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(54) ELECTROHYDRAULIC PROPORTIONAL CONTROL VALVE ASSEMBLIES

ELEKTROHYDRAULISCHE PROPORTIONALE STEUERVENTILVORRICHTUNG

ENSEMBLES DE VANNES ELECTROHYDRAULIQUES A REGULATION PAR ACTION PROPORTIONNELLE

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Description

[0001] This invention relates to electrohydraulic proportional control valve assemblies for controlling fluid actuated devices.

[0002] It is known (e.g. from EP-A-0462 589) to utilise a proportional control valve assembly for controlling a fluid actuated device, such as a control ram for a lifting arm of an earth moving vehicle for example, in response to a demand signal supplied by an operator actuated joystick. Such a control valve assembly typically incorporates a main spool valve having a first actuating port for bidirectional fluid flow between the spool valve and a first port of the fluid actuated device, a second actuating port for bidirectional fluid flow between the spool valve and a second port of the fluid actuated device, a pump port for input fluid flow to the spool valve from a hydraulic pump, a tank port for output fluid flow from the spool valve to a hydraulic tank, and a spool for controlling the direction and rate of fluid flow between the first actuating port and the pump or tank port and the direction and rate of fluid flow between the second actuating port and the pump or tank port.

[0003] This control valve assembly may also incorporate a pressure compensator in the form of an auxiliary spool valve which is controlled so as to maintain a constant pressure drop across the spool of the main spool valve. Such a control valve assembly enables the fluid actuated device to be controlled independently of the load, so that, in the case of a control ram for a lifting arm of an earth moving vehicle for example, the arm is lifted or lowered at a substantially uniform rate regardless of the size of the load lifted by the arm or of variation in loading during lifting due to the structure of the arm itself. However such control valve assemblies are of complex mechanical construction, and this can render the control valve assemblies costly and difficult to manufacture. Furthermore such control valve assemblies are capable of only limited control functions, and in particular are prone to malfunction in an over-running load condition, that is when external forces acting on the fluid actuated device due to gravity act in the same direction as the moving part of the fluid actuated device is being moved under hydraulic control.

[0004] It is proposed in International Published Application No. WO 93/01417 to provide such a control valve assembly with a change-over valve incorporating a position sensor which determines which of the two actuating ports connected to the fluid actuated device is at the higher pressure, and which supplies an electrical position signal indicative of which port is at the higher pressure to a processor which also receives an electrical pressure signal indicative of the higher pressure from a pressure sensor, as well as a directional signal indicative of the direction in which the spool is to be displaced from its neutral position by manual movement of an operator-actuated lever. The processor incorporates a comparator which establishes whether the input port as indicated by the directional signal is at the higher pressure, and provides an output signal to a positioning device for controlling the output of the pump in dependence on the result of this comparison and in accordance with the requirement of the load. Although such an assembly incorporates special control measures responsive to an over-running load condition, these measures operate only in response to actual movement of the spool on operator actuation, so that there is still a risk of malfunction in such an over-running load condition.

[0005] It is an object of the invention to provide a novel proportional control valve assembly which can be produced in a straightforward manner and which provides a large number of control functions.

[0006] According to the present invention there is provided an electrohydraulic proportional control valve assembly as defined in the accompanying claims.

[0007] Such a control valve assembly utilises adjustment of the position of the two valve members to control the flow rate and/or pressure at the ports of a fluid actuated device, such as a hydraulic cylinder or hydraulic motor, in dependence on the sensed valve member position, the sensed pressures in the ports and the sensed pump pressure and in response to the operator actuated demand signal, produced by operator actuation of a joystick for example. The valve members are continuously controlled by the servo control means in response to a continually updated actuating signal adapted to drive the valve members to positions corresponding to through-flow cross-sections appropriate to the required flow and pressure conditions and the desired operating mode of the fluid actuated device, and a large number of control functions can be provided by appropriate programming of the control circuitry. For example, the flow rate and/or pressure at the ports of the fluid actuated device may be controlled so that the device is adjustable at a uniform rate which is independent of the load, that is so that the rate of movement of the moving part of the device is not affected by variation of the applied load or supply pressure, either in a passive load condition or in an over-running load condition. Furthermore servo control of valve member position in dependence on the feedback position signals ensures highly accurate valve member positioning, without requiring either detailed analysis of valve characteristics or adjustment to take account of wear.

[0008] The provision of two separate valve means having separately movable valve members is advantageous as it enables differential opening and closing of the first and second actuating ports to effect control of the fluid actuated device. Independent control of the flow rate and/or pressure at the two ports of the fluid actuated device by such valve means thus enables operation of the fluid actuated device at a higher level of efficiency and safety than is possible in prior control arrangements in which efficiency losses are incurred as a result of the need to displace the moving part of the device against a back pressure. Furthermore, in the event of pressure overload, for example due to movement of the moving part of the device being blocked by external overloading, or where free floating of the load is required, one or both of the valve members may be opened to tank in order to vent the two sides of the fluid actuated device separately or simultaneously.

[0009] In order that the invention may be more fully understood, a preferred embodiment of control valve assembly in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a hydraulic circuit diagram of the assembly;

Figure 2 is a diagrammatic sectional view through a part of the assembly;

Figure 3 is a block diagram showing the electrical interconnections between various parts of the assembly; and

Figure 4 is a logic diagram illustrating control functions of the assembly.

[0010] Referring to Figure 1 the illustrated electrohydraulic proportional control valve assembly 1 comprises first and second spool valves 2 and 3 connected to first and second actuating ports 4 and 5 for controlling fluid flow to opposite sides of a movable piston 6 of a fluid actuated device 7 in the form of a hydraulic cylinder or motor. The first and second spool valves 2 and 3 have spools 12 and 13 which are axially movable by pilot fluid flows controlled by electrically operated pilot actuator valves 44 and 45 (described more fully below with reference to Figure 2) between end positions in which the spool 12 or 13 places the corresponding actuating port 4 or 5 in communication with either a pump port 15 or 16 connected to the output of a pump 17 or a tank port 18 or 19 connected to a tank 20. The fluid supplied to the pilot actuator valves 44 and 45 is regulated by a pilot pressure regulator 14.

[0011] The spool 12 or 13 or each spool valve 2 or 3 is movable to effect opening of the spool valve 2 or 3 either to the pump port 15 or 16 or the tank port 18 or 19 over a throughflow cross-section which may be varied proportionately between a minimum opening value and a maximum opening value in dependence on the position of the spool 12 or 13. Furthermore both spools 12 and 13 are spring biased towards their neutral positions (in which they are shown in Figure 1), and position sensors 23 and 24 are provided for supplying electrical position signals indicative of the positions of the spools 12 and 13. In addition a pressure relief valve 25 is provided for venting the output of the pump 17 to the tank 20 in a manner which will be described in more detail below. Four pressure sensors 26, 27, 28 and 29 are provided for supplying electrical pressure signals P_A, P_B, P_S and P_T indicative of the fluid pressures in the first and second actuating ports 4 and 5, the pump port 15 or 16 and the tank port 18 or 19.

[0012] As shown diagrammatically on the right hand side of Figure 1, the pilot pressure regulator 14 may also serve to regulate pilot fluid supply to the pilot actuator valves of a further pair of spool valves, identical to the spool valves 2 and 3, for controlling supply of fluid to a further fluid actuated device 30. The two devices 7 and 30 may be two rams for controlling different linkage axes of an earth moving vehicle for example, and may be controlled by two valve slices in the assembly as described in more detail below.

[0013] Figure 2 shows a section through a valve slice part incorporating one of the first and second spool valves 2 and 3 and one of the associated pilot actuator valves 44 and 45, two such parts being provided in each valve slice. The pilot actuator valve 44 or 45 comprises a moving coil 35 fixed to a pilot spool 36 which is centred by two springs 37 and 38, the coil 35 being displaceable in an annular air gap 39 within a magnetic former 40 when a current is supplied to the coil 35 so as to provide magnetic interaction between the magnetic field associated with the current flow and the magnetic flux produced in the air gap 39 by the former 40. The pilot actuator valve 44 or 45 has two actuating ports 46 and 47 connected to the ends of the spool valve 2 or 3 by connecting conduits 48 and 49 respectively, as well as a tank port 70 connected to the tank and two pump ports 71 and 72 connected to pump either directly or by way of the pilot pressure regulator 14. The spool 12 or 13 of the spool valve 2 or 3 is centred by two springs 73 and 74 and has an extension 75 at one end enabling a position feedback signal dependant on the position of the spool 12 or 13 to be outputted by the position sensor 23 or 24.

