United States Patent [19]

Spirdco

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[45] **Dec. 4, 1973**

[54] **HYDROSTATIC TRANSMISSION**

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[52] U.S. Cl. **60/462**, 60/465
[51] Int. Cl. **F16h 39/46**
[58] Field of Search...................... 60/445, 451, 452, 60/19, 459, 462, 463, 465

[56] **References Cited**

UNITED STATES PATENTS

3,359,727	12/1967	Hann et al.	60/465 X
3,430,722	3/1969	Budzich	60/452 X

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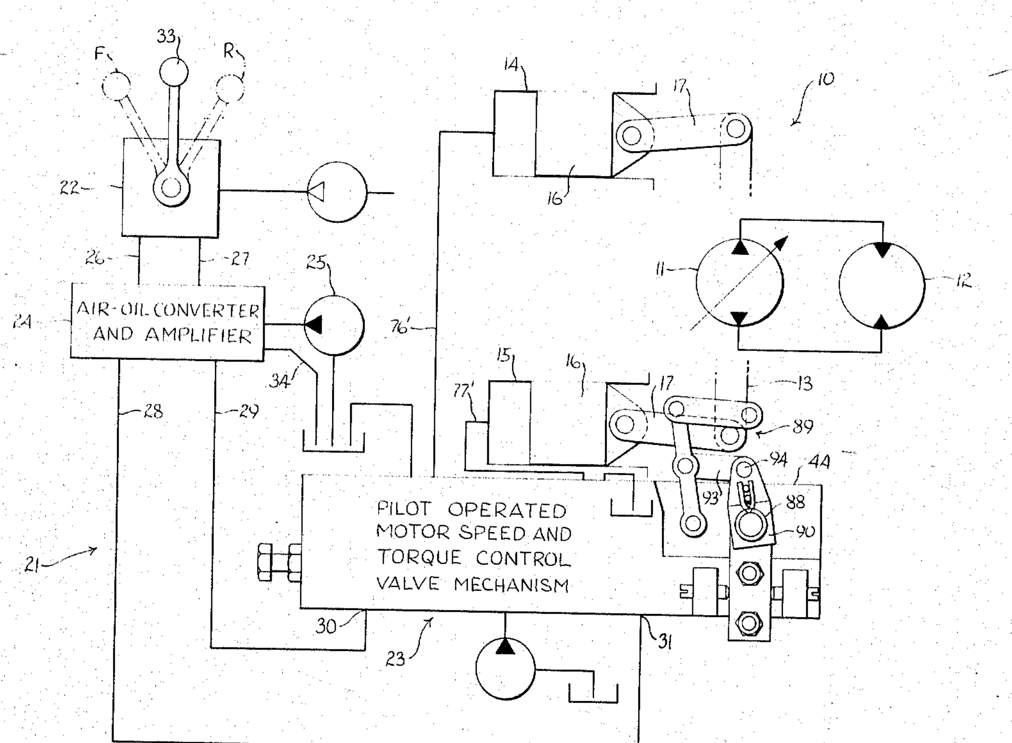
[57] **ABSTRACT**

A hydrostatic transmission including a fluid motor driven by a variable displacement pump under the control of a pilot operated valve means. The valve means comprises a first control valve which is operable to effect hydraulic adjustment of the pump displacement control member to thereby govern motor speed, and a second control valve which governs pump output pressure and hence motor torque. The position of the displacement control member is translated into a feedback force on the speed control valve tending to return it to closed position; and the pressure in the hydraulic actuator for the displacement control member is translated into a feedback force on the second control valve tending to return it to its null position.

13 Claims, 8 Drawing Figures



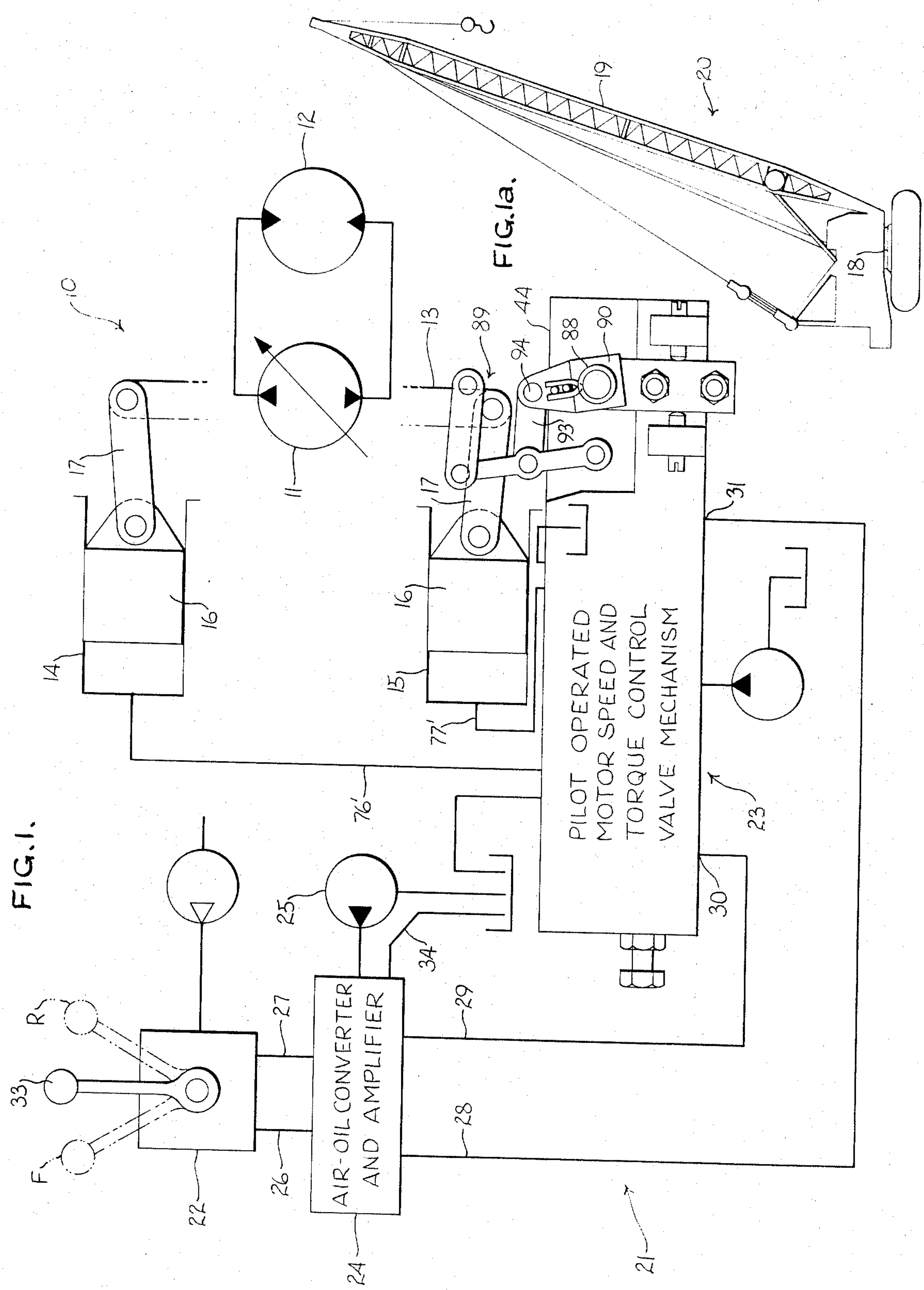

PILOT OPERATED MOTOR SPEED AND TORQUE CONTROL VALVE MECHANISM
AIR-OIL CONVERTER AND AMPLIFIER

FIG.1.

FIG.1a.

