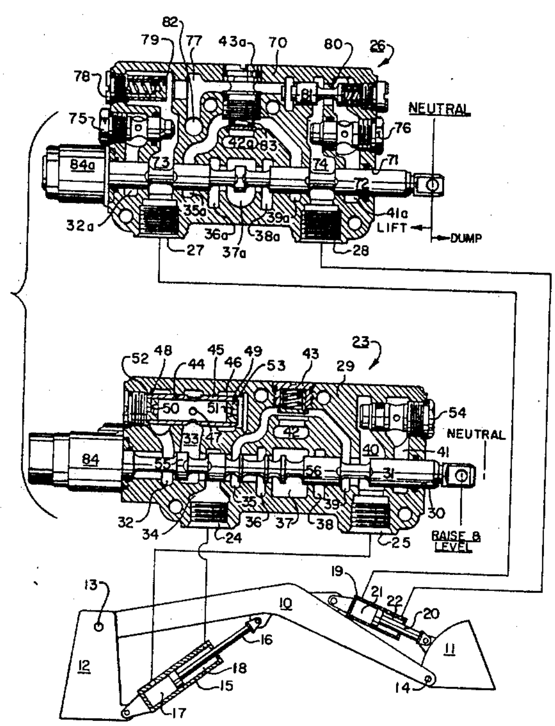
ABSTRACT: A control system for the selective operation of hydraulic cylinders positioning the boom and bucket of a front end loader. A multiple spool valve is provided with a control spool for the boom and a control spool for the bucket. When the boom is actuated by directing pressure fluid to one end of the boom cylinder, the fluid displaced from the other end of the boom cylinder is selectively directed through a transfer circuit to a flow divider that diverts a predetermined portion of the displaced fluid to actuate the bucket cylinder and maintain the bucket level when the boom is raised and/or lowered. Additional controls may include a pressure relief valve for the transfer circuit, a check valve downstream of the flow divider preventing reverse flow through the transfer circuit, and a piston responsive to transfer circuit pressure to meter fluid displaced from the bucket cylinder and prevent cavitation in the system.



PATENTED FEB 16 1971 3,563,137

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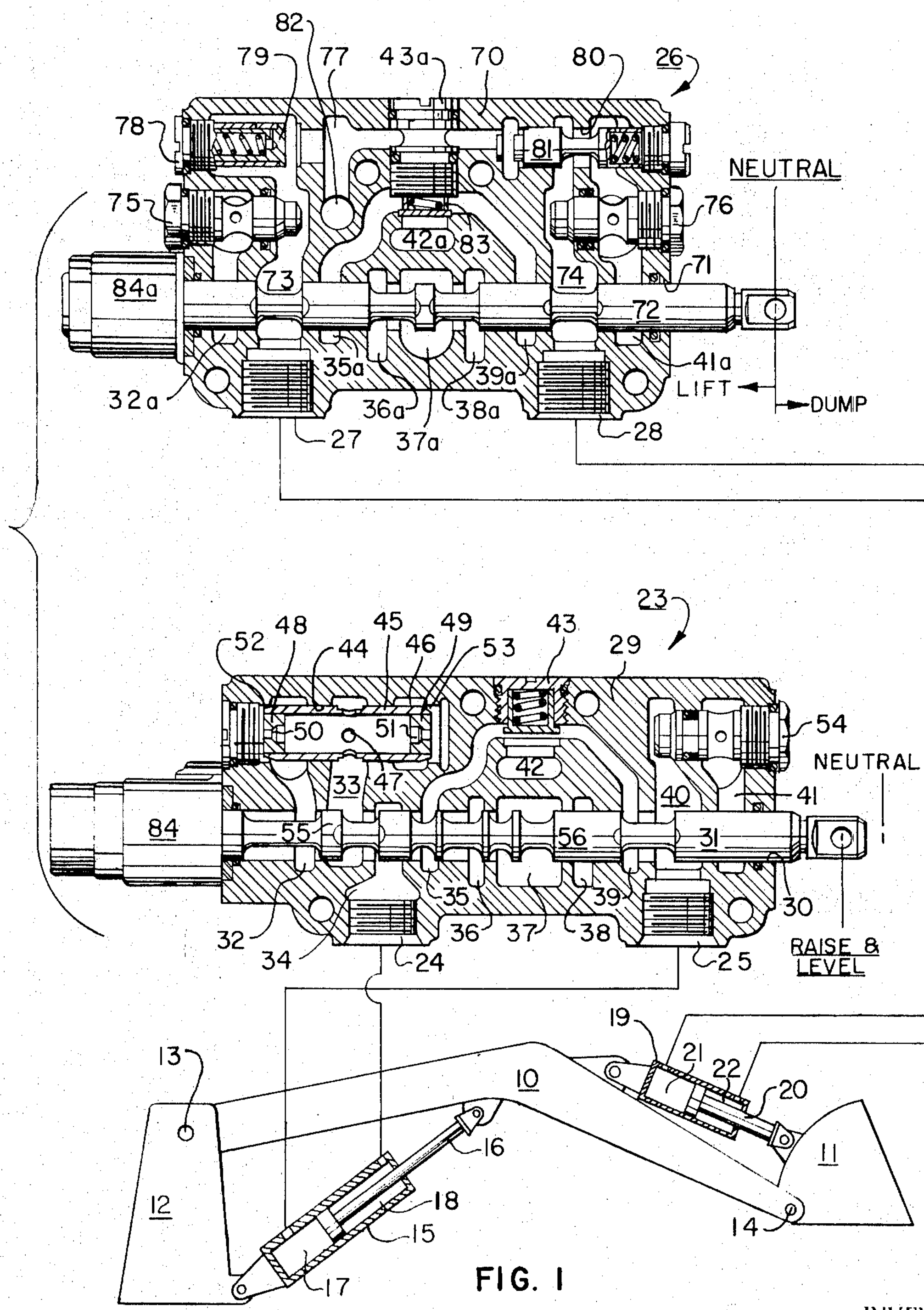

FIG. 1

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PATENTED FEB 16 1971 3,563,137