[0014] With the spool 36 of the pilot actuator valve 44 or 45 in the neutral position as shown in Figure 2, only slight fluid leakage will take place through the pilot actuator valve, and hence the spool 12 or 13 of the main spool valve 2 or 3 will be held in its neutral position by the springs 73 and 74, as also shown in the figure. When a position control current is supplied to the coil 35, a force acts on the spool 36 so as to move it in one or other direction (dependant on the sense of the current) until an equilibrium position is reached in which the force is balanced by the forces exerted by the springs 37 and 38. If the spool 36 moves to the right as shown in the figure, this results in passages of a throughflow cross-section determined by the magnitude of the current being opened between the pump port 71 and the actuating port 46 and between the tank port 70 and the actuating port 47, with the result that a controlled displacement flow of pilot fluid is applied along the conduit 48 to the left hand end of the spool 12 or 13 of the main spool valve 2 or 3, and at the same time controlled venting of pilot fluid from the right hand end of the spool 12 or 13 takes place by way of the conduit 49 to tank. This causes the main spool 12 or 13 to be driven to the right as shown in the figure, with the speed of movement being determined by the degree of opening of the pilot actuator valve 44 or 45, until the position feedback signal outputted by the position sensor

23 or 24 indicates that the spool has been driven to the required position at which time the current to the coil 35 is cut off and the spool 36 of the pilot actuator valve 44 or 45 is returned to its neutral position by the springs 37 and 38. This results in movement of the main spool 12 or 13 being stopped so that the spool is held in the required position to which it has been driven by virtue of the fluid pressures acting on the two ends of the spool.

[0015] In practice the pilot actuator valve current is controlled in a complex way by the control circuitry in order to achieve optimum dynamic and position control characteristics, that is in order to rapidly drive the main spool 12 or 13 to the required position and in order to accurately retain the spool in that position for as long as necessary. This may in practice require energisation of the coil 35 by a small current under servo control even when movement of the main spool 12 or 13 is not required, so as to provide small fluid flows through the pilot actuator valve 44 or 45 to compensate for fluid leakage so as to retain the main spool 12 or 13 in the position to which it has been driven. However any current required to maintain the main spool in position will be very low, and will not adversely affect the generally low current consumption of the control circuitry which accurately monitors the position of the main spool valve 12 or 13 by means of the position sensor 23 or 24 at all times and controls the current to the coil 35 continuously so as to provide the required feedback control of the main spool position.

[0016] Since the moving coil 35 and the spool 36 to which it is fixed are of light construction, the coil 35 has low power consumption and the control circuitry requires only low power, low cost components. Furthermore high speed movement of the spool 36 is possible in response to the applied current under servo control, and rapid reversal of spool movement can be effected by reversal of the current in the coil 35 to cause the spool 36 to move in the opposite direction. Thus not only can the supply of fluid from the pump to the main spool 12 or 13, and corresponding venting of fluid from the main spool 12 or 13 to tank, be controlled rapidly so as to provide for accurate dynamic control of the main spool position in response to the position feedback signal, but also the control of the piston 6 of the fluid actuated device 7 can be effected with response times sufficient to enable highly advantageous control of the load in a manner which has not previously been possible with known control arrangements. For example, when the movement of the load is blocked, such as when the bucket of an excavator meets an obstruction, an appropriate pressure relief signal triggered by sensing of a pressure overload by one of the pressure sensors 26 and 27 can cause operation of the appropriate pilot actuator valve 44 or 45 so as to rapidly open one of the main spools 12 and 13 to tank, in order to reduce the pressure in the fluid actuated device in such a manner as to avoid damage due to over pressure. Such pressure relief occurs particularly rapidly due to the high speed dynamic response of the pilot actuator valves 44 and 45. Other control features enabled by the high speed dynamic response of the pilot actuator valves 44 and 45 under servo control will be discussed below.

[0017] Referring to Figure 3 the complete control valve assembly comprises, for example, a bank of two valve slices 50 and 51 of the general form described, each of which has a first actuating port 4 and a second actuating port 5 for connection to a respective fluid pressure actuated device (not shown), and an end slice 52 connected to the valve slices 50 and 51 and having a pump port 53 and a tank port 54. The end slice 52 serves to control the supply pressure of hydraulic fluid from a fixed displacement pump (not shown) connected to the pump port 53 in dependence on demand signals indicative of the demand for fluid to be supplied to the valve slices 50 and 51, in order to ensure that fluid is supplied only when required and in order to place the pump on standby if there is no requirement for fluid supply to the valve slices 50 and 51. During operator actuation the pressure relief valve 25 shown in Figure 1 is controlled in dependence on the load pressures sensed by the pressure sensors 26 and 27 to control the pressure of fluid supplied by the pump so that it exceeds the highest load pressure sensed by a predetermined amount. When no pressure load is sensed, the pressure relief valve 25 routes the fluid back to the tank at a nominal low pressure. Alternatively, where a variable displacement pump is provided, the valve 25 may be configured to pilot the displacement control of the pump in such a way as to ensure supply of fluid in accordance with the requirements of the system. Although only two valve slices 50 and 51 are shown in Figure 3 for simplicity, it should be appreciated that a bank of four to ten valve slices is more likely to be provided in a practical embodiment.

[0018] Furthermore a control computer 55 is electrically connected to the valve slices 50 and 51 and to a joystick 56 by a serial communications network, so as to monitor operator actuation of the joystick 56, and so as to supply to the valve slices 50 and 51 pressure (P) or flow (Q) demand signals, and pressure-flow (P-Q) select signals. In addition the control computer 55 serves to supply initial set up data to the valve slices 50 and 51 on initial set up programming utilising a plug-in programmer 57, and also to provide error monitoring of the valve slices 50 and 51. If required, provision may be made for temporary connection to the valve slices 50 and 51 of a plug-in driver 58 for emergency operation of the valve slices 50 and 51. Also, if required, a health monitor display 59 may be connected to the control unit 55 to indicate correct operation of the valve slices 50 and 51.

[0019] The manner in which the control computer 55 is used to control the valve slices 50 and 51 in order to effect the required control of the fluid pressure actuated devices will now be briefly described with reference to Figure 4, it being understood that the control logic for carrying out the control functions described with reference to Figure 4 is incorporated in the valve slices 50 and 51 themselves and not in the control computer 55 which serves to provide overall system control. The control computer 55 supplies a pressure-flow (P-Q) select signal to each valve slice and a selection is made by a selector in each valve slice in dependence on this signal as to whether pressure control or flow control is to be effected.

[0020] Referring to Figure 4, it will be appreciated that the particular control mode in which the fluid actuated device is to be controlled is determined by the form of the select signal supplied by the control computer in dependence on the demand signal supplied by operator actuation of the joystick and/or control mode selector buttons or switches, as indicated by the control mode iteration loop 80 in the figure. If the flow control mode is selected, a flow demand signal Q_{DEM} is supplied to a selector 81 which determines the required direction of fluid flow to the fluid actuated device, that is whether the flow is to port A or port B. In the event of zero flow being required, the control is effected so that both main spools are held in their neutral positions. In the event of flow to port A being required, a further selector 82 determines whether the pressure in the port A is greater than or less than the pressure in the port B, that is whether the load is to be treated as a passive load or an over running load. In the event of a passive load, the required throughflow cross-section a of the spool valve for controlling the flow to the port A is calculated at 83 by dividing the flow demand signal Q_{DEM} by the value $\sqrt{(P_S - P_A)}$ and a constant of proportionality. A nominal downstream back pressure to be applied at the port B is set at 84, and the required positions of the two spools are then controlled at 85 by supplying control signals to the pilot actuator valve of the upstream spool valve in order to set the required throughflow cross-section a and by supplying control signals to the pilot actuator valve of the downstream spool valve so as to set the downstream back pressure at a predetermined level.