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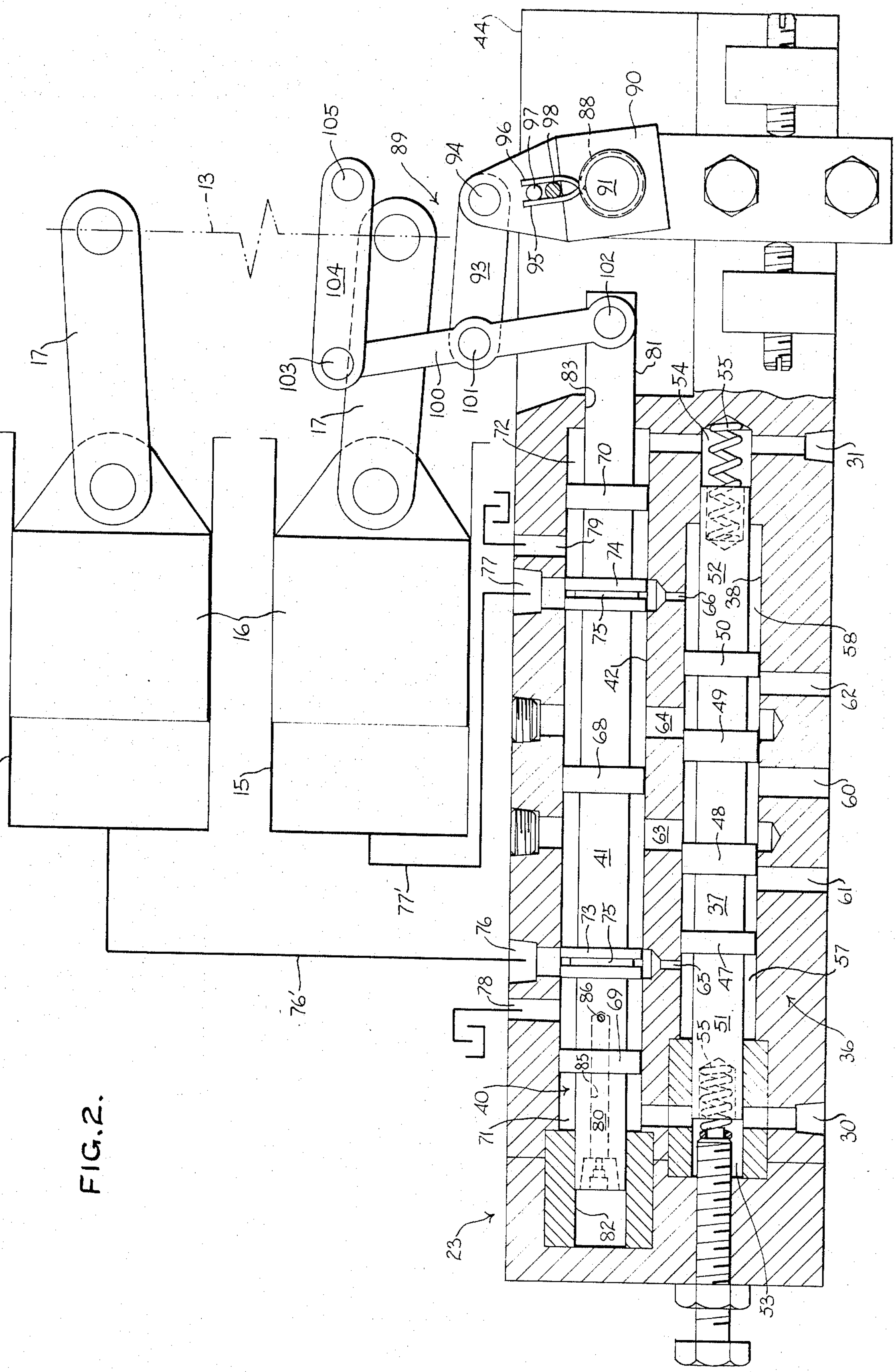

FIG. 2.

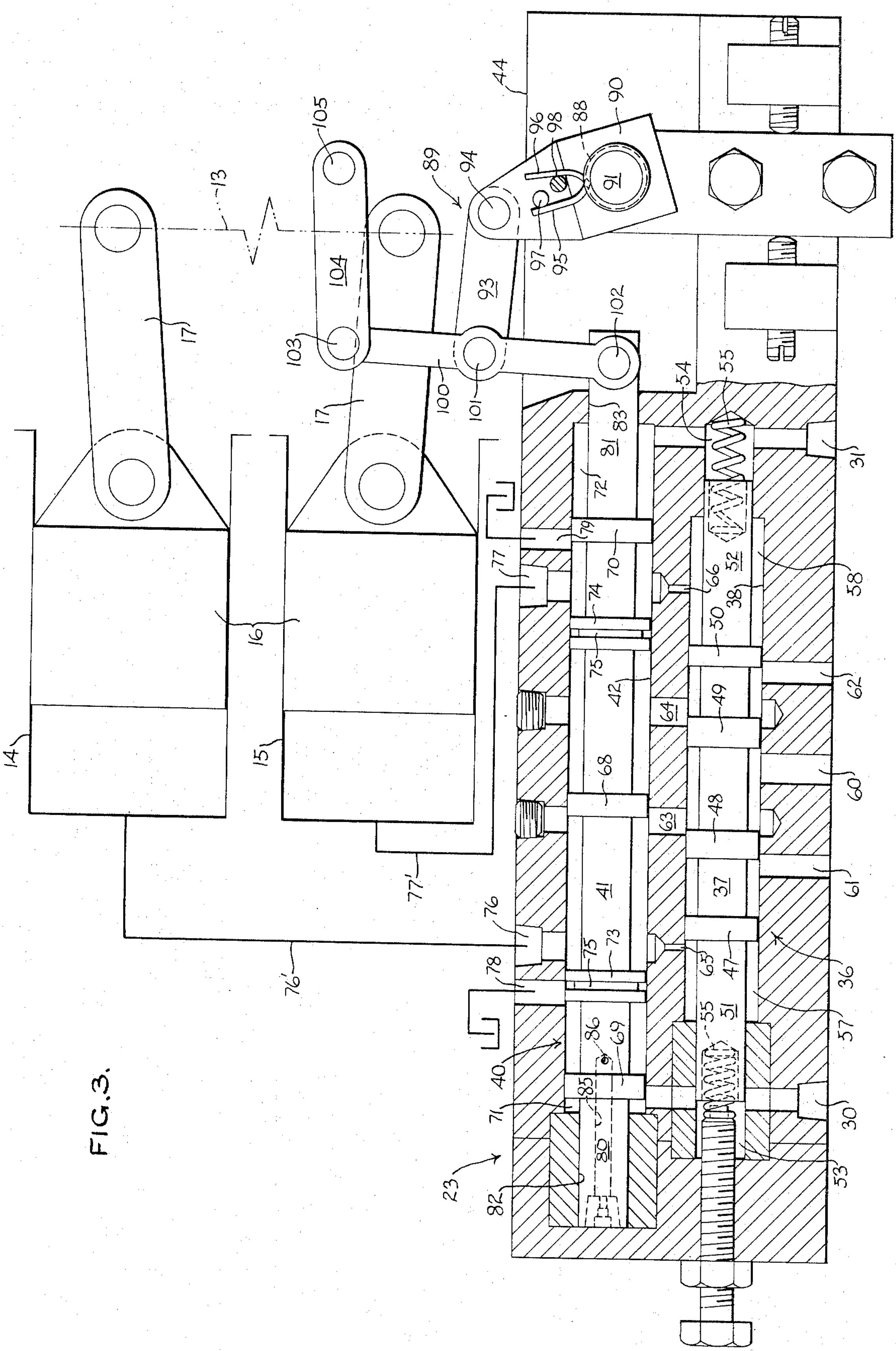

FIG. 3.

