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(54) **Hydraulic pilot control system**

(57) This disclosure is directed towards a hydraulic pilot control system (28,79,82) which provides tactile feedback to a control lever (40) by using a hydraulic signal to provide the feedback. The hydraulic pilot control system (28,79,82) comprises a control lever (40), a hydraulic valve (33), a main hydraulic circuit (44) and a hydraulic feedback circuit. The hydraulic valve (33) is controlled by the control lever (40) and comprises at least on valve actuator responsive to movement of the control lever (40) for controlling pressurised hydraulic fluid in the main hydraulic circuit (44). The hydraulic feedback circuit is configured to provide a feedback signal indicative of a load to which the main hydraulic circuit (44) is subjected. The feedback signal is used to provide tactile feedback to the control lever (40).

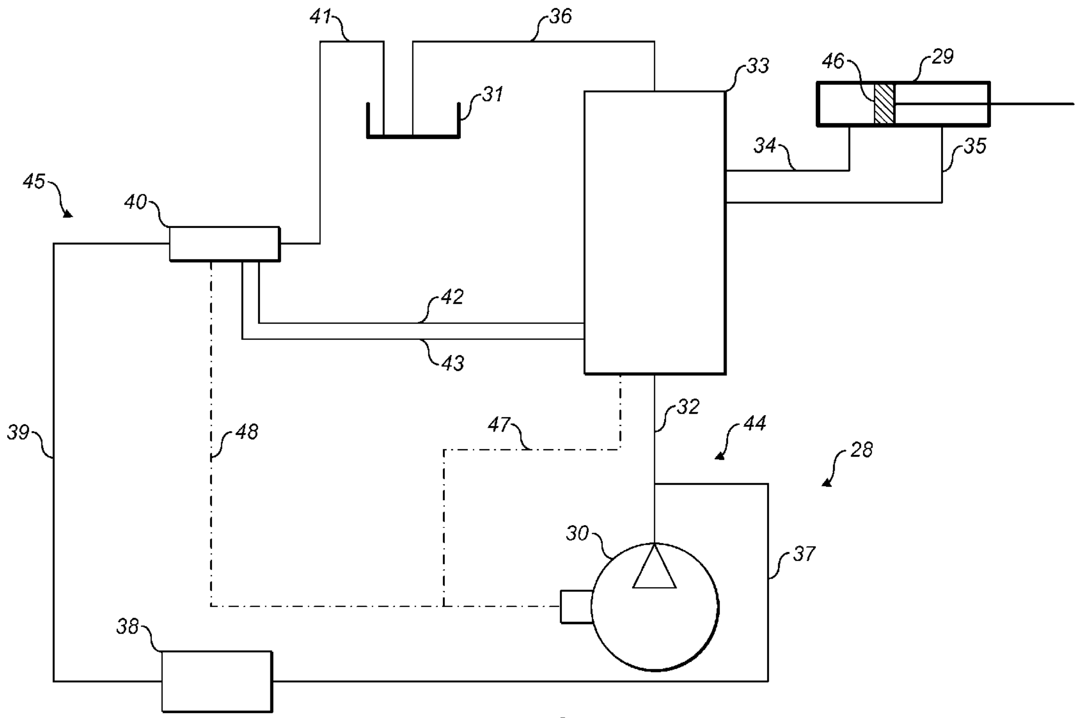


FIG. 2



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## Description

### Technical Field

**[0001]** This disclosure is directed towards a hydraulic pilot control system which provides tactile feedback to a control lever by using a hydraulic signal to provide the feedback.

### Background

**[0002]** Hydraulic systems are commonly employed in the control of work machines, such as backhoes, excavators, loaders and the like and the associated work tools, such as booms, buckets, diggers and the like. An operator manipulates a control lever, such as a joystick, to control the movement of the machine or its work tool(s). Such control levers can be used, using pneumatic, electrical or hydraulic means, to actuate the components of the main hydraulic system of the machine, such as valves or pumps, to direct hydraulic fluid to the actuators of the main hydraulic system which are attached to, and therefore may move, the work tools. Further control circuitry, such as load sense systems, may also be included in order that the force provided by the hydraulic fluid to the actuators is automatically adjusted to match the load required by the work tools to perform the movements indicated by the control lever.

**[0003]** As a result, the control lever may be fluidly separated from the main hydraulic system and the operator of the control lever may not receive feedback regarding the load required by the work tool to perform a requested movement or action. This may be a disadvantage as the operator may not be immediately aware that the movement or action requested through the control lever requires a significantly high or low fluid load. For example, an operator controlling an earth moving machine, having a bucket connected to the machine via a series of arms or booms, may not be aware that the bucket has struck a hard object, such as a gas pipe or rock, which they may not wish to dig through. Tactile feedback can be provided to the control lever such that the effort required to manipulate the control lever varies in relation to the force applied by the hydraulic fluid to the actuators.

**[0004]** An example of a known hydraulic system in which tactile feedback is provided to a control lever is disclosed in US-B-6,508,058. In the system described therein a control lever, comprising a series of linked arms, is hydraulically connected to a pilot operated control valve. This pilot operated control valve adjusts the flow of hydraulic fluid around a main hydraulic circuit, thereby controlling a load bearing hydraulic actuator. The hydraulic actuator is also fluidly connected to two feedback drivers. These feedback drivers are mechanically connected to one of the linked arms, thereby translating the effort required to move the hydraulic actuator back to the operator.

**[0005]** However, the feedback drivers are connected to an arm of the control lever and therefore the feedback cannot be provided to a control lever which does not incorporate any arms. Furthermore, the disclosed system provides both position and force feedback simultaneously to the control lever, such that the position of the control lever represents the position of the hydraulic actuator. As a result it cannot be applied to a system in which the control lever returns to its neutral position upon release whilst the hydraulic actuator remains in position.

**[0006]** A further disadvantage of the system of US-B-6,508,058 is that the feedback signal initiates in the high pressure circuit. If the pressure of the hydraulic fluid in the actuators is significantly high, additional hydraulic feedback circuitry must be provided to reduce the pressure in the feedback drivers to a level that does not impinge upon the operator's movements of the control lever. Additionally, significant energy losses may arise as the hydraulic fluid is drawn from the main hydraulic circuit and fed into the feedback drivers.

