(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 591 224 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.01.2020 Bulletin 2020/02

(21) Application number: **18425052.0**

(22) Date of filing: **05.07.2018**

(51) Int Cl.:
F04B 1/20 *(2006.01)* ***F04B 1/30*** *(2006.01)*
F04B 1/32 *(2006.01)* ***F04B 23/02*** *(2006.01)*
F03C 1/06 *(2006.01)* ***F03C 1/40*** *(2006.01)*
F03C 1/32 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) PISTON HYDRAULIC DEVICE

(57) The piston hydraulic device comprises a cylinder block having a plurality of cylinder assemblies, having a cylinder and a piston, and being rotatable about a first rotation axis. A port plate has a first port and a second port. A plurality of first conduits connect a respective cylinder alternately to the first port or the second port relative to the angular position of the cylinder assembly about the first rotation axis. At least one second conduit connects between at least one first conduit and an accumulator. At least one directional system fluidly connects to at least one first conduit and to the at least one second conduit. The at least one directional system is configured to convey return fluid from the cylinder assembly to the port plate in a first operative condition and to divert return fluid from the cylinder assembly to the accumulator in a second operative condition.

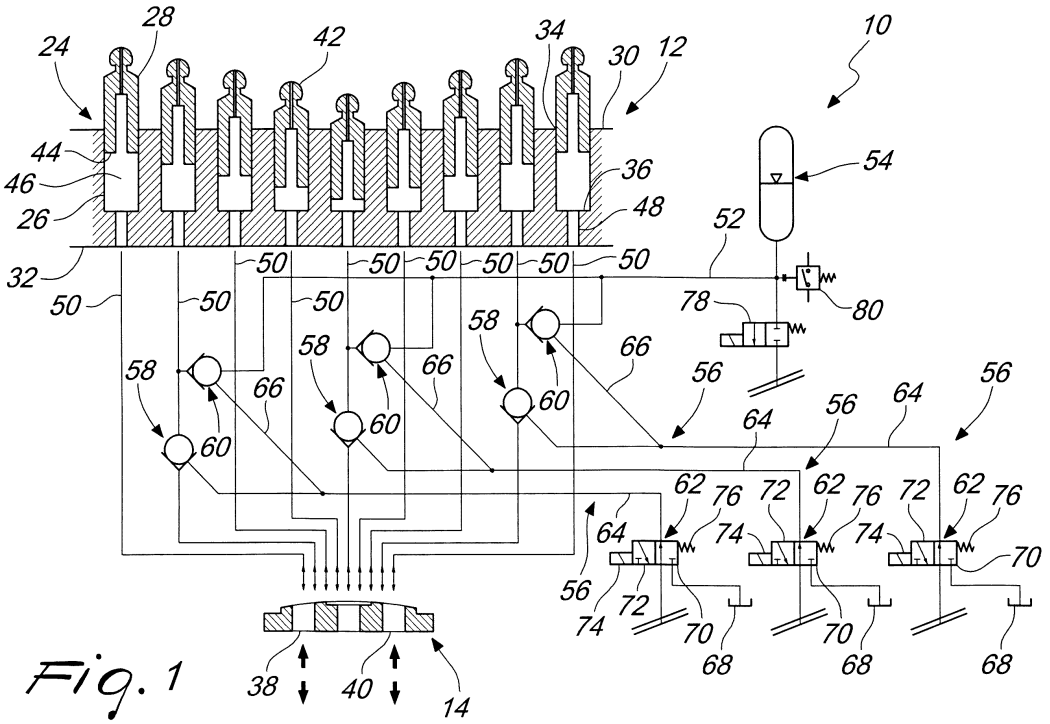

Fig. 1

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Description

Technical Field

[0001] This disclosure relates to the field of piston hydraulic devices such as pumps or motors, particularly variable displacement piston hydraulic devices, and more particularly to the control of fluid displacement in the piston hydraulic devices.

Background

[0002] Piston hydraulic devices may be axial piston machines or radial piston. The Piston hydraulic devices may be operated as pumps or motors.