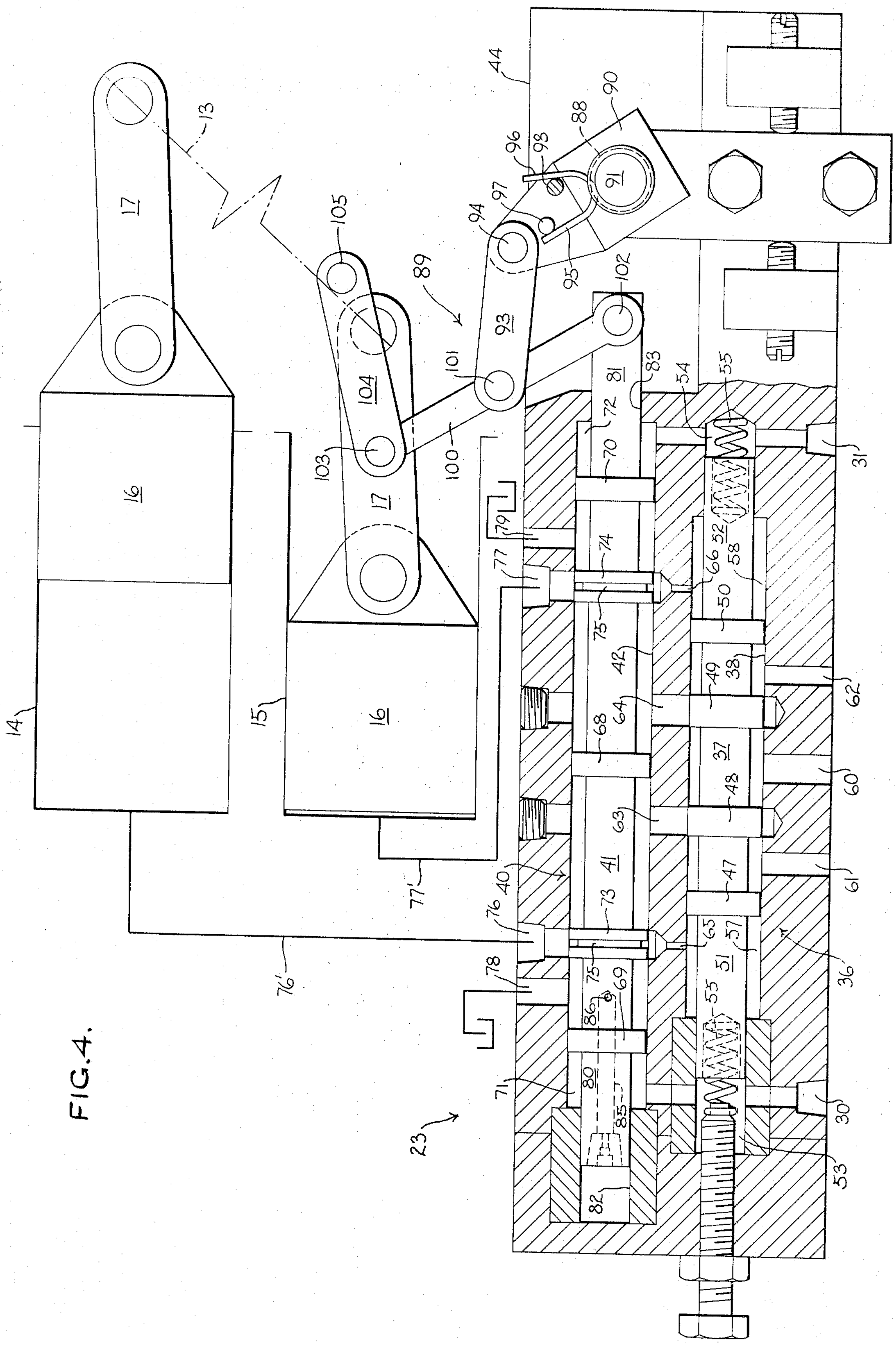

FIG. 4.

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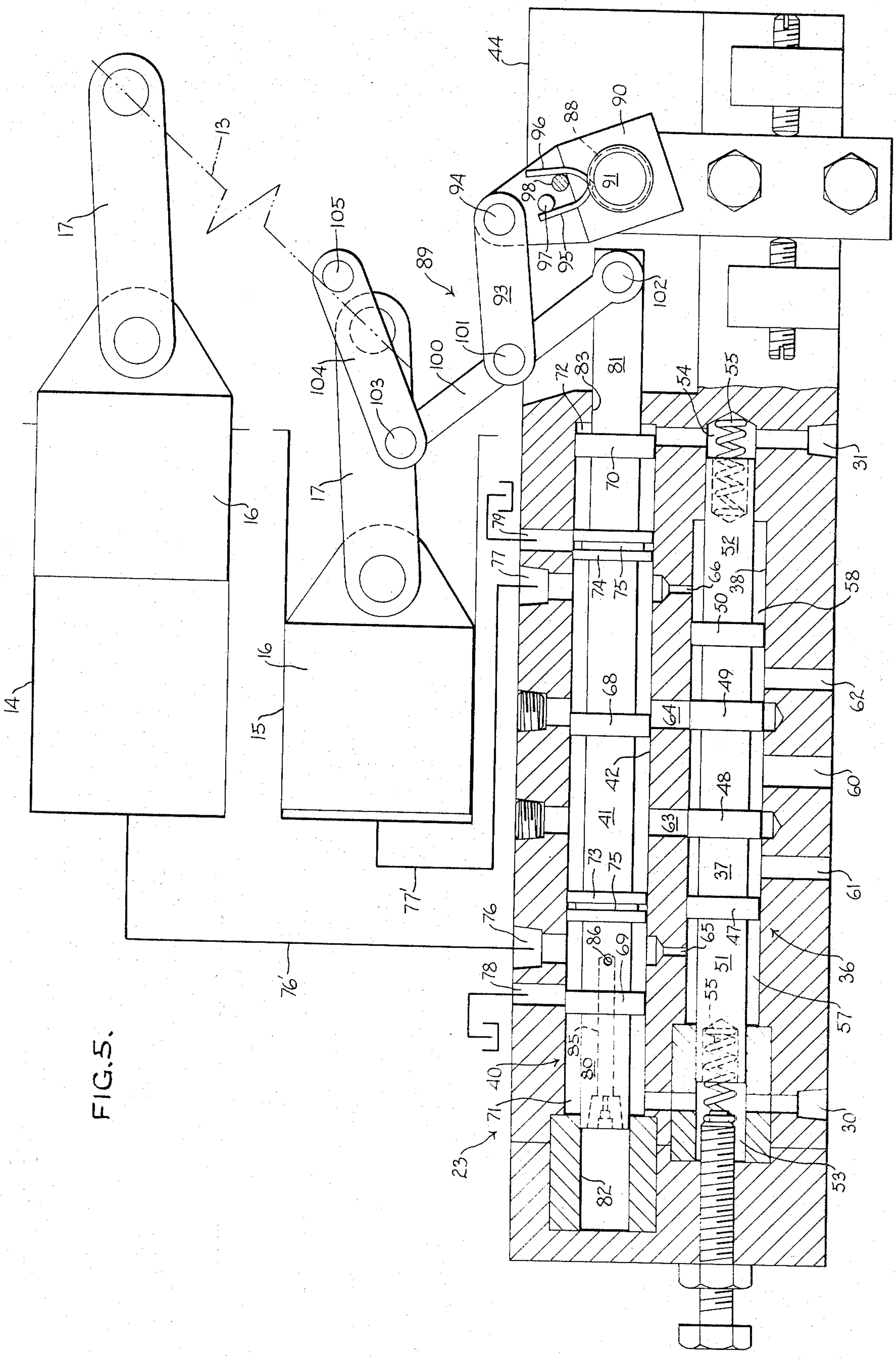

FIG.5.