### Summary

**[0007]** According to one aspect of the present disclosure there is provided a hydraulic pilot control system comprising: a control lever; a hydraulic valve controlled by the control lever comprising: at least one valve actuator responsive to movement of the control lever for controlling pressurised hydraulic fluid in a main hydraulic circuit; a hydraulic feedback circuit configured to provide a feedback signal indicative of a load to which the main hydraulic circuit is subjected; wherein the feedback signal is used to provide tactile feedback to the control lever.

**[0008]** This disclosure further provides a method of controlling a hydraulic pilot control system having a manually operable control lever wherein; movement of the control lever controls a valve actuator which is configured to control pressurised hydraulic fluid in a main hydraulic circuit; generating a hydraulic feedback signal indicative of a load to which the main hydraulic circuit is subjected; and using the hydraulic feedback signal to provide tactile feedback to the control lever.

**[0009]** By way of example only, embodiments of a hydraulic system which provides tactile feedback to an operator are now described with reference to, and as shown in, the accompanying drawings.

### Brief Description of the Drawings

**[0010]**

Figure 1 is a side elevation of one type of hydraulic machine which may be controlled by the hydraulic control system of this disclosure;

Figure 2 is a schematic representation of one embodiment of the hydraulic control system of this disclosure;

Figure 3 is a cross-sectional end elevation of an embodiment of a hydraulically operated control lever of the hydraulic control system of Figure 2;

Figure 4 is a schematic representation of a further embodiment of the hydraulic control system of this disclosure which provides feedback to a hydraulically operated control lever; and

Figure 5 is a schematic representation of yet another embodiment of the hydraulic control system of this disclosure which provides feedback to a non-hydraulically operated control lever.

## Detailed description

**[0011]** The present disclosure is generally directed towards a hydraulic control system for providing tactile feedback to a control lever which is used to control one or more actuators in a hydraulic circuit. The feedback may be provided by a load sense hydraulic signal, the pressure of which is related to the hydraulic fluid pressure required in the actuators to perform a motion demanded by the control lever.

**[0012]** Figure 1 illustrates one embodiment of a hydraulic machine 10 which includes a hydraulic system that controls the position of a work tool 11 and a work implement 12. In this exemplary embodiment the machine 10 is an excavator. However, the tactile feedback system of the present disclosure may be used in a wide range of machines 10, such as, for example, backhoe loaders, track loaders, front shovels, bulldozers and wheel loaders. The work implement 12 of this exemplary embodiment is a bucket. However, the work implement 12 may be any type of implement controlled by a hydraulic system such as, for example, shovels, grapples, hammers, shears, saws, forks, augurs or material handling arms.

**[0013]** The work tool 11 comprises a work implement 12 and means for attachment to the main body 13 of the machine 10. The attachment means may comprise a boom 14 and a stick 15. The work implement 12 may be pivotally attached to the stick 15 by means of a coupling which allows the work implement 12 to rotate relative to the stick 15 about pivot point 16, in a motion indicated by arrow 17. The stick 15 may be pivotally attached to the boom 14 in a manner which allows the stick 15 to rotate relative to the boom 14 about pivot point 18, in a motion indicated by arrow 19. The boom 14 may be pivotally attached to the main body 13 in a manner which allows the boom 14 to rotate relative to the main body 13 about pivot point 20, in a motion indicated by arrow 21. Movement of the boom 14, the stick 15 and the work implement 12 is effected by hydraulic actuators 22, 23, 24. The actuators 22, 23, 24 illustrated in Figure 1 are piston type hydraulic actuators. However, the actuators 22, 23, 24 may be of any hydraulically powered type.

**[0014]** The main body 13 of the machine 10 may sit on a rotational assembly 25 which is connected to a base 26. The base 26 may be permanently or temporarily fixed to the ground or it may include apparatus which allows the machine 10 to move along the ground such as, for example, tracks or wheels. The rotational assembly 25 allows the main body 13 to rotate about a vertical axis 27, thereby enabling three dimensional movement of the work implement 12. Three dimensional movement of the work implement 12 may also be achieved by allowing multiaxial motion of the boom 14, the stick 15 and the work implement 12 at each of the pivot points 16, 18, 20. This may require more than one hydraulically powered actuator at each of the pivot points 16, 18, 20.

**[0015]** The actuators 22, 23, 24 (and any further actuators which may be included to implement three dimensional motion of the boom 14, the stick 15 and work implement 12) may be controlled by one or more hydraulic systems. An embodiment of a hydraulic pilot control system 28 which may be used to control a single actuator 29 is shown in Figure 2.

**[0016]** In this exemplary embodiment a pump 30 is fluidly connected to a hydraulic reservoir 31 (this connection is not shown in Figure 2). The pump 30 is also fluidly connected, by means of a conduit 32, to a hydraulic valve 33, which may be a pilot operated valve. Conduits 34, 35 fluidly connect each end of the actuator 29 to the hydraulic valve 33, and the supply of hydraulic fluid to the actuator 29 is controlled by valve actuators in the hydraulic valve 33. The valve actuators may be spools and the position of the spools may control the supply of hydraulic fluid to the actuator 29. The hydraulic valve 33 is fluidly connected to the hydraulic reservoir 31 via a conduit 36.

**[0017]** The pump 30 is also fluidly connected, by means of a conduit 37, to a self-regulating pressure reducing valve 38, which, in turn, is connected via a conduit 39, to a control lever 40 which may be hydraulically operated. The control lever 40 may be manually operable and may be of any type, such as, for example, a joystick, a steering wheel, a push button, a series of push buttons or a foot pedal. The control lever 40 is fluidly connected, by means of a conduit 41, to the hydraulic reservoir 31. A further fluid connection is provided between the hydraulic valve 33 and the control lever 40 by conduits 42, 43.

**[0018]** The conduits 32, 34, 35, 36, 37, the actuator 29 and the hydraulic valve 33 form a main hydraulic circuit 44 which may operate at a high pressure. By maintaining a high pressure in the main hydraulic circuit 44, for example over 15 MPa, the actuator 29 is able to apply a high force to the work tool 11.