[0021] In the event of an overrunning load the required throughflow cross-section a of the spool valve for controlling the flow through the port B is calculated at 86 by dividing the flow demand signal Q_{DEM} by the value $\sqrt{(P_B - P_T)}$ and the constant of proportionality (where P_T is the sensed tank pressure or an assumed tank pressure where a tank sensor is not provided), and control of the filling of the upstream side of the piston of the fluid actuated device by way of the port A is set at 87, so that control of the required positions of the two spools at 88 provides for controlled metering out of fluid from the port B by appropriate setting of the throughflow cross-section a of the downstream valve and controlled filling by way of the port A under control of the upstream valve. In view of the ability of the pilot actuator valves to switch rapidly between supply of fluid in one direction to the main spool valves and supply of fluid in the opposite direction, such a control arrangement enables discontinuous switching from a passive load condition to an overrunning load condition, as when a lifting arm of an earth moving vehicle is swung by the fluid actuated device through an over centre position so that the direction in which gravity acts on the load is in the same direction as piston movement, rather than in the opposite direction as it is prior to the over centre position being reached. The provision of a tank sensor enables more accurate control in the event of an overrunning load, and avoids any control discontinuities.

[0022] If the selector 81 determines that the required direction of fluid flow is to the port B of the fluid actuated device, then a similar series of control steps are carried out to the steps already described except that the control in relation to the ports A and B is reversed so that the calculations utilise the sensed pressure signal P_B in place of P_A and vice versa. In each case the spool positions are continuously monitored by the position sensors, and the signals supplied to the pilot actuator valves are varied as required in dependence on the position feedback signals from the position sensors.

[0023] In the event that pressure control is selected, the pressures applied at the two ports A and B of the fluid actuated device are controlled in dependence on movement of the joystick by the operator such that the joystick movement determines the rate of change of pressure (magnitude and sense) applied to the load and, in the event of movement of the joystick being stopped, no further pressure change is applied to the load. Initially the pressure demand is calculated at 89 from the joystick input signal. A selector 90 then determines whether the pressure demand requires the application of pressure to the port A or the port B. If the pressure demand is zero both port pressures are set to a nominal value. If the pressure demand requires application of pressure to the port A, a selector 91 first determines whether or not oscillating pressure is to be applied to the piston, for example in order to vibrate the load when a compaction mode has been selected. Depending on the result of this selection the required pressure at the port A is set to the demand pressure and the required pressure at the port B is set to a nominal value at 92, and the required control signals to the pilot actuator valves of the two spool valves are applied at 93 in order to control the positions of the main spools incrementally in dependence on the position feedback signals in order to set the required pressures in the ports A and B.

[0024] If the pressure demand requires application of pressure to the port B, a similar sequence of control steps is effected except that the demand pressure is applied to the port B and the pressure in the port A is set to a nominal value, that is a predetermined pressure above the sensed or assumed tank pressure. In the event that the compaction mode is selected, a sine wave varying cyclic demand pressure is added to the basic demand pressure so that the load is vibrated by the resulting pressure control.

[0025] The pressure control mode can be utilised with advantage in various operating conditions. For example, when lifting a load, the pressure control mode can be initiated so as to provide continuous pressure counterbalancing of the load and so as to allow the load to be manipulated manually with the application of only small pressures. Furthermore, if the load is an excavating arm carrying a bucket for digging through the ground for example, the applied pressure can be controlled so that, in the event of the bucket hitting an obstruction such an underground utility, a predetermined pressure limit will not be exceeded, and there is no danger of damage to the underground utility by the application of excess pressure.

[0026] If a float mode is selected by the operator by actuation of a special switch, both main spools are controlled at 94 so as to open both sides of the piston of the fluid actuated device to tank so as to enable free floating movement of the piston and any load coupled thereto.

[0027] Whilst the above described valve assembly utilizes first and second spool valves 2 and 3 for controlling fluid flow to and from the fluid actuated device, an alternative, non-illustrated valve assembly in accordance with the invention utilizes a pair of poppet valves in place of each such spool valve for controlling respectively the flow of fluid to the device from the pump by way of the associated actuating port and the flow of fluid from the device to the tank by way of the actuating port. In each case the pair of poppet valves associated with each actuating port is controlled by the pilot actuator valves to provide the required fluid flows in the various control modes. Furthermore each of the pilot actuator valves may itself comprise a pair of poppet valves for controlling the fluid flows to and from the main valve or valves in response to current actuation of the moving coil.

Claims

1. An electrohydraulic proportional control valve assembly (1) for controlling a bidirectional fluid actuated device (7) having first and second ports and a movable part (6) disposed between the first and second ports to be acted on on opposite sides by fluid supplied to the first port and by fluid supplied to the second port, the valve assembly having a first actuating port (4) for bidirectional fluid flow between the valve assembly and the first port of the fluid actuated device (7), a second actuating port (5) for bidirectional fluid flow between the valve assembly and the second port of the fluid actuated device (7), a pump port (15,16) for input fluid flow to the valve assembly from a hydraulic pump (17), and a tank port (18,19) for output fluid flow from the valve assembly to a hydraulic tank (20), the valve assembly comprising first valve means (2) connected to the first actuating port (4), the pump port (15) and the tank port (18) for controlling the direction and rate of fluid flow between the first actuating port (4) and the pump port (15) and between the first actuating port (4) and the tank port (18), and second valve means (3) connected to the second actuating port (5), the pump port (16) and the tank port (19) for controlling the direction and rate of fluid flow between the second actuating port (5) and the pump port (16) and between the second actuating port (5) and the tank port (19), the first valve means (2) having at least one first valve member (12) which is movable to vary the throughflow cross-section for fluid flow between the first actuating port (4) and the pump or tank port (15 or 18), and the second valve means (3) having at least one second valve member (13) which is movable, independently of movement of the first valve member(s) (12), to vary the throughflow cross-section for fluid flow between the second actuating port (5) and the pump or tank port (16 or 19), position sensing means (23,24) for supplying electrical position signals indicative of the actual positions of the first and second valve members (12 and 13), pressure sensing means (26, 27 and 28) for supplying electrical pressure signals indicative of the fluid pressures in the first and second actuating ports (4 and 5) and the pump port (15, 16), and servo control means for controlling the positions of the first and second valve members (12 and 13) in dependence on the electrical position and pressure signals and in response to an electrical demand signal provided in response to operator actuation, in order to set the throughflow cross-sections for fluid flow through the first and second valve means (2 and 3) between the first actuating port (4) and the pump or tank port (15 or 18) and between the second actuating port (5) and the pump or tank port (16 or 19) to effect the required control of the movable part (6) of the fluid actuated device (7),
wherein a select signal supplied by a control computer in dependance on said electrical demand signal causes a selection to be made as to whether pressure control or flow control is to be effected; and wherein,
where the flow control mode is selected, control is effected by determining whether the flow of fluid is to the first actuating port or the second actuating port and by setting the fluid flow cross-section through the relevant valve means ; alternatively, where pressure control is selected, the pressures applied at both actuating ports are controlled.

2. An assembly according to claim 1, wherein the first and second valve members (12 and 13) are spools which are axially displaceable to vary the throughflow cross-section for fluid flow between each actuating port and the pump or tank port.

3. An assembly according to claim 1 or 2, wherein the servo control means includes electrically operable pilot valve means (44, 45) for controlling the position of each of the valve members (12, 13) by applying a controlled displacement flow of pilot fluid to one part of the valve member, whilst at the same time

applying controlled venting of pilot fluid from another part of the valve member, sufficient to drive the valve member to a required position in a first operating mode, and by subsequently discontinuing said displacement flow of pilot fluid to the valve member and said venting of pilot fluid so as to hold the valve member in said required position in a second operating mode.

4. An assembly according to claim 3, wherein the pilot valve means comprises a first pilot valve (44) for effecting bidirectional axial movement of the first valve member (12), and a second pilot valve (45) for effecting bidirectional axial movement of the second valve member (13) independently of movement of the first valve member (12).

5. An assembly according to claim 4, wherein each pilot valve comprises an actuating coil (35) movable relative to a magnetic former (40) by the application of an electrical actuating current to the coil, and a valve element (36) movable by the coil to simultaneously control application of pilot fluid to said one part of the valve member and venting of pilot fluid from said other part of the valve member.

6. An assembly according to any one of claims 3, 4 or 5, wherein a pilot pressure regulator (14) is provided to regulate the pressure of fluid supplied to said pilot valve means (44,45) to hold the last-named pressure substantially constant.

7. An assembly according to claim 1 or claim 2, wherein the servo control means includes electrically operable pilot valve means (44,45) for controlling the position of each of the valve members (12,13) and wherein a pilot pressure regulator (14) is provided to regulate the pressure of fluid supplied to said pilot valve means (44,45) to hold the last-named pressure substantially constant.

8. An assembly according to any preceding claim, wherein the servo control means is operable, in a pressure control mode, to control the positions of the first and second valve members (12 and 13) in response to an operator actuated electrical pressure demand signal corresponding to a required load pressure, in order to apply controlled fluid flow to one of the actuating ports (4 or 5) and controlled venting of fluid from the other actuating port (5 or 4) to produce a pressure difference across the fluid actuated device (7) corresponding to the required load pressure.

9. An assembly according to any preceding claim, wherein the servo control means is operable, in a float mode, to control the positions of the first and second valve members (12 and 13) in response to an operator actuated electrical float demand signal, in order to vent fluid from both actuating ports (4 and 5) so as to allow free floating movement of a load coupled to the fluid actuated device (7).

10. An assembly according to any preceding claim, wherein the servo control means is operable, in a compaction mode, to control the positions of the first and second valve members (12 and 13) in response to an operator actuated electrical compaction demand signal, in order to rapidly alternate the direction of fluid flow to the actuating ports (4 and 5) so as to vibrate a load coupled to the fluid actuated device (7).

11. An assembly according to any preceding claim, wherein the servo control means is operable, in a pressure relief mode, to control the positions of the first and second valve members (12 and 13) in response to an electrical pressure relief signal triggered by sensing of a pressure overload in one of the actuating ports (4,5) by the pressure sensing means (26,27), in order to provide controlled venting of fluid from said one actuating port to relieve the pressure.

12. An assembly according to any preceding claim, wherein the pressure sensing means comprises a first pressure sensor (26) for supplying a first electrical pressure signal indicative of the fluid pressure in the first actuating port (4), a second pressure sensor (27) for supplying a second electrical pressure signal indicative of the fluid pressure in the second actuating port (5), a third pressure sensor (28) for supplying a third electrical pressure signal indicative of the fluid pressure in the pump port (15, 16), and a fourth pressure sensor (29) for supplying a fourth electrical pressure signal indicative of the fluid pressure in the tank port (18,19), and wherein the servo control means is adapted to control the positions of the first and second valve members (12,13) in dependence on the first, second, third and fourth electrical pressure signals.

13. An assembly according to any preceding claim, wherein a control computer (55) is provided for monitoring the operator actuated electrical demand signals and for providing overall function control of the servo control means in dependence on the demand signals.

14. An assembly according to any preceding claim, which is of modular construction and includes a bank of valve slices assembled together and adapted to control a plurality of fluid pressure actuated devices.

Patentansprüche

1. Elektrohydraulische Proportionalregelungsventilanordnung (1) zum Steuern einer von einem in zwei Richtungen strömenden Strömungsmittel betätigten Vorrichtung (7) mit einer ersten und einer zweiten Öffnung und einem beweglichen Teil (6), das zwischen der ersten und der zweiten Öffnung so angeordnet ist, daß auf gegenüberliegende Seiten durch ein der ersten Öffnung zugeführtes Strömungsmittel und ein der zweiten Öffnung zugeführtes Strömungsmittel eingewirkt wird, wobei die Ventilanordnung aufweist: eine erste Betätigungsöffnung (4) für einen in zwei Richtungen erfolgenden Strömungsmittelstrom zwischen der Ventilanordnung und der ersten Öffnung der strömungsmittelbetätigten Vorrichtung (7), eine zweite Betätigungsöffnung (5) für einen in zwei Richtungen erfolgenden Strömungsmittelstrom zwischen der Ventilanordnung und der zweiten Öffnung der strömungsmittelbetätigten Vorrichtung (7), eine Pumpenöffnung (15, 16) für die Strömungsmittelstromeingabe zur Ventilanordnung von einer hydraulischen Pumpe (17) und eine Tanköffnung (18, 19) für die Strömungsmittelausgabe von der Ventilanordnung zu einem hydraulischen Tank (20), wobei die Ventilanordnung umfaßt: erste Ventilmittel (2), die mit der ersten Betätigungsöffnung (4), der Pumpenöffnung (15) und der Tanköffnung (18) verbunden sind, um Richtung und Durchsatz eines Strömungsmittelstroms zwischen der ersten Betätigungsöffnung (4) und der Pumpenöffnung (15) und zwischen der ersten Betätigungsöffnung (4) und der Tanköffnung (18) zu steuern, und zweite Ventilmittel (3), die an die zweite Betätigungsöffnung (5), die Pumpenöffnung (16) und die Tanköffnung (19) angeschlossen sind, um Richtung und Durchsatz des Strömungsmittelstroms zwischen der zweiten Betätigungsöffnung (5) und der Pumpenöffnung (16) und zwischen der zweiten Betätigungsöffnung (5) und der Tanköffnung (19) zu steuern, wobei die ersten Ventilmittel (2) mindestens ein erstes Ventilteil (12) aufweisen, das beweglich ist, um den Durchflußquerschnitt für den Strömungsmittelstrom zwischen der ersten Betätigungsöffnung (4) und der Pumpen- oder Tanköffnung (15 oder 18) zu ändern, und die zweiten Ventilmittel (3) mindestens ein zweites Ventilteil (13) aufweisen, das unabhängig von der Bewegung des ersten Ventilteils bzw. der ersten Ventilteile (12) beweglich ist, um den Durchflußquerschnitt für den Strömungsmittelstrom zwischen der zweiten Betätigungsöffnung (5) und der Pumpen- oder Tanköffnung (16 oder 19) zu ändern, Lageerfassungsmittel (23, 24), um elektrische Lagesignale zu liefern, die eine Aussage über die tatsächlichen Lagen des ersten und des zweiten Ventilteils (12 und 13) liefern, Druckerfassungsmittel (26, 27 und 28), um elektrische Drucksignale zu liefern, die eine Aussage über die Strömungsmitteldrücke in der ersten und der zweiten Betätigungsöffnung (4 und 5) und der Pumpenöffnung (15, 16) liefern, und Servo-Regelungsmittel zum Regeln der Lagen des ersten und des zweiten Ventilteils (12 und 13) in Abhängigkeit von den elektrischen Lage- und Drucksignalen und als Antwort auf ein elektrisches Anforderungssignal, das auf Betätigung durch eine Bedienungsperson bereitgestellt wird, um die Durchflußquerschnitte für den Strömungsmittelstrom durch die ersten und zweiten Ventilmittel (2 und 3) zwischen der ersten Betätigungsöffnung (4) und der Pumpen- oder Tanköffnung (15 oder 18) und zwischen der zweiten Betätigungsöffnung (5) und der Pumpen- oder Tanköffnung (16 oder 19) einzustellen, um die geforderte Steuerung des beweglichen Teils (6) der strömungsmittelbetätigten Vorrichtung (7) zu bewirken,
wobei ein Auswahlsignal, das durch einen Steuerrechner in Abhängigkeit von dem elektrischen Anforderungssignal geliefert wird, bewirkt, daß eine Auswahl darüber getroffen wird, ob Drucksteuerung oder Strömungssteuerung bewirkt werden soll; und wobei,
wenn die Strömungssteuerungs-Betriebsart ausgewählt wird, eine Steuerung bewirkt wird, indem bestimmt wird, ob der Strömungsmittelstrom zur ersten Betätigungsöffnung oder zur zweiten Betätigungsöffnung gerichtet ist, und indem der Querschnitt des Strömungsmittelstroms durch die in Betracht kommenden Ventilmittel eingestellt wird; und
alternativ, wenn die Drucksteuerungs-Betriebsart ausgewählt wird, die an beiden Betätigungsöffnungen angelegten Drücke gesteuert werden.

2. Anordnung nach Anspruch 1, wobei das erste und das zweite Ventilteil (12 und 13) Steuerkolben sind, die axial verschiebbar sind, um den Durchflußquerschnitt für einen Strömungsmittelstrom zwischen jeder Betätigungsöffnung und der Pumpen- oder Tanköffnung zu ändern.

3. Anordnung nach Anspruch 1 oder 2, wobei die Servo-Regelungsmittel elektrisch betreibbare Hilfssteuerventilmittel (44, 45) aufweisen, um die Lage eines jeden der Ventilteile (12, 13) zu regeln, indem einem Teil des Ventilteils eine gesteuerte Verdrängungsströmung eines Hilfssteuerströmungsmittels zugeführt wird, während gleichzeitig ein gesteuerter Abfluß eines Hilfssteuerströmungsmittels von einem anderen Teil des Ventilteils bewirkt wird, was ausreicht, um das Ventilteil in einer ersten Betriebsart in eine geforderte Lage zu bewegen, und indem die Verdrängungsströmung des Hilfssteuerströmungsmittels zum Ventilteil und der Abfluß des Hilfssteuerströmungsmittels nachfolgend unterbrochen wird, um das Ventilteil in einer zweiten Betriebsart in der geforderten Lage zu halten.