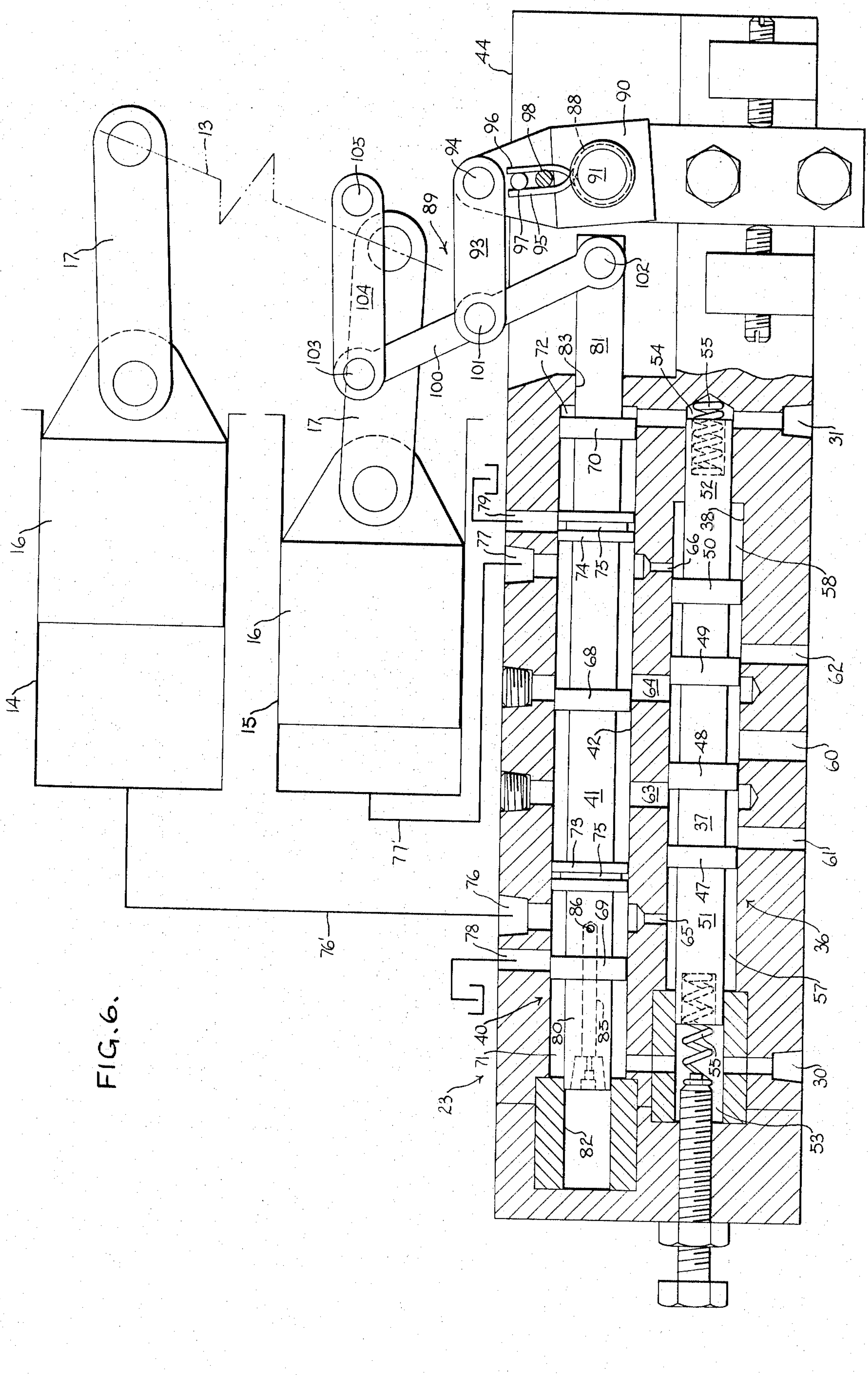

FIG. 6.

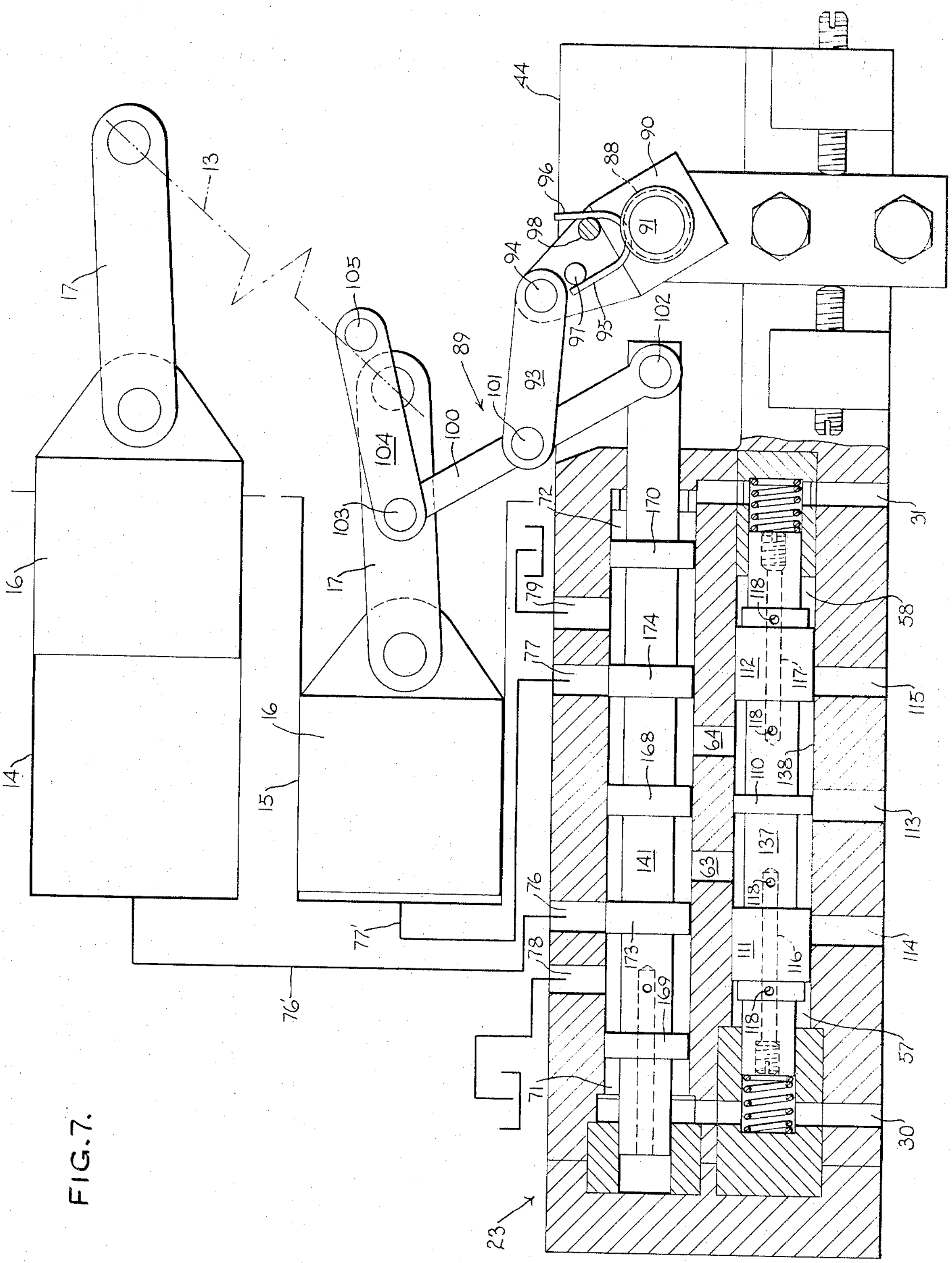

FIG. 7.

HYDROSTATIC TRANSMISSION

This invention relates to hydrostatic transmissions and to control means therefor, and its purpose is to provide an improved hydrostatic transmission which features exceptionally good control over motor torque as well as motor speed, regardless of the direction of motor operation. In other words, it is the object of this invention to make possible precise control over the acceleration and the speed of a load driven by the fluid motor.

More specifically, it is a purpose of the invention to provide a hydrostatic transmission such as described in the preceding paragraph with control means which will allow the motor to rotate freely in the forward or reverse directions under the influence of the load thereon; and which also provides for destroking of the pump at a rate to produce an effective braking force upon the motor at times when it is being driven by the load.

In general, it is an object of this invention to provide a hydrostatic transmission embodying the features set forth above, which is exceptionally well suited for use in industrial applications where control over motor torque and speed are essential, as for example paper converting apparatus, wire drawing machinery, steel coiling drives, but which is particularly adapted for control of the swing drive systems of cranes, backhoes, or even traction drives such as used on cranes, backhoes and related apparatus.

