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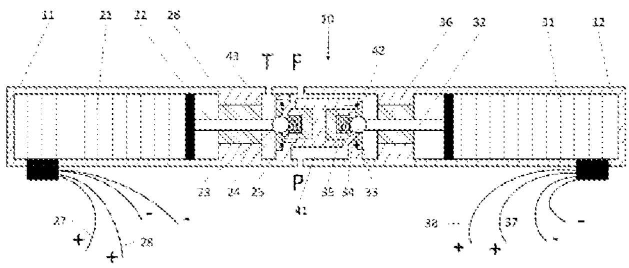
(54) Title **Control Valve**

(57) Abstract

The invention concerns a control valve where its output can be controlled to operate at a set pressure regardless of the supply pressure. The valve is especially designed for use in a subsea control module.



DESCRIPTION:

The invention relates to a control valve having a supply port connected to a hydraulic fluid supply line, an outlet port having a fluid line connecting the port with a function in a device such as an actuator and a return port having a fluid line connecting the return port with an outlet such as a reservoir, said control valve comprising at least one valve element operated by an actuator that regulates the flow between the supply port and the function port.

The invention also relates to a method for supplying hydraulic fluid at a predetermined pressure to a function in a subsea well.

Traditionally the subsea control modules (SCM) use directional control valves (DCV) that are solenoid actuated, where the valve when actuated links a supply pressure hydraulic line to a function line to deliver hydraulic fluid at a pre-determined pressure to a consumer. A return spring brings the valve back to its initial position when power is cut, linking the function line to the return line bleeding the hydraulic pressure to the ambient static head pressure in subsea applications. This is also known as a fail-safe valve.

Since the traditional DCV does not have the ability to control flow and pressure at the output port, the subsea control module (SCM) must necessarily contain several input pressure headers when different output pressures are needed in the hydraulic system where the SCM is used.

This leads to a complex hydraulic circuit in case several output pressures are required by the system.

Another disadvantage with traditional DCVs is that its dynamic seals always impose some leak from the hydraulic supply port and function port to the return port. This precludes the use of a traditional valve as an isolation element to perform a pressure test at the function line.

The object of the invention is to provide hydraulic fluid at a set pressure to a function in a subsea well installation. This is achieved by measuring the pressure in the flow path (45) supplying hydraulic fluid, comparing said pressure with a predetermined pressure and activating an actuator to adjust the opening of the valve to achieve said predetermined pressure.

Another object of the invention is to provide a subsea control module having a control valve with a pressure transmitter in the function fluid line, said transmitter sending signals to a processor that compares the read pressure with a set pressure and operates the actuator based on input and desired pressure levels.

In a preferred embodiment of the invention the actuator is a piezoelectric actuator.

The valve is especially suitable in a subsea control module for use in subsea oil and gas exploration.

The invention shall now be described in more detail with reference to the enclosed drawings where:

Fig. 1 is a drawing of a valve,

Fig. 2 is a diagram of the valve functions, and

Fig. 3 is a diagram showing a control module with several valves in.

In Fig. 1 a valve comprises a housing 10 having an inlet or supply port P, an output or function port F and a return port T.

At a first end 11 of the valve there is an actuator 21. This is connected to a valve stem 22 that pushes against a valve element 23. The valve element 23 is held against a valve seat 24 by a spring 25. The stem 22 passes through a packing gland 26 that isolates the valve from the actuator and stops hydraulic fluid from leaking into the actuator cavity.

Similarly, at the second end 12 of the valve there is a second actuator 31. This is identical to the first end actuator in that it has a valve stem 32 that pushes against a valve element 33 that is held against a valve seat 34 by a spring 35. The stem 32 passes through a packing gland 36 that isolates the valve from the actuator and stops hydraulic fluid from leaking into the actuator cavity.

A first cavity 41 is in communication with the supply port P, a second cavity 42 communicates with the function port F and a third cavity 43 communicates with the return port T. As can be understood from the drawing, when valve 33 is opened, fluid will flow from the supply line 44 (Fig. 2) through port P and through the cavities 41, 42 in the control valve and through hydraulic line 45 (Fig. 2) to a function, for example an actuator.

When valve 23 is opened, fluid will flow from the function through cavities 42 and 43, bleeding pressure in the function and draining hydraulic fluid to an outlet that may be a reservoir for fluid or to the environment.