**[0019]** The conduits 39, 41, 42, 43 and the control lever 40 form a hydraulic pilot circuit 45 which may operate at a low pressure. The self-regulating pressure reducing valve 38 may be specified to ensure that the pressure of the hydraulic fluid in the hydraulic pilot circuit 45 is reduced to a constant level, for example below 5 MPa, at which an operator of the control lever 40 may manipulate the control lever 40 with relative ease and without being fatigued by the manipulation. The self-regulating pressure reducing valve 38 also acts to ensure that the pressure of the hydraulic fluid supplied to the control lever 40 remains constant when the output of the pump 30 is varied.

**[0020]** The control lever 40 controls the flow of hydraulic fluid in the conduits 42, 43, which in turn controls the the valve actuators in the hydraulic valve 33. The valve actuators control the flow of hydraulic fluid in the main hydraulic circuit 44 and therefore control the position of a piston 46 inside the actuator 29. Thus the control lever 40 can be manipulated to control the position of the piston 46 of the actuator 29.

**[0021]** To overcome a resistance experienced by the piston 46, as the piston 46 performs an action demanded by the control lever 40, the pressure of the hydraulic fluid in the actuator 29 may be increased by increasing the output of the pump 30. It is therefore useful to provide a form of automatic control of the pump 30 output and a method for doing so that is well known to those skilled in the art is by the inclusion of a load sense circuit. Generally, the pressure of a load sense hydraulic signal is indicative of, and may be in a mathematical relationship with, the pressure in the main hydraulic circuit 44 or the pressure difference between the conduits 34, 35 connecting the actuator 29 to the hydraulic valve 33. The mathematical relationship may be of any type, including proportional, inversely proportional, exponential, trigonometric, polynomial, logarithmic, nonlinear and linear. One method of generating the load sense hydraulic signal is by measuring the pressure drop across an orifice, which may be the hydraulic valve 33.

**[0022]** In this embodiment a load sense hydraulic signal, consisting of hydraulic fluid, is fed back from the hydraulic valve 33 to the pump 30 via a load sense conduit 47. The load sense hydraulic signal may therefore be a feedback signal which is indicative of the load to which the main hydraulic circuit 44 and piston 46 are subjected. The output of the pump 30 will be related to the pressure of the load sense hydraulic signal. The pressure of the load sense hydraulic signal may be detected by a pressure sensor and, using electrical circuits, the drive power supplied to the pump 30 may be adjusted or the swash plate angle within the pump 30 may be adjusted. Alternatively, the swash plate angle within the pump 30 may be adjusted by the pressure of the load sense hydraulic signal using mechanical means.

**[0023]** Due to the self regulating pressure reducing valve 38, the pressure in the hydraulic pilot circuit 45 is not related to the pressure in the main hydraulic circuit 44. Therefore the operator of the control lever 40 does not receive feedback regarding the force applied by the actuator 29 to perform a demanded action. In the present disclosure feedback may be provided using the load sense hydraulic signal. In the embodiment shown in Figure 2, a load sense conduit 48 extends from the load sense conduit 47 and transfers the load sense hydraulic signal to the control lever 40. The pressure of the load sense hydraulic signal may be used to provide a form of tactile feedback to the control lever 40.

**[0024]** During operation of the hydraulic pilot control system 28, pump 30 supplies control lever 40 with hydraulic fluid via the conduits 37, 39 and the self-regulating pressure reducing valve 38. When the control lever 40 is manipulated by an operator the hydraulic fluid flows from the control lever 40 to the hydraulic valve 33 via the conduit 42 and returns from the hydraulic valve 33 to the control lever 40 via the conduit 43. The movement of the hydraulic fluid along the conduits 42, 43 causes the valve actuators inside the hydraulic valve 33 to move into an 'open' position. Hydraulic fluid is also supplied, via the conduit 32, to the hydraulic valve 33. Since the valve actuators are in the 'open' position, the pressure of the hydraulic fluid in the conduit 35 and on one side of the piston 46 increases and the piston 46 of the actuator 29 moves, which in turn adjusts the position of the work tool 11. The hydraulic fluid on the opposite side of the piston 46 and in the conduit 34 is forced along conduit 36 towards the hydraulic reservoir 31.

**[0025]** If the movement of the piston 46 of the actuator 29 is resisted, the pressure of the load sense hydraulic signal will change and this will induce a change in the output of the pump 30. Whilst a resistance exists against the movement of the piston 46 tactile feedback will be provided to the control lever 40. When there is no resistance to the movement of the piston 46 the tactile feedback provided to the control lever 40 will change.

**[0026]** Once the operator considers that the work tool 11 is in place the control lever 40 may be adjusted so that the valve actuators in the hydraulic valve 33 return to a 'closed' position and the hydraulic fluid remains in the conduits 34, 35 and the actuator 29. As a result the piston 46 and thus the work tool 11 may remain in position upon release of the control lever 40. Alternatively, if the valve actuators of the hydraulic valve 33 are arranged as such, the piston 46 may return to a neutral position.

**[0027]** In this disclosure the load sense hydraulic signal may provide feedback to the control lever 40 by any means. One embodiment of the provision of feedback to the control lever 40 is shown in Figure 3, wherein the control lever 40 is a hydraulic pilot joystick 49. Figure 3 illustrates the hydraulic pilot joystick 49 in a neutral position, in which a handle 50 is positioned such that no motion of the work tool 11 is being demanded.

**[0028]** In the neutral position two plungers 51, 52 are supported by a housing 53 and by a first pair of pistons 54, 55 located in piston chambers 56, 57 within the housing 53. Springs 58, 59, placed in the piston chambers 56, 57, are supported by a second pair of pistons 60, 61 and are used to bias the first pair of pistons 54, 55 into a first position, thereby holding the plungers 51, 52 in the neutral position shown in Figure 3. Control rods 62, 63 are connected to lower ends of the plungers 51, 52 and both are able to move vertically.

**[0029]** Load sense chambers 64, 65 contain hydraulic fluid which supports the second pair of pistons 60, 61. Seals 66, 67, for example ring seals, may be placed in between the edges of the second pair of pistons 60, 61 and the walls of the piston chambers 56, 57 and load sense chambers 59, 60 in order that hydraulic fluid from the load sense chambers 64, 65 does not leak into the piston chambers 56, 57. The hydraulic fluid is supplied to the load sense chambers 64, 65 via conduits 68, 69 and this provides a load sense hydraulic signal. With reference to the embodiments shown in Figure 2 and 3, conduits 68, 69 may be supplied from load sense conduit 48.