With these observations and objectives in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings, which exemplify the invention, it being understood that changes may be made in the specific apparatus disclosed herein without departing from the essentials of th invention set forth in the appended claims.

The accompanying drawings illustrate two complete examples of exbodiments of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

FIG. **1** is a diagrammatic view illustrating a hydrostatic transmission and control means embodying this invention;

FIG. **1***a* is an outline view of a crane having a boom whose swing is controlled by the transmission of this invention;

FIG. **2** is a more or less diagramatic view showing the motor speed and torque control valves in a "ready" position;

FIGS. **3**, **4**, **5** and **6** are views similar to FIG. **2** but showing the valves in different control positions; and

FIG. **7** illustrates a slightly modified form of porting for the control valve of this invention.

Referring now to FIG. **1** of the accompanying drawings, the numeral **10** generally designates a hydrostatic transmission comprising a variable displacement bidirectional pump **11** and a reversible rotary fluid motor **12** driven thereby and having its ports connected with the pump ports in a closed circuit system.

The displacement of the pump is controlled by tilting a displacement control member or swash plate indicated at **13** from a zero displacement position such as shown, to an angular position at one side or the other of zero depending upon whether the pump is operated to drive the motor in the forward or reverse directions.

Such adjustment of the swash plate is effected by hydraulic actuating means here shown as comprising a pair of single acting hydraulic cylinders **14** and **15** having their pistons **16** operatively connected with the swash plate **13** by links **17**. Either cylinder can be activated by flow of pressure fluid into a cylinder port in its head, to effect extension of its piston and tilting of the swash plate in one direction, provided the cylinder port for the other cylinder is vented at that time. Thus, with reference to FIG. **1**, the cylinder **14** is adapted to effect clockwise tilting of the swash plate while the cylinder **15** is adapted to effect counterclockwise tilting of the plate.

Though the hydrostatic transmission of this invention can be used to advantage in many different types of apparatus including industrial machinery, it is especially useful with certain kinds of material handling machines having heavy loads which must be swung back and forth about a vertical axis. Cranes and backhoes are examples of the latter, since they are typically provided with a boom that is supported on a turntable **18** carried by the machine. For convenience, the transmission will be hereinafter referred to as one which controls swinging motion of the boom **19** of a crane **20**.

The speed and direction of motor operation are functions of the transmission which are governed by the control system **21** thereof. The control system includes a master control in the form of an air pilot valve **22** which is mounted in the cab of the crane, and has its inlet connected with the delivery port of an air compressor; a motor speed and torque control valve mechanism **23** governed by the pilot valve **22**; and an air-oil converter and amplifier unit **24** connected between the pilot valve **22** and the motor speed and torque control valve mechanism **23**, and having its inlet connected with the delivery port of a hydraulic pump **25**.

Air lines **26** and **27** connect the service outlets of the pilot valve **22** with the air-oil converter **24**, and the latter is provided with output ports for oil under pressure which are connected by pilot control lines **28** and **29** with a pair of pilot ports **30** and **31**, respectively, in the motor speed and torque control valve mechanism **23**. The pressure of oil diverted to one or the other of the pilot lines **28** and **29** will be about three times the pressure of air entering the amplifier from pilot **22**. By way of example, the pressure of oil in pilot line **28** or **29** can be varied by the pilot valve **22** from 0 to about 90 psi.

The operation of the air pilot **22** is more or less conventional. Its actuating handle **33** is normally held in the neutral position seen in solid lines in FIG. **1**, in which position the pilot effects venting of both pilot ports **30** and **31** to an exhaust line **34** connecting with the air-oil converter **24**. The handle may be actuated to the left to the broken line position "F" to provide for full speed forward operation of the motor **12**, or to any position intermediate the latter position and neutral to effect operation of the motor at a speed proportional to the extent of handle motion away from neutral. Similarly, the handle can be moved to the right, toward the broken line position designated "R" to effect reverse operation of the motor at a speed proportional to the extent of handle motion away from its neutral position.

Depending upon the position of the handle **33**, the pilot lines **28** and **29** will either be vented, as in the neutral position of the pilot **22**; or the pilot line **29** will be vented upon movement of the pilot handle toward the "F" position, and oil from pump **25** will be diverted into the companion line **28** at a pressure proportional to the extent of handle motion away from neutral; or these pressure conditions in pilot lines **28** and **29** will be reversed upon movement of the handle **33** from neutral toward its "R" position.

The air-oil amplifier **24**, of course, can be said to provide a source of pilot fluid under pressure for actuation of the valve mechanism **23**.

The motor speed and torque control valve mechanism **23** responds to the pilot pressure conditions produced at its ports **30, 31** to effect adjustment of the swash plate angle through activation of one or the other of the hydraulic actuating cylinders **14, 15** therefor. The valve mechanism **23**, however, it also responsive to feedback forces which reflect swash plate angle and pump output pressure, and thus cause the motor to be operated at the desired speed and torque and in the direction determined by the setting of the pilot handle **33.**

The valve mechanism **23** comprises a motor torque control valve **36** having a fluid pressure actuatable valve spool **37** endwise slidably received in a bore **38,** to govern pump output pressure; and a motor speed control valve **40** having a fluid pressure actuatable valve spool **41** endwise slidably received in a bore **42,** to govern swash plate angle.

While the valves **36** and **40** may be provided with separate housings, they have here been illustrated as sharing a common body **44** in which the bore **42** is above and in parallel relation to the bore **38.**

The valve spool **37** has four axially spaced lands **47, 48, 49** and **50,** and opposite end portions **51** and **52** which are smaller in diameter than the lands and which project into cylinder-like pressure chambers **53** and **54,** respectively, to serve as pistons therein.

The pilot ports **30** and **31,** communicate with the chambers **53** and **54,** respectively, to provide for pilot actuation of the spool **37** in one direction or the other out of a null position. Such motion of the spool is yieldingly resisted by springs **55** acting on its opposite ends.

The spaces in the bore **38** outwardly of the endmost lands **47** and **50** and surrounding the smaller diameter end portions **51, 52** of the spool also provide pressure chambers **57** and **58,** respectively, for the reception of feed back fluid from the swash plate actuating cylinders **14** and **15** in a manner to be described hereinafter.

FIG. **4** illustrates the valve mechanism **23** when its valve spool **41** is in a normally closed position and spool **37** is in its null position. As therein seen, a number of drilled ports open to the bore **38** in which spool **37** operates. One of these is an inlet port **60,** which provides for the admittance of charge fluid to the valve mechanism from one of the several pumps on the crane. The inlet port communicates with the bore **38** substantially midway between lands **48** and **49** on spool **37.** A pair of drain ports **61** and **62** at opposite sides of the inlet port **60** open to the bore **38** at locations outwardly of lands **48** and **49,** respectively, and between said lands and the outer most lands **47** and **50** on the spool. A pair of service outlets **63** and **64** which communicate the bore **38** with the companion bore **42,** are closed by lands **48** and **49,** respectively, in the null position of valve spool **37.** Finally, restricted ports **65** and **66** open to those portions of the bore **38** which provide the aforementioned pressure chambers **57** and **58,** respectively.

The speed control spool **41** has five axially spaced lands thereon, one of which, designated **68,** is located substantially midway between the zones at which the service outlets **63** and **64** open to bore **42.** The endmost lands **69** and **70** are spaced a distance from the opposite ends of the spool **41** and cooperate with the ends of the bore **42** to define pressure chambers **71** and **72** which are communicated with the pilot ports **30** and **31,** respectively. The two remaining lands **73** and **74** are located at opposite sides of the center land **68,** but inwardly of the endmost lands. The lands **73** and **74** normally block communication between the bore **42** and a pair of service ports **76** and **77,** and each such land has a circumferential groove **75** therein. The service ports **76** and **77** not only communicate with the bore **42** in which the speed control spool operates, but they also communicate with the pressure chambers **57** and **58** in the adjacent bore **38,** through the restricted ports **65** and **66,** and also through the circumferential grooves **75** in lands **73** and **74** when the spool is in its closed position.