As shown in Fig. 1 the control valve can be regarded as composed by two independently piloted check valves. The supply check valve allows flow from function port F to supply port P when pressure at F is greater than pressure at P and blocks the flow from port P to port F until the ball element 33 is manually pushed to open by the valve stem 32 when actuator 31 is energized, allowing free flow in both directions between P and F for as long as the valve element is open.

The return check valve allows flow from return port T to function port F when pressure at T is greater than pressure at F and blocks the flow from port F to port T until the valve element 23 is manually pushed to open by the stem 22 when actuator 21 is energized, allowing free flow in both directions between F and T for as long as the valve element is open.

In a preferred embodiment each actuator is made up of two separate units to achieve redundancy. To that end there are two sets of cables - 27, 28 and 37, 38 respectively.

In a preferred embodiment the actuators comprise several piezoelectric elements arranged in a stack. The piezoelectric element is a polarized ceramic or crystalline material that experiences mechanical deformation when an electrical charge is applied. The electrical charge creates a linear movement and force. Piezo actuators utilize this principle to achieve their precise linear movement, high force generation, and high load capabilities. This makes piezoelectric actuators suitable for high precision applications. In addition, a piezoelectric actuator can give an extremely fast response as well as high acceleration rates.

When fluid flows across a restriction, the pressure drop is proportional to the restriction. This can be used to precisely control the pressure in the function line so that the pressure can be tailor- made to match the need of a specific function. In a control module it therefore will be possible to have a single input pressure header but several output function line pressures.

The precision of piezoelectric elements makes it possible to precisely control the flow restriction in which both supply and return check valves will be piloted, creating a very precise control of flow from port P to F or from port F to T, this feature is key to precisely control the desired pressure at the port F.

In Fig. 2 there is shown a schematic of the valve used as a control valve according to the invention. A hydraulic fluid supply line 44 is connected to a hydraulic function line 45 through the valve. The supply line 44 supplies pressure at a set value, for example 10 psi. A return line 46 drains the function line when the valve is set to return. A high-resolution pressure transmitter 51 reads the pressure in the function line 45. The signal from the pressure transmitter is sent through cable 52 to a processor 53. The processor includes a unit that receives the signal from the pressure transmitter 51. The processor is also connected to a power supply 59. The processing unit compares the value from the pressure transmitter and compares it with a set pressure or reference value. The processor controls the actuators 21, 31 by transmitting power through cables 56, 57 to the actuators 21, 31.

The set pressure can be changed by changing parameters in the processor.

When it is desired to increase the pressure in the function line 45, the supply check valve 33 is piloted until the pressure at F reaches a desired value. Conversely, when it is desired to reduce the pressure in the function line 45, the return check valve 23 is piloted until the pressure at F reduces to the desired value. At all times, whenever the pressure at port P drops to a value below the pressure at the port F, then pressure at the output port F will follow independent of the activation of the piezoelectric elements. This means that if the pressure at port P is forced to ambient static head all output pressures in all port F of all SCM universal control valves will also be forced to ambient static head creating a failsafe close characteristic.

As shown in Fig. 3 the subsea control module may contain a number of valves 10',.., 10^n. Each valve has a separate function line 45', .., 45^n. There will normally be a single processor operating a number of valves. The battery 59 supplies electric power to the processor.

In each function line 45 in the subsea control module (SCM) equipped with the control valve the high-resolution pressure transmitter reads the pressure in real time and compares with an operator programmed set value, whenever the difference between the programmed set point and the read pressure value is different from zero, the processing unit will send a value through cables 37, 38 to the actuator 31, ranging from 0 to 100% corresponding to the desired position of the piezoelectric elements. In short, values greater than zero (Set Point > port F) will make the power system send a voltage to the actuator 31, thus activating the piezoelectric element in the supply check valve increasing the pressure at F while values lower than zero (Set Point < port F) will make the power system to send a voltage to the piezoelectric element in the return check valve decreasing the pressure at F.

CONSTRUCTION:

The universal control valve is composed of a machined stainless-steel body capable of holding up to 20kpsi pressure in any of its cavities. The piezoelectric elements are stacked with sufficient elements to provide a long enough displacement to push the check valve elements through the acting stem. The piezoelectric elements are redundant, meaning that there are effectively two stacks on each supply and return side. Each of these stacks can provide the necessary stroke to pilot its respective ball element.

In combination with a pressure transmitter at the port F and a controller, it can regulate the pressure at the port F to any set value between the pressure at the ports T and P.

When both piezoelectric elements are de-energized, the port F will not receive flow from the port P as well are will not vent to the port T, this creates a fully trapped pressure at the circuit connected to the port F, no leakage, which is the criteria to validate a pressure test of the connected circuit

PRESSURE TEST:

To perform a pressure test, the valve port F is supplied with hydraulic fluid at the desired test pressure and the processor is set to test pressure mode meaning it will not react to any pressure deviation in the line 45. Since the port F is fully isolated from the supply pressure at port P and return at port T, the test pressure is maintained for as long as the pressure test is occurring.

EMERGENCY FUNCTION

In case of a failure, where the piezoelectric elements cannot be energized or if they fail to change length, the port F can be bled simply by bleeding hydraulic pressure at the port P. when this happens the pressure trapped at the port F will become greater than at the port P and the pressure difference will act to push the supply check valve 34, 35 to open so pressure at port F will bleed to the port P until they equalize.

The control valve can be used to provide any pressure output at the port F from water static head to the supply port P pre-set pressure. Also, it can provide a full isolation of the function port F from the supply port P and return port T working as a reliable barrier used when pressure testing the function port F and the elements attached to it.

The universal control valve has a failsafe function where the pressure at the function port F is bled when the pressure at the supply port P is set to the ambient pressure independent of any electric commands to the acting piezoelectric stack. This provides an important safety feature used in case the function line port F must be bled during a communication failure of the subsea control module (SCM).

CLAIMS

1. A control valve (10) having a first port (P) connected to a supply of pressurized hydraulic fluid, a second port (F) in fluid communication with the first port and having an output line (45) connected to a device for supplying said pressurized hydraulic fluid to the device and a third port (T) in fluid communication with the second port (F) and connected to a return fluid outlet, said control valve comprising at least one valve element (23, 33) operated by an actuator (21; 31), and a processor (53) electrically connected to the actuator (21; 31) and to a pressure transmitter (51) , characterized in that the pressure transmitter (51) is located in the output line (45), said processor (53) receiving a signal from the pressure transmitter (51), comparing said signal with a pre-set value, and operating the actuator to achieve the pre-set pressure, and that the actuator is a piezoelectric actuator.
2. Control valve according to claim 1, characterized in that it comprises a power supply (59).
3. Control valve according to claim 1, characterized in that the processor compares the measured pressure with a reference pressure and operates the actuator.
4. Control valve according to claim 1, characterized in that the actuator (21; 31) comprises several piezoelectric elements forming a stack
5. Control valve according to claim 4, characterized in that the actuator (21; 31) comprises two redundant piezoelectric stacks.
6. Control valve according to claim 1, characterized in that the control valve comprises a second valve element (33) operated by a second actuator (31) for controlling the fluid flow between the supply and return port.
7. Control valve according to claim 1, characterized in that it comprises electric cables (55, 56) connecting the processor (53) with the actuators (21, 31).
8. Method for supplying hydraulic fluid at a predetermined pressure to a function in a subsea well, comprising a control module with at least one control valve (10) having a fluid flow path (41, 42, 45) therethrough, an actuator (31) operating the valve for controlling said flow path, and a processor (53), comprising the steps of measuring the pressure in the output line (45), comparing said pressure with a predetermined value and activating the actuator (31) to adjust the opening of the valve to achieve said predetermined pressure.
9. Method according to claim 1, where the control module consists of several control valves ($10'$,..,10^n), where each control valve can be adjusted individually.
10. Method according to claim 1, where the valve is used for pressure testing by closing the supply /F) and return (T) ports such that the pressure in the output line (45) can be monitored.

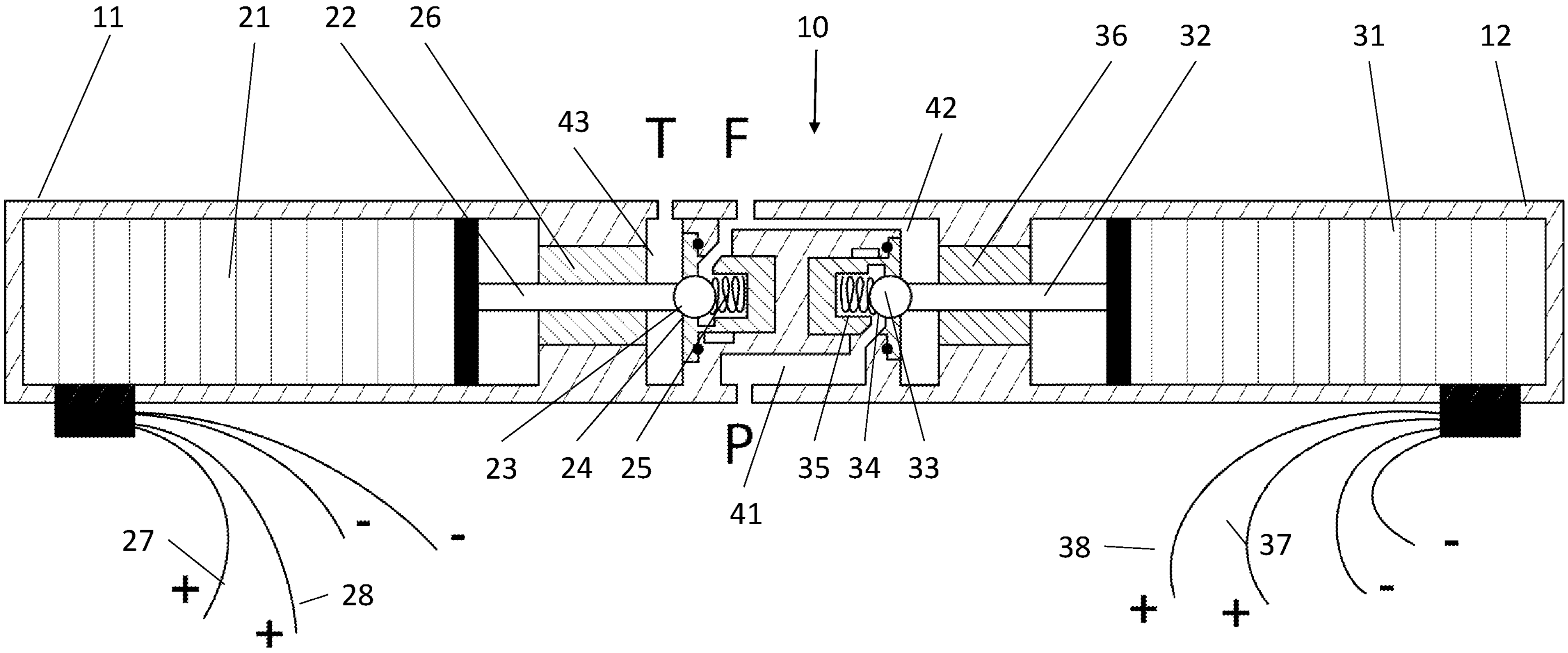


Fig. 1

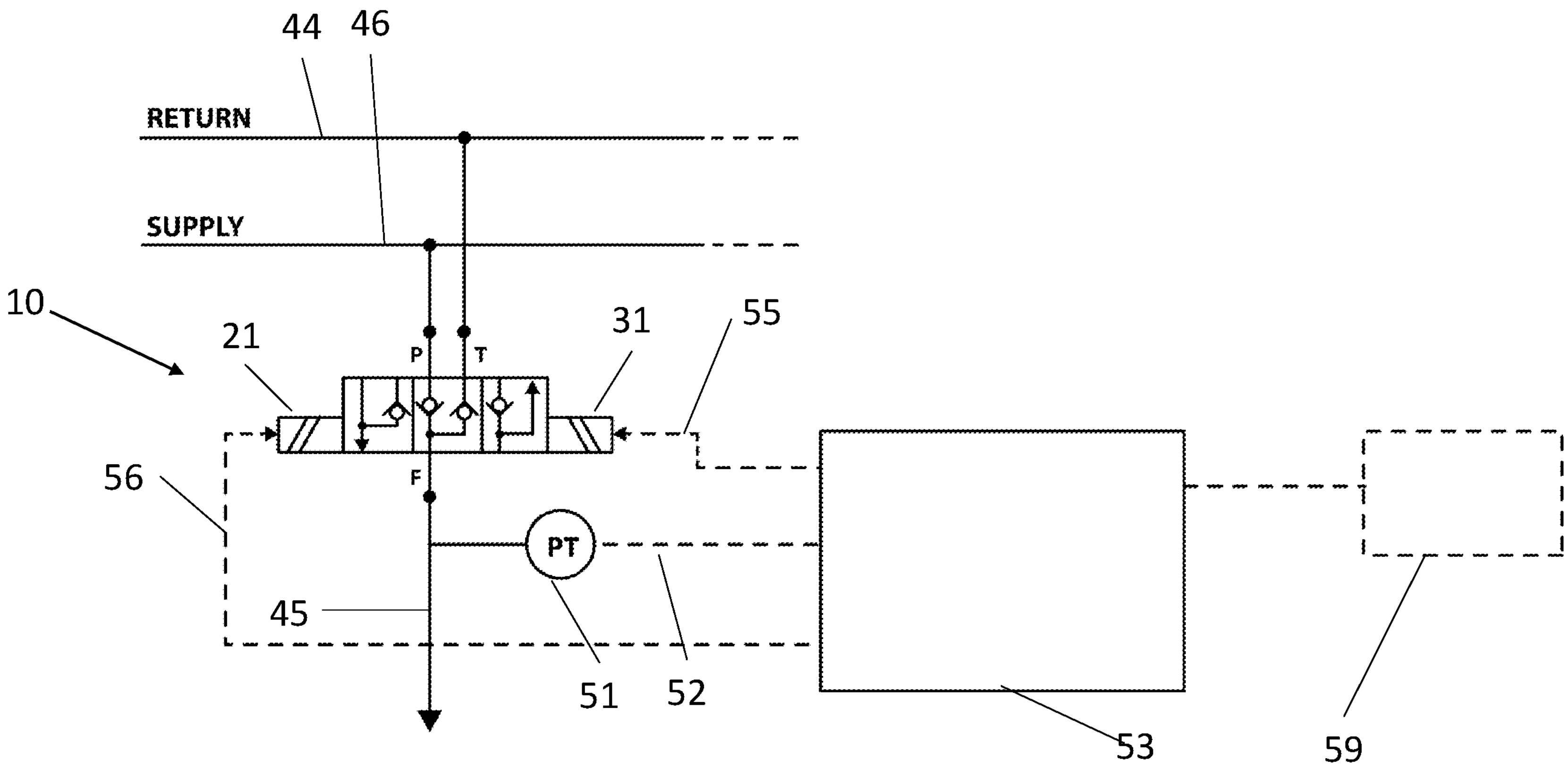


Fig. 2

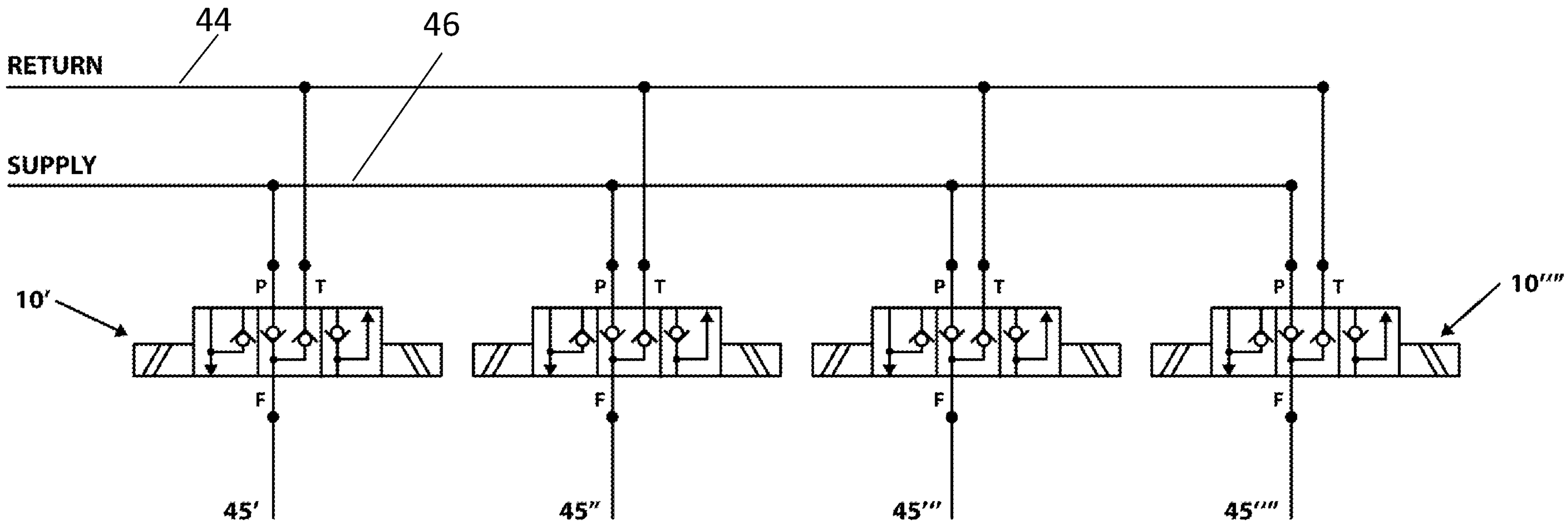


Fig. 3