4. Anordnung nach Anspruch 3, wobei die Hilfssteuer-

ventilmittel ein erstes Hilfssteuerventil (44) zum Bewirken der axialen Bewegung des ersten Ventilteils (12) in beiden Richtungen und ein zweites Hilfssteuerventil (45) zum Bewirken der axialen Bewegung des zweiten Ventilteils (13) in beiden Richtungen unabhängig von der Bewegung des ersten Ventilteils (12) aufweisen.

5. Anordnung nach Anspruch 4, wobei jedes Steuerventil umfaßt: eine Betätigungsspule (35), die durch das Anlegen eines elektrischen Betätigungsstroms an die Spule relativ zu einem magnetischen Umformer (40) beweglich ist, und ein Ventilelement (36), das durch die Spule bewegt werden kann, um gleichzeitig die Zuführung eines Hilfssteuerströmungsmittels zu dem einen Teil des Ventilteils und den Abfluß eines Hilfssteuerströmungsmittels von dem anderen Teil des Ventilteils zu steuern.

6. Anordnung nach einem der Ansprüche 3, 4 oder 5, wobei eine Hilfssteuerdruck-Reguliereinrichtung (14) vorgesehen ist, um den Druck des Strömungsmittels zu regulieren, das den Hilfssteuerventilmitteln (44, 45) zugeführt wird, um den letztgenannten Druck im wesentlichen konstant zu halten.

7. Anordnung nach Anspruch 1 oder Anspruch 2, wobei die Servo-Regelungsmittel elektrisch betreibbare Hilfssteuerventile (44, 45) umfassen, um die Lage jedes der Ventilteile (12, 13) zu regeln, und
wobei eine Hilfssteuerdruck-Reguliereinrichtung (14) vorgesehen ist, um den Druck des Strömungsmittels zu regulieren, das den Hilfssteuerventilmitteln (44, 45) zugeführt wird, um den letztgenannten Druck im wesentlichen konstant zu halten.

8. Anordnung nach einem der vorhergehenden Ansprüche, wobei die Servo-Regelungsmittel in einer Drucksteuerungs-Betriebsart betreibbar sind, um die Lagen des ersten und des zweiten Ventilteils (12 und 13) zu regeln, als Antwort auf ein von einer Bedienungsperson betätigtes elektrisches Druckanforderungssignal, das einem geforderten Lastdruck entspricht, um einer der Betätigungsöffnungen (4 oder 5) einen gesteuerten Strömungsmittelstrom zuzuführen und einen gesteuerten Strömungsmittelabfluß aus der anderen Betätigungsöffnung (5 oder 4) zu bewirken, um eine Druckdifferenz in der strömungsmittelbetätigten Vorrichtung (7) zu erzeugen, die dem geforderten Lastdruck entspricht.

9. Anordnung nach einem der vorhergehenden Ansprüche, wobei die Servo-Regelungsmittel in einer Schwebe-Betriebsart betreibbar sind, um die Lagen des ersten und des zweiten Ventilteils (12 und 13) zu regeln, als Antwort auf ein von einer Bedienungsperson betätigtes, elektrisches Schwebe-Anforderungssignal, um Strömungsmittel aus beiden Betätigungsöffnungen (4 und 5) abgehen zu lassen, um frei schwebende Bewegung einer Last, die mit der strömungsmittelbetätigten Vorrichtung (7) gekoppelt ist, zu ermöglichen.

10. Anordnung nach einem der vorhergehenden Ansprüche, wobei die Servo-Regelungsmittel in einer Verdichtungs-Betriebsart betreibbar sind, um die Lagen des ersten und des zweiten Ventilteils (12 und 13) zu regeln, als Antwort auf ein von einer Bedienungsperson betätigtes, elektrisches Verdichtungs-Anforderungssignal, um rasch die Strömungsmittelstromrichtung zu den Betätigungsöffnungen (4 und 5) zu ändern, um eine Last, die mit der strömungsmittelbetätigten Vorrichtung (7) gekoppelt ist, vibrieren zu lassen.

11. Anordnung nach einem der vorhergehenden Ansprüche, wobei die Servo-Regelungsmittel in einer Druckentlastungs-Betriebsart betreibbar sind, die Lagen des ersten und des zweiten Ventilteils (12 und 13) zu regeln, als Antwort auf ein elektrisches Druckentlastungssignal, das dadurch ausgelöst wird, daß eine Druck-Überlast in einer der Betätigungsöffnungen (4, 5) von den Druckerfassungsmitteln (26, 27) erfaßt wird, um einen gesteuerten Strömungsmittelabfluß aus der einen Betätigungsöffnung zu ermöglichen, um den Druck abzubauen.

12. Anordnung nach einem der vorhergehenden Ansprüche, wobei die Druckerfassungsmittel umfassen: einen ersten Druckfühler (26) zum Liefern eines ersten elektrischen Drucksignals, das eine Aussage über den Strömungsmitteldruck in der ersten Betätigungsöffnung (4) liefert, einen zweiten Druckflihler (27) zum Liefern eines zweiten elektrischen Drucksignals, das eine Aussage über den Strömungsmitteldruck in der zweiten Betätigungsöffnung (5) liefert, einen dritten Druckfühler (28) zum Liefern eines dritten elektrischen Drucksignals, das eine Aussage über den Strömungsmitteldruck in der Pumpenöffnung (15, 16) liefert, und einen vierten Druckfühler (29) zum Liefern eines vierten elektrischen Drucksignals, das eine Aussage über den Strömungsmitteldruck in der Tanköffnung (18, 19) liefert, und
wobei die Servo-Regelungsmittel dafür eingerichtet sind, die Lagen des ersten und des zweiten Ventilteils (12, 13) in Abhängigkeit vom ersten, zweiten, dritten und vierten elektrischen Drucksignal zu regeln

13. Anordnung nach einem der vorhergehenden Ansprüche, wobei ein Steuerrechner (55) vorgesehen ist, um die durch eine Bedienungsperson betätigten elektrischen Anforderungssignale zu überwachen und eine Gesamtfunktionssteuerung der Servo-Regelungsmittel in Abhängigkeit von den Anforderungssignalen durchzuführen.

14. Anordnung nach einem der vorhergehenden Ansprüche, die einen modularen Aufbau hat und eine Reihenanordnung aus Ventilscheiben aufweist, die zusammengefügt und dafür angepaßt sind, eine Vielzahl von strömungsmitteldruckbetätigten Vorrichtungen zu steuern.