Drain ports **78** and **79,** respectively adjacent to the service ports **73** and **74,** are communicable with the latter under the control of the lands **73** and **74** on spool **41.** The service ports **76** and **77** are connected with the swash plate actuating cylinders **14** and **15** by service lines **76′** and **77′**, respectively.

As before, the opposite end portions **80** and **81** of the spool **41** are smaller in diameter than the lands thereon, but in this case they project entirely through the pressure chambers **71, 72** and into holes **82** and **83,** respectively, in the body. Accordingly, pilot fluid flowing into one or the other of these chambers from port **30** or **31** acts upon the corresponding land **69** or **70** to effect actuation of the spool **41** out of its closed position, to an operating position at one side or the other of its closed position.

The hole **82** in the body, outwardly of the left hand end of the spool **41,** is vented to th drain passage **78** by means of axial and radial holes **85** and **86,** respectively, in the spool **41.** The other end portion **81** of valve spool **41** projects out of the body through the hole **83** therein for a purpose now about to be described.

The swash plate **13** is normally held in a zero displacement position such as indicated in FIG. **2,** by means of a preloaded torsion spring **88,** which also acts upon the speed control spool **41** through articulated linkage generally designated **89,** to yieldingly hold said spool in the closed position shown. It will be recalled that in that closed position, the lands **73** and **74** on the spool **41** close off communication between the bore **42** and service ports **76** and **77.**

The linkage **89** comprises a rocker arm **90** mounted on the valve body by means of a pivot **91** disposed on an axis that crosswise intersects the axis of the speed control spool **41,** at a location outwardly of its end portion **81.** The rocker arm extends upwardly from its pivot and its outer end is connected to one end of a substantially horizontal link **93** by a pin **94.**

The torsion spring **88** is coiled about the pivot **91** and its arm **95** and **96** extend upwardly to embrace a pair of abutments **97** and **98.** The abutment **98** is fixed with respect to the valve body in any suitable fashion, but the abutment **97** is mounted on the rocker arm to move back and forth therewith. Hence, the torsion spring yieldingly resists rocking of the arm in either direction about its pivot **91**, from the position of the arm seen in FIG. 2.

The articulated linkage **89** further comprises a substantially upright link **100** having its midportion pivotally connected as at **101** to the outer end of the horizontal link **93**. The lower end of the link **100** is pivotally connected to the outer end of the spool extension **81** by a pin **102**, and its upper end is pivotally connected as at **103** to one end of a link **104**. The link **104** extends substantially horizontally toward the swash plate and is connected to the latter by a pivot pin **105**.

Because of the link connection between the speed control spool **41** and the rocker arm **90** described above, the torsion spring will yieldingly resist both axial movement of the spool and tilting adjustment of the swash plate in either direction.

Both spools **37** and **41** are actuatable in opposite directions from their normal positions seen in FIG. **4** in consequence of flow of pilot fluid into a selected one of the pilot ports **30** or **31** while the non-selected pilot port is vented. Hence, the valve spool **37** will be shifted to the right from its null position seen in FIG. 4, by flow of fluid from the amplifier **24** into port **30** and chamber **53**. Port **30**, however, also communicates with chamber **71** to the left of the land **69** on the speed control spool **41**, so that pilot fluid flowing into said chamber from port **30** effects movement of spool **41** to an operating position to the right of its normally closed position.

The other pilot port **31** at the opposite end of the valve body similarly communicates with pressure chambers **54** and **72** for valve spools **37** and **41**, respectively, it being understood that the right hand end of the spool **37** is acted upon by pressure of pilot fluid in chamber **54** while pilot fluid in chamber **72** acts upon the outer face of the land **70** on spool **41**.

With the described porting arrangement for valves **36** and **40**, it will be evident that so called "charge" pressure fluid entering the inlet port **60** from one of the several pumps on the crane can be selectively directed out of either service outlet **63** or **64** by the pump pressure control spool **37**, and relayed to one or the other of the swash plate actuating cylinders **14, 15** by the speed control valve spool **41**.

In operation, leftward actuation of the handle on the pilot valve **22** to produce a pilot pressure, for example, of 25 psi at port **31** and zero pressure at port **30**, effects movement of the pump pressure control spool **37** by the pressure of pilot fluid in its chamber **54** to a "ready" position such as seen in FIG. 2, to the left of its null position. In that ready position of spool **37**, the charge port **60** is communicated with the bore **42** for spool **41** via service outlet **63**. The torsion spring **88** is strong enough to prevent the speed control spool **41** from being also moved to the left by force which pilot fluid in chamber **72** then exerts upon its land **70**.

As the handle **33** of the pilot valve is moved on, in the same direction, to the desired transmission control position selected by the crane operator, for instance, the full speed forward position of the motor designated "F," port **30** will remain at zero pressure but the pressure of pilot fluid at port **31** will be increased to substantially the maximum output pressure of the air-oil amplifier **23**, namely to about **90** psi. This increased pressure in valve chamber **72** produces a force on land **70** of the speed control spool **41** which exceeds the opposing force of the torsion spring **88** and causes the spool **41** to move to an operating position to the left of its closed position and thereby communicate its service port **76** with the charge fluid inlet **60** via port **63**, and its other service port **77** with the reservoir port **79**.

FIG. 3 depicts the operating positions of both spools **37** and **41** at the time charge fluid is about to enter cylinder **14** to effect clockwise actuation of the swash plate out of its zero stroke position.

As charge fluid from the inlet **60** flows into swash plate actuating cylinder **14**, the plate tilts in the clockwise direction toward an output position determined by the position of the handle **33** on the pilot valve **22** and the pilot pressure at port **31**. This initiates pumping action and operation of the motor in the selected forward direction, to start boom swing in the corresponding direction. At the same time, of course, such adjusting motion of the swash plate will effect retraction of the piston in cylinder **15** through link **17**, and fluid expelled therefrom will be exhausted to the reservoir via service port **77**, bore **42** and drain port **79**.

It should be observed that the above described pilot actuation of the speed control spool **42** is translated into counterclockwise rocking motion of the arm **90** on its pivot **91**, through the connected links **93** and **100**, so that the arm carried pin **97** acts upon the end **95** of the torsion spring to effect further loading thereof.

As the swash plate continues to move toward its FIG. **4** position representing the selected maximum output of the pump, it also acts through the linkage **104, 100** and **93** to effect further counterclockwise rocking of the arm **90** and additional loading of the torsion spring **88**, until the maximum output position of the swash plate is reached. At that time the feedback force exerted on the speed control spool **41** by the spring loaded linkage **89** will have increased to a value sufficient to overcome the actuating force exerted on spool land **70** by pilot fluid in chamber **72**, and the torsion spring **88** will return the spool to its closed position seen in FIg. 4, blocking service ports **76** and **77**. It is to be understood, of course, that as the spool **41** reaches its closed position, the opposing spring and pilot pressure forces acting upon the spool **41** will be equal. It will also be understood the feedback force on the spool **41** is proportional to the extent of movement of the swash plate out of its zero displacement position.

An important feature of the invention is achieved through the application of feedback force to the pressure control spool **37**, of a value which increases in proportion to the output pressure of the pump and opposes the action of pilot fluid on said spool. The pressure in either cylinder **14** or **15** to which charge fluid is being diverted by the two spools **37** and **41** is proportional to pump output pressure at any given speed, and these cylinders are at all times communicated with the pressure chambers **57** and **58** in the bore **38** for the pressure control spool **37**. Accordingly, when charge fluid is flowing into cylinder **14** to effect the described clockwise tilting of the swash plate, chamber **57** in bore **38** will be maintained at the same pressure as fluid in the cylinder **14**, while chamber **58** will be vented to port **79**.

With this arrangement, it will be seen that should the output pressure tend to rise beyond the selected value, the pressure in cylinder **14** and in the feedback chamber **57** will increase accordingly. As a result, the feedback force exerted on the land **47** of the pressure control spool **37** will then overcome the opposing force exerted on the spool by pilot fluid in chamber **54**, and the increased feedback force on the spool will effect reversal of its operating position.