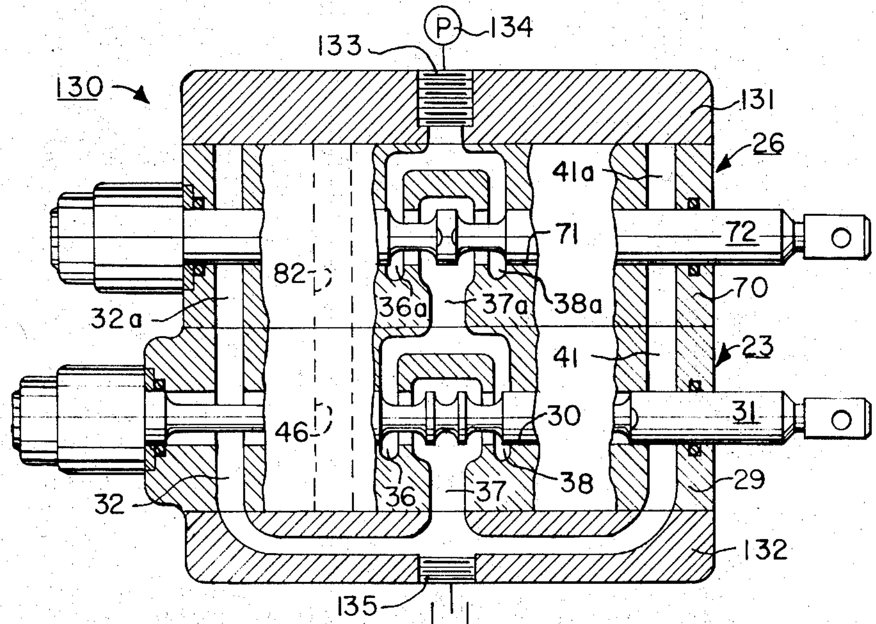

FIG. 2

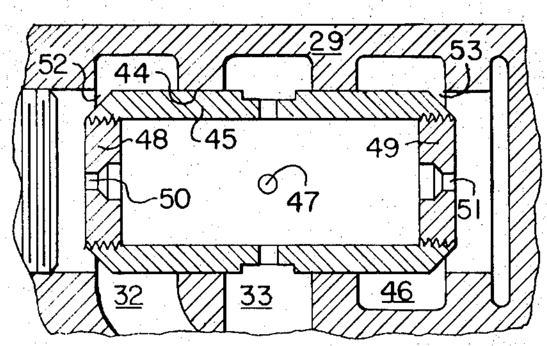

FIG. 3

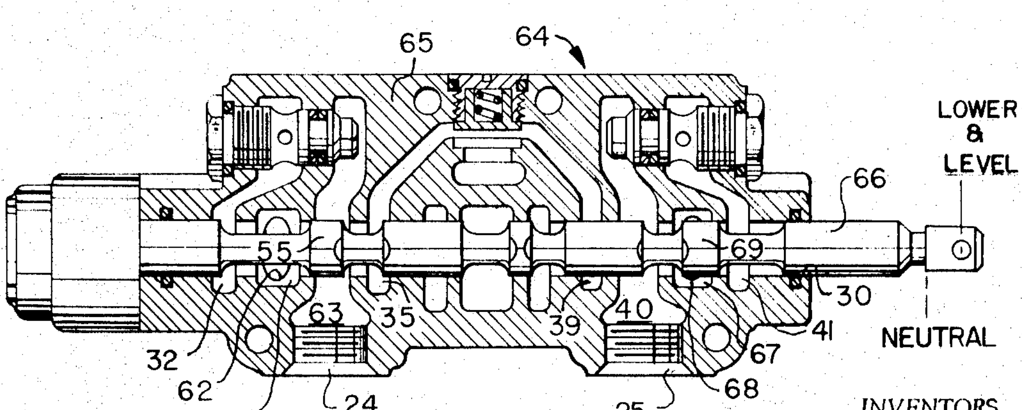

FIG. 9

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PATENTED FEB 16 1971 3,563,137

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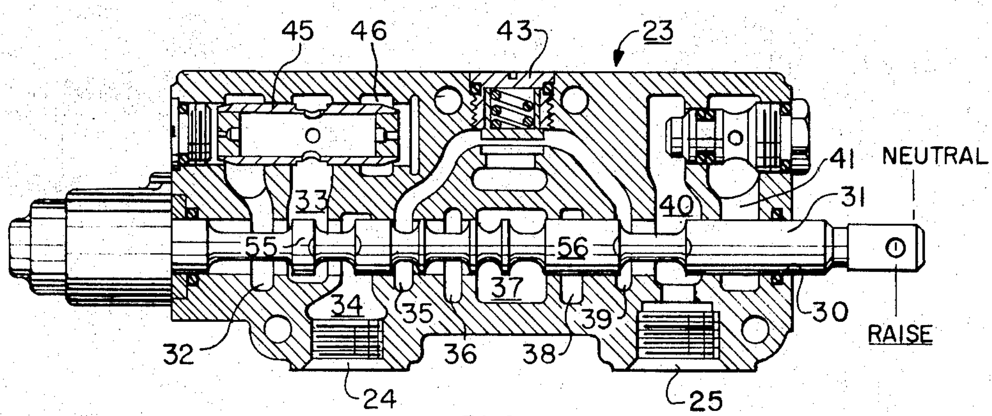

FIG. 4

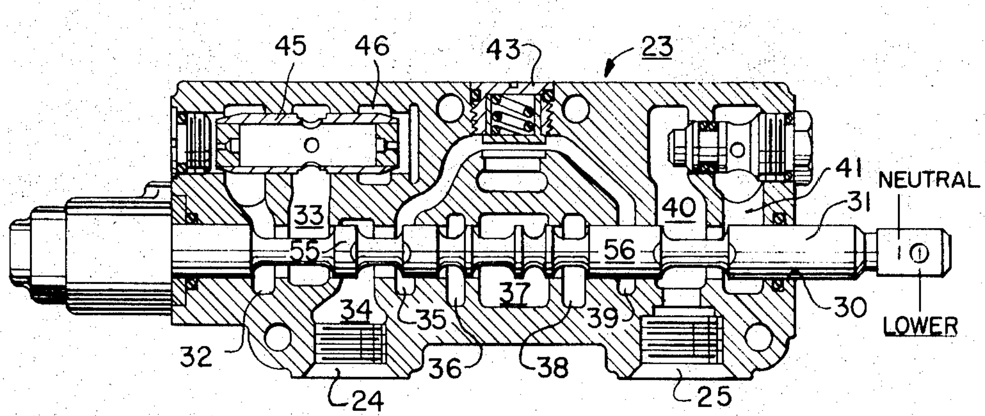

FIG. 5

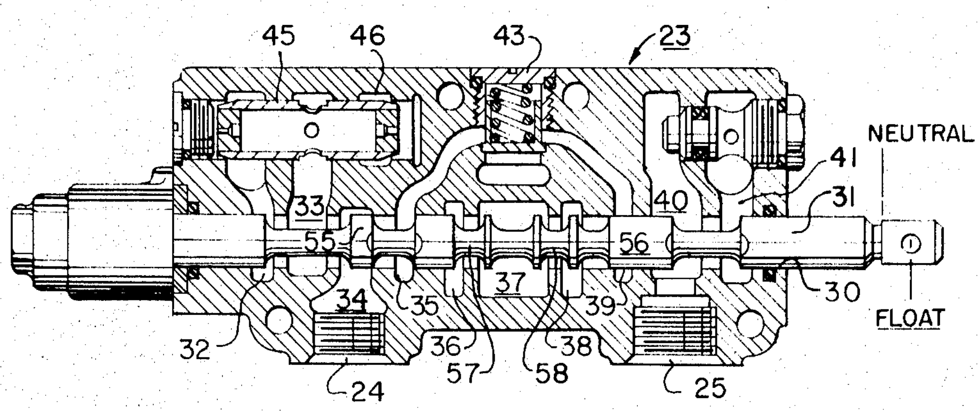

FIG. 6

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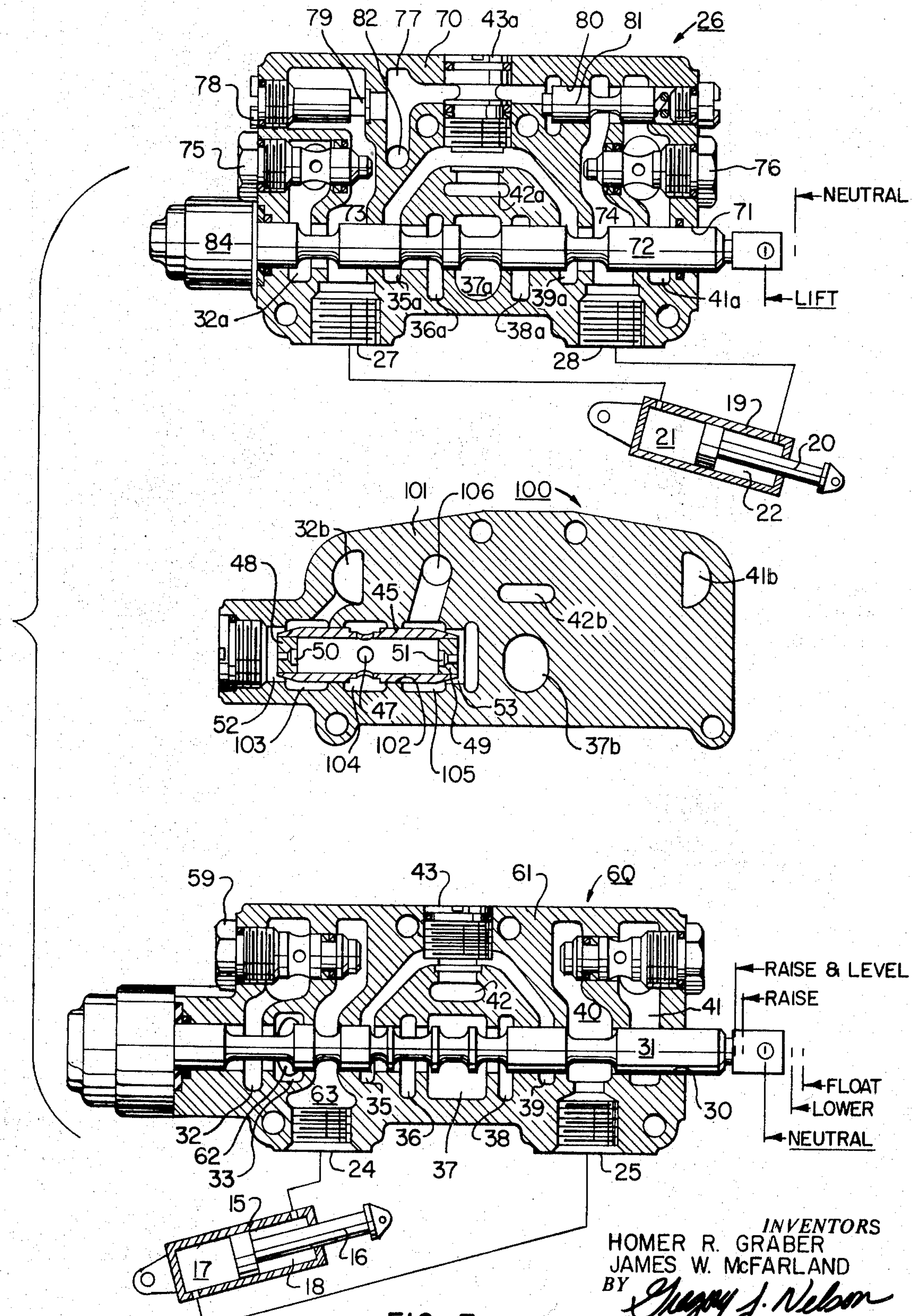