**[0030]** Hydraulic fluid from the conduit 39 of the hydraulic pilot circuit 45 is supplied to an inlet chamber 70 via an inlet port 71. The hydraulic fluid flows from the hydraulic pilot joystick 49 from an outlet chamber 72 via an outlet port (not shown) to the conduit 41 of the hydraulic pilot circuit 45. The conduits 42, 43, which allow hydraulic fluid to flow between the control lever 40 and the hydraulic valve 33, are connected to control ports 73, 74 in the main housing 53 of the hydraulic pilot joystick 49. In the neutral position shown, hydraulic fluid from conduits 42, 43 may flow into a control rod chamber 75, 76 and into the outlet chamber 72.

**[0031]** When the handle 50 is moved from the neutral position, one of the plungers 51, 52 is pressed into the main housing 53 by a slider 77, and the slider 77 and handle 50 rotate around a pivot point 78. When one of the plungers 51, 52 moves downwards the corresponding control rod 62, 63 moves downwards and closes the connection between the corresponding control rod chamber 75, 76 and the outlet chamber 72. When the plunger 51, 52 is pressed down further, the control rod chamber 75, 76 connects to the inlet chamber 70 and hydraulic fluid flows out of the control port 73, 74 and into the conduit 42, 43 to the hydraulic valve 33. As a result, the valve actuators in the hydraulic valve 33 and the piston 46 of the actuator 29 move.

**[0032]** When the pressure of the load sense hydraulic signal changes the pressure of the hydraulic fluid in the load sense chambers 64, 65 also changes and the second pair of pistons 60, 61 rises or falls. As a result, the springs 58, 59 are compressed, such that the force applied rises linearly with the corresponding compression of the spring. Therefore, if the springs 58, 59 are compressed by the second pair of pistons 60, 61, the force imposed upon the first pair of pistons 54, 55 and therefore the plungers 51, 52 by the springs 58, 59 rises. The operator of the hydraulic pilot joystick 49 thus experiences increased resistance to the movement of the handle 50, thereby receiving tactile feedback of the force applied by the piston 46 of the actuator 29 as a result of the movement demanded.

**[0033]** A further embodiment of a hydraulic pilot control system 79 for the provision of tactile feedback to the control lever 40 is shown in Figure 4. In this embodiment a load sense conduit 80 draws the load sense hydraulic signal from the load sense conduit 47 and feeds the load sense hydraulic signal to a variable orifice valve 81. The variable orifice valve 81 is located in the conduit 41 which returns fluid from the control lever 40 to the hydraulic reservoir 31. The load sense hydraulic signal from the load sense conduit 80 adjusts the size of the orifice of the variable orifice valve 81. The adjustment of the size of the orifice enables the control of the pressure of the hydraulic fluid in the hydraulic pilot circuit 45. Since the operator must overcome the pressure in hydraulic pilot circuit 45 to move the control lever 40, the resistance to the movement of the control lever 40 may be controlled.

**[0034]** For example, if the pressure of the load sense hydraulic signal in the load sense conduit 80 increases, the orifice size of the variable orifice valve 81 reduces and thereby increases the pressure of the hydraulic fluid in the hydraulic pilot circuit 45. The resistance to the movement of the control lever 40 increases and the operator therefore receives tactile feedback regarding the force applied by the actuator 29 to perform a demanded motion.

**[0035]** A further embodiment of a hydraulic pilot control system 82 for the provision of tactile feedback to a control lever 83 is shown in Figure 5. In this embodiment, the control lever 83 may be hydraulically operated or may be electrically operated. The control lever 83 may be manually operated and may be of any type, such as, for example, a joystick, a steering wheel, a push button, a series of push buttons or a foot pedal. The control lever 83 may actuate the hydraulic valve 33 by using an electric circuit, which may include the use of electric solenoids to actuate the valve actuators in the hydraulic valve 33.

**[0036]** The load sense hydraulic signal may be fed to the control lever 83 by a load sense conduit 48. A sensory device, such as a pressure sensor, may be integrated in the control lever 83 to detect the pressure of the load sense hydraulic signal in the conduit 48 and convert this information into an electrical signal. This electrical signal may be used to drive a motor with an off-centred mass connected to its output. The motor and off-centred mass may be placed in the control lever 83 and when the motor is switched on by the electrical signal the off-centred mass will rotate and the control lever 83 will vibrate. The magnitude and frequency of the vibrations may be adjusted by adding a control circuit between the sensor and the motor. Therefore feedback relating to the pressure of the load sense hydraulic signal, and therefore the force required by the actuator 29 to perform a requested motion, may be provided to the operator in the form of vibrations.

**[0037]** In a further embodiment, the sensory device may be integrated in the load sense conduit 47 or the hydraulic valve 33. The electrical signal generated by the sensory device may be transmitted to the control lever 83 via an electronic circuit or wirelessly using a transmitter and a receiver. This embodiment allows the control lever 83 to be placed at a distance from the actuator 29 and may even be placed externally to the work tool 11.

**[0038]** In the exemplary embodiment disclosed herein only a single control lever 40, 83 and single actuator 29 have been described. However, it is common for the hydraulic systems of a machine 10 with a complex arrangement of work tools 11 to contain more than one actuator 29, more than one control lever 40, 83 and possible more than one hydraulic pilot control system 28, 79, 82. The embodiments discussed herein may be adapted for complex work tools 11 by using a hydraulic valve 33 with valve actuators adapted to accept multiple inputs (to receive signals from the control levers) and multiple outputs (to control the actuators).

Industrial Applicability

**[0039]** The disclosed system for providing tactile feedback to a control lever 40, 83 may be used in a range of hydraulic operated work tools 11.

**[0040]** Embodiments of the disclosed system may allow for the feedback circuitry to be separate from the high pressure hydraulics used to move the work tool 11. The tactile feedback provided to the control lever 40, 83 may still be representative of the pressure in the high pressure hydraulics used to move the work tool 11.