This is to say that the spool 37 will then be moved to the right to an operating position such as seen in FIG. 6 to communicate its associated service outlet 63 with the drainport 61. Because spool 41 remains in its left-hand position seen in FIG. 3 at this time, service port 76 will then be communicated with the drain port, ans cylinder 14 will accordingly be vented and relieved of excess pressure.

The pressure in cylinder 14 and in the feedback chamber 57 will then drop to the selected output value, at which time the pressure of pilot fluid in chamber 54 will move the pressure control spool 37 back to its position seen in FIG. 3, to cut off service outlet 63 from the vent port 61 and to re-establish communication between the charge port 60 and cylinder 14 via the service outlet 63.

When the swash plate reaches the desired output portion, the speed control spool is returned to its closed position by spring 88; and the pressure control spool 37 will also be returned to its null position as soon as the cylinder pressure exerted on its land 47 equals the opposing force exerted on the spool by pilot fluid in chamber 54 at its right hand end. FIG. 4 portrays these conditions of the valve mechanism 23 at the time the swash plate 13 attains the selected output position.

The operator can return the handle 33 of the pilot valve to neutral as soon as the two spools 37 and 41 reach their FIG. 4 positions, to thus relieve the pilot ports 30, 31 of control pressure. Both pilot ports will then be at zero pressure, and the torsion spring 88 will pull the speed control spool 41 outwardly to an operating position such as seen in FIG. 5, to the right of its closed position shown in FIG. 4. In this new position, the spool 41 vents cylinder 14 and communicates cylinder 15 with the service outlet 64 governed by the pressure control spool 37.

The FIG. 5 position of the two valve spools can be said to represent the start of "free swing" for the boom of the crane. Braking may, of course, be initiated as soon as the two spools reach their FIG. 5 positions, as would be the case when a backhoe is equipped with the transmission of this invention. With a crane, however, "free swing" of the boom is desirable, to let the load carried thereby swing the boom for a distance toward the location at which the load is to be deposited. Of course, the boom must be slowed and stopped, in order for the operator to be able to lower the load at the desired location.

To effect smooth and gentle braking of the boom, the operator actuates the handle 33 of the pilot valve 22 to the right of neutral, partway toward its "R" position. This pressurizes the left hand pilot port 30 and vents the right hand pilot port 31, so that pilot fluid will flow into chamber 53 at the left hand end of the pressure control spool 37 and actuate the same to an operating position to the right of its null position.

Since the speed control spool is already in its right hand operating position, and will be maintained in that position by the action of pilot fluid in chamber 71 on its land 69, charge fluid will then be directed to service outlet 64 for flow to cylinder 15 via service port 77, to effect extension of the piston therein. This produces counterclockwise or pump destroking tilting of the swash plate, toward its zero displacement position. Fluid expelled from cylinder 14 at this time returns to tank via service port 76 and reservoir port 78 then in communication therewith.

This pump destroking motion of the swash plate effects braking of the motor 12, and the braking effect, of course, is proportional to the magnitude of pilot pressure at the pilot port 30.

During braking in this manner, the speed control spool 41 will remain in its right hand operating position seen in FIG. 5 until the boom comes to rest. The operator then actuates the pilot handle 33 toward but not all the way back to neutral, to an extent sufficient to effect reduction in the pressure of pilot fluid in port 30 to a value at which the force it exerts on land 69 of spool 41 will be slightly overcome by the force of the torsion spring 88 on the spool. Spool 41 is then returned to its closed position at which the opposing forces thereon will be again in balance.

Once boom swing has been stopped, the small braking effort which is produced with the pilot handle 33 held only a slight distance to the "R" side of neutral will be sufficient to hold the boom stationary.

Braking of boom swing in the case of a backhoe can be effected by moving the pilot handle 33 all the way to its "R" position, to produce full braking in consequence of subjection of pilot port 30 to the maximum 90 psi pressure. The swash plate will be tilted back in the pump destroking direction, toward zero displacement by such operation of the pilot valve, but neither the pump nor the motor will reverse until the boom stops swinging. As soon as boom swing is halted, the operator can return the pilot handle to a position displaced only a very slight amount toward the "R" side of neutral and the valve mechanism 23 will function to hold the boom stationary.

The boom of either a crane or a backhoe will be swung in the opposite direction, of course, in consequence of the operation of the two spools 37 and 41 following actuation of the pilot handle 33 to a position part way or all the way to its "R" position, depending upon the swing speed desired by the operator.

Free swing in said opposite direction is accomplished in the manner described earlier, but braking, of course, will require the operator to then swing the control handle 33 of the pilot valve over to the "F" side of neutral.

FIG. 7 illustrates a modified form of swing control valve like that described, but with slightly different porting and valve spools. The valve spools are shown in their null positions corresponding to those of the spools in FIG. 4. Though the speed control valve spool 141 again has five lands 168, 169, 170, 173 and 174 thereon, arranged as before, the feedback grooves have been eliminated from those lands 173 and 174 which block the service ports 76 and 77, respectively, in the closed position of the spool.

The pressure control valve spool 137, however, has only three axially spaced lands thereon — namely, a center land 110 and flanking lands 111 and 112. The center land 110 is directly opposite a drain port 113 in the null position of the spool shown, but it is narrow enough to afford communication between the drain port and the bore 138 in which the spool operates. The flanking lands 111 and 112 have considerably greater axial length than the center land 110 and they extend across the junctions of the bore with a pair of inlet or charge fluid ports 114 and 115, respectively. It is believed to be apparent that in operation, the service port 76 will be supplied with charge fluid from inlet 114 via service outlet **63**, while the service port **77** will be supplied with charge fluid from the other inlet **115** via service outlet **64**.

Whereas the service ports **76** and **77** were heretofore communicated with the cylinder feedback chambers **57** and **58** through restricted ports opening to the bore for the pressure control spool, such feedback fluid is here fed to chambers **57** and **58** through internal duct means in the pressure control spool **137**. This duct means comprises axial passages **116** and **117** in the spool, plugged at their outer ends, for chambers **57** and **58**, respectively. Radial holes **118** in spool **137** communicate passage **116** with bore **138** at opposite sides of the land **111**, and similar radial holes communicate passage **117** with the bore **138** at opposite sides of the land **112**.

With this arrangement, the pressure of charge fluid flowing to cylinder **14** from inlet port **114** will be manifested in the pressure chamber **57** via passage **116** in spool **137**, and a feedback force proportional to pump output pressure will be thereby exerted on the land **111** tending to move spool **137** to the right in opposition to the force exerted on the spool by pressure of pilot fluid at the pilot port **31**. Similarly, the pressure of charge fluid flowing to cylinder **15** from inlet port **115** will be manifested in the chamber **58** via passage **117**, and a feedback force proportional to pump output pressure will be exerted on land **112** in opposition to the force which pilot fluid in port **30** exerts on the pressure control spool.

In all other respects, the control valve mechanism of FIG. 7 is like that previously described, and it functions in the same way.

From the foregoing description, together with the accompanying drawings, it will be apparent to those skilled in the art that this invention provides a swing control valve mechanism which is particularly well adapted for use with material handling apparatus of the type having a boom which must be swung from side to side during operation of the apparatus.

Those skilled in the art will appreciate that the invention can be embodied in forms other than as herein disclosed for purposes of illustration.

The invention is defined by the following claims:

1. Control means for a hydrostatic transmission of the type including a fluid motor, a pump to drive the motor and having a displacement control member which is movable in one direction from a zero displacement position to initiate pumping action and to increase pump displacement in accordance with the extent of such movement, and hydraulic actuating means connected with said member for moving the same in said direction, said control means being characterized by:

A. first pilot operated valve means for controlling motor speed and actuatable by pilot pressure from a normally closed to an operating position directing pressure fluid entering the same to said hydraulic actuating means to thereby effect movement of the displacement control member in the direction to initiate pumping action;

B. spring loaded means connected with the displacement control member and with said first valve means for applying to the latter a feedback force tending to move the same toward closed position, and which feedback force increases in proportion to the extent the displacement control member is moved in said direction;

C. second pilot operated valve means for controlling pump output pressure, said second valve means being actuatable by pilot pressure from a null position to an operating position directing pressure fluid from a source to said first valve means;

D. spring means yieldingly resisting such pilot actuation of said second valve means;

E. and means to monitor the pressure of fluid in said hydraulic actuating means and to translate said pressure into a feedback force on said second valve means tending to return the same to its null position.