FIG. 7

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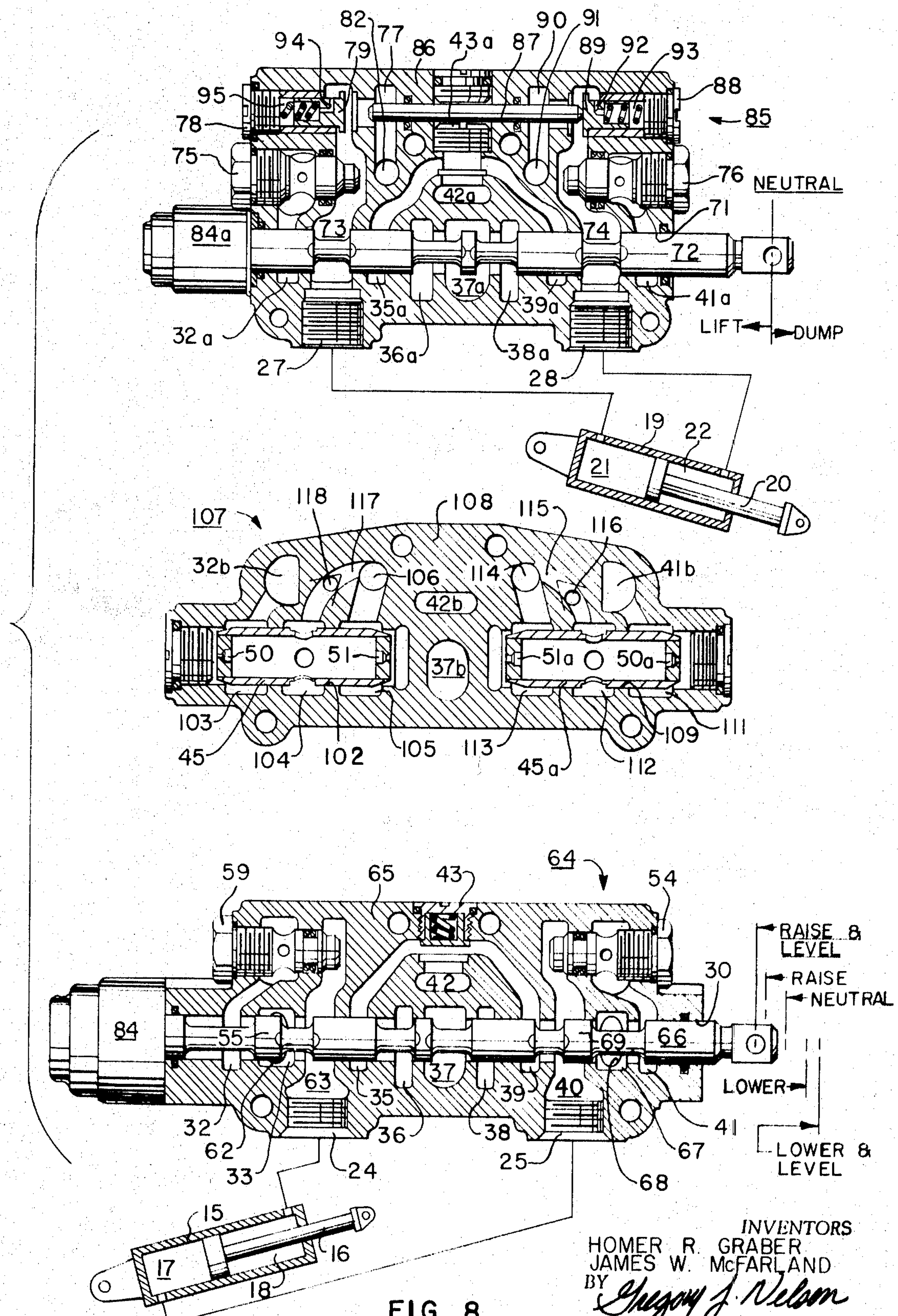

FIG. 8

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HYDRAULIC SELF-LEVELING CONTROL FOR BOOM AND BUCKET

BACKGROUND OF THE INVENTION

This invention relates generally to controls for fluid power systems. More particularly, this invention relates to directional fluid control valves that selectively effect automatic leveling of the bucket on a front end loader or similar device, during movement of the boom arm to which the bucket is attached.

It is conventional practice to provide a hydraulic cylinder for manipulating the bucket of a front end loader, and another cylinder for raising and lowering the boom arm. In addition to various mechanical linkages that move the bucket and keep it level while the boom is being raised, hydraulic self-leveling means have also been devised to divert fluid displaced from the boom cylinder and direct it to operate the bucket cylinder so as to keep the bucket level. A serious drawback to these hydraulic systems is the requirement of matching the sizes of the boom and bucket cylinders so that the volume displaced from the boom cylinder will extend the bucket cylinder the precise distance to hold the bucket level as the boom is raised. As a result, a more expensive, unnecessarily large bucket cylinder is included in the hydraulic system. Further, because opposite ends of a hydraulic cylinder have different displacements due to the space taken by the cylinder rod at one end, bucket leveling can be effected in only one direction of boom movement.

It is therefore apparent that a hydraulic bucket leveling system not requiring matched boom and bucket cylinders would provide a more versatile and economic hydraulic control for front end loaders.

SUMMARY OF THE INVENTION

To this end, the present invention contemplates a hydraulic control system that directs only the necessary portion of boom displaced fluid to actuate the bucket cylinder, thereby permitting greater leniency in the size and design of the boom and bucket cylinders.

Accordingly, the invention broadly contemplates a control system for selectively actuating a first hydraulic motor by a portion of the fluid displaced from a second hydraulic motor.

Another object of this invention is to provide a control valve assembly and fluid system for actuating the boom and bucket motors of a front end loader whereby the bucket is automatically leveled during both the raising and lowering of the boom.

A more specific objective of this invention is to provide a control valve assembly including separate valves for regulating the boom and the bucket and a flow divider for directing a portion of fluid returning to the boom control valve into the bucket control valve to operate the bucket cylinder.

Another objective of this invention is to provide a control valve assembly characterized by the foregoing objectives wherein manual actuation of the bucket valve overrides the automatic bucket leveling operation

For such a control valve assembly, it is another object of this invention to provide a spool-type boom control valve which has a float position connecting both ends of the boom cylinder to low pressure.

A further object of this invention is to provide a bucket leveling control system comprising a bank of spool-type sectional control valves which can be interchangeably assembled.

Other objects and advantages of the present invention are described in, or will become apparent from, the following detailed description and accompanying drawings of the preferred embodiments.

Briefly, one form of the invention comprises a spool-type control valve selectively interconnecting opposite ends of a boom cylinder motor to a source of fluid pressure and drain to maneuver the boom. A similar control valve directs fluid to and from a hydraulic cylinder motor for positioning a bucket attached to the boom. The boom valve has a transfer passage into which displaced fluid from the boom cylinder can be directed upon proper positioning of the boom valve spool. A flow divider in the transfer passage directs a portion of the boom displaced fluid to the bucket control valve and the remainder to drain. The transferred fluid flows to one end of the bucket cylinder, with pressure of the transferred fluid actuating a piston to connect the other end of the bucket cylinder with drain, whereby the bucket operates in the desired manner in correlation with boom movement.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a partial schematic of the hydraulic controls for a front end loader including longitudinal section views of the control valves, with the bucket valve in neutral and the boom valve in raise-and-level position;

FIG. 2 is a partial transverse section of a stack valve assembly including the control valves shows in FIG. 1;

FIG. 3 is an enlarged section view of the flow divider;

FIG. 4 is a section view of the boom valve of FIG. 1 in a raise position;

FIG. 5 is a view similar to FIG. 4 with the boom valve in lowering position;

FIG. 6 is a view similar to FIG. 4 with the boom valve in float position;

FIG. 7 is a partial schematic of another embodiment of the fluid control system, with the bucket valve in lift position and the boom valve in neutral position;

FIG. 8 is a partial schematic of another embodiment of the invention, with the bucket valve in neutral and the boom valve in raise-and-level position; and

FIG. 9 is a view of the boom valve of FIG. 8 in lower-and-level position.

DESCRIPTION, FIG. 1

More particularly, FIG. 1 illustrates a boom arm **10** and bucket **11** as commonly mounted to the frame **12** of a mobile vehicle. Boom **10** is pivotally attached to the vehicle at pivot **13** for up-and-down movement, while bucket **11** is mounted to the boom at pivot **14** to facilitate scooping and dumping movements. Pressurization of the head end **17** of boom cylinder **15** causes extension of rod **16** and raises the boom, while pressurization of rod end **18** retracts rod **16** and lowers the boom arm. Pressurizing head end **21** of bucket cylinder **19** extends rod **20** and rotates bucket **11** clockwise about pivot **14** and boom **10**, and pressurizing rod end **22** retracts rod **20** to rotate the bucket counterclockwise. The opposite ends of cylinders **15** and **19** are respectively connected to boom control valve **23** and bucket control valve **26** at control ports **24, 25** and **27, 28.**

Body **29** of boom valve **23** has a longitudinal bore **30** in which a cannelured control spool **31** is movable to different positions to selectively interconnect and isolate various passages numbered **32** through **41** communicating with bore **30** at spaced positions. Passages **32** and **41** communicate with a low pressure fluid return reservoir, and port passages **34** and **40** respectively connect with cylinder chambers **18** and **17** through ports **24** and **25**. Passages **36, 37** and **38** form the central bypass portion of the open center fluid delivery system, which system also includes pressure fluid delivery passage **42** and the branch passages **35** and **39** connectable with passage **42** across one-way lift check valve **43**.

Port passage relief valve **54** is interposed between passages **40** and **41** to protect port passage **40** and boom cylinder chamber **17** from overpressurization by diverting fluid from passage **40** to drain passage **41** in response to excessive pressure in the port passage. Relief valve **54** is of conventional structure and operation well known to the art and will not be described in detail.

A transfer passage **33** extends in body **29** from bore **30** to parallel blind bore **44** that is intercepted by drain passage **32** and auxiliary outlet passage **46**. Flow divider **45**, movable within bore **44**, is formed as a hollow sleeve having orifice plugs 48 and 49 securely fastened at either end to define a hollow interior communicating with transfer passage 33 through cross bores 47. The flow divider is clearly illustrated in FIG. 3. Orifice holes 50 and 51, normally of different sizes, connect the flow divider interior respectively with drain passage 32 and auxiliary outlet 46 across the flow orificing restrictions 52 and 53 formed between the chamfered ends of flow divider sleeve 45 and the cooperating portions of valve body 29. The proportional type flow divider 45 directs a certain percentage of flow from transfer passage 33 to auxiliary outlet 46, and diverts the remaining flow to drain passage 32.

Referring again to FIG. 1, bucket valve 26 is structurally similar to boom valve 23, having a fluid delivery system comprising bypass passages 36*a*, 37*a*, 38*a*, and pressure delivery passages 35*a* and 39*a*. Moving cannelured control spool 72 either direction within bore 71 directs pressure fluid to port passages 73 and 74 from adjacent passages 35*a* and 39*a* that connect with passage 42*a* across lift check valve 43*a*. Passages 32*a* and 41*a*, connected with a low pressure reservoir, also communicate with bore 71. Port passage relief valves 75 and 76, similar in structure and function to relief valve 54 of the boom valve, are respectively interposed between the port passages 73, 74 and drain passages 32*a*, 41*a* to protect the chambers 21 and 22 of bucket cylinder 19 from overpressurization.

An auxiliary fluid inlet bore 82 and passage 77 in bucket valve 26 directly communicate with the auxiliary outlet passage 46 of boom valve 26 when valves 23 and 26 are assembled, as shown in dotted lines in FIG. 2. Valves 23 and 26 are of the sectional type that are secured together in side-by-side relationship, along with other sectional control valves if desired, to form a conventional stack valve assembly 130. Port plates 131 and 132 fastened at either end of the bank of valves have a pressure port 133 connected with pump 134 and a drain port 135 communicating with a low pressure reservoir to provide common fluid supply and drain systems for valves 23 and 26. As seen, pressure port 133 communicates with passages 36*a* and 38*a* of the central bypass system and drain port 135 connects with passages 32, 37 and 41. Since passages 82 and 46 extend transversely through valve bodies 70 and 29, and because of their similarity in structure as shown in FIG. 2, valves 23 and 26 may be interchangeably assembled with boom valve 23 next to inlet port plate 131 and bucket valve 26 next to outlet port plate 132.

Again in FIG. 1, auxiliary passage 77 in bucket valve 26 communicates with port passage 73 and the head chamber 21 of bucket cylinder 19 across a one-way check valve 78 that opens, as shown, when pressure in passage 77 overcomes passage 73 pressure and the check valve spring bias. Check valve 78 has a poppet 79 spring biased to a closed position wherein it mates against a cooperating seat formed in valve body 70 to prevent fluid flow from passage 73 to passage 77. Hydraulically actuated unloading piston 81 in bore 80 is movable from the open position shown wherein passages 74 and 41*a* communicate across bore 80, leftwardly to a closed position blocking flow through bore 80. Piston 81 is spring biased toward its closed position and opened by pressure in auxiliary passage 77. The spring preload on piston 81 is greater than the spring preload on check valve poppet 79. The various operational modes will now be discussed in detail.

OPERATION, FIG. 1

Neutral Positions

Referring to FIG. 2 with both spools 72 and 31 in neutral, fluid entering inlet port 133 openly bypasses to drain port 135 by flowing from passages 36*a*, 38*a* through bore 71 to passages 37*a*, 36 and 38, across bore 30 to passage 37 and port 135. Actuating either spool 72 or 31 away from neutral blocks this bypass flow at bore 71 or 30, so that pressure builds in port 133; passages 42, 42*a* of FIG. 1, connected with inlet port 133, then deliver the pressure fluid across the lift checks 43, 43*a* to the valve work ports. Upon subsequent release of the spool, the centering spring assembly 84 or 84*a* returns it to neutral.

With spool 72 of bucket valve 26 in the neutral position, FIG. 1, both work ports 73, 74 are isolated from adjacent passages to hydraulically lock both cylinder chambers 21, 22 and hold the bucket in position. Similarly, boom 10 is locked in position when spool 31 is in neutral and blocking port passages 34 and 40 from adjacent passages 33, 35 and 39, 41. Spool 31 is illustrated in neutral in FIG. 7.

Bucket Lift

To rotate bucket 11 counterclockwise to effect a scooping and lifting action, spool 72 is manually moved leftwardly from neutral. (Such position of spool 72 is shown in FIG. 7). Central bypass flow through passage 37*a* is blocked at bore 72, and pressure fluid delivered through passage 42*a* forces open the spring biased poppet 83 of lift check 43*a* to flow into branch passage 39*a* and continue through bore 71, port passage 74, port 28 and the rod chamber 22 of cylinder 19. Rod 20 retracts under hydraulic pressure, and fluid displaced from head chamber 21 returns to port 27 and passage 73 of valve 26, and flows across bore 71 to drain passage 32*a*.

Bucket Dump

Dumping bucket 11 by rotating it clockwise is selected by manually moving spool 72 to the right from the FIG. 1 neutral position. In a similar manner, the reduced diametral portions of spool 72 connect passages 35*a* and 73 to deliver pressure fluid to cylinder chamber 21 and interconnect port passage 74 with drain passage 41*a* at bore 71 to conduct away displaced fluid from chamber 22. Pressure in passage 73 positively holds poppet 79 in its closed position to prevent transfer of pressurized fluid from passage 73 to boom control valve 23.

Boom Raise-and-Level

The raise-and-level operation extends rod 16 to raise boom 10 and proportionally extends rod 20 of bucket cylinder 19 in order to keep bucket 11 in its same position relative to the ground as it was prior to raising boom 10. For example, bucket 11 is placed in a level position before actuating the boom; in subsequently rotating boom 10 30° counterclockwise about pivot 13, bucket 11 must, at the same time, rotate 30° clockwise about pivot 14 to remain in its original level position. To accomplish this correlated, slave operation of cylinder 19, fluid transfer means including passages 33, 46, 82 and 77 are incorporated to deliver fluid to cylinder 19 during boom raising.

The raise-and-level position of spool 31 shown in FIG. 1 blocks flow through the central bypass system and directs pressure fluid from branch passage 39 to port passage 40, port 25 and head chamber 17 of cylinder 15. Boom 10 is driven upwardly and fluid displaced to port 24 from cylinder chamber 18 passes across bore 30 into transfer passage 33 which is blocked from drain passage 32 by spool land 55. The boom cylinder displaced fluid continues through cross bores 47 to the hollow interior of flow divider 45 wherein a specified portion is directed to auxiliary outlet passage 46 and connecting auxiliary inlet passages 82 and 77. Pressure in passage 77 builds sufficiently to open check valve 78 and move unloading piston 81 rightwardly to the position shown. The regulated fluid flow into passage 77 then continues to head chamber 21 of cylinder 19 to rotate the bucket clockwise, with displaced fluid from rod chamber 22 returning through port 28, passage 74 and bore 80 into drain passage 41*a*.

In the fluid flow from transfer passage 33 to each of downstream passages 46 and 32, flow divider 45 places two orifices in series, the first orifice 50, 51 being fixed in size to determine the portion of flow delivered to each downstream passage, and the second orifice 52, 53 being variable in size to compensate for the difference in downstream pressures. By shifting within bore 44, flow divider 45 varies the sizes of secondary restrictions 52 and 53 so that pressure between orifices 50 and 52 at the left end balances pressure at the right end between orifices 51 and 53. With orifice 51 larger than orifice 50 for example, the majority of flow from passage 33 passes through larger orifice 51 to passage 46; flow divider 45 moves leftwardly to reduce the size of orifice 52 and build sufficient back pressure between orifices 50 and 52 to balance pressure from passage 46 exerted on the right end of the flow divider. The equal pressures at either end accordingly dictate equal pressure drops across orifices 50 and 51, so that the sizes of these orifices solely determine the rates of flow to passages 46 and 32.

Orifices 50 and 51 are appropriately sized in accordance with the volume capacities of cylinder chambers 18 and 21 to transfer the required fluid from chamber 18 through orifice 51 to chamber 21 to rotate bucket 11 and maintain the original bucket level position as the boom raises. Fluid in excess of that required by chamber 21 passes through orifice 50 to drain passage 32. Additionally, the present invention can divert more or less fluid to bucket cylinder chamber 21 by changing the sizes of orifices 50 and 51, to rotate the bucket to a load dumping or a tilted-back position respectively during boom raising. Generally, therefore, bucket 11 is automatically driven from a prescribed initial position to a predetermined end position during the raise stroke of the boom in accordance with the selection of orifice sizes in flow divider 45.

Unloading piston 81 is moved to an open position only when pressure exists in passage 77. Inadvertent drainage of fluid from cylinder chamber 22 and consequent movement of the bucket is prevented when spool 31 is not in raise-and-level position by the interconnection of passage 33 and drain passage 32 through bore 30 to relieve pressure in passage 77 and allow piston 81 to be spring biased to the closed position. Additionally, pressure operated piston 81 prevents cavitation in bucket cylinder chamber 21 during the raise-and-level operation. Whenever rod 20 tends to be pulled outwardly by a heavy load faster than the transferred fluid is flowing into chamber 21 and, accordingly, begins to establish cavitation of chamber 21, pressure in passage 77 drops and piston 81 moves toward its closed position to restrict or completely block flow from chamber 22 to drain. This metering action by piston 21 thus limits the speed of movement of rod 20 to match the rate of flow into chamber 21 and maintains positive pressure in passage 77 and chamber 21.

The automatic positioning of bucket cylinder 19 in the boom raise-and-level position can be selectively overridden by moving bucket spool 72 to a cylinder actuating position. Leftward actuation of spool 72 from neutral connects passage 73 with drain passage 32*a* and passage 74 with pressurized branch passage 39*a*. The consequent loss of pressure in passages 73 and 77 allows piston 81 to move leftwardly to isolate pressure carrying passage 74 from drain passage 41*a*. Bucket 11 rotates counterclockwise, and displaced fluid from chamber 21 exhausts across bore 71 to drain passage 32*a*. The boom is capable of continuing to raise in this override condition, with a slight pressure in passage 77 opening check valve 78 (through such pressure does not overcome the stronger spring bias on piston 81) and allowing boom displaced fluid also to exhaust to drain passage 32*a*. In moving bucket spool 72 rightwardly from neutral, pressure fluid delivered from passage 35*a* to passage 73 (acting with the transferred fluid from passage 77 if the boom continues to raise) drives bucket 11 clockwise, while passage 74 is connected with drain passage 41*a* across both bores 71 and 80 for exhausting fluid from cylinder chamber 22. During raise-and-level operation, therefore, bucket 11 can be selectively positioned in the normal manner by actuating spool 72 to override the bucket leveling operation.

Automatic slave positioning of cylinder 19 may also be accomplished by the present system when boom 10 is in a lowering cycle. For example, by reversing the connections of the cylinder chambers with the valve ports so that chambers 17 and 18 respectively connect with ports 24 and 25, and chamber 21 and 22 respectively connect with ports 28 and 27, the fluid displaced from head chamber 17 of boom cylinder 15 during lowering of boom 10 will now be conducted through the transfer means to rod chamber 22 of cylinder 19 to retract rod 20. In comparison to the raise-and-level operation, this lower-and-level operation requires the orifices of the flow divider to be sized to divert a smaller portion of the fluid from head chamber 17, which has greater displacement than rod chamber 18, into the rod chamber 22 of cylinder 19 which has less displacement than head chamber 21. It can be seen that a hydraulic system for effecting automatic lower-and-level has been heretofore impractical, as cylinder 19 would have to be larger than cylinder 20 so that the total volume of fluid displaced from head chamber 17 and transferred to rod chamber 22 would appropriately move the bucket to keep it level as boom 10 lowers.

Boom Raise

Boom 10 can be selectively raised without automatically leveling the bucket by positioning spool 31 slightly rightwardly from the FIG. 1 raise-and-level position to a position as shown in FIG. 4. In this position spool land 55, being narrower than passage 33, affords intercommunication between port passage 34, transfer passage 33 and drain passage 32. Pressure fluid is still delivered from branch passage 39 to port passage 40 to raise the boom; however, displaced fluid from the boom cylinder flows directly from port 24 and passage 34 through passage 33 and bore 30 to drain passage 32, rather than being transferred to the bucket control valve. The bucket will remain hydraulically locked in position while the boom is so raised since no pressure fluid is transferred to passage 77 of bucket valve 26 (FIG. 1) to open poppet 79 and piston 81.

Boom Lower

As shown in FIG. 5, spool 31 is moved to the right of neutral to lower the boom arm. Central passage 37 is again blocked from passages 36 and 38 so that pressure fluid from the valve inlet opens lift check 43 to deliver fluid through branch passage 35 to passage 34 and the rod end of the boom cylinder. Displaced fluid from the opposite cylinder end returns to port 25 of valve 23 and continues through bore 30 to drain passage 41. Passage 33 remains in communication with drain passage 32 and is blocked from passage 34 by land 55 to relieve pressure from the transfer passage means.

Boom Float

A float position of spool 31 is incorporated in control valve 23, as illustrated in FIG. 6, wherein both port passages 34 and 40 are connected with drain passages 32, 41 through bore 30. Reduced diametral portions 57 and 58 reestablish the central bypass flow of the open center fluid delivery system through interconnection of passages 36, 37 and 38, which accordingly relieves pressure from passage 42 to close check valve 43. Again, passage 33 is drained through bore 30 to relieve pressure from the transfer passage means and render inoperative the automatic actuation of the bucket.

With both ports 24 and 25 and the opposite ends of the boom cylinder so drained, the boom rod can freely move within the boom cylinder, and the boom is capable of floating over irregular terrain. Maintenance of a low back pressure within drain passages 32 and 41 to which the cylinder chambers are connected in float position, positively prevents formation of cavitation conditions within the boom cylinder chambers during float operation.

In addition to providing a preferred float operation, location of transfer passage 33 intermediate port passage 34 and drain passage 32 circumvents hydraulic lock of the transfer passage means. As described, transfer passage 33 communicates with drain passage 32 in all positions of spool 31 with the exception of the raise-and-level position wherein it connects with port passage 34. Never being hydraulically isolated, the transfer passage means, therefore, are not subject to collection of pressure fluid leakage, and the consequent inadvertent opening of piston 81 and undesired bucket movement is avoided.

FIG. 7 EMBODIMENT

As shown by like numerals for like parts, FIG. 7 is similar in construction and operation to the FIG. 1 control system and additionally includes port passage relief valve **59** in boom valve **60**, and a flow divider valve section **100** sandwiched between the boom and bucket control valve sections. Bucket control valve section **26** is shown with its spool **72** positioned in a rod retracting position, and spool **31** of the boom valve is in neutral.

Port passage relief valve **59** is interposed between port passage **63** and drain passage **32** of valve body **61** to divert fluid to drain passage **32** and prevent excessive pressure buildup in passage **63**. Valve **59** is similar in construction and operation to conventional port passage relief valves **54**, **75** and **76**. In raise-and-level operation the relief valve **59** protects both interconnected passages **33** and **63**, and is preset to a higher pressure setting than is port relief valve **75** of control valve **26** to which transfer passage **33** is interconnected in the raise-and-level operation. This higher relief pressure setting on valve **59** takes into account the pressure drops in the fluid transferring from passage **33** to passage **73** so that pressure in passage **73** can build to the level allowed by relief valve **75**. Also, when rod **20** reaches the end of its stroke while spool **31** is in raise-and-level position, relief valve **59** protects passages **33** and **63**; relief valve **75** cannot reliably communicate with and protect these passages in such instance because check valve **78** may be locked in a closed position.

Flow divider section **100** is interposed between valves **26** and **60** in the valve bank assembly and has transverse through passages **32*b***, **37*b***, **41*b*** and **42*b*** properly interconnecting with the boom and bucket valve passages denoted by corresponding numerals. Flow divider **45** in axial bore **102** is located in the transfer passage means in the same manner as in FIG. 1, since: transverse through passage **104** communicates with bore **62** and transfer passage **33** of boom valve **60**; the left passage **103** connects with drain passage **32*b***; and the right passage **105** connects with through passage **106** that leads to auxiliary inlet bore **82** of valve **26**. Accordingly, the operation of flow divider **45** and the FIG. 7 system is the same as described with respect to FIG. 1.

DESCRIPTION, FIG. 8

The hydraulic control system of FIG. 8 is capable of selectively automatically positioning the bucket when the boom is both raised and lowered, by diverting a portion of displaced fluid from boom cylinder **15** to bucket cylinder **19**. The control system comprises a boom control valve **64**, flow divider valve section **107** and bucket valve **85** generally similar in construction to the valve sections of previous embodiments as illustrated by using the same numerals to identify like features.

Control spool **66** of boom valve **64** is movable from neutral to four cylinder actuating positions and has no float position, though such may be incorporated if desired. Body **65** has a second fluid transfer passage **67** intermediate port passage **40** and drain passage **41**. A transverse through bore **68** similar to bore **62** communicates with passage **67** and functions to deliver displaced fluid from cylinder chamber **17** to control valve **85** when spool **66** is in lower-and-level position.

Flow divider section **107** between valve sections **64** and **85** in the assembled bank of valve sections functions to deliver a specified portion of fluid from valve **64** to valve **85** as well as provide a free flow return passage to drain for fluid displaced from cylinder **20**. In addition to flow divider **45** in bore **102**, body **108** includes bore **109** which receives a second, identical flow divider **45*a*** that operates in like manner as flow divider **45** to regulate flow to bucket cylinder chamber **22** during lower-and-level operation. Three passages **111**, **112** and **113** intercept bore **109** at spaced locations: passage **111** connects with drain passage **41*b***; passage **113** communicates with transverse through bore **114** that connects to auxiliary inlet bore **91** of bucket valve **85**; and passage **112** extends transversely through body **108** to communicate with bore **68** of valve **64**. Also included within body **108** are a flow divider bypass

passage **115** extending between bore **114** and passage **112**, and a similar bypass passage **117** between bore **106** and passage **104**. Check valves schematically illustrated at **116** and **118** are located in passages **115** and **117** to assure that fluid flows from passages **112**, **104** to passages **114**, **106** respectively via the flow divider orifices **51** and **51*a***.

Bucket control valve **85** has an elongated plunger piston **87** and spring loaded check valve **88** in place of the unloading piston **81** of the previously described embodiment of the bucket valve. Check valve **88**, like check valve **78** in structure and function, has a poppet **89** normally spring biased to a closed position blocking flow between port passage **74** and passage **90** in body **86**. Pressure in either of passages **77** to **90** operates directly and through piston **87** to open both check valves **78** and **88**. For instance, as shown in FIG. **8**, high pressure in passage **77** acts directly on poppet **79** to move it leftwardly to the open position, and forces piston **87** rightwardly to engage and move poppet **89** rightwardly to the open position. With low pressure in both of passages **77** and **90**, the spring bias on poppets **79** and **89** move them inwardly to closed positions as piston **87** is not long enough to simultaneously contact both poppets **79**, **89**.

OPERATION, FIG. 8

The operation of FIG. **8** in the neutral, bucket lift, bucket dump, boom raise and boom lower modes is as described with respect to FIG. 1 and need not again be set forth in detail. Note that land **69** of spool **66**, similar to land **55**, is not as wide as passage **67** so that selection of the boom lower operation positions land **69** midway in passage **67** to permit interconnection of the three adjacent passages **40**, **67** and **41**, and thereby direct displaced fluid entering port **25** and passage **40** to drain passage **41**. In boom raise and boom lower, check valves **78** and **88** remain closed as passages **77** and **90** of the bucket valve are drained through boom valve passages **62** and **67** which are respectively communicating with drain passages **32** and **41**.

Boom Raise-and-Level

Boom spool **66** is illustrated in raise-and-lvel position in FIG. **8**. The transfer of a portion of displaced fluid from cylinder chamber **18** to cylinder chamber **21** to effect the raise-and-level operation is the same as described with respect to the previous embodiments, check valve **118** in flow divider section **107** being held closed by pressure in passage **104** to direct the transferring fluid through flow divider **45** to bore **106**. However, fluid displaced from bucket cylinder **19** returns through the boom valve to discharge to drain: Pressure in passage **77**, having opened check valve **88** by forcing piston **87** rightwardly, allows fluid displaced from chamber **22** to return through passages **74**, **90** and **91** to bore **114** of the flow divider section. This return flow bypasses flow divider **45*a*** by opening check valve **116** and continues to conduit **115**, passages **112**, bore **68**, passage **67** and through the bore **30** to drain passage **41** in the boom control valve.

Boom Lower-and-Level

By moving spool **66** to the right until land **69** interrupts flow between passages **67** and **41** as shown in FIG. **9**, the lower-and-level operation is selected. Transfer passage **33** is connected with drain passage **32** through the spool bore, and pressure fluid from branch passage **35** is directed to passage **63**, port **24** and the boom cylinder rod chamber to retract the boom cylinder. Fluid displaced from the boom cylinder returns to port **25**, passage **40** and continues through passage **67** and bore **68** out of valve **64** and into flow divider section **108** (FIG. **8**) at passage **112**. This transfer fluid flow closes ball check valve **116** and passes to the interior of flow divider **45*a*** to there be divided, with a specified portion directed through orifice **51*a*** to passages **113** and **114** and the remainder diverted through orifice **50***a* to drain. The transferred fluid in passage **114** continues to passage **90** of bucket valve **85** to open poppet **89** and urge piston **87** leftwardly to engage and open poppet **79**. Fluid in passage **90** continues past poppet **89** to port passage **74** and cylinder chamber **22** and retracts bucket cylinder rod **20** in correlation with the boom cylinder rod retraction to keep the bucket level during boom lowering. Exhausted fluid from bucket cylinder chamber **21** returns past open check valve **78** to passage **77**, bore **82** and bore **106** of the flow divider section. The return flow bypasses flow divider **45** by opening check valve **118** and continues to passage **104** into valve **64** (FIG. 9) at passage **33** and through the spool bore **30** to drain passage **32**.

Selective overriding of the automatic leveling actuation of the bucket cylinder is accomplished upon movement of bucket spool **72** away from neutral. This function is the same in lower-and-level as it is in raise-and-level. Referring to FIG. 8 and the raise-and-level operation, to override and retract rod **20**, spool **72** is moved leftwardly from neutral to interconnect passage **39***a* with port passage **74** and connect drain passage **32***a* with port passage **73**. Pressure fluid introduced into passage **74** passes through opening **92** to the rear of poppet **89** into spring carrying chamber **93** to assist the spring bias of check valve **88** in moving poppet **89** to its closed position. Pressure in passage **74** and chamber **93** exerts sufficiently greater force on poppet **89** than pressure in passage **77** exerts on piston **87**, and poppet **89** cannot open. The pressure fluid in passage **74** passes onto cylinder chamber **22** to retract rod **20** and thereby override the raise-and-level operation. Fluid displaced from chamber **21** drains through passage **73**, bore **71** to passage **32***a*. Assuming the boom continues raising at this time, the fluid in passage **77** displaced from cylinder **15** opens check valve **78** to flow to drain passage **32***a*.

Moving spool **72** rightwardly to extend rod **20** during raise-and-level simply complement the flow of pressure fluid to chamber **21** and draining of fluid from chamber **22**.

Overriding during lower-and-level is accomplished in the same manner, and poppet **79**, accordingly, has an opening **94** communicating chamber **95** with passage **73** to assure closure of check valve **78** upon introduction of pressure fluid into passage **73** from passage **35***a*.

Automatic bucket leveling while lowering and raising the boom can be effected without including a flow divider in each path of transferring fluid flow from passages **33** and **67** to the bucket valve. Leveling while raising the boom can instead be accomplished by the prior art method of matching the cylinder sizes so that all fluid displaced from boom cylinder chamber **18** during raising is used by bucket cylinder chamber **21** in extending rod **20**, and during boom lowering is effected by the improved method of the present invention. Flow divider **45** is now and it along with bore **102**, passages **103**, **105** and check valve **118** can be eliminated from flow divider section **107** to leave continuous fluid communication between passage **33** of valve **64** and bore **82** of valve **85** through the flow divider section. The operation in raise-and-level and in lower-and-level is the same as before except all fluid displaced from f the boom cylinder is transferred to the bucket cylinder in raise-and-level, while still only a specific portion of fluid, as controlled by flow divider **45***a*, is transferred from boom to bucket during lower-and-level. The adaptability of the correlated bucket movement described before is now, of course, available only while the boom is being lowered.

Modifications to the construction and uses of the invention as specifically set forth in the foregoing description will be apparent to those skilled in the art. For instance, the several valve sections depicted in each of the embodiments may be incorporated into a unitary control valve, or a different pressure fluid delivery system may be used to supply fluid to the bucket and boom control valves, or various forms of flow dividers may be used in place of that shown, or a pair of cylinder actuators may be substituted for either of the single cylinders **15** or **19**. Accordingly, the specific embodiments of the invention herein described are to be considered exemplary in nature and not limiting to the scope and spirit of the invention as set forth in the appended claims.

We claim:

1. A hydraulic system for controlling the related operation of at least a first and second fluid actuated motor, comprising:
- a pressure fluid supply, a reservoir, and control valve means communicating with the fluid supply, reservoir and first motor;
- fluid transfer means operatively connected to said control valve means and the second motor to accommodate fluid flow therebetween;
- a first control element in said control valve means shiftable to a transfer position directing pressure fluid to the first motor to actuate same and directing fluid displaced from the first motor to said transfer means through said control valve means; and
- flow divider means interposed in said fluid transfer means for directing a predetermined portion of said displaced fluid to the second motor to actuate same in correlation with actuation of the first motor.

2. The hydraulic system of claim **1** further comprising check valve means located in said fluid transfer means intermediate said flow divider means and the second motor adapted to prevent reverse flow through said transfer means from the second motor to said control valve means.

3. The hydraulic system of claim **1** further comprising second control valve means communicating with the pressure fluid supply, reservoir and the second motor, said second valve means having an associated second control element shiftable to direct fluid from the pressure fluid supply to the second motor to actuate same and override actuation of the second motor by said predetermined portion of displaced fluid.

4. The hydraulic system of claim **1** wherein said flow divider means communicates with the reservoir through a discharge duct, and directs the remainder of said displaced fluid to said discharge duct and reservoir.

5. The hydraulic system of claim **4** wherein said flow divider means includes a first flow restrictor interposed in the flow path from said fluid transfer means to said discharge duct and a second flow restrictor interposed in the flow path from said fluid transfer means to the second motor, the relative sizes of said restrictions determining said portion of displaced fluid directed to the second motor.

6. The hydraulic system of claim **1** wherein said first motor has opposing variable volume fluid chambers and said first control element is movable to a float position connecting both said chambers and said fluid transfer means with the reservoir.

7. The hydraulic system of claim **6** wherein said first control element interconnects said fluid transfer means with the reservoir in all positions of said first control element other than said transfer position

8. The hydraulic system of claim **1** wherein said second motor has opposing variable volume fluid chambers and is actuatable upon introduction of said predetermined portion of displaced fluid into one of said chambers, and said fluid transfer means include a hydraulically operable piston controlling communication between the other of said chambers and the reservoir, said piston movable to an open position connecting said other chamber with the reservoir in response to a predetermined pressure in said fluid transfer means.

9. The hydraulic system of claim **8** further comprising a check valve in said fluid transfer means intermediate said flow divider means and said one chamber adapted to prevent reverse flow from said one chamber to said control valve means.

10. A control for a hydraulic power system including a fluid supply, a reservoir, first and second double acting hydraulic motors having movable barriers therein dividing each of said motors into two variable volume chambers, said control comprising:
- a hydraulic valve assembly operatively connected to said supply and reservoir for supply and return of hydraulic fluid, said valve assembly including first and second control passages connected to actuate said fist motor by delivering and returning hydraulic fluid therefrom and third and forth passages connected to actuate said second

motor by delivering and returning hydraulic fluid therefrom;

a fluid transfer passage adjacent said first passage and communicating with said third passage;

a first control element selectively shiftable to actuate said first motor, having a first position connecting said first passage with said transfer passage and said second passage with said fluid supply whereby fluid discharged from said first motor is delivered to said transfer passage;

a second control element shiftable to actuate said second motor and having a neutral position wherein said transfer passage is in communication with one chamber of said second motor through said third passage and the other chamber is in communication with said froth passage;

a flow divider interposed in said transfer passage communicating with said reservoir, and being adapted to direct a predetermined portion of flow in said transfer passage to said third passage and directing remaining flow to reservoir;

check valve man in said transfer passage intermediate said flow divider and said third passage blocking reverse flow from said third passage to said first passage; and

pressure responsive means communicating with said transfer passage controlling communication between said fourth passage and said reservoir, whereby positioning said first control element in said first position and said second element in said neutral position directs fluid to said first motor to actuate same, directs fluid displaced from said first motor through said transfer passage to said flow divider whereby a predetermined portion of said displaced fluid is directed to said second motor to actuate same in correlation with actuation of the first motor, and whereby pressure in said transfer means actuates said pressure responsive means to permit return of flow from said second motor to said reservoir through said fourth passage.

11. The control of claim **10** further comprising a pressure relief valve adapted to relieve fluid from said transfer passage to limit pressure therein to a predetermined value.

12. The control of claim **10** wherein shifting said second control element away from said neutral position to actuate the second motor overrides actuation of the second motor by said predetermined portion of displaced fluid.

13. A control valve assembly for selectively actuating first and second fluid motors comprising:

a housing having a supply passage for connection with a source of pressure fluid, a fluid discharge passage for connection with a low pressure reservoir, and first and second axial bores intercepted at spaced positions by said supply and discharge passages;

first and second control passages intersecting said first axial bore and connectable with opposite ends of the first motor;

third and fourth control passages intersecting said second axial bore and connectable with opposite end of the second motor;

first and second cannelured control spools respectively disposed in said first and second axial bores, each movable to various positions interconnecting said control passages with the inlet and discharge passages for selective actuation to the first and second motors;

a transfer passage extending from said third control passage to intercept said first bore intermediate and adjacent said first control passage and said discharge passage, said first spool in a first position interconnecting said first control passage with said transfer passage and blocking same from said discharge passage, and in all other positions interconnecting said transfer passage and said discharge passage;

a flow divider comprising a movable body located in the housing in a third axial bore intercepted by said transfer and discharge passages, said body having first and second flow restrictors formed thereon restricting fluid flow from said transfer passage to said third control passage and said discharge passage respectively, whereby a predetermined percentage of flow in said transfer passage is directed through said first restriction to said third control passage and the remainder is directed through said second restriction to said discharge passage;

a spring biased check valve in said transfer passage intermediate said flow divider and said third control passage permitting one-way flow through said transfer means from said first control passage to said third control passage; and

a hydraulically operable piston biased to a closed position and responsive to a predetermined pressure in said transfer passage to move to an open position interconnecting said fourth control passage with said discharge passage at a position spaced from said first and second axial bores.

14. The control valve assembly of claim **13** wherein said housing comprises an assembly of section valves including:

a first sectional valve having disposed therein said first axial bore, said first control spool, said first and second control passages, said third axial bore and said flow divider;

a second sectional valve operatively adjacent said first sectional valve having disposed therein said second axial bore, said second control spool, said third and fourth control passages, said check valve, and said piston;

end plates enclosing said sectional valves provided with inlet and outlet openings respectively in communication with said supply and discharge passages in said assembly; and

wherein said transfer, supply and discharge passages extend substantially transversely through said sectional valves.

15. The control valve assembly of claim **13** further including a pressure relief valve in said housing extending between said first control passage and said discharge passage, adapted to divert fluid from said first control passage to the discharge passage in response to a predetermined pressure in said first control passage to limit pressure therein.

16. The control valve assembly of claim **15** wherein said housing comprises an assembly of section valves including:

a first sectional valve having disposed therein said first axial bore, said first control spool, said first and second control passages, and said pressure relief valve;

a second sectional valve having disposed therein said second axial bore, said second control spool, said third and fourth control passages, said check valve, and said piston;

a third sectional valve interposed between the first and second sectional valves, having disposed therein said third axial bore and said flow divider;

end plates enclosing said sectional valves provided with inlet and outlet openings respectively in communication with said supply and discharge passages in said assembly; and

wherein said transfer, supply and discharge passages extend substantially transversely through said sectional valves.

17. In a hydraulic system including a pump, a reservoir, a first double acting motor having fist and second variable volume fluid chambers, a second double acting motor having third and fourth variable volume fluid chambers, a control valve operatively connected with the pump, reservoir and first motor, and a movable control element mounted in said control valve adapted to connect said first motor fluid chambers with the pump and reservoir to actuate the first motor; wherein the improvement comprises:

first fluid transfer means operatively connected with said control valve adapted to interconnect said first and third fluid chambers upon positioning said control element in a first transfer position directing pressure fluid from said pump to said second chamber, whereby displaced fluid from said first chamber flows to said third chamber to actuate the second motor in a first direction;

second fluid transfer means operatively connected with said control valve adapted to interconnect said second and fourth fluid chambers upon movement of said control element to a second transfer position directing pressure fluid from said pump to said first chamber, whereby displaced fluid from said second chamber is directed to said fourth chamber to actuate the second motor in a second direction opposite said first direction;

a flow divider communicating with the reservoir and interposed in said first fluid transfer means to direct a predetermined portion of fluid flow therein to a said third chamber and divert the remainder of fluid flow in said first fluid transfer means to reservoir; and

discharge means connected with said second motor and the reservoir operative upon movement of said control element to said first transfer position to interconnect said fourth chamber with the reservoir, and operative upon movement of said control element to said second transfer position to interconnnect said third chamber with the reservoir.

18. The hydraulic system of claim **17** further including a second flow divider communicating with the reservoir and interposed in said second fluid transfer means to direct a predetermined portion of fluid flow therein to said fourth chamber and divert the remainder of fluid flow in said second transfer means to reservoir.

19. The hydraulic system of claim **18** wherein said first transfer means includes a first check valve located intermediate the first flow divider and said third chamber biased to a closed position blocking flow therebetween and responsive to a predetermined pressure in said first transfer means to move to an open position, and wherein said second transfer means includes a second check valve located intermediate said second flow divider and said fourth chamber biased to a closed position blocking flow therebetween and responsive to a predetermined pressure in said second transfer means to move to an open position.

20. The hydraulic system of claim **19** wherein said control element connects said second transfer means with the reservoir in said first transfer position, and said discharge means include:

a plunger operably engaging said second check valve and adapted to open same in response to said predetermined pressure in said first transfer means;

a bypass passage connected with said second transfer means in parallel with said second flow divider; and

a unidirectional valve in said bypass passage blocking flow therethrough from said control valve to said second motor, whereby in said first transfer position pressure in said first transfer means opens said second check valve to establish a flow path from said fourth passage through said second transfer means and said bypass passage to the reservoir.

21. In a hydraulic valve assembly including a body having first and second axial bores intersected by a pressure inlet connected to a pump and a fluid outlet connected to a reservoir, first and second control passages intersecting the first axial bore and connected to expanding and contracting chambers of a first double acting motor, third and fourth control passages intersecting the second axial bore and connected to expanding and contracting chambers of a second double acting motor, and first and second spools mounted in said first and second axial bores respectively and shiftable away from neutral to positions directing fluid to and from said control passages to actuate said motors, wherein the improvement comprises:

first and second fluid transfer circuits in said assembly extending from said first axial bore to said third and fourth control passages respectively;

a said first spool having transfer positions for actuating both said motors wherein the first spool is adapted to simultaneously connect the inlet with the expanding chamber of the first motor to actuate same, one transfer circuit with the contracting chamber of the first motor to transfer fluid displaced therefrom as actuating flow to the expanding chamber of the second motor, and the other transfer circuit with the outlet to transfer to reservoir the return flow displaced from the contracting chamber of the second motor;

a flow divider interposed in each transfer circuit and communicating with the outlet adapted to direct a preselected portion of said transfer actuating flow to said second motor and the remainder to the outlet whereby the second motor is actuated in predetermined correlation with the first motor;

a bypass conduit communicating with each transfer circuit and arranged parallel to said flow dividers to permit said transfer return flow to bypass said flow dividers;

a unidirectional flow valve interposed in each bypass conduit permitting only said transfer return flow therethrough; and

a check valve in each transfer circuit located intermediate the second motor and the bypass conduit openable in response to pressure in either of the transfer circuits when said second spool is in neutral, and responsive to a shift of said second spool away from neutral to move to a closed position blocking transmittal of said transfer actuating flow to the second motor.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,563,137 Dated February 16, 1971

Inventor(s) Homer R. Graber et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 4, change comma (,) to a period (.); line 18 change "shows" to --shown--. Column 4, line 16, change "72 to --71--. Column 5, line 75, change "chamber" to --chambe Column 8, line 13, change "to" to --or--; line 43, change "lvel" to --level--. Column 9, line 35, change "complement to --complements--; line 49, between "and during" insert --leveling--; line 51, between "now and" insert --unnecessa line 57, delete "f"; line 58, change "specific" to --specified--. Column 11, line 20, change "man" to --means line 55, change "end" to --ends--.

Signed and sealed this 24th day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

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Commissioner of Patents