[0003] Variable axial piston hydraulic devices may be swash plate type devices or bent axis type devices. Swash plate type axial piston devices have a tiltable swash plate that controls the stroke of the piston within a rotating cylinder block. With bent axis type axial piston devices, the pistons are at an angle to the drive shaft and thrust plate.

[0004] In both the "swash plate" and the "bent axis" types, the devices comprise a cylinder block carrying the pistons. The cylinder block rotates about a first axis. The devices also comprise a transmission shaft that rotates around a second axis of rotation, also called the transmission axis. Through this shaft mechanical work that is carried out for the compression of fluid (in the case of the pumps) or mechanical work (in the case of the motors) is determined by the pressure of the operating fluid.

[0005] In the swash plate type device, the first and second axes coincide. The swash plate has a variable inclination to vary the stroke of the pistons between the dead points and, accordingly, the displacement of the machine. For varying displacement in the swash plate type device, the inclination of the plate is varied to change the stroke of the pistons.

[0006] In bent-axis type device, the first and the second axis are incident. The relative inclination of these axes is varied to vary the stroke of the pistons between the dead points and, accordingly, the displacement of the machine. For varying displacement in the bent-axis type device, the inclination of the cylinder block is varied.

[0007] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of the prior art system.

Brief Summary of the Invention

[0008] The present disclosure describes a piston hydraulic device. The piston hydraulic device comprises a cylinder block having a plurality of cylinder assemblies, the cylinder block being rotatable about a first rotation axis wherein each cylinder assembly comprises a cylinder and a piston. A port plate has a first port and a second port. A plurality of first conduits connect a respective cylinder alternately to the first port or the second port relative to the angular position of the cylinder assembly about the first rotation axis. At least one second conduit connects between at least one first conduit and an accumulator. At least one directional system fluidly connects to at least one first conduit and to the at least one second conduit. The at least one directional system is configured to convey return fluid from the cylinder assembly to the port plate in a first operative condition and to divert return fluid from the cylinder assembly to the accumulator in a second operative condition.

Brief Description of the Drawings

[0009] The foregoing and other features and advantages of the present disclosure will be more fully understood from the following description of various embodiments, when read together with the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a piston hydraulic device in a first embodiment according to the present disclosure wherein the directional control valves are in the first position;

Fig. 2 is a schematic illustration of a piston hydraulic device in a second embodiment according to the present disclosure;

Fig. 3 is a schematic illustration of a piston hydraulic device in a third embodiment according to the present disclosure wherein the directional control valves are in the first position;

Fig. 4 is a schematic illustration of a piston hydraulic device in the fourth embodiment according to the present disclosure;

Fig. 5 is a cross sectional view of a portion of a swash plate type axial piston hydraulic device according to the present disclosure; and

Fig. 6 is a cross sectional view of a portion of a bent axis type axial piston hydraulic device according to the present disclosure.

Detailed Description

[0010] This disclosure generally relates to a piston hydraulic device. The device is configured to have discrete variation of fluid displacement and energy recovery with respect to the return fluid leaving from a piston chamber.

[0011] Fig. 1 schematically illustrates a piston hydraulic device **10** (hereinafter referred to as "device") in the first embodiment. Fig. 1 illustrates an axial piston hydraulic device **10.** In an alternative embodiment, the device **10** may be a radial piston hydraulic device. The device **10** comprises a cylinder block **12,** a port plate **14,** a plurality of first conduits **50,** at least one second conduit **52** and at least one directional system **56.**

[0012] The cylinder block **12** comprises a plurality of cylinder assemblies **24.** The cylinder block **12** is rotatable about a first rotation axis **A** (not shown). The cylinder block **12** is rotatably supported in the device **10.** Cylinder

block **12** is rotatably supported in a housing (not shown) of the device **10.** The cylinder assemblies **24** are radially positioned in the cylinder block **12** relative to the first rotation axis **A.** The cylinder assemblies **24** are mutually angularly spaced about the cylinder block **12.** The cylinder block **12** has first block surface **30** and a second block surface **32.** First and second block faces **30, 32** are formed on opposite sides of the cylinder block **12.** First and second block faces **30, 32** are parallel.

[0013] Each cylinder assembly **24** comprises a cylinder **26** and a piston **28.** The cylinders **26** have respective openings **34** on the first block surface **30.** Pistons **28** extend and retract in the cylinders **26.** Pistons **28** extend from the openings **34.** Cylinders **26** have a base **36.** A cylinder conduit **48** extends from the base **36** to the second block face **32.** Cylinder conduit **48** communicates with the cylinder **26.** Fluid enters and exits the cylinder **26** through the cylinder conduit **48.** Pistons **28** have a piston head 42 and a piston base **44.** Piston head **42** is positioned external to the cylinder **26.** Piston base **44** travels in the cylinder **26** during a stroke of the piston **28.** Piston base **44** moves away from the base **36** of the cylinder **26** during an extraction stroke. Piston base **44** moves towards the base **36** of the cylinder **26** during a return stroke. Each piston **28** moves along the respective cylinder **26** in parallel to the first rotation axis **A.**

[0014] Base **44** of piston **28** defines a chamber **46** in the cylinder **26.** The chamber **46** varies in volume as the piston **28** extends and retracts in the cylinder **26.** Change in the fluid in the chamber **46** acts on the piston base **44.** The chamber **46** varies in volume from a maximum volume which is reached when the piston **28** is at the top dead centre of an extraction stroke to a minimum volume which is reached when the piston **28** is at the bottom dead centre of a return stroke.

[0015] The port plate **14** has a first port **38** and a second port **40.** Port plate **14** is supported in the housing (not shown) of the device **10.** Port plate **14** is positioned adjacent the cylinder block **12.** Port plate **14** is positioned so as to face the second block face **32.** Cylinder block **12** is rotatable relative to the port plate **14.** The first and second ports **38, 40** are angularly spaced relative to the first rotation axis **A.** The first and second ports **38, 40** are positioned in respective separate angular sectors of the port plate **14.** In an embodiment, first and second ports **38, 40** are angularly extended on the port plate **14.** The cylinders **26** are configured to be alternately fluidly connected to the first and second ports **38, 40** as the cylinder block **12** rotates relative to the port plate **14.** The cylinder conduit **48** of respective cylinders **26** fluidly alternately connects with the first and second ports **38, 40.** The first and second ports **38, 40** are configured to be connected to different operating fluid sources. The fluid sources are a high pressure fluid source or a low pressure fluid source.

[0016] The plurality of first conduits **50** alternately fluidly connects respective cylinder assemblies **24** to the port plate **14.** The plurality of first conduits **50** alternately fluidly connects respective cylinder **26** to the first port **38** or the second port **40.** The plurality of first conduits **50** alternately fluidly connects respective cylinder conduits **48** to the first port **38** or the second port **40.** The plurality of first conduits **50** alternately fluidly connects respective cylinder conduits **48** to the first port **38** or the second port **40** relative to the angular position of the cylinder assembly **24** about the first rotation axis **A.** Each cylinder **26** alternately connects to the first port **38** or the second port **40** of the port plate **14** as the cylinder block **12** rotates about the first rotation axis **A.**

[0017] The at least one second conduit **52** is connected to at least one first conduit **50.** The at least one second conduit **52** is connected to an accumulator **54.** The at least one second conduit **52** is connected between the at least one first conduit **50** and the accumulator **54.** The second conduit **52** is formed as an annular channel in cross section. The second conduit **52** is formed in the housing (not shown) of the device **10.**

[0018] In an embodiment, the device **10** has a single second conduit **52** connected to the accumulator **54.** In alternative embodiment, the device has a plurality of second conduits **52** each connected to a respective accumulator **54.** The plurality of second conduits **52** are each connected to respective first conduits **50.**

[0019] The at least one directional system **56** is fluidly connected to the at least one first conduit **50.** The at least one directional system **56** is fluidly connected to the at least one second conduit **52.** The at least one directional system **56** is configured to convey return fluid from the cylinder assembly **24** to the port plate **14** in a first operative condition. Return fluid exits the chamber **46** of the cylinder **26** as the piston **28** undergoes a return stroke. Return fluid flows into the at least one first conduit **50** from the cylinder assembly **24.** The at least one directional system **56** is configured to divert return fluid from the cylinder assembly **24** to the accumulator **54** in a second operative condition. Return fluid moves from the at least one first conduit **50** to the at least one second conduit **52.**

[0020] In the first embodiment, device **10** has a plurality of directional systems **56.** The plurality of directional systems **56** are fluidly connected to the respective first conduits **50.** The plurality of directional systems **56** are fluidly connected to a single second conduit **52.** The plurality of directional systems **56** are interposed between the plurality of respective first conduits **50** and the accumulator **54.** The plurality of directional systems **56** are each operatable independently.

[0021] In the second embodiment, as illustrated in Fig. 2, device **10** has a plurality of directional systems **56** that are each connected to respective second conduits **52.** The plurality of directional systems **56** are each operatable independently. Each second conduit **52** is connected to a respective accumulator **54.** The plurality of directional systems **56** are interposed between the respective first conduits **50** and the respective accumulators **54.**

[0022] With respect to Fig. 1 and 2, the at least one

directional system **56** is configured to fluidly disconnect the cylinder assembly **24** from the accumulator **54** in the first operative condition. Fluid is prevented to flow from the cylinder assembly **24** to the accumulator **54** during piston **28** retraction and extraction. The at least one directional system **56** is configured to fluidly connect the cylinder assembly **24** to the port plate **14.** Fluid is permitted to flow from the cylinder assembly **24** to the port plate **14** during piston **28** retraction. Fluid is permitted to flow from the port plate **14** to the cylinder assembly **24** and during piston **28** extraction.

[0023] The at least one directional system **56** is configured to fluidly disconnect the cylinder assembly **24** from the port plate **14** in the second operative condition at piston **28** retraction. Fluid is prevented to flow from the cylinder assembly **24** to the port plate **14** during retraction of the piston **28** and fluid is permitted to flow from the port plate **14** to the cylinder assembly **24** during extraction of the piston **28.** The at least one directional system **56** is configured to fluidly connect the cylinder assembly **24** to the accumulator **54** in the second operative condition at piston **28** retraction. Fluid is permitted to flow from the cylinder assembly **24** to the accumulator **54** during retraction of the piston **28** and fluid is prevented to flow from the cylinder assembly **24** to the accumulator **54** at piston **28** extraction.

[0024] With reference to Figs. 1 and 2, the at least one directional system **56** comprises a first control valve **58,** a second control valve **60** and a pilot valve **62.** The first control valve **58** is positioned in the at least one first conduit **50** to control fluid flow between the cylinder assembly **24** and the port plate **14.** The first control valve **58** controls the fluid flow between the cylinder **26** and the first port **38** or the second port **40.** The second control valve **60** is positioned in the at least one second conduit **52** to control fluid flow to the accumulator **54.** The second control valve **60** is positioned in the at least one second conduit **52** to control fluid flow from the at least one fluid conduit **50** to the at least second fluid conduit **52.** The pilot valve **62** is fluidly connected to the first and second control valves **58, 60.** The pilot valve **62** controls the actuation of the first and second control valves **58, 60.**

[0025] The at least one second conduit **52** is connected to the at least one first conduit **50** between the first control valve **58** and the respective cylinder assembly **24.** The point of connection of the at least one second conduit **52** and the at least one first conduit **50** is positioned between the first control valve **58** and the respective cylinder assembly **24.** In an embodiment, the point of connection of the at least one second conduit **52** and the at least one first conduit **50** is positioned between the first control valve **58** and the cylinder conduit **48** of respective cylinders **26.**

[0026] The first control valve **58** is actuatable to open in the first operative condition so as to permit fluid to flow between the port plate **14** and the cylinder assembly **24.** The first control valve **58** is actuatable to close in the second operative condition so as to obstruct fluid flow from the cylinder assembly **24** to the port plate **14.** In an embodiment, the first control valve **58** is a check valve.

[0027] The first control valve **58** is actuatable to open or to close. In the open condition, the first control valve **58** is actuated so as to remain open. The first control valve **58** permits fluid to flow from the port plate **14** to the cylinder assembly **24,** during extraction of the piston **28,** and permits fluid to flow from the cylinder assembly **24** and to the port plate **14,** during retraction of the piston **28.** In the closed condition, the first control valve **58** is actuated to close so as to operate as a check valve. The first control valve **58** permits fluid to flow from the port plate **14** to the cylinder assembly **24,** during extraction of the piston **28.** The force of the pressure of the fluid from the port plate **14** is sufficient to overcome the force holding the first control valve **58** in the closed position. The first control valve **58** prevents fluid to flow from the cylinder assembly **24** and to the port plate **14,** during retraction of the piston **28.**

[0028] The second control valve **60** is actuatable to close in the first operative condition so as to obstruct fluid flow from the cylinder assembly **24** to the accumulator **54.** The second control valve **60** is actuatable to open in the second operative condition so as to permit fluid flow from the cylinder assembly **24** to the accumulator **54.** In an embodiment, the second control valve **60** is a check valve.

[0029] The second control valve **58** is actuatable to close or to open. In the closed condition, the second control valve **60** is actuated to remain closed. The second control valve **60** prevents fluid to flow from the first conduit **50** through the second conduit **52** to the accumulator **54.** Force of the pressure of the fluid from the port plate **14** or the cylinder assembly **24** is not sufficient to overcome the force holding the second control valve **60** in the closed position. Second control valve **60** prevents fluid to flow to the accumulator **54** from either from the cylinder assembly **24** or from the port plate **14.** In the open condition, second control valve **60** is actuated to open so as to operate as a check valve. The second control valve **60** permits fluid to flow from the first conduit **50** through the second conduit **52** to the accumulator **54.** Second control valve **60** permits fluid to flow to the accumulator **54** from the cylinder assembly **24.** The force of the pressure of the fluid from the cylinder assembly **24,** during retraction of the piston **28,** is sufficient to overcome the force of holding the second control valve **60** in the closed position. The force of the pressure of the fluid from the port plate **14,** during extraction of the piston **28,** is not sufficient to overcome the force holding the second control valve **60** in the closed position.

[0030] The pilot valve **62** is connected to the first control valve **58** through a first pilot line **64.** The pilot valve **62** is connected to the second control valve **60** through a second pilot line **66.** The second pilot line **66** is connected to the first pilot line **64.** A pilot signal is sent from the pilot valve **62** to the first and second control valves **58, 60** for the actuation thereof. The pilot signal is sent through the

first and second pilot lines **64, 66.** The first and second control valves **58, 60** are actuated by the same pilot signal. The pilot signal is provided by a pressure source (not shown). The pressure of the pilot signal may be selected as required.

[0031] The pilot valve **62** is actuatable between a first position **70** and a second position **72.** In the first position **70,** the first and second pilot lines **64, 66** are fluidly connected to the pressure source. The pilot signal is sent to the first and second control valves **58, 60** from the pressure source. The at least one directional system **56** is set to the first operative condition when the pilot valve **62** is actuated to the first position **70.** The pilot signal actuates the first control valve **58** to remain open and actuates the second control valve **60** to remain closed.

[0032] In the second position **72** the first and second pilot lines **64, 66** are fluidly connected to a tank **68.** The pressurized fluid is drained from the first and second pilot lines **64, 66** to the tank **68.** The at least one directional system **56** is set to the second operative condition when the pilot valve **62** is actuated to the first position **72.** The drop in pressure in the first and second pilot lines **64, 66** actuates the first control valve **58** to close and actuates the second control valve **60** to open. The first and second control valves **58, 60** operate as check valves.

[0033] The pilot valve **62** is actuatable between the first position **70** and the second position **72** through mechanical means. The mechanical means is electronically controlled. In an embodiment, the mechanical means is an actuation member **74.** Actuation member **74** may be comprised in the pilot valve **62.** A controller (not shown) may be operatively associated with the pilot valve **62** for switching between the first and the second positioned **70, 72.**

[0034] In a further embodiment, the actuation member **74** may operate in conjunction with a return spring **76.** The pilot valve **62** may be normally in the first position **70.** The activation of the actuation member **60** may actuate the pilot valve **62** from the first position **70** to the second position **72.** The deactivation of the actuation member **60** permits the return spring **62** to return the pilot valve **62** from the second position **72** to the first position **70.** In an embodiment, the directional control valve **56** is a three way two position valve.

[0035] In an embodiment, the accumulator **54** is fluidly connected to a work tool (not shown). The fluid connection to the work tool is controlled by a normally closed two position valve **78.** As required, the pressurized fluid stored in the accumulator may be released through the two position valve **78** for use in operations such as to operate the work tool. With respect to Fig. 2, the device **10** comprises a plurality of accumulators **54.** Each accumulator **54** is connected to a respective second conduit **52.** Each conduit is connected to a respective directional system **56.**

[0036] In an embodiment, the accumulator **54** is connected to a pressure switch **80.** The pressure switch **80** is set to activate at a predetermined pressure value. The predetermined pressure value may be set to correspond to the maximum pressure of the accumulator **54.** When the pressure in the accumulator **54** reaches the predetermined pressure value, the pressure switch **80** sends a signal to an electric power unit (not shown) for activation of the actuation means **74.** The actuation means **74** actuates the pilot valve **62** from the second position **72** to the first position **70** to thereby setting the directional system **56** to the first operative condition so as to prevent more oil being sent to the accumulator **54.** With respect to Fig. 2, with a plurality of accumulators **54** the respective pressure switches **80** have the same predetermined pressure values. In an alternate embodiment, the respective pressure switches **80** may have different predetermined pressure values.

[0037] In respect to the device **10** acting as a motor and in the first operative condition, with the piston **28** retracted in the cylinder **26,** the connection to a port **38, 40** with high pressure fluid permits pressurised fluid to flow to the chamber **46** so as to extract the piston **28.** In the first operative condition fluid is permitted to flow through first conduit **50** by the first control valve **58** that is actuated to the open position. Fluid is prevented from flowing to the accumulator **54** through the second conduit **52** by the second control valve **60** that is actuated to the closed position.

[0038] With the piston **28** extracted in the cylinder **26,** the connection to a port **38, 40** with low pressure fluid enables return fluid to flow from the cylinder **26** so as to allow the retraction of the piston **28.** Second control valve **60** obstructs fluid from flowing to the accumulator **54.** Fluid is permitted to flow through the first control valve **58** to the port plate **14** and out through either port **38, 40.**

[0039] In respect to the device **10** acting as a motor and in the second operative condition, with the piston **28** retracted in the cylinder **26,** the connection to a port **38, 40** with high pressure fluid permits pressurised fluid to flow to the chamber **46** so as to extract the piston **28.** In the second operative condition fluid is permitted to flow through the first conduit **50** to the chamber **46** through the first control valve **58.** The second control valve **60** is actuated to the open position. Fluid is prevented from flowing to the accumulator **54** through the second conduit **52** as the fluid pressure is not sufficient to overcome the second control valve **60.**

[0040] In an embodiment, fluid may be prevented from flowing to the accumulator **54** when the pressure in the accumulator **54** is low and/or the pressure along the first conduit **50** is high. Fluid may flow through the second control valve **60** to the accumulator **54** if the fluid pressure in the accumulator **54** is low. Fluid may flow through the second control valve **60** to the accumulator **54** when pressure along the first conduit **50** is high. With reference to Figs. 3 and 4, the device **10** may further comprise a third pilot line **88** to prevent flow of high pressure fluid to the accumulator **54.** The third pilot line connects the second control valve **60** to a respective first conduit **50.** The third pilot line **88** connects to the first conduit **50** upstream

from the first control valve **58.** The third pilot line **88** connects to the first conduit **50** between the first control valve **58** and the port plate **14.** Figs 3 and 4 operate as in Figs. 1 and 2 respectively with the exception of the third pilot line **88.**

[0041] With reference to Figs, 1 and 2 with the piston **28** extracted in the cylinder **26,** the connection to a port **38, 40** with low pressure fluid enables return fluid to flow from the cylinder **26** so as to allow the retraction of the piston **28.** First control valve **58** prevents fluid from flowing to the port plate **14** and out through either port **38, 40.** As the pressure in first conduit **50** rises, the pressure reaches a point to overcome the second control valve **60** so that fluid flows to the accumulator **54** through the second conduit **52.**

[0042] In respect to the device **10** acting as a pump and in the first operative condition, with the piston **28** retracted in the cylinder **26,** the connection to a port **38, 40** with the low pressure fluid permits pressurised fluid to flow to the chamber **46** so as to extract the piston **28.** In the first operative condition fluid is permitted to flow through first conduit **50** by the first control valve **58** that is actuated to the open position. Fluid is prevented from flowing to the accumulator **54** through the second conduit **52** by the second control valve **60** that is actuated to the closed position.

[0043] With the piston **28** extracted in the cylinder **26** the connection to a port **38, 40** with the high pressure fluid enables return fluid to flow from the cylinder **26** so as to allow the retraction of the piston **28.** Second control valve **60** obstructs fluid from flowing to the accumulator **54.** Fluid is permitted to flow through the first control valve **58** to the port plate **14** and out through either port **38, 40.**

[0044] In respect to the device **10** acting as a pump and in the second operative condition, with the piston **28** retracted in the cylinder **26,** the connection to a port **38, 40** with the low pressure fluid permits pressurised fluid to flow to the chamber **46** so as to extract the piston **28.** In the second operative condition fluid is permitted to flow through the first conduit **50** to the chamber **46** by the first control valve **58** that returns to the closed position. The second control valve **60** is actuated to the open position. Fluid is prevented from flowing to the' accumulator **54** through the second conduit **52** as the fluid pressure is not sufficient to overcome the second control valve **60.**

[0045] With the piston **28** extracted in the cylinder **26** the connection to a port **38, 40** with the high pressure fluid enables return fluid to flow from the cylinder **26** so as to allow the retraction of the piston **28.** First control valve **58** prevents fluid from flowing to the port plate **14** and out through either port **38, 40.** As the pressure in first conduit **50** rises, the pressure reaches a point to overcome the second control valve **60** so that fluid flows to the accumulator **54** through the second conduit **52.**

[0046] Fig. 5 illustrates the device **10** as a swash plate type axial piston hydraulic device. Device **10** comprises a housing **82.** A rotor **86** is coupled to the cylinder block **12.** The rotor **86** is adapted to be coupled to a drive shaft or to a driven shaft (not shown). The rotor **86** is rotatably supported by the housing **82** around the first rotation axis **A.** A swash plate **84** is coupled to the housing **82.** The rotor **86** is inserted passing through the swash plate **84.** The swash plate **84** has ring conformation. The port plate **14** is coupled to the housing **82.** In an embodiment, the at least one directional system **56** is coupled to the housing **82.** In a further embodiment, a plurality of directional systems **56** are coupled to the housing **82.** The cylinder block **12** is rotatably supported in the housing **82.** Pistons **28** are movably positioned in the respective cylinders **26.** Pistons **28** are coupled to the swash plate **84.** Cylinder conduits **48** extend from the base **36** of respective cylinders **26.**

[0047] The first conduit **50** extends from the cylinder block **12** