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- (71) **Applicant:** EATON CORPORATION [US/US]; 1000
Eaton Boulevard, Cleveland, Ohio 44122 (US).
- (72) **Inventor:** LARISH, Chad Anthony; 12828 Hiway
Trail, Minnetonka, Minnesota 55305 (US).
- (74) **Agent:** KOWALCHYK, Katherine M.; Merchant &
Gould P.C., P.O. Box 2903, Minneapolis, Minnesota
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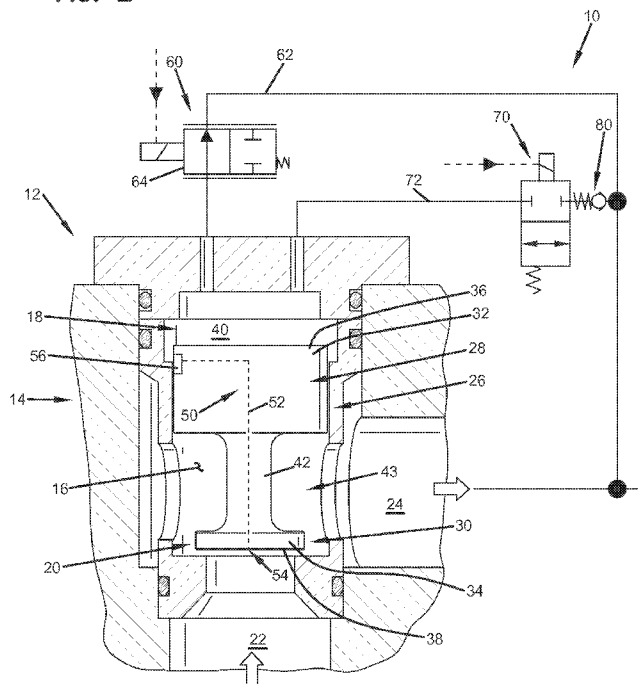
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[Continued on next page]

(54) Title: VALVE SYSTEM FOR BI-DIRECTIONAL FLOW CONTROL

FIG. 2



(57) Abstract: The valve system for controlling flow in normal and reverse directions is disclosed. The valve system includes a valve housing, a valve body and a valve control arrangement. The valve housing defines a valve bore and first and second ports in fluid communication with the valve bore. The valve body is movably accommodated within the valve bore to control fluid communication through the valve bore between the first and second ports. The valve body may move to a closed position where fluid communication through the valve bore between the first and second ports is closed. The valve arrangement can operate in four modes of operation. In the first mode, the operating pressure from the first port interacts with the valve body to retain the valve body in the closed position within the valve bore. In the second mode, the position of the valve body within the valve bore is controlled to provide a controlled rate of flow through the valve bore from the first port to the second port. In the third mode, the operating pressure from the second port interacts with the valve body to retain the valve body in the closed position within the valve bore. In the fourth mode, the operating pressure from the second port interacts with the valve body to move the valve body away from the closed position within the valve bore when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount, thereby permitting flow through the valve bore from the second port to the first port when the valve body is moved away from the closed position.



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VALVE SYSTEM FOR BI-DIRECTIONAL FLOW CONTROL

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is being filed on November 20, 2014, as a PCT International Patent application and claims priority to U.S. Patent Application Serial No. 61/909,428 filed on November 27, 2013, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

Valve assemblies are used in various applications. Example of the valve assemblies includes a hydraulic feedback valve system acting as a flow amplifier. The valve body of the hydraulic feedback valve system may operate to amplify a small pilot flow through a feedback passage that forms part of a feedback control circuit. A small proportional valve in the feedback control circuit of the valve system permits handling of large flows passing through the system.

Such a hydraulic feedback valve system is primarily used to control flow through the system in one direction. In some applications, it is desired to have a valve system that is capable of selectively controlling flow in a reverse direction. Although some valve assemblies have introduced valve arrangements to control flow in a reverse direction, it is only available with relatively significant design changes in the valve bodies.

SUMMARY

The present disclosure relates generally to a valve system. In one possible configuration and by non-limiting example, the valve system includes a valve arrangement for controlling flow both in a normal direction and in a reverse direction.

In one embodiment, the valve system includes a valve housing, a valve body or spool, and a valve control arrangement. The valve housing defines a valve bore and first and second ports in fluid communication with the valve bore. The valve body is movably accommodated within the valve bore to control fluid communication through the valve bore between the first and second ports. The valve body can move to a closed position within the valve bore where fluid communication is closed between the first and second ports through the valve bore. In particular, the valve body is arranged within the valve bore and movable within the valve bore along a longitudinal axis of the valve bore to control fluid communication through the valve bore between the first and second ports.

For this operation, the valve body may move between an open position where the valve body opens fluid communication through the valve bore between the first and second ports, and a closed position where fluid communication through the valve bore between the first and second ports is closed.

5 The valve arrangement can operate in four modes of operation. The first and second modes are operable when an operating pressure at the first port is greater than an operating pressure at the second port. In the first mode, the operating pressure from the first port interacts with the valve body to retain the valve body in the closed position within the valve bore. In the second mode, the position of the valve body within the valve
10 bore is controlled to provide a controlled rate of flow through the valve bore from the first port to the second port. The third and fourth modes are operable when the operating pressure at the second port is greater than the operating pressure at the first port. In the third mode, the operating pressure from the second port interacts with the valve body to retain the valve body in the closed position within the valve bore. In the fourth mode, the
15 operating pressure from the second port interacts with the valve body to move the valve body away from the closed position (that is, to move into the open position) within the valve bore when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount. In the fourth mode, flow is permitted through the valve bore from the second port to the first port when the valve body is moved away
20 from the closed position.

 In some embodiments, the valve bore extends between first and second ends of the valve bore, and the first port is arranged at the second end of the valve bore and the second port is arranged at a side of the valve bore. The valve body includes a first end adjacent the first end of the valve bore and a second end adjacent the second end of
25 the valve bore, and the first end of the valve body that cooperates with the valve housing defines a control chamber at the first end of the valve bore.

 The first end of the valve body may include a first land having a first end face and a second land having a second end face. The first land may have a larger diameter than the second land, and the second end face may have a smaller surface area
30 than the first end face.

 The valve body may also include a valve stem extending between the first and second ends of the valve body, or between the first and second lands of the valve body, and is arranged to be in general alignment with the second port.

The second end, or the second land, of the valve body may be configured to selectively close the first port to prevent fluid communication through the valve bore between the first and second ports in the closed position.

In other embodiments, the valve body may define a control flow passage
5 extending through the valve body for providing fluid communication between the first port and the control chamber.

The control flow passage may include a flow metering portion adjacent the first end of the valve body for metering flow through the control flow passage based on a position of the valve body within the valve bore. The flow metering portion may be
10 configured to increase a cross-sectional passage area of the control flow passage as the valve body moves toward the control chamber and decrease the cross-sectional passage area of the control flow passage as the valve body moves away from the control chamber.