Revendications

1. Ensemble de vannes électrohydrauliques de commande par action proportionnelle (1) permettant de commander un dispositif actionné par l'écoulement bidirectionnel d'un fluide (7), comportant des premier et second passages et une partie mobile (6) disposée entre les premier et second passages sur laquelle doivent agir, sur ses côtés opposés, le fluide délivré au premier passage et le fluide délivré au second passage, l'ensemble de vannes comportant un premier point d'accès de commande (4) prévu pour permettre l'écoulement bidirectionnel du fluide entre l'ensemble de vannes et le premier passage du dispositif actionné par l'écoulement de fluide (7), et un second point d'accès de commande (5) prévu pour permettre l'écoulement bidirectionnel du fluide entre l'ensemble de vannes et le second passage du dispositif actionné par l'écoulement de fluide (7), un point d'accès (15, 16) à une pompe prévu pour permettre l'écoulement de fluide entrant d'une pompe hydraulique (17) à l'ensemble de vannes, et un point d'accès (18, 19) à un réservoir prévu pour permettre l'écoulement de fluide sortant de l'ensemble de vannes à un réservoir hydraulique (20), l'ensemble de vannes comprenant un premier moyen formant soupape (2) relié au premier point d'accès de commande (4), au point d'accès à la pompe (15) et au point d'accès au réservoir (18), de façon à commander la direction et la vitesse de l'écoulement de fluide entre le premier point d'accès de commande (4) et le point d'accès à la pompe (15), et entre le premier point d'accès de commande (4) et le point d'accès au réservoir (18), et un second moyen formant soupape (3) relié au second point d'accès de commande (5), au point d'accès à la pompe (16) et au point d'accès au réservoir (19), de façon à commander la direction et la vitesse de l'écoulement de fluide entre le second point d'accès de commande (5) et le point d'accès à la pompe (16), et entre le second point d'accès de commande (5) et le point d'accès au réservoir (19), le premier moyen formant soupape (2) comportant au moins un premier organe de soupape (12) qui est mobile de façon à faire varier la section transversale à travers laquelle s'écoule le fluide entre le premier point d'accès de commande (4) et le point d'accès à la pompe ou au réservoir (15 ou 18), et le second moyen formant soupape (3) comportant au moins un second organe de soupape (13) qui est mobile, indépendamment du mouvement du ou des premier(s) organe(s) de soupape (12), de façon à faire varier la section transversale à travers laquelle s'écoule le fluide entre le second point d'accès de commande (5) et le point d'accès à la pompe ou au réservoir (16 ou 19), des moyens de détection de position (23, 24) destinés à délivrer des signaux électriques de position représentatifs des positions réelles des premier et second organes de soupape (12 et 13), des moyens de détection de pression (26, 27 et 28) destinés à délivrer des signaux électriques de pression représentatifs des pressions de fluide au niveau des premier et second points d'accès de commande (4 et 5), et au niveau du point d'accès à la pompe (15, 16), et un moyen formant servocommande destiné à commander les positions des premier et second organes de soupape (12 et 13) en fonction des signaux électriques de position et de pression et en réponse à un signal électrique de demande délivré en réponse à l'actionnement d'un opérateur, en vue du réglage des sections transversales au travers desquelles s'écoule le fluide, à travers les premier et second moyens formant soupapes (2 et 3) entre le premier point d'accès de commande (4) et le point d'accès à la pompe ou au réservoir (15 ou 18), et entre le second point d'accès de commande (5) et le point d'accès à la pompe ou au réservoir (16 ou 19), ce qui effectue la commande désirée de la partie mobile (6) du dispositif actionné par l'écoulement de fluide (7),
où un signal sélectionné délivré par un ordinateur de contrôle en fonction dudit signal électrique de demande exige qu'on se décide si la commande de pression ou la commande de fluide doit être effectuée; et
où,
lorsque le mode de commande de pression est sélectionné, le contrôle est effectué en déterminant si l'écoulement du fluide se fait vers le premier point d'accès de commande ou le second point d'accès de commande et en réglant la section transversale par laquelle s'écoule le fluide par le biais d'un moyen formant soupape; ou alors, lorsque la commande de pression est sélectionnée, les pressions exercées sur les deux points d'accès de commande sont contrôlés.

2. Ensemble selon la revendication 1, dans lequel les premier et second organes de soupape (12 et 13) sont des tiroirs qui sont déplaçables axialement de façon à faire varier la section transversale à travers laquelle s'écoule le fluide entre chaque point d'accès de commande et le point d'accès à la pompe ou au réservoir.

3. Ensemble selon la revendication 1 ou 2, dans lequel le moyen formant servocommande comprend des moyens formant soupapes pilotes (44, 45) pouvant

fonctionner électriquement, destinés à commander la position de chacun des organes de soupape (12, 13) en appliquant un écoulement de déplacement commandé de fluide pilote sur une partie de l'organe de soupape, tout en appliquant en même temps une évacuation commandée de fluide pilote d'une autre partie de l'organe de soupape, de façon suffisante pour entraîner l'organe de soupape à une position désirée dans un premier mode de fonctionnement, et en interrompant ultérieurement ledit écoulement de déplacement de fluide pilote vers ledit organe de soupape et ladite évacuation de fluide pilote, de façon à maintenir ledit organe de soupape dans ladite position désirée dans un second mode de fonctionnement.

4. Ensemble selon la revendication 3, dans lequel les moyens formant soupapes pilotes comprennent une première soupape pilote (44) destinée à effectuer le déplacement axial bidirectionnel du premier organe de soupape (12), et une seconde soupape pilote (45) destinée à effectuer le déplacement axial bidirectionnel du second organe de soupape (13) indépendamment du déplacement du premier organe de soupape (12).

5. Ensemble selon la revendication 4, dans lequel chaque soupape pilote comprend une bobine de commande (35) mobile par rapport à un manchon magnétique (40) par l'intermédiaire de l'application d'un courant de commande électrique sur la bobine, et un élément de soupape (36), mobile sous l'action de la bobine, destiné à commander simultanément l'application de fluide pilote sur ladite une partie de l'organe de soupape et l'évacuation de fluide pilote de ladite autre partie de l'organe de soupape.

6. Ensemble selon l'une quelconque des revendications 3, 4 ou 5, dans lequel on dispose d'un régulateur de pression pilote (14) pour régler la pression du fluide délivré auxdits moyens formant soupapes pilotes (44, 45), de façon à maintenir la pression dernièrement citée sensiblement constante.

7. Ensemble selon la revendication 1 ou la revendication 2, dans lequel le moyen formant servocommande comprend des moyens formant soupapes pilotes pouvant fonctionner électriquement (44, 45) destinés à commander la position de chacun des organes de soupape (12, 13), et dans lequel on dispose d'un régulateur de pression pilote (14) pour régler la pression du fluide délivré auxdits moyens formant soupapes pilotes (44, 45), de façon à maintenir la pression dernièrement citée sensiblement constante.

8. Ensemble selon l'une quelconque des revendications précédentes, dans lequel le moyen formant servocommande peut fonctionner, dans un mode de commande de pression, de façon à commander les positions des premier et second organes de soupape (12 et 13) en réponse à un signal de demande électrique de pression lié à l'actionnement d'un opérateur correspondant à une pression de charge désirée, afin d'appliquer un écoulement de fluide commandé au niveau d'un des points d'accès de commande (4 ou 5) et une évacuation de fluide commandée de l'autre point d'accès de commande (5 ou 4), de façon à produire une différence de pression à travers le dispositif actionné par l'écoulement de fluide (7) correspondant à la pression de charge désirée.

9. Ensemble selon l'une quelconque des revendications précédentes, dans lequel le moyen formant servocommande peut fonctionner, dans un mode de flottaison, de façon à commander les positions des premier et second organes de soupape (12 et 13) en réponse à un signal de demande électrique de flottaison lié à l'actionnement d'un opérateur, afin d'évacuer le fluide des deux points d'accès de commande (4 et 5), de façon à permettre un mouvement de flottaison libre d'une charge couplée au dispositif actionné par l'écoulement de fluide (7).

10. Ensemble selon l'une quelconque des revendications précédentes, dans lequel le moyen formant servocommande peut fonctionner, dans un mode de compression, de façon à commander les positions des premier et second organes de soupape (12 et 13) en réponse à un signal de demande électrique de compression lié à l'actionnement d'un opérateur, afin d'alterner rapidement la direction de l'écoulement de fluide en direction des points d'accès de commande (4 et 5), de façon à faire vibrer une charge couplée au dispositif actionné par l'écoulement de fluide (7).

11. Ensemble selon l'une quelconque des revendications précédentes, dans lequel le moyen formant servocommande peut fonctionner, dans un mode de délestage de pression, de façon à commander les positions des premier et second organes de soupape (12 et 13) en réponse à un signal électrique de délestage de pression déclenché par la détection d'une surcharge de pression au niveau de l'un des points d'accès de commande (4, 5) par les moyens de détection de pression (26, 27), afin d'assurer une évacuation commandée du fluide dudit point d'accès de commande, de façon à délester la pression.

12. Ensemble selon l'une quelconque des revendications précédentes, dans lequel les moyens de détection de pression comprennent un premier capteur de pression (26) destiné à délivrer un premier signal électrique de pression représentatif de la pression de fluide au niveau du premier point d'accès de commande (4), un second capteur de pression (27) destiné à délivrer un second signal électrique de pression représentatif de la pression de fluide au niveau du second point d'accès de commande (5), un troisième capteur de pression (28) destiné à délivrer un troisième signal électrique de pression représentatif de la pression de fluide au niveau du point d'accès à la pompe (15, 16), et un quatrième capteur de pression (29) destiné à délivrer un quatrième signal électrique de pression représentatif de la pression de fluide au niveau du point d'accès au réservoir (18, 19), et dans lequel le moyen formant servocommande est conçu pour commander les positions des premier et second organes de soupape (12, 13) en fonction des premier, second, troisième et quatrième signaux électriques de pression.

13. Ensemble selon l'une quelconque des revendications précédentes, dans lequel on dispose d'un ordinateur de commande (55) pour surveiller les signaux de demande électriques liés à l'actionnement d'un opérateur et pour effectuer la commande du fonctionnement global du moyen formant servocommande en fonction des signaux de demande.

14. Ensemble selon l'une quelconque des revendications précédentes, qui a une construction modulaire et comprend une rangée de blocs soupapes assemblés les uns aux autres et conçus pour commander une pluralité de dispositifs actionnés par une pression de fluide.

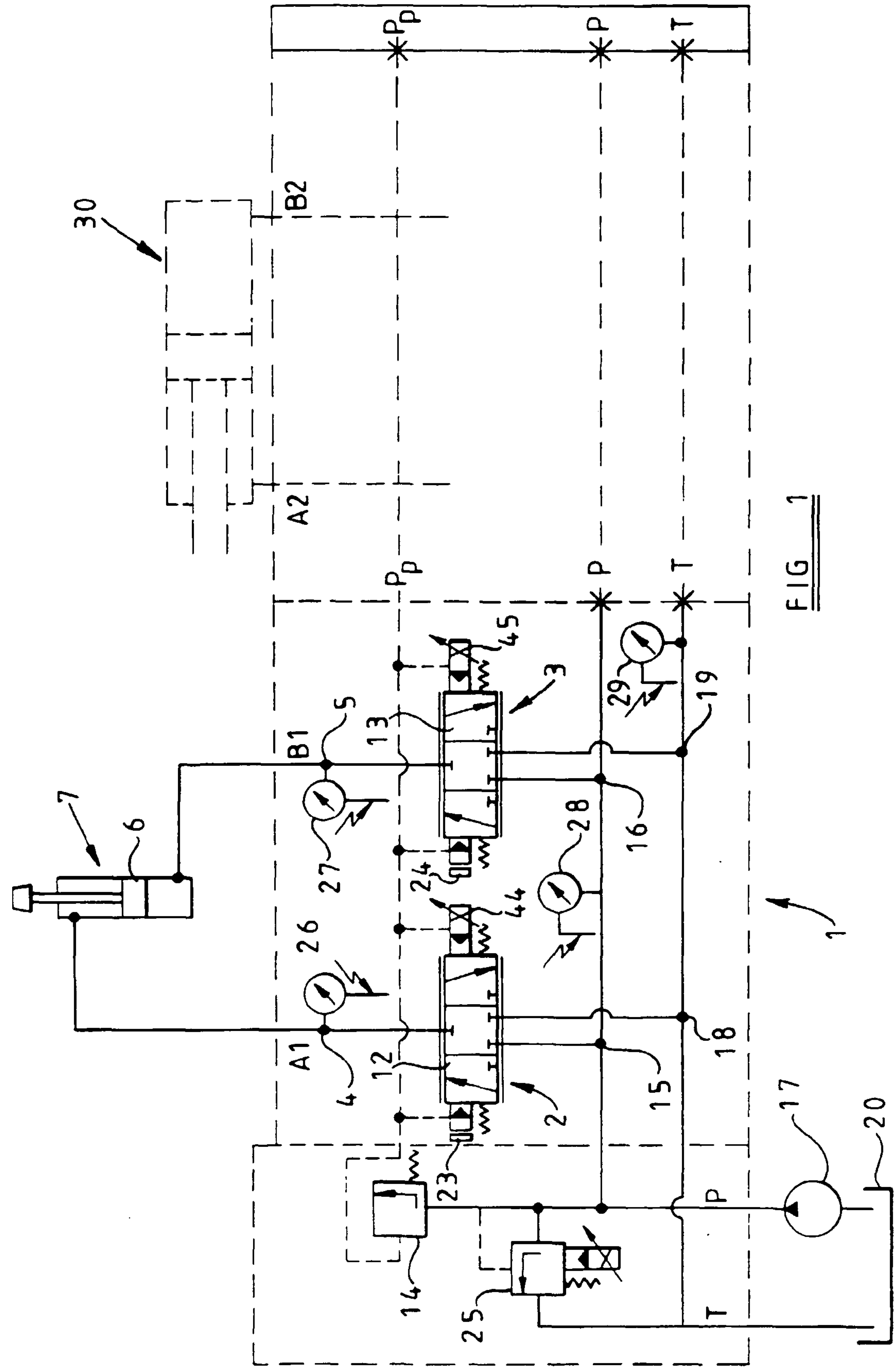

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FIG 1

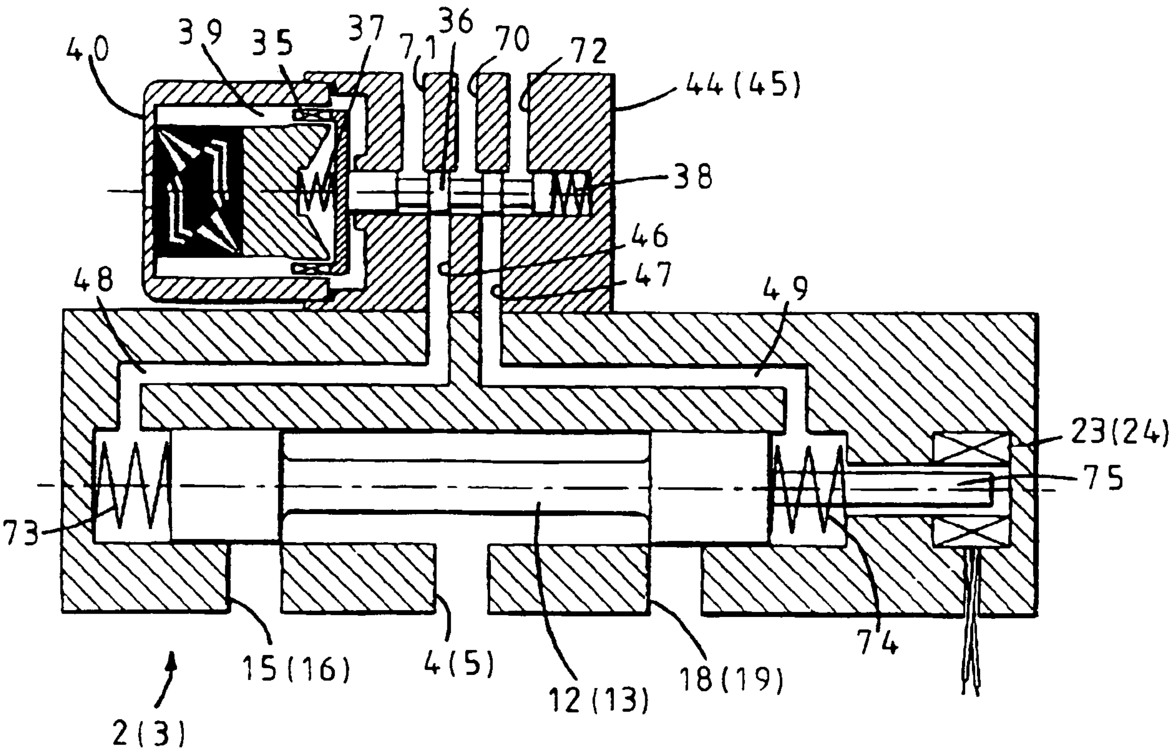
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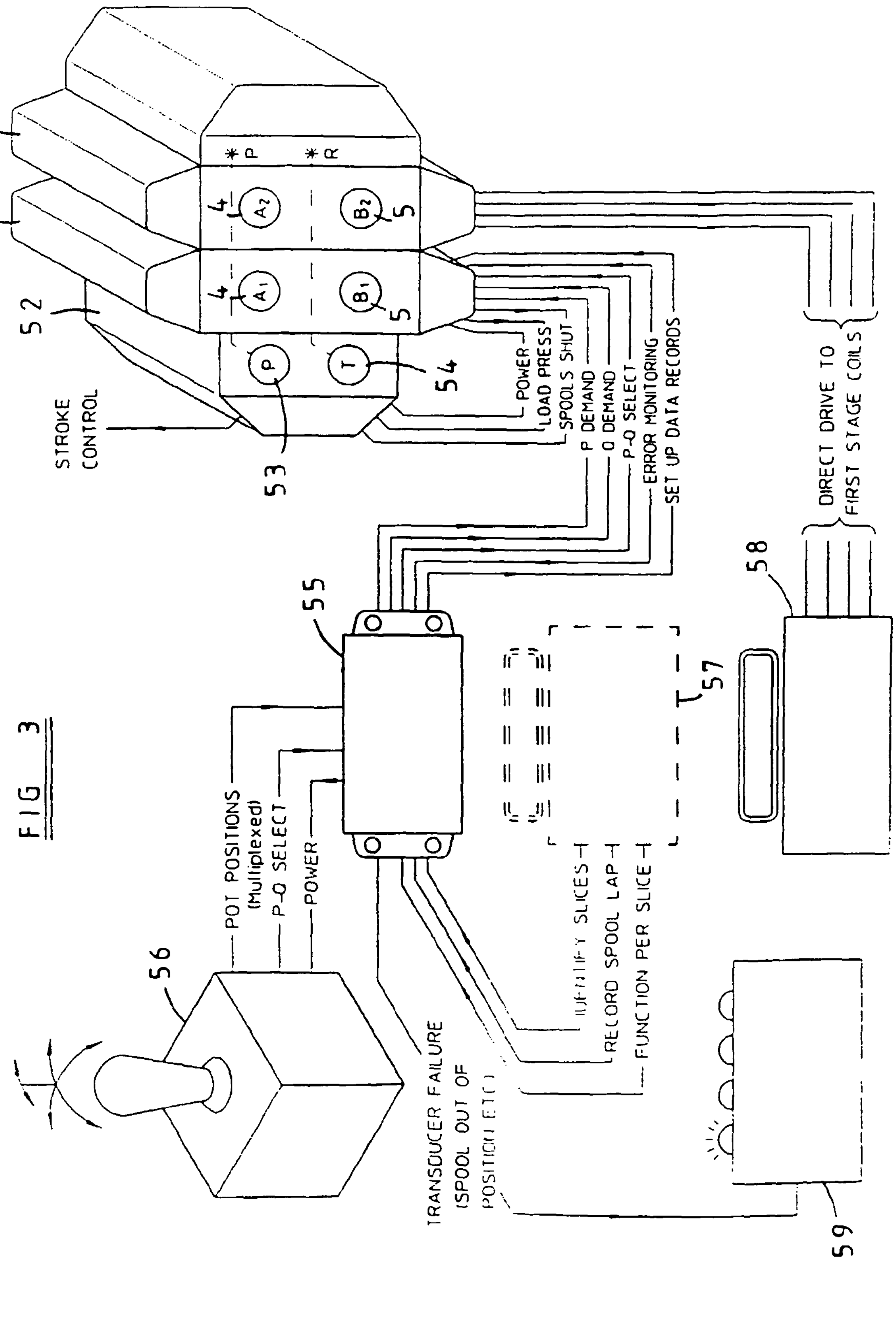
FIG 2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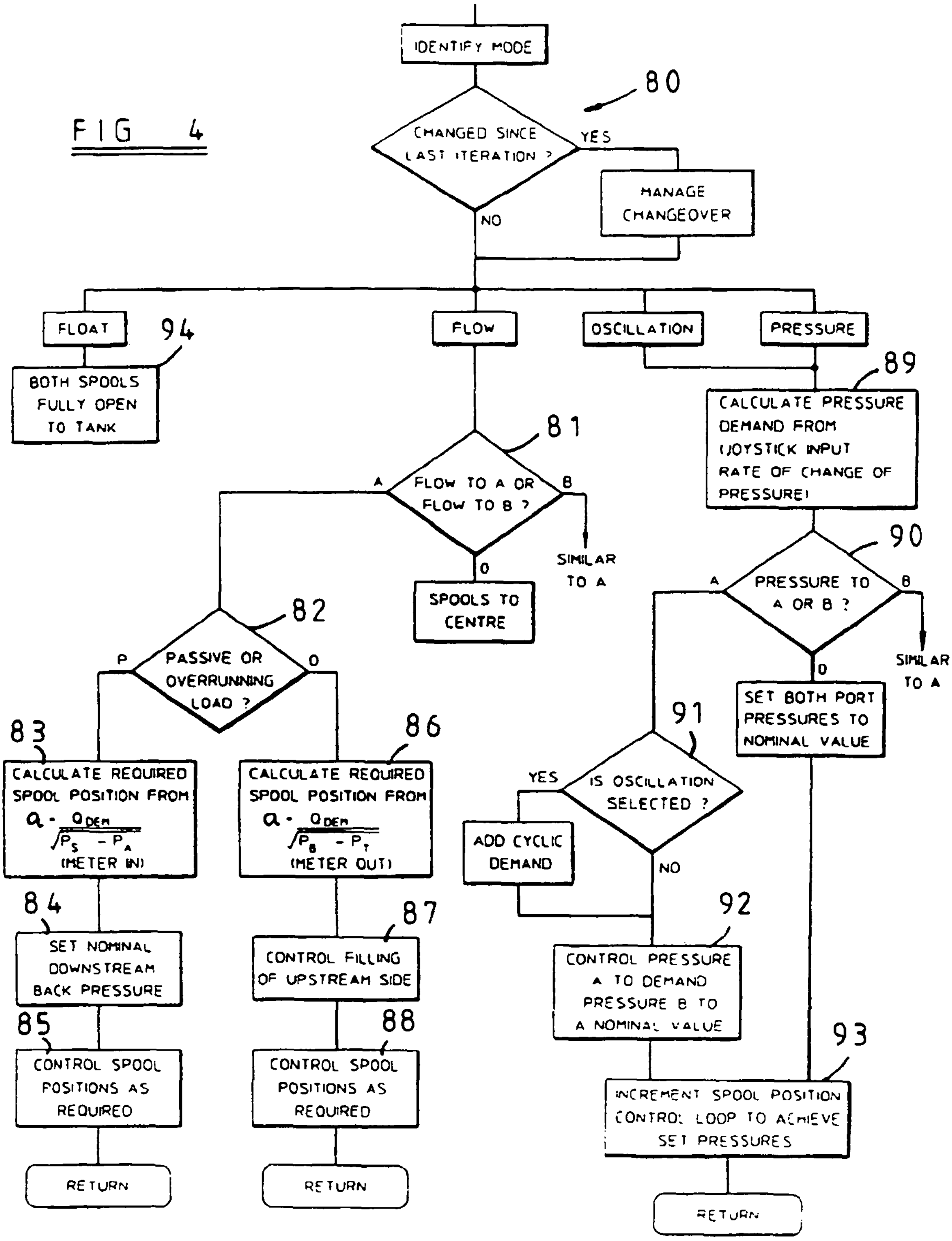
P-Q SELECT
ERROR MONITORING
SET UP DATA RECORDS
DIRECT DRIVE TO FIRST STAGE COILS
POT POSITIONS (Multiplexed)
P-Q SELECT
POWER
RECORD SPOOL LAP
FUNCTION PER SLICE
TRANSDUCER FAILURE

FIG 3

FIG 4


IDENTIFY MODE
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CHANGED SINCE LAST ITERATION ?
YES
MANAGE CHANGEOVER
NO
FLOAT
94
BOTH SPOOLS FULLY OPEN TO TANK
FLOW
OSCILLATION
PRESSURE
89
CALCULATE PRESSURE DEMAND FROM (JOYSTICK INPUT RATE OF CHANGE OF PRESSURE)
81
A
FLOW TO A OR FLOW TO B ?
B
SIMILAR TO A
0
SPOOLS TO CENTRE
90
A
PRESSURE TO A OR B ?
B
SIMILAR TO A
0
SET BOTH PORT PRESSURES TO NOMINAL VALUE
82
P
PASSIVE OR OVERRUNNING LOAD ?
O
83
CALCULATE REQUIRED SPOOL POSITION FROM $a \cdot \frac{Q_{DEM}}{\sqrt{P_S - P_A}}$ (METER IN)
86
CALCULATE REQUIRED SPOOL POSITION FROM $a \cdot \frac{Q_{DEM}}{\sqrt{P_B - P_T}}$ (METER OUT)
91
YES
IS OSCILLATION SELECTED ?
ADD CYCLIC DEMAND
NO
84
SET NOMINAL DOWNSTREAM BACK PRESSURE
87
CONTROL FILLING OF UPSTREAM SIDE
92
CONTROL PRESSURE A TO DEMAND PRESSURE B TO A NOMINAL VALUE
85
CONTROL SPOOL POSITIONS AS REQUIRED
88
CONTROL SPOOL POSITIONS AS REQUIRED
93
INCREMENT SPOOL POSITION CONTROL LOOP TO ACHIEVE SET PRESSURES
RETURN
RETURN
RETURN

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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