## Claims

**1.** A hydraulic pilot control system (28, 79, 82) comprising:

a control lever (40);
a hydraulic valve (33) controlled by the control lever (40) comprising:

at least one valve actuator responsive to movement of the control lever (40) for controlling pressurised hydraulic fluid in a main hydraulic circuit (44);

a hydraulic feedback circuit configured to provide a feedback signal indicative of a load to which the main hydraulic circuit (44) is subjected;
wherein the feedback signal is used to provide tactile feedback to the control lever (40).

**2.** The hydraulic pilot control system (28, 79, 82) of claim 1 further comprising a pump (30) configured to supply hydraulic fluid to the main hydraulic circuit (44), wherein an output of the pump (30) is controlled by the feedback signal.

**3.** The hydraulic pilot control system (28, 79) of claims 1 and 2 wherein the control lever (40) is fluidly connected to a hydraulic pilot circuit (45) which is at a lower pressure than the pressure of the main hydraulic circuit (44).

**4.** The hydraulic pilot control system (28, 79) of claim 3 wherein the hydraulic pilot circuit (45) is fluidly connected to the main hydraulic circuit (44) via a self-regulating pressure reducing valve (38).

**5.** A hydraulic pilot control system (28, 82) as claimed in any one of the preceding claims further comprising at least one spring (58, 59) biasing the control lever (40) towards a neutral position and the feedback signal is used to modify the spring (58, 59) compression to provide the tactile feedback to the control lever (40).

**6.** The hydraulic pilot control system (28, 82) of claim 5 wherein each spring (58, 59) is supported by a piston (66, 67) and the feedback signal moves the piston (66, 67) to adjust the compression of the spring (58, 59).

**7.** A hydraulic pilot control system (79) as claimed in claims 1 to 4 further comprising a variable orifice valve (81) located in a conduit (41) between the control lever (40) and a hydraulic reservoir (31) and the feedback signal is used to vary the size of the variable orifice valve (81) to provide a variable back pressure to the control lever (40) to provide the tactile feedback to the control lever (40).

**8.** A hydraulic pilot control system (28, 82) as claimed in claims 1 to 4 further comprising a vibrating device located in the control lever (40), and the feedback signal is used to activate the vibrating device to provide the tactile feedback to the control lever (40).

**9.** The hydraulic pilot control system (28, 82) of claim 8 wherein the vibrating device comprises a motor and an eccentric weight attached to the output shaft of the motor.

**10.** The hydraulic pilot control system (28, 79, 82) of any one of the preceding claims wherein the control lever (40) is a joystick, a steering wheel, a push button, a series of push buttons or a foot pedal.

**11.** The hydraulic pilot control system (28, 79, 82) of any one of the preceding claims wherein the main hydraulic circuit (44) includes an actuator (29) to which hydraulic fluid is supplied by the hydraulic valve (33) and upon which the load is subjected.

**12.** The hydraulic pilot control system (28, 79, 82) claimed in any one of the preceding claims wherein the feedback signal is generated by a pressure drop across part of the main hydraulic circuit (44).

**13.** The hydraulic pilot control system (28, 79, 82) of claims 11 and 12 wherein the pressure drop is across the conduits (34, 35) which fluidly connect the actuator (29) to the hydraulic valve (33).

**14.** A hydraulic pilot control system (28, 79, 82) as claimed in any one of the preceding claims which is used to control the position of a work implement (12) on a hydraulic machine (10).

**15.** A method of controlling a hydraulic pilot control system (28, 79, 82) having a manually operable control lever (40) wherein;
movement of the control lever (40) controls a valve actuator which is configured to control pressurised hydraulic fluid in a main hydraulic circuit (44);
generating a hydraulic feedback signal indicative of a load to which the main hydraulic circuit (44) is subjected; and
using the hydraulic feedback signal to provide tactile feedback to the control lever (40).

**16.** A method as claimed in claim 15 wherein the hydraulic feedback signal modifies the compression of a spring (58, 59).

**17.** A method as claimed in claim 15 wherein the hydraulic feedback signal modifies the orifice size of a variable orifice valve (81) located in a conduit (41) between the control lever (40) and a hydraulic reservoir (31).

**18.** A method as claimed in claim 15 wherein the hydraulic feedback signal activates a vibrating device in the control lever (40).

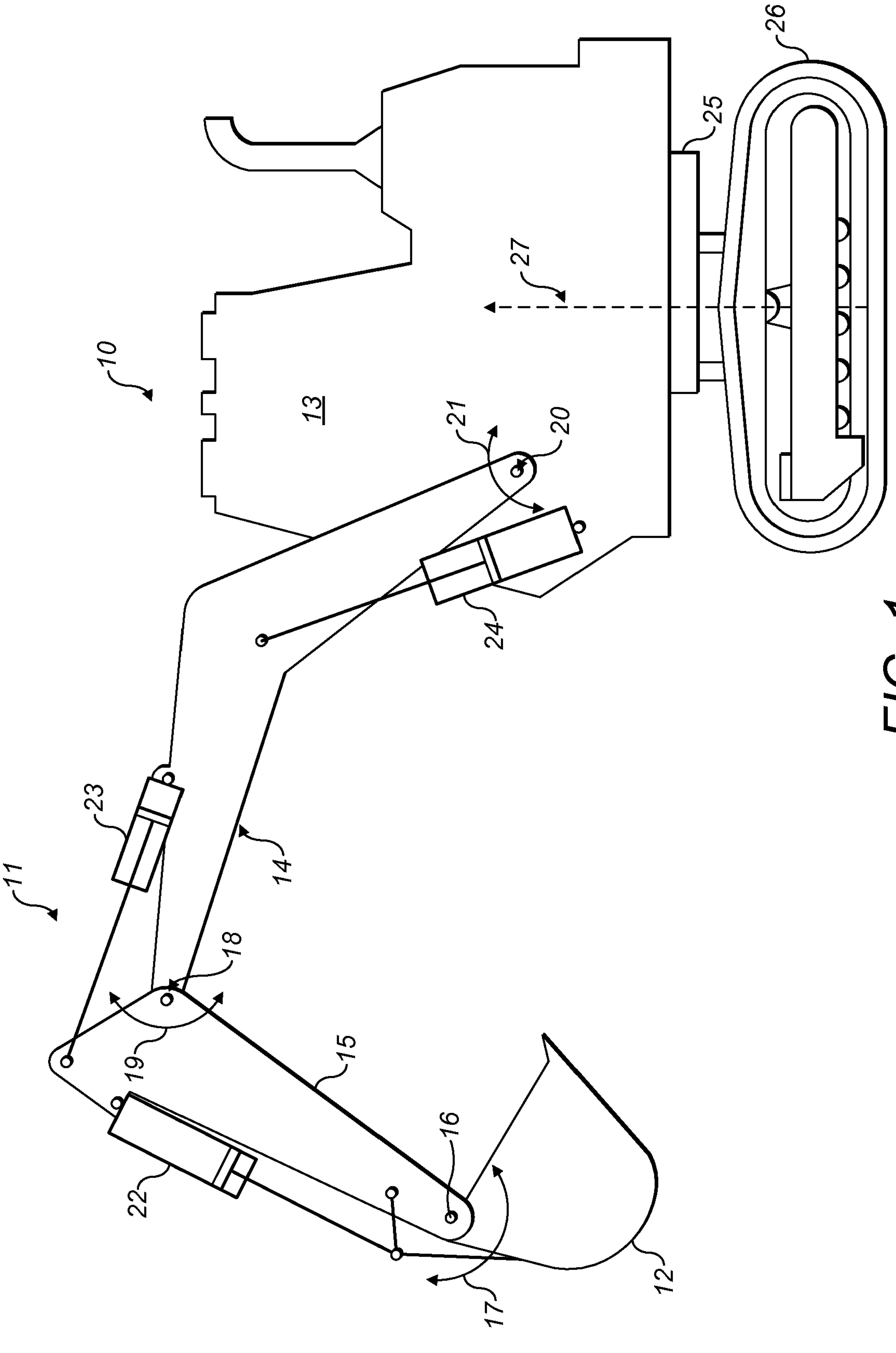


FIG. 1

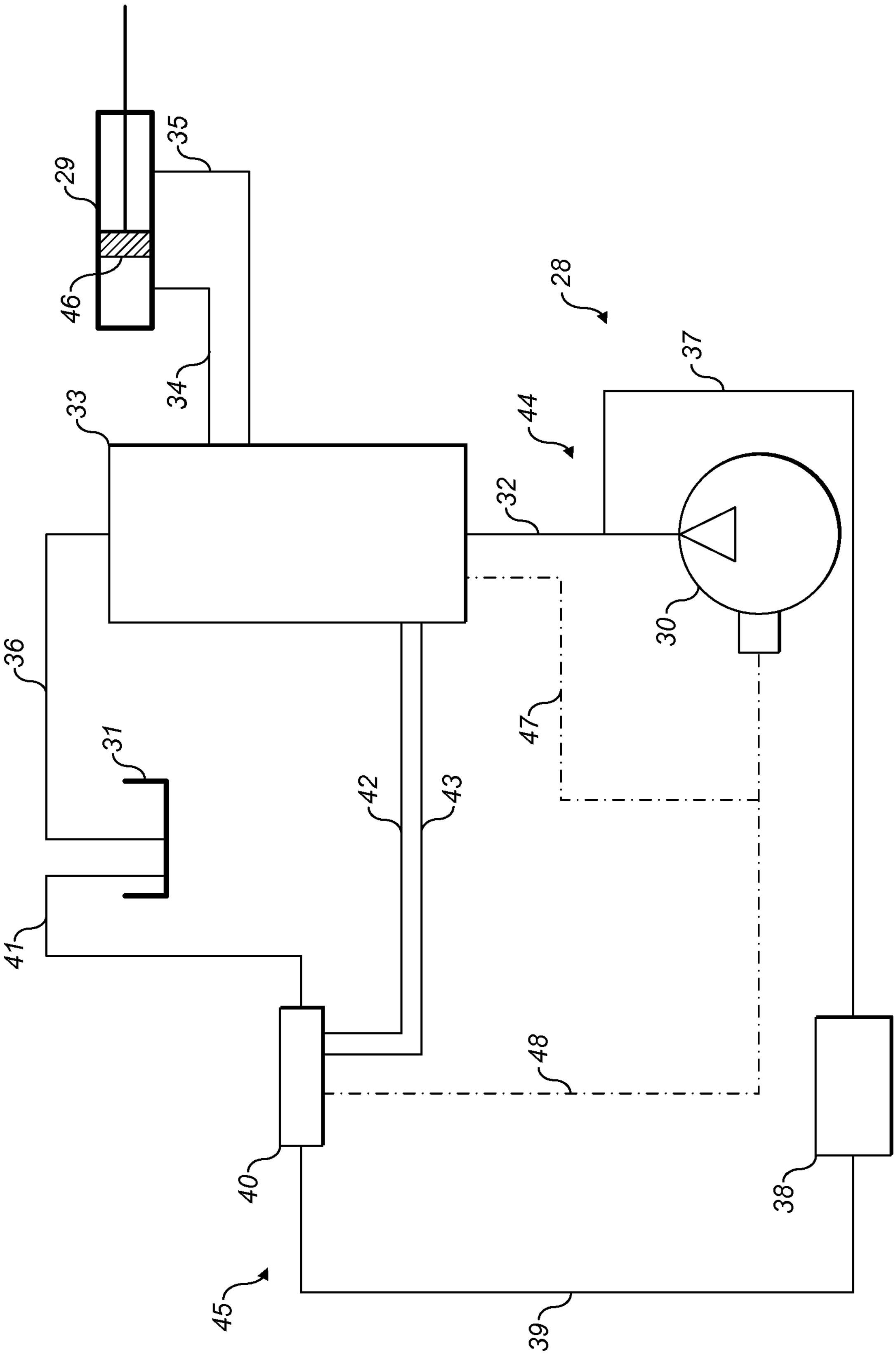


*FIG. 2*

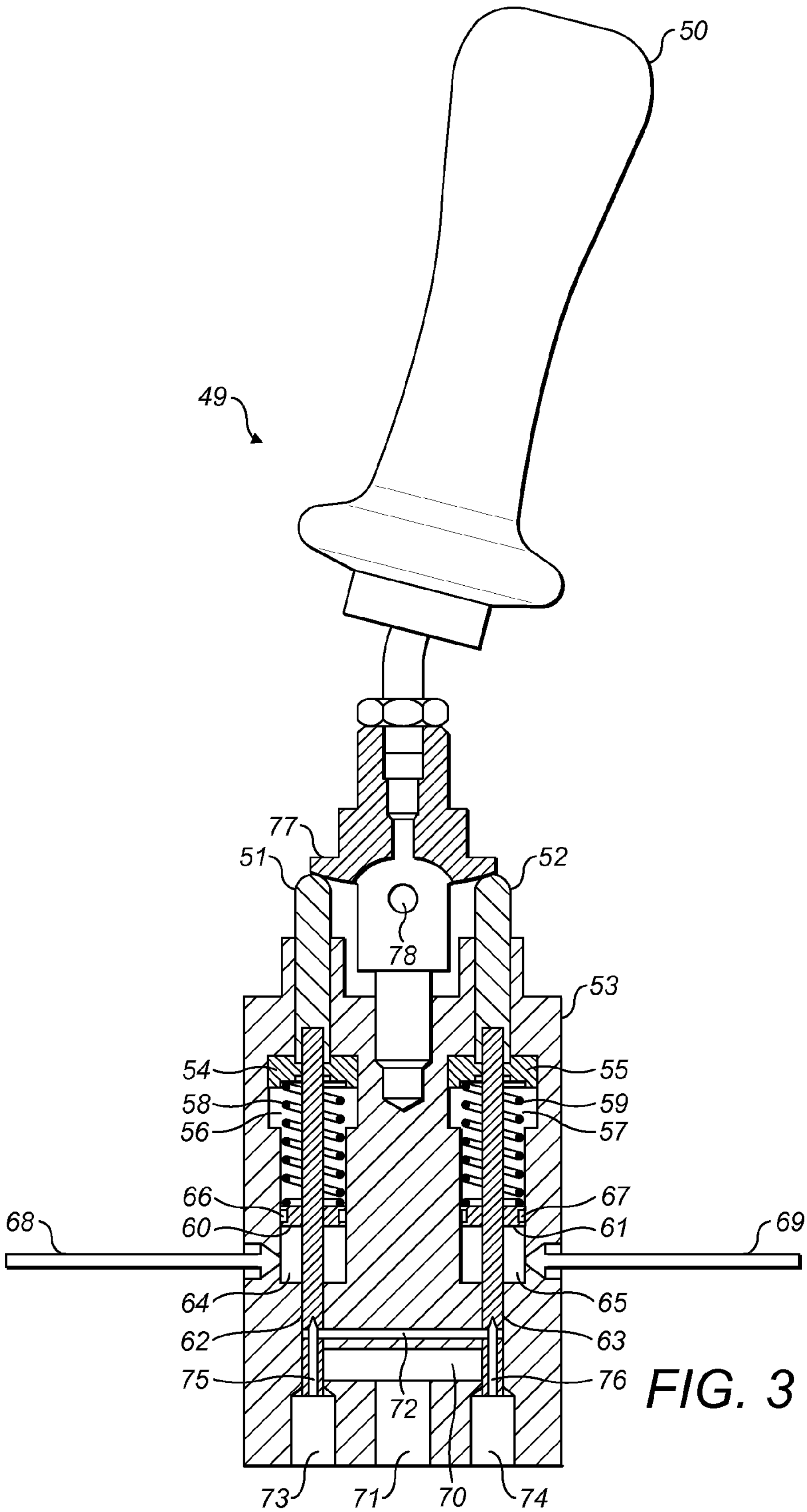
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FIG. 3

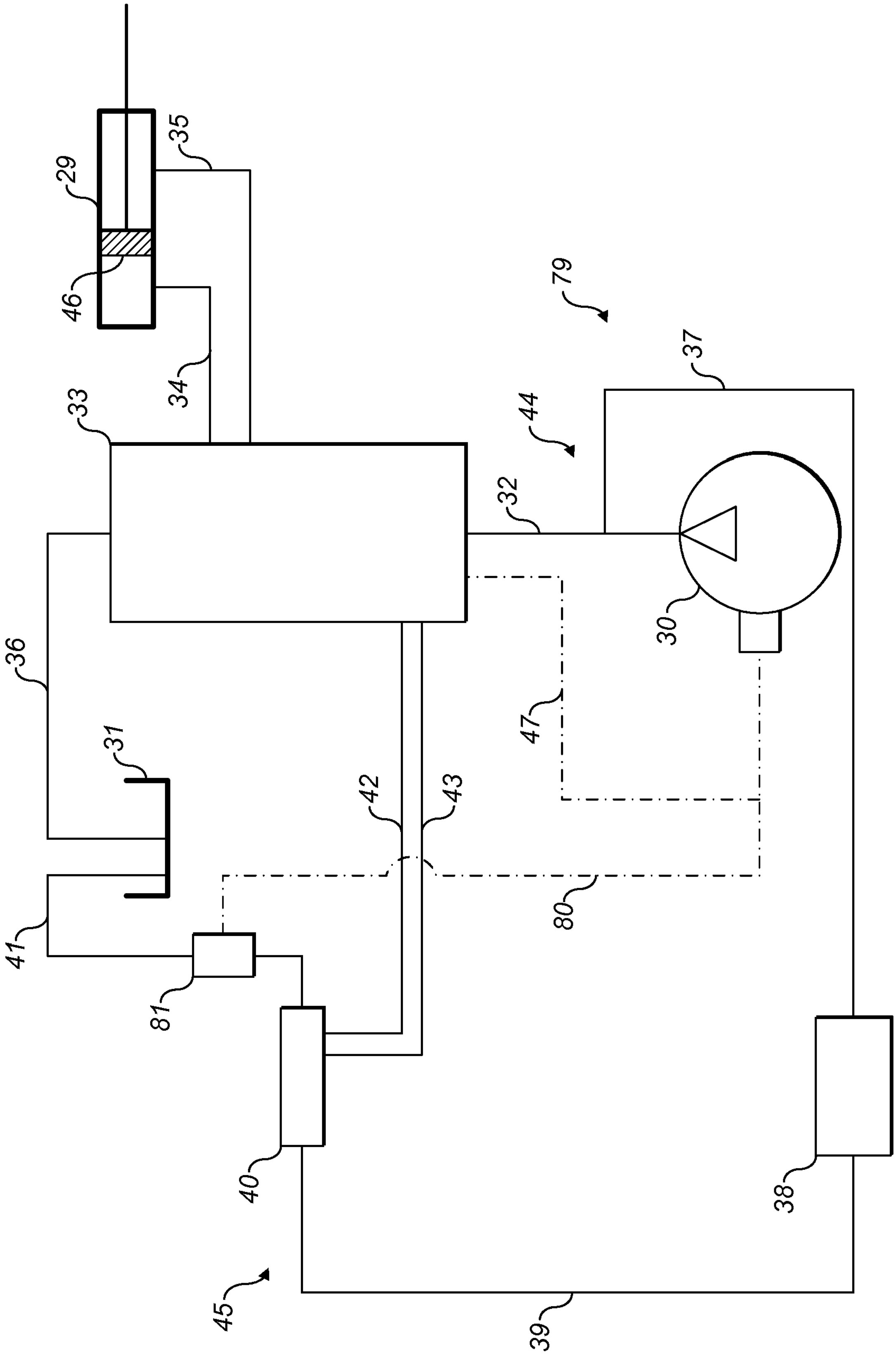


FIG. 4

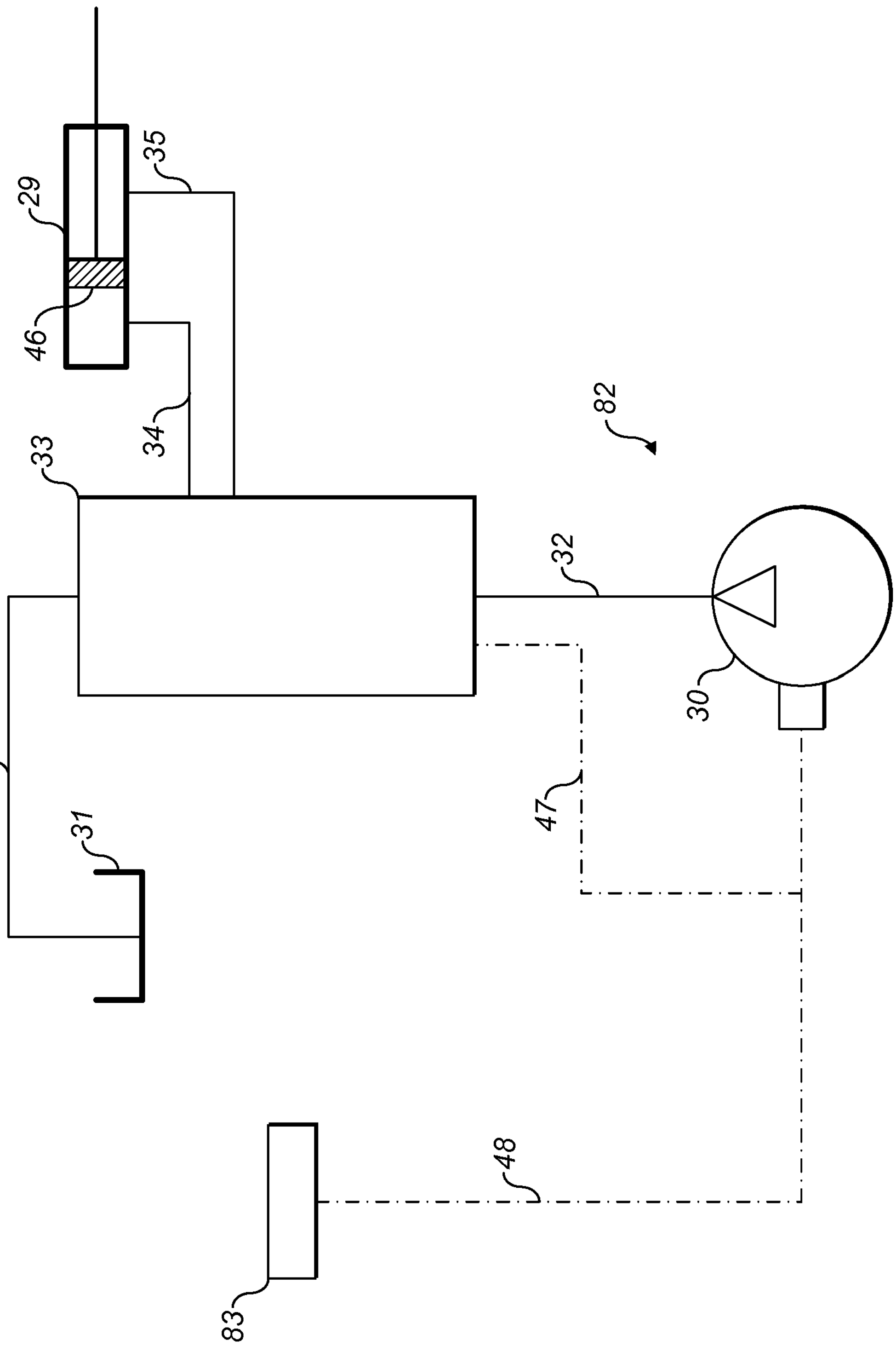


FIG. 5

Europäisches Patentamt
European Patent Office
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# EUROPEAN SEARCH REPORT

Application Number
EP 11 16 9795

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X<br>Y | JP 2005 025713 A (ISHIKAWA KAZUMI) 27 January 2005 (2005-01-27)<br>* abstract; figure 9 * | 1,10-15<br>2-4 | INV.<br>E02F9/20<br>E02F9/22<br>F15B13/14 |
| X<br>Y | JP 8 312605 A (SUMITOMO CONSTR MACH) 26 November 1996 (1996-11-26)<br>* abstract; figures 1, 2 *<br>* paragraph [0019] * | 1,8-15, 18<br>2-4 | |
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| Y | JP 2000 220604 A (HITACHI CONSTRUCTION MACHINERY) 8 August 2000 (2000-08-08)<br>* abstract; figure 1 * | 2-4 | |

TECHNICAL FIELDS SEARCHED (IPC)

E02F
F15B
B60K
B62D
G05G

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 11 November 2011 | Bultot, Coralie |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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