In still other embodiments, the valve system may include first and second flow paths, each extending from the control chamber to the second port. The valve system
15 may further include a pilot valve positioned along the first flow path. The pilot valve is operable in a first state where the pilot valve closes fluid communication between the control chamber and the second port along the first flow path and in a second state where the pilot valve opens fluid communication between the control chamber and the second port along the first flow path. The pilot valve may be proportionally controlled in the
20 second state to provide a controlled flow rate through the first flow path from the control chamber to the second port.

In further embodiments, the valve system may include a reversing flow control valve positioned along the second flow path. The reversing flow control valve may be operable in a first state where the reversing flow control valve is open to allow
25 fluid flow therethrough and in a second state where the reversing flow control valve is closed to prevent fluid flow therethrough.

The valve system may include a one-way check valve positioned along the second flow path. The one-way check valve is configured and arranged to allow fluid flow through the second flow path in a direction from the second port to the control
30 chamber and prevent fluid flow through the second flow path in a direction from the control chamber to the second path.

When the valve system is operating in the first mode of operation, the pilot valve is operated in the first state. In this mode, the operating pressure from the first port pressurizes the control chamber and acts on the first end of the valve body to retain the

valve body in the closed position within the valve bore. When the valve system is operating in the second mode, the pilot valve is operated in the second state to reduce the pressure in the control chamber such that the valve body moves away from the closed position within the valve bore and provides a controlled rate of flow through the valve bore from the first port to the second port.

When the valve system is operating in the third mode, the pilot valve is operated in the first state, and the reversing flow control valve is operated in the first state. In this mode, the operating pressure from the second port pressurizes the control chamber and acts on the first end of the valve body to retain the valve body in the closed position within the valve bore.

When the valve system is operating in the fourth mode, the pilot valve is operated in the first state, and the reversing flow control valve is operated in the second state. In this mode, the operating pressure from the second port interacts with the valve body to move the valve body away from the closed position when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount, so that flow is permitted through the valve bore from the second port to the first port when the valve body moves away from the closed position. In some embodiments, the predetermined amount is associated with a resulting force exerting on the valve body by the operating pressures from the first and second ports. The predetermined amount may be modified by a various factors such as design of the valve system including the shape or dimension of the valve body.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, cross-sectional view of an example valve system in a first mode of operation thereof.

FIG. 2 is a schematic, cross-sectional view of the valve system of FIG. 1 in a second mode of operation.

FIG. 3 is a schematic, cross-sectional view of the valve system of FIG. 1 still in the second mode of operation.

FIG. 4 is a schematic, cross-sectional view of the valve system of FIG. 1 in a third mode of operation.

FIG. 5 is a schematic, cross-sectional view of the valve system of FIG. 1 in a fourth mode of operation.

DETAILED DESCRIPTION

Various embodiments will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not
5 intended to be limiting and merely set forth some of the many possible embodiments for the appended claims.

FIG. 1 is a schematic, cross-sectional view of an example valve system in a first mode according to the present disclosure. The valve system 10 is configured as a
10 hydraulic fluid control valve for controlling a flow of a pressurized fluid between two ports defined in the valve system. In this example, the valve system 10 includes a main stage valve 12, a pilot valve 60, a reversing flow control valve 70, and a one-way check valve 80.

The main stage valve 12 includes a valve housing 14 that defines a valve
15 bore 16. The valve bore includes a first end 18 and a second end 20 thereof and extends along its longitudinal axis or valve bore axis between the first end 18 and the second end 20. The valve housing 14 also includes a first port 22 located at the first end 18 and a second port 24 located at a side of the valve bore 16.

The main stage valve 12 also includes a valve body or spool 26. The valve
20 body or spool 26 is moveably accommodated within the valve bore 16. The spool 26 is configured to be displaceable within the valve bore 16 along the longitudinal axis of the valve bore 16. The relative position of the spool 26 within the valve bore 16 determines a main flow between the first port 22 and the second port 24 in different operational modes as explained below. The spool 26 may be of different types. In this example, the spool 26
25 is of the seat valve type or poppet valve type, having a head 28 at a first end of the spool 26 adjacent the first end 18 of the valve bore 16 and a closing member 30 at a second end of the spool 26 adjacent the second end 20 of the valve bore 16. In this example, the head 28 and the closing member 30 are configured to be disc-shaped. However, embodiments of the spool of the present invention may have any types suitable for opening or closing of
30 the main flow.

The head 28 of the spool 26 includes a first land 32 having a first end face 36. The closing member 30 of the spool 26 includes a second land 34 having a second end face 38. The first land 32 is configured to have a larger diameter than the second land 34. The second end face 38 has a smaller surface area than the first end face 36. The spool 26

also includes a valve stem 42 extending between the first land 32 and the second land 34 along the longitudinal axis of the valve bore 16. In this example, the valve stem 42 can have a smaller diameter than the first land 32 and the second land 34. The valve stem 42 has a groove 43 that surrounds the valve stem 42. In other embodiments, the valve stem
5 42 can have different shapes depending on the design of the valve system 10.

The main stage valve 12 includes a control chamber 40 that is defined by the valve housing 14 and the first end face 36 of the first land 32 at the first end 18 of the valve bore 16. The second end face 38 of the second land 34 is arranged to face toward the first port 22.

10 The spool 26 includes a control flow passage 50 defined therein for implementing a feedback control circuit between the first port 22 and the control chamber 40. The control flow passage 50 extends through the spool 26 and provides fluid communication between the first port 22 and the control chamber 40. The control flow passage 50 is configured as a feedback duct 52 extending through the spool 26 between an
15 inlet 54 and an outlet 56. The inlet 54 is formed in the second land 34 of the spool 26 at the second end of the spool 26. The outlet 56 is arranged in a peripheral surface of the first land 32 of the spool 26 adjacent the first end of the spool 26. The outlet 56 may be configured as a longitudinal aperture or slot. Thus, the feedback control circuit begins from the first port 22 into the inlet 54, extends through the feedback duct 52 to the outlet
20 56, and reaches the control chamber 40 out of the outlet 56. As explained below, the feedback control circuit continues to a pilot valve 60 and further extends from the pilot valve 60 into the second port 24 via a first flow path 62.

The outlet 56, together with a metering edge 58 defined by the valve housing 14, forms a variable orifice or flow metering portion adjacent the first end of the
25 spool 26 in the control chamber 40. The flow metering portion operates to meter flow through the control flow passage 50 based on a position of the spool 26 within the valve bore 16. The flow metering portion increases a cross-sectional passage area of the control flow passage 50 as the spool 26 moves toward the control chamber 40, thereby permitting for increased flow between the control chamber 40 and the first port 22. In contrast, the
30 flow metering portion decreases the cross-section passage area of the control flow passage 50 as the spool 26 moves away from the control chamber 40, thereby decreasing fluid flow between the control chamber 40 and the first port 22.

The spool 26 may move between an open position and a closed position within the valve bore 16. When the spool 26 is in the open position, the second land 34 of

the spool 26 opens fluid communication through the valve bore 16 between the first port 22 and the second port 24. When the spool 26 is in the closed position, the second land 34 of the spool 26 closes fluid communication through the valve bore 16 between the first port 22 and the second port 24. When the spool 26 is in the closed position, the outlet 56 of the control flow passage 50 is almost, but not entirely, closed. Although the spool 26 is in the closed position, the outlet 56 is partially exposed over the metering edge 58 to the control chamber 40 (that is, the flow metering portion is open), and thus the control flow passage 50 still remains open and maintains the feedback control circuit.

The pilot valve 60 is arranged along the first flow path 62 extending from the control chamber 40 to the second port 24. The pilot valve 60 may operate between a first state and a second state. In the first state, the pilot valve 60 closes fluid communication between the control chamber 40 and the second port 24 via the first flow path 62 (see FIG. 1). In the second state, the pilot valve 60 gradually opens fluid communication along the first flow path 62 and provides a controlled flow rate via the first flow path 62 from the control chamber 40 to the second port 24 (see FIG. 2). As a default setting, the pilot valve 60 may be in the first state (the closed state) when it is in a de-energized state (see FIG. 1), and may be in the second state (the open state) when it is in an energized state (see FIG. 2). To switch the pilot valve 60 into the second state, in some embodiments, an input signal, such as an electric current, is supplied to a solenoid in the pilot valve 60 to gradually move a valve spool 64 from the first state as shown in FIG. 1 to the right into the second state, which is a gradually opened state of the pilot valve 60. In some embodiments, the pilot valve 60 is configured to open in proportion to the amount of the input signal supplied to the pilot valve 60.

The reversing flow control valve 70 is arranged along a second flow path 72 extending between the control chamber 40 and the second port 24. The reversing flow control valve 70 may operate between a first state and a second state. In the first state, the reversing flow control valve 70 is open to allow fluid flow from the second port 24 to the control chamber 40 via the second flow path 72. In the second state, the reversing flow control valve 70 is closed to prevent fluid flow through the second flow path 72. As a default setting, the reversing flow control valve 70 may be in the first state (the open state) when it is in a de-energized state, and may be in the second state (the closed state) when it is in an energized state.

The one-way check valve 80 is positioned along the second flow path 72. The one-way check valve 80 is configured to allow fluid flow through the second flow

path 72 in a direction from the second port 24 to the control chamber 40, and prevents fluid flow via the second flow path 72 in the opposite direction, that is, in a direction from the control chamber 40 to the second port 24.

The valve system 10 according to the present disclosure may operate in four different operating modes. The first and second modes of operation are selectable when a first operating pressure (P1), a pressure of fluid flow at, or from, the first port 22, is greater than a second operating pressure (P2), a pressure of fluid flow at, or from, the second port 24. The third and fourth modes are operable when the second operating pressure (P2) is greater than the first operating pressure (P1). Each of the four operating modes is hereinafter explained.

[The First Mode of Operation]

Turning back to FIG. 1, the valve system 10 is operating in the first operating mode where the spool 26 remains in the closed position within the valve bore 16 while the first operating pressure (P1) is greater than the second operating pressure (P2). Therefore, the spool 26 prevents fluid from flowing through the valve bore 16 between the first port 22 and the second port 24. In the first mode of operation, the pilot valve 60 is in the first state where it closes fluid communication between the control chamber 40 and the second port 24 via the first flow path 62. In the first mode, the reversing flow control valve 70 may be either in the first state or in the second state. Although the reversing flow control valve 70 is in the first state (see FIG. 1) where it opens fluid communication between the control chamber 40 and the second port 24 via the second flow path 72, fluid flow does not occur from the control chamber 40 with the first operating pressure (P1) to the second port 24 with the second operating pressure (P2), which is lower than the first operating pressure (P1), because of the one-way check valve 80 along the second flow path 72.

In the first mode of operation, the first operating pressure (P1) from the first port (22) pressurizes the control chamber 40 through the control flow passage 50 and acts on the first end face 36 of the spool 26, thereby retaining the spool 26 in the closed position within the valve bore 16. In particular, the first operating pressure (P1) in the first port 22 is communicated to the control chamber 40 via the feedback duct 52 of the control flow passage 50 and the outlet 56 exposed over the metering edge 58. Because the first end face 36 of the first land 32 presented to the first operating pressure (P1) is larger in the control chamber 40 than the second end face 38 of the second land 34 presented to the first operating pressure (P1), and the second operating pressure (P2) acting on the surface of

the spool 26 presented in the second port 24 is relatively low, the spool 26 remains seated on the first port 22 (that is, the closed position) as illustrated in FIG. 1.

[The Second Mode of Operation]

FIGS. 2 and 3 illustrate the second mode of operation of the valve system 10 of FIG. 1. In the second mode, the spool 26 moves into the open position within the valve bore 16, thereby opening fluid communication via the valve bore 16 between the first port 22 and the second port 24. Because the first operating pressure (P1) is greater than the second operating pressure (P2), fluid flow occurs from the first port 22 to the second port 24 via the valve bore 16 when the spool 26 is in the open position. To switch from the first mode to the second mode, the pilot valve 60 is controlled to shift from the first state, in which fluid communication is closed between the control chamber 40 and the second port 24 via the first flow path 62, to the second state. In the second state of the pilot valve 60, the pilot valve 60 is gradually controlled to provide a controlled flow rate via the first flow path 62 from the control chamber 40 to the second port 24. Therefore, the control chamber 40 is gradually opened to the second port 24 that has a lower pressure (the second operating pressure (P2)) than in the first port 22 with the first operating pressure (P1). The pressure in the control chamber 40 then decreases and causes the spool 26 to move away from its closed position and toward into the control chamber 40 and open the first port 22 to the second port 24 through the valve bore 16. The pressure in the control chamber 40 will then adjust to a level between the pressures in the first port 22 and the second port 24, resulting in the spool 26 being balanced by equal resulting, opposite forces exerting on the first end face 36 of the spool 26 exposed to the control chamber 40 and on the rest of the surface of the spool 26 exposed to the first and second ports 22 and 24. As the pilot valve 60 is further opened, the pressure again decreases in the control chamber 40, resulting in the spool 26 moving further into the control chamber 40. The position of the spool 26 within the valve bore 16 depends on a particular design of the valve system 10 including the outlet 56 of the control flow passage 50 and the degree of opening of the pilot valve 60.

In the second mode of operation, the reversing flow control valve 70 may be either in the first state (as shown in FIG. 3) or in the second state (as shown in FIG. 2) because fluid will not flow in any direction between the control chamber 40 and the second port 24 regardless of the state of the reversing flow control valve 70. As in the first mode of operation, the second operating pressure (P2) lower than the first operating pressure (P1) and the operation of the one-way check valve 80 prevents fluid flow from

the control chamber 40 to the second port 24 although the reversing flow control valve 70 is in the first state (the opened state) as shown in FIG. 3.

[The Third Mode of Operation]

FIG. 4 illustrates the third mode of operation of the valve system 10 of FIG.

- 5 1. The third mode is operable when the second operating pressure (P2) is greater than the first operating pressure (P1). In the third mode, the pilot valve 60 is operated in its first state where the pilot valve 60 closes fluid communication between the control chamber 40 and the second port 24 via the first flow path 62, and the reversing flow control valve 70 is operated in its first state where the reversing flow control valve 70 opens fluid
10 communication between the control chamber 40 and the second port 24 via the second flow path 72. Because the one-way check valve 80 allows fluid flow through the second flow path 72 from the second port 24 to the control chamber 40, fluid can flow through the second flow path 72 from the second port 24 to the control chamber 40. Therefore, the second operating pressure (P2) from the second port 24 pressurizes the control chamber 40
15 through the second flow path 72 and acts on the first end face 36 of the spool 26, thereby retaining the spool 26 in the closed position within the valve bore 16. In particular, the second operating pressure (P2) in the second port 24 is communicated to the control chamber 40 via the second flow path 72. Because the second operating pressure (P2) is greater than the first operating pressure (P1), the spool 26 remains seated on the first port
20 22 (that is, the closed position) as illustrated in FIG. 4.

[The Fourth Mode of Operation]

- FIG. 5 illustrates the fourth mode of operation of the valve system 10 of FIG. 1. The fourth mode is operable when the second operating pressure (P2) is greater than the first operating pressure (P1). In the fourth mode, the pilot valve 60 is operated in
25 its first state where the pilot valve 60 closes fluid communication between the control chamber 40 and the second port 24 via the first flow path 62, and the reversing flow control valve 70 is operated in its second state where the reversing flow control valve 70 closes fluid communication between the control chamber 40 and the second port 24 via the second flow path 72. In the fourth mode, the second operating pressure (P2) from the
30 second port 24 interacts with the surface of the spool 26 exposed to the second operating pressure (P2) from the second port 24 and moves the spool 26 into the open position within the valve bore 16, thereby opening fluid communication via the valve bore 16 between the first port 22 and the second port 24. Because the second operating pressure (P2) is greater than the first operating pressure (P1) in the fourth mode, fluid flow happens

from the second port 24 to the first port 22 via the valve bore 16 when the spool 26 is in the open position. In the meantime, as the spool 26 moves away from the closed position (into the open position), fluid also flows from the control chamber 40 through the control flow passage 50 of the spool 26 to the first port 22.

5 In the fourth mode, the first flow path 62 and the second flow path 72 are all closed and thus the control chamber 40 is not in fluid communication with the second port 24. On the other hand, as in the first mode of operation, the first operating pressure (P1) in the first port 22 is communicated to the control chamber 40 via the control flow passage 50. Thus, the first operating pressure (P1) from the first port 22 pressurizes the
10 control chamber 40 through the control flow passage 50 and acts on the first end face 36 of the spool 26.

 The fourth mode of operation occurs when the second operating pressure (P2) of the second port 24 exceeds the first operating pressure (P1) of the first port (22) by a predetermined amount. In particular, in the fourth mode, the first operating pressure
15 (P1) from the first port 22 presses on the first end face 36 of the spool 26 in a downward direction (in a direction toward the first port 22). In the meantime, the first operating pressure (P1) acts on the second end face 38 of the spool 26 in an upward direction (in a direction away from the first port 22) (in FIG. 5). Furthermore, the second operating pressure (P2) of the second port 24 acts on the surface of the spool 26 that is exposed to
20 the second operating pressure (P2) present within the groove 43 (e.g., the underside of the first land 32 and the top side of the second land 34). The underside of the first land 32 has a larger surface area than the top side of the second land 34. Therefore, the spool 26 will move away from the closed position only when the resulting force in the opposite directions becomes positive in the upward direction (in a direction away from the first port
25 22). In some embodiments, such a predetermined amount that causes the spool 26 to move away from the closed position in the fourth mode is determined by various factors such as a particular design of the valve system 10 including the shape or dimension of the spool 26.

 The above specification, examples and data provide a complete description
30 of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

WHAT IS CLAIMED IS:

1. A valve system comprising:

a valve housing defining a valve bore, the valve housing also defining first and second ports in fluid communication with the valve bore;

a valve body positioned within the valve bore, the valve body being movable within the valve bore along a longitudinal axis of the valve bore to control fluid communication through the valve bore between the first and second ports, and the valve body being movable to a closed position within the valve bore in which fluid communication through the valve bore between the first and second ports is closed;

a valve control arrangement that is operable in first and second modes when an operating pressure at the first port is larger than an operating pressure at the second port, wherein when the valve arrangement is operating in the first mode the operating pressure from the first port interacts with the valve body to retain the valve body in the closed position within the valve bore, and wherein when the valve arrangement is operating in the second mode the position of the valve body within the valve bore is controlled to provide a controlled rate of flow through the valve bore from the first port to the second port; and

the valve control arrangement also being operable in third and fourth modes when the operating pressure at the second port is larger than the operating pressure at the first port, wherein when the valve arrangement is operating in the third mode the operating pressure from the second port interacts with the valve body to retain the valve body in the closed position within the valve bore, and wherein when valve arrangement is operating in the fourth mode the operating pressure from the second port interacts with the valve body to move the valve body away from the closed position within valve bore when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount, wherein flow is permitted through the valve bore from the second port to the first port when the valve body is moved away from the closed position.

2. The valve system of claim 1, wherein the valve bore extends between first and second ends of the valve bore, and wherein the first port is arranged at the second end of the valve bore and the second port is arranged at a side of the valve bore,

wherein the valve body includes a first end adjacent the first end of the valve bore and a second end adjacent the second end of the valve bore, and

wherein the first end of the valve body that cooperates with the valve housing defines a control chamber at the first end of the valve bore.

3. The valve system of claim 2, wherein the first end of the valve body includes a first land having a first end face and a second land having a second end face, wherein the first land has a larger diameter than the second land, and wherein the second end face has a smaller surface area than the first end face.

4. The valve system of claim 2, wherein the valve body includes a stem extending between the first and second ends of the valve body and being in general alignment with the second port.

5. The valve system of claim 2, wherein the second end of the valve body closes the first port to prevent fluid communication through the valve bore between the first and second ports in the closed position.

6. The valve system of claim 2, wherein the valve body defines a control flow passage extending through the valve body for providing fluid communication between the first port and the control chamber.

7. The valve system of claim 6, wherein the control flow passage includes a flow metering portion adjacent the first end of the valve body for metering flow through the control flow passage based on a position of the valve body within the valve bore.

8. The valve system of claim 7, wherein the flow metering portion increases a cross-sectional passage area of the control flow passage as the valve body moves toward the control chamber and decreases the cross-sectional passage area of the control flow passage as the valve body moves away from the control chamber.

9. The valve system of claim 2, further comprising a pilot valve positioned along a first flow path extending from the control chamber to the second port, wherein the pilot valve is operable in a first state where the pilot valve closes fluid communication between the control chamber and the second port along the first flow path and in a second state

where the pilot valve opens fluid communication between the control chamber and the second port along the first flow path.

10. The valve system of claim 9, wherein the pilot valve is proportionally controlled in the second state to provide a controlled flow rate through the first flow path from the control chamber to the second port.

11. The valve system of claim 9, further comprising a reversing flow control valve positioned along a second flow path extending from the control chamber to the second port, wherein the reversing flow control valve is operable in a first state where the reversing flow control valve is open to allow fluid flow therethrough and in a second state where the reversing flow control valve is closed to prevent fluid flow therethrough.

12. The valve system of claim 11, further comprising a one-way check valve positioned along the second flow path, wherein the one-way check valve allows fluid flow through the second flow path in a direction from the second port to the control chamber and prevents fluid flow through the second flow path in a direction from the control chamber to the second path.

13. The valve system of claim 9, wherein the valve system is operable in first and second modes when an operating pressure at the first port is larger than an operating pressure at the second port, wherein when the valve system is operating in the first mode, the pilot valve is operated in the first state and the operating pressure from the first port pressurizes the control chamber and acts on the first end of the spool to retain the valve body in the closed position within the valve bore, and wherein when the valve system is operating in the second mode the pilot valve is operated in the second state to reduce the pressure in the control chamber such that the valve body moves away from the closed position within the valve bore and provides a controlled rate of flow through the valve bore from the first port to the second port.

14. The valve system of claim 11, wherein the valve system is operable in a third mode when an operating pressure at the second port is larger than an operating pressure at the first port, wherein when the valve system is operating in the third mode the pilot valve is operated in the first state, the reversing flow control valve is operated in the first state and

the operating pressure from the second port pressurizes the control chamber and acts on the first end of the valve body to retain the valve body in the closed position within the valve bore.

15. The valve system of claim 11, wherein the valve system is operable in a fourth mode when an operating pressure at the second port is larger than an operating pressure at the first port, wherein when the valve system is operating in the fourth mode the pilot valve is operated in the first state, the reversing flow control valve is operated in the second state and the operating pressure from the second port interacts with the valve body to move the valve body away from the closed position when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount, and wherein flow is permitted through the valve bore from the second port to the first port when the valve body moves away from the closed position.

16. A valve system comprising:

a main stage valve comprising:

a valve housing defining a valve bore that extends along a valve bore axis between first and second ends of the valve bore, the valve housing also defining a first port at the second end of the valve bore and a second port at a side of the valve bore;

a valve body positioned within the valve bore, the valve body being movable within the valve bore along a longitudinal axis of the valve bore to control fluid communication through the valve bore between the first and second ports, the valve body having a first end adjacent the first end of the valve bore and a second end adjacent the second end of the valve bore, the first end of the valve body including a first end face that cooperates with the valve housing to define a control chamber at the first end of the valve bore, the second end of the valve body including a second end face that faces toward the first port, the second end face having a smaller surface area than the first end face, the spool also defining a control flow passage that extends through the valve body for providing fluid communication between the first port and the control chamber, and the valve body being movable to a closed position within the valve bore in which the second end of the valve body closes fluid communication through the valve bore between the first and second ports;

first and second flow paths that extend from the control chamber to the second port;

a pilot valve positioned along the first flow path, the pilot valve being operable in a first state where the pilot valve closes fluid communication between control chamber and the second port along the first flow path, and the pilot valve being operable in a second state where the pilot valve is proportionally controlled to provide a controlled flow rate through the first flow path from the control chamber to the second port;

a reversing flow control valve positioned along the second flow path, the reversing flow control valve being operable in a first state in which the reversing flow control valve is open to allow fluid flow therethrough and a second state in which the reversing flow control valve is closed to prevent fluid flow therethrough; and

a one-way check valve positioned along the second flow path which allows fluid to flow through the second flow path in a direction from the second port to the control chamber and prevents fluid to flow through the second flow path in a direction from the control chamber to the second port.

17. A valve system comprising:

a main stage valve comprising:

a valve housing defining a valve bore that extends along a longitudinal axis of the valve bore between first and second ends of the valve bore, the valve housing also defining a first port at the second end of the valve bore and a second port at a side of the valve bore;

a spool positioned within the valve bore, the spool being movable within the valve bore along the longitudinal axis of the valve bore to control fluid communication through the valve bore between the first and second ports, the spool having a first end adjacent the first end of the valve bore and a second end adjacent the second end of the valve bore, the first end of the spool including a first land and the second end of the spool including a second land, the first land having a larger diameter than the second land, the first land including a first end face that cooperates with the valve housing to define a control chamber at the first end of the valve bore, the second land including a second end face that faces toward the first port, the second end face having a smaller surface area than the first end face, the spool including a stem that extends between the first and second lands and that is in general alignment with the second port, the spool also defining a control flow passage that extends through the spool for providing fluid communication between the first port and the control chamber, and the spool being movable to a closed

position within the valve bore in which the second land closes fluid communication through the valve bore between the first and second ports;

first and second flow paths that extend from the control chamber to the second port;

a pilot valve positioned along the first flow path, the pilot valve being operable in a first state where the pilot valve closes fluid communication between control chamber and the second port along the first flow path, and the pilot valve being operable in a second state where the pilot valve is proportionally controlled to provide a controlled flow rate through the first flow path from the control chamber to the second port;

a reversing flow control valve positioned along the second flow path, the reversing flow control valve being operable in a first state in which the reversing flow control valve is open to allow fluid flow therethrough and a second state in which the reversing flow control valve is closed to prevent fluid flow therethrough;

a one-way check valve positioned along the second flow path which allows fluid to flow through the second flow path in a direction from the second port to the control chamber and prevents fluid to flow through the second flow path in a direction from the control chamber to the second port;

the valve system being operable in first and second modes when an operating pressure at the first port is larger than an operating pressure at the second port, wherein when the valve system is operating in the first mode the pilot valve is operated in the first state and the operating pressure from the first port pressurizes the control chamber and acts on the first end face of the spool to retain the spool in the closed position within the valve bore, and wherein when the valve system is operating in the second mode the pilot valve is operated in the second state to reduce the pressure in the control chamber such that the spool moves away from the closed position within the valve bore and provides a controlled rate of flow through the valve bore from the first port to the second port; and

the valve system also being operable in third and fourth modes when the operating pressure at the second port is larger than the operating pressure at the first port;

wherein when the valve system is operating in the third mode the pilot valve is operated in the first state, the reversing flow control valve is operated in the first state and the operating pressure from the second port pressurizes the control chamber and acts on the first end face of the spool to retain the spool in the closed position within the valve bore; and

wherein when the valve system is operating in the fourth mode the pilot valve is operated in the first state, the reversing flow control valve is operated in the second state and the operating pressure from the second port interacts with the spool to move the spool away from the closed position when the operating pressure of the second port exceeds the operating pressure of the first port by a predetermined amount, and wherein flow is permitted through the valve bore from the second port to the first port when the spool moves away from the closed position.

18. The valve system of claim 16, wherein the first state of the pilot valve is a de-energized state and the second state of the pilot valve is an energized state.

19. The valve system of claim 16, wherein the first state of the reversing flow control valve is a de-energized state and the second state of the reversing flow control valve is an energized state.

20. The valve system of claim 16, wherein the control flow passage includes a flow metering portion adjacent the first end of the spool that meters flow through the control flow passage based on a position of the spool within the valve bore, wherein the metering portion increases a cross-sectional passage area of the control flow passage as the spool moves toward the control chamber to allow for increased flow between the control chamber and the first port and decreases the cross-sectional passage area of the control flow passage as the spool moves away from the control chamber for reduced flow between the control chamber and the first port.

FIG. 1

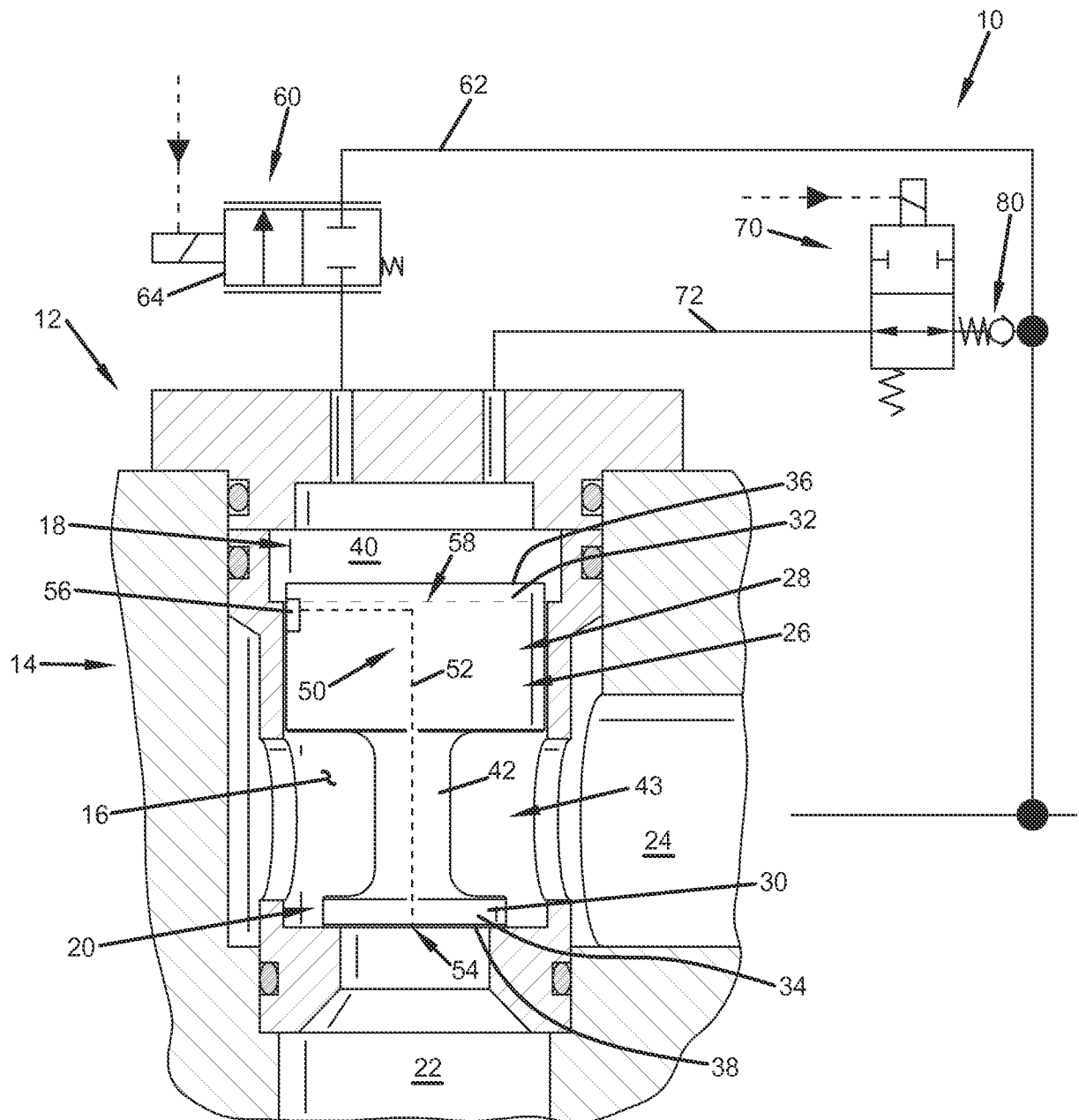


FIG. 2

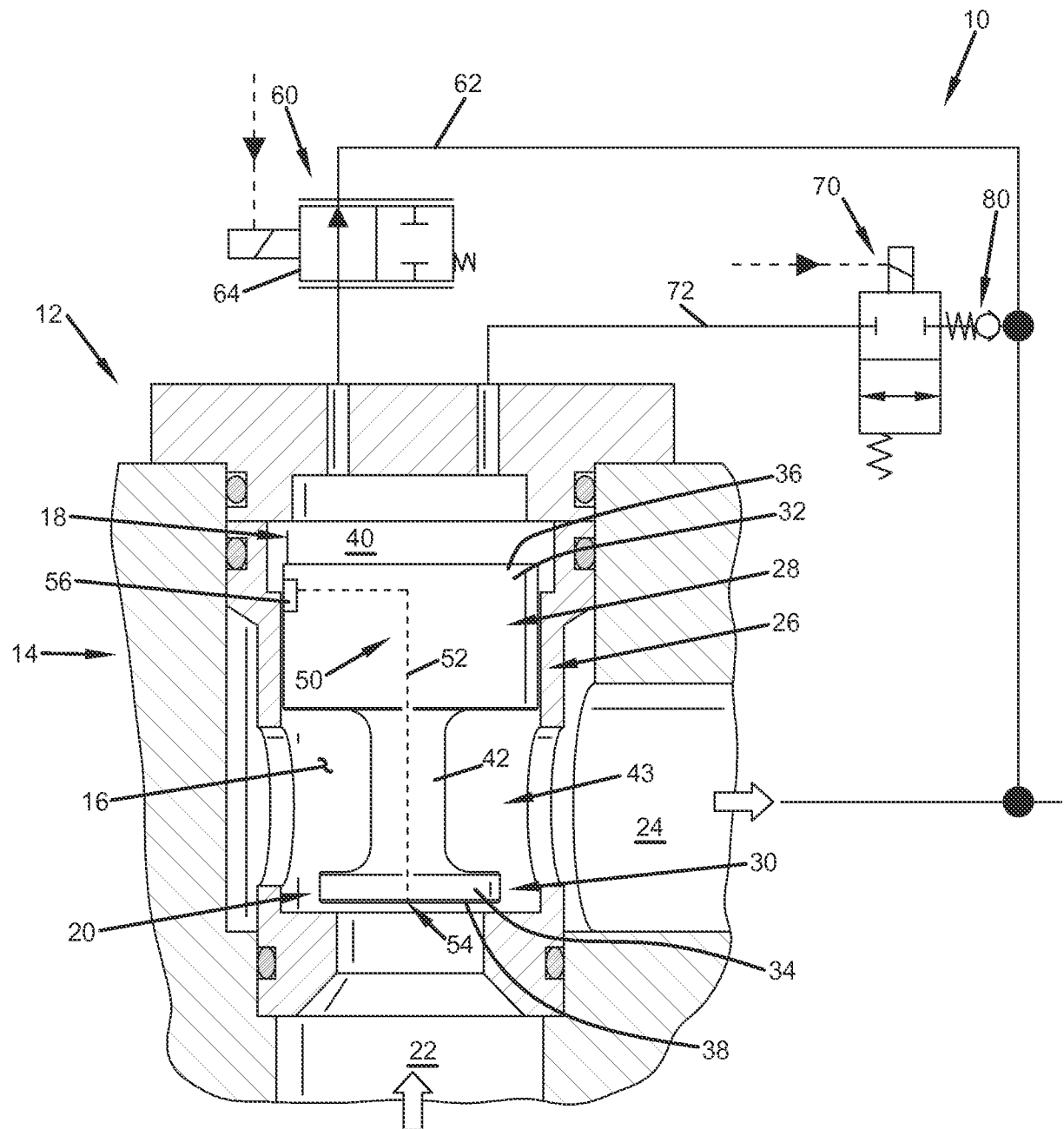


FIG. 3

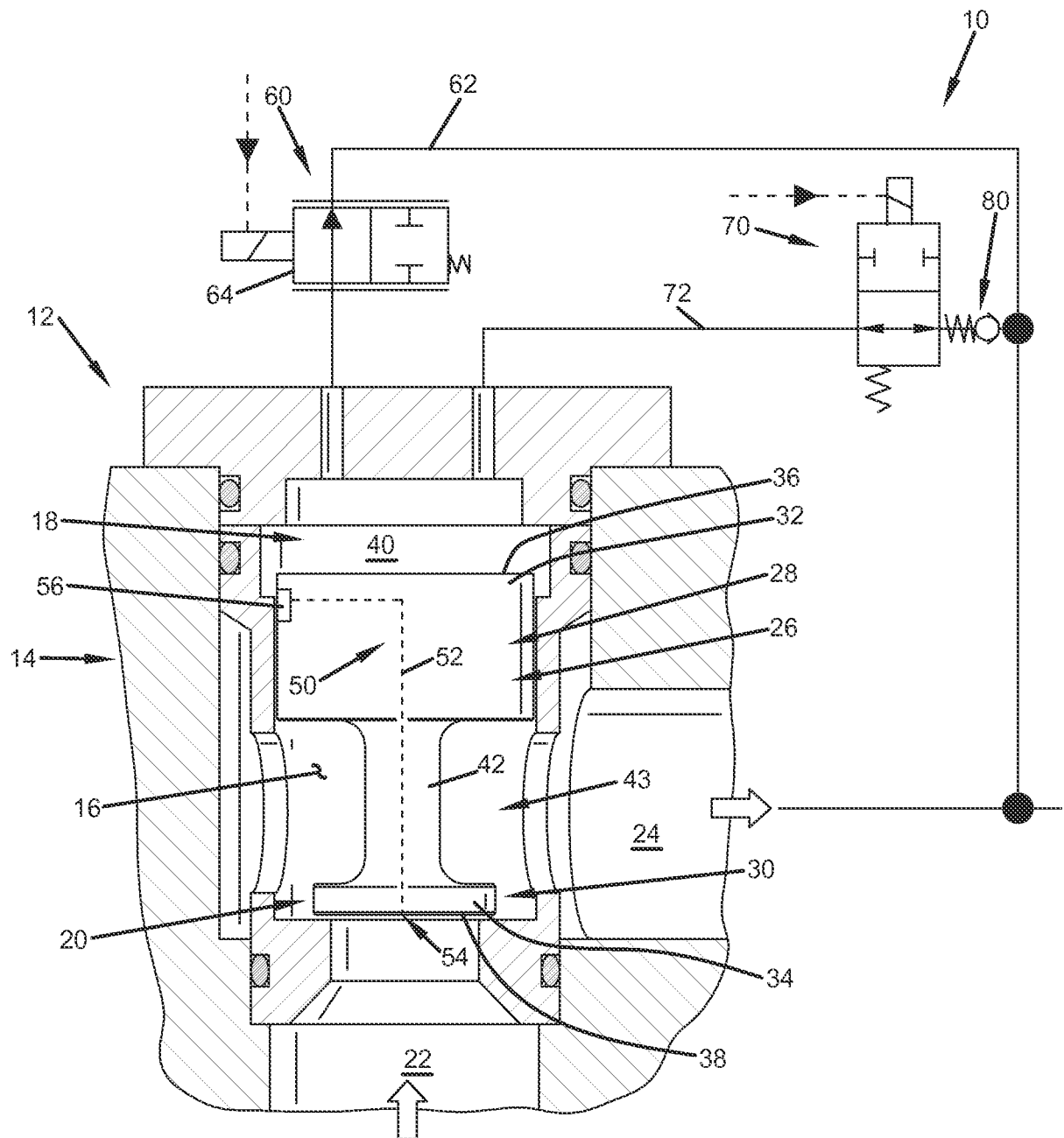


FIG. 4

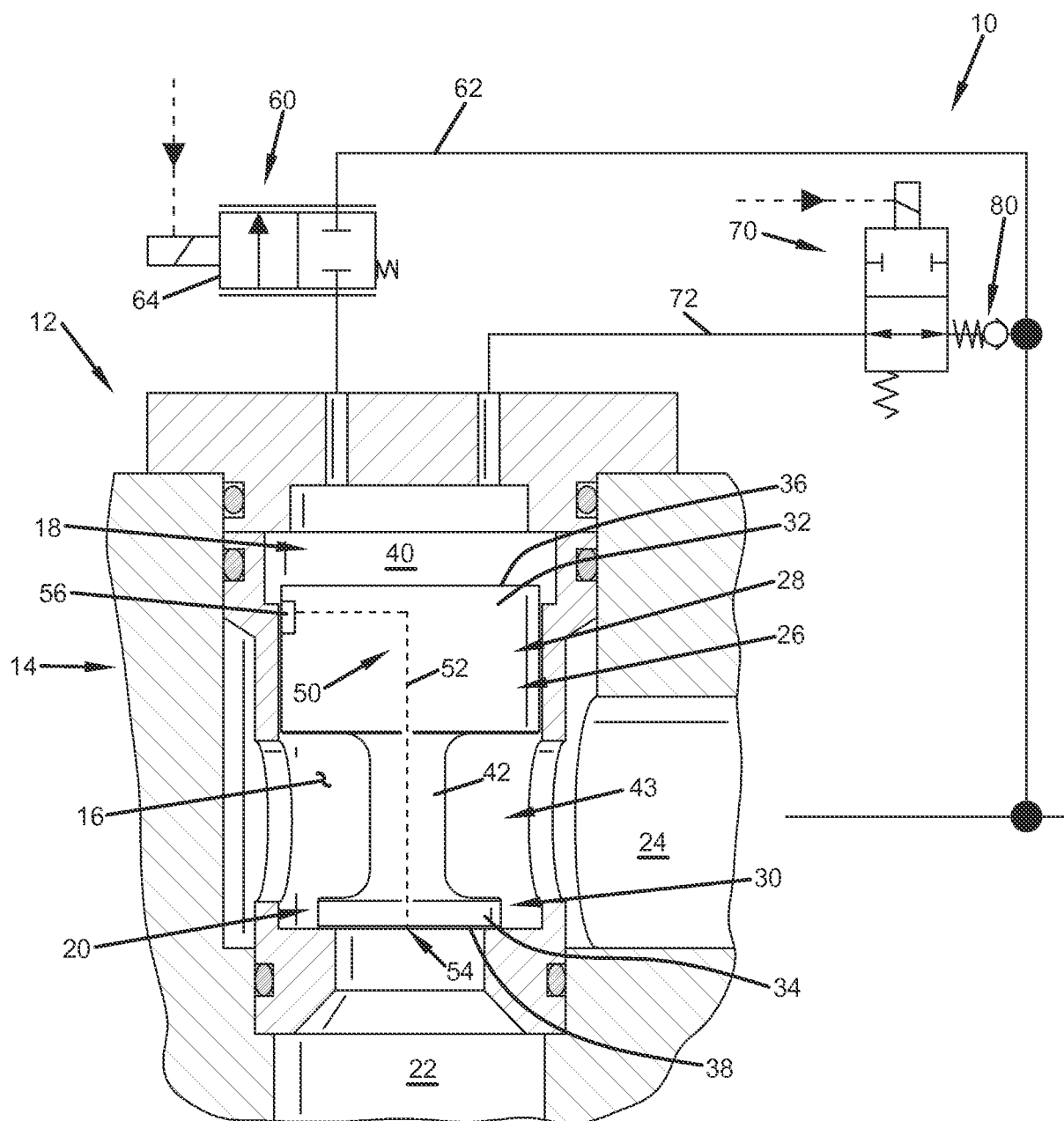
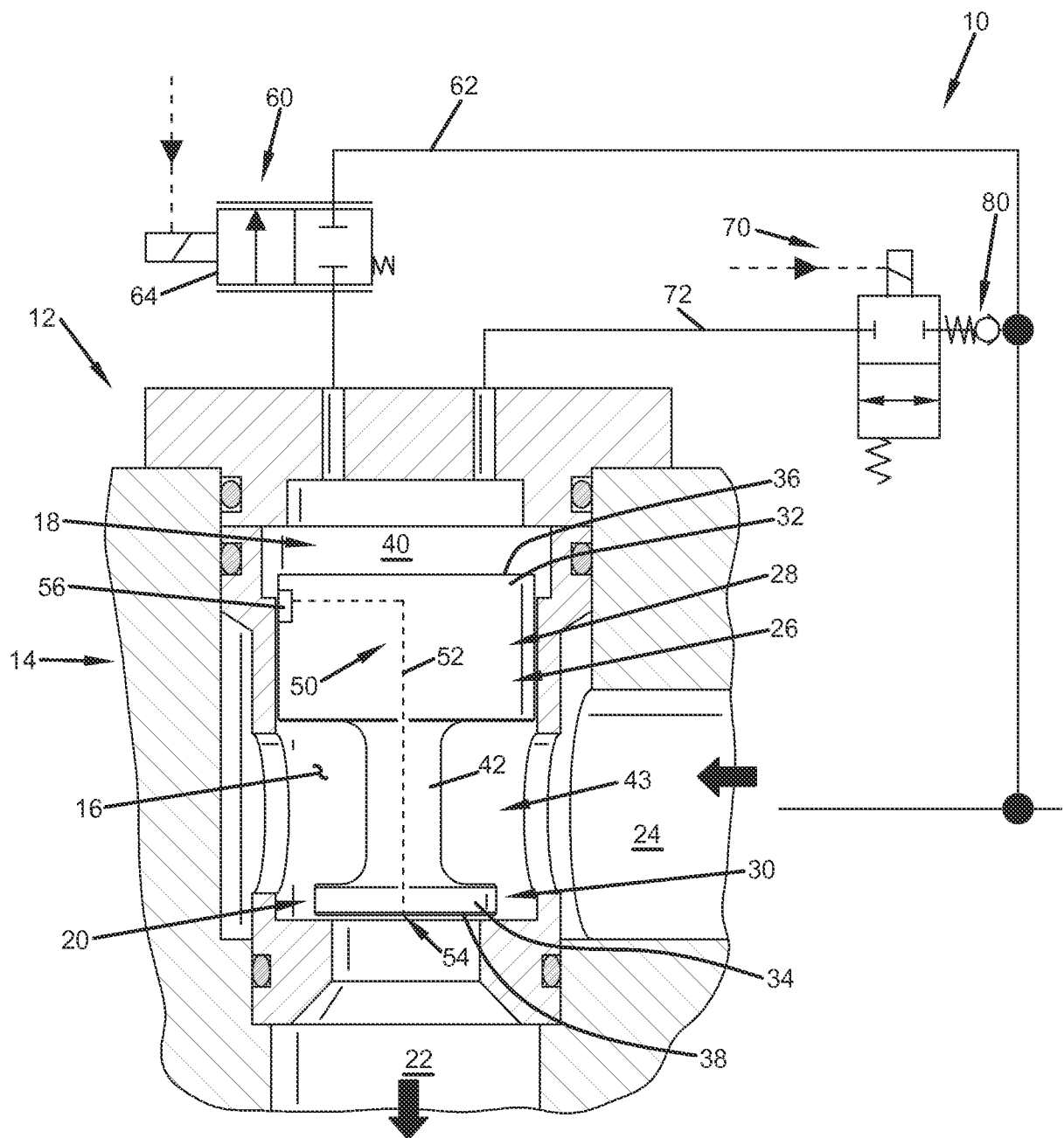


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/066539**A. CLASSIFICATION OF SUBJECT MATTER****F16K 1/34(2006.01)i, F16K 31/122(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16K 1/34; F16K 31/12; F16K 41/10; F16K 1/32; F16K 15/18; F16K 31/122

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: valve, second port, mode, spool, predetermine, pressure, pilot valve, reversing flow, control valve, one-way check valve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009-0072180 A1 (JOHNSON et al.) 19 March 2009 See paragraphs [0042],[0043],[0048]-[0056], claims 1-10, and figures 2,3,6-10.	1-20
A	US 2012-0153193 A1 (GU et al.) 21 June 2012 See paragraphs [0024]-[0027], claim 1, and figures 7-12.	1-20
A	US 2012-0273074 A1 (YAMADA et al.) 01 November 2012 See paragraphs [0021],[0066]-[0076], claim 1, and figures 1,8-10.	1-20
A	US 2009-0194728 A1 (PICKETT et al.) 06 August 2009 See abstract, paragraphs [0024]-[0026], claim 1, and figure 4.	1-20
A	US 2011-0284790 A1 (IKEDA et al.) 24 November 2011 See abstract, claim 1, and figures 1.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 March 2015 (15.03.2015)

Date of mailing of the international search report

16 March 2015 (16.03.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. ++82 42 472 7140

Authorized officer

KIM, Jin Ho

Telephone No. +82-42-481-8699



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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