2. The control means of claim **1**, further characterized by:

A. means providing a source of pilot fluid under pressure, for effecting movement of the first and second valve means to said operating positions thereof, said last named means having an actuator whose setting determines pilot output pressure, and hence the desired motor speed and torque;

B. and said spring loaded means comprising a spring through which said feedback force is applied to the first valve means and which becomes loaded to an extent sufficient to effect return of said first valve means to closed position when the displacement control member reaches an adjusted position corresponding to the selected motor speed.

3. The control means of claim **2**, wherein the feedback pressure in said hydraulic actuating means is proportional to pump output pressure at any given speed of motor operation, and the force exerted on the second valve means by said feedback pressure attains a value great enough to effect return of the second valve means to its null position when the desired pump output pressure is attained.

4. The control means of claim **3**, wherein said spring loaded means is operable upon release of pilot pressure from said first and second valve means to effect shifting of said first valve means to a position at which it vents said hydraulic actuating means.

5. Control means for a hydrostatic transmission of the type including a reversible fluid motor, a pump to drive the motor in a direction and at a speed depending upon the extent and the direction in which a pump displacement control member is moved out of a zero displacement position, and hydraulic actuator means operatively connected with said control member to move the same in a direction depending upon which of two actuator ports pressure fluid is directed into, said control means being characterized by:

A. first and second pilot operated valves each having a control spool and spring means to yieldingly resist motion thereof out of a null position in a bore in which the spool is axially slidable, said spools being actuatable by pilot pressure to operating positions at opposite sides of their null positions;

B. the first valve controlling motor speed and having a pair of service ports opening from its bore, one for each of said actuator ports and communicated therewith;

C. the spool of said first valve being operable to direct pressure fluid entering its bore to either service port thereof to thereby effect movement of the displacement control member out ot its zero displacement position in a direction and to an extent depending upon the direction and extent of movement of said first spool out of its null position;

D. spring loaded means connected with the displacement control member and with said first spool for applying to the latter a feedback force which is proportional to the extent the displacement control member is moved from its zero displacement position and which force tends to return said first spool to its null position;

E. said second valve controlling pump output pressure and having an inlet connectible with a pressure fluid source, and a pair of outlet ports each leading to the bore of the first valve to communicate with one of said service ports under the control of said first spool;

F. and means for translating the pressure of fluid supplied to either actuator port into a feedback force on the second spool which feedback force tends to return said second spool to its null position.

6. Control means for a hydrostatic transmission having a fluid motor driven by a pump at a speed determined by the extent of movement of a pump displacement control member out of a zero displacement position, and having hydraulic actuating means for said member, characterized by:

A. a first valve actuatable in one direction and against spring bias from a closed position to an operating position at which it directs pressure fluid from an inlet to said hydraulic actuating means to thereby effect movement of the displacement control member in one direction out ot its zero displacement position;

B. means for subjecting said first valve to pilot pressure so as to effect actuation thereof to its said operating position;

C. spring loaded means connected with the displacement control member and with said first valve for imposing upon the latter a feedback force opposing the force of pilot pressure thereon, which feedback force is proportional to the extent the control member is moved out of its zero displacement position;

D. a second valve actuatable against spring force from a null position to an operating position at which it directs pressure fluid from a source to the inlet of said first valve;

E. means for subjecting the second valve to the same pilot pressure as the first valve, so as to effect actuation of the second valve to said operating position thereof;

F. and means to monitor the pressure of fluid in said hydraulic actuator means and for translating said pressure into a feedback force on said second valve tending to return the same to its null position.

7. The control means of claim 6, further characterized by:

A. said first valve being pilot actuatable in the opposite direction from its closed position to a second operating position at which it effects venting of said hydraulic actuating means;

B. and said spring loaded means comprises a preloaded torsion spring which yieldingly resists motion of said first valve in either direction out of its closed position.

8. The control means of claim 1, wherein said feedback force on the speed control valve means effects return thereof to its closed position against the force which pilot pressure exerts thereon at times when the displacement control member reaches an adjusted position corresponding to a predetermined pilot pressure.

9. The control means of claim 8, wherein said second valve means is returned to its null position by said feedback force thereon whenever the latter reaches a value in excess of a predetermined pilot pressure.

10. The control means of claim 9, wherein release of said pilot pressure at the time the displacement control member reaches the desired adjusted position causes said spring loaded means to effect movement of the first valve means to a second open position at which it vents said hydraulic actuating means and allows the motor to operate freely under the inertia of the load driven thereby as long as said second valve means remains in its null position.

11. The control means of claim 1, further characterized by:

A. return movement of said displacement control member toward its zero displacement position effecting destroking of the pump and braking of the motor;

B. said hydraulic actuating means having a first port into which pressure fluid can be directed by the speed control valve means to effect movement of the displacement control member in said one direction, and having a second port into which pressure fluid can be directed to effect said return movement of the displacement control member;

C. and each of said first and second valve means being actuatable to other operating positions to effect delivery of pressure fluid to said second port of the hydraulic actuating means.

12. In apparatus having a heavy member mounted for rotary movement about an upright axis, a reversible fluid motor to drive said member, a pump to drive the motor and having a displacement control member movable in opposite directions from a zero displacement position to initiate pumping action and motor operation in a direction and at a speed depending upon the extent and direction said control member is moved away from its zero position, reversible hydraulic actuator means for said control member having a pair of ports providing for flow of pressure fluid to and from the actuator means for operation thereof in opposite directions, and a pilot operated control valve mechanism for said actuator means, characterized by:

A. a first control valve to govern pump output pressure and having charge fluid inlet means, a pair of service outlets, and a valve spool actuatable by pilot pressure from a null position closing the service outlets to operating positions at opposite sides of its null position to selectively communicate said service outlets with the inlet means;

B. a second control valve to govern motor speed, and which is supplied with charge fluid from said service outlets of the first control valve, said second control valve having a pair of service ports respectively connected with the ports of the actuator means, fluid return means, and a valve spool actuatable by pilot pressure from a closed position blocking the service ports to operating positions at opposite sides of its closed position to direct pressure fluid supplied thereto from the first control valve to either port of the actuator means while communicating the other port thereof with the fluid return means;

c. spring loaded means connected with the displacement control member and with the spool of said second control valve for applying to the latter a feedback force tending to return said spool to its closed position, and which feedback force increases in proportion to the extent the displacement control member is moved in said direction;

D. and means to monitor the pressure of fluid in said hydraulic actuator means and to translate said pressure into a feedback force on the spool of said first control valve tending to return said spool thereof to its null position.

13. A hydrostatic transmission and control means therefor, comprising the combination of:

A. a pump having a displacement adjusting member;

B. a fluid motor driven by the pump at a speed depending upon the position of said member;

C. means providing a hydraulic actuator connected with said member and having an inlet port into which pressure fluid can be directed to effect movement of said member in the direction to increase the displacement of the pump and accordingly increase the speed of the motor;

D. first and second pilot actuatable control valve mechanisms having a common pilot pressure passage;

E. the first valve mechanism having a charge fluid inlet and a valve member which normally occupies a null position but which is actuatable against spring force by pilot pressure in said passage to an operating position at which it directs charge fluid to said second valve mechanism;

F. said second valve mechanism having a valve element actuatable by pilot pressure in said passage from a closed position to an operating position at which it relays pressure fluid from said first valve mechanism to said actuator port;

G. link means connecting said displacement adjusting member with said valve element;

H. spring means connected with said valve element to yieldingly resist movement thereof toward its said operating position, said spring means being connected with the link means so as to be further loaded as a consequence of adjustment of said member to increase pump displacement;

I. and means for translating the pressure of charge fluid present at said actuator port into a force on said valve member which opposes the force exerted thereon by pilot pressure in said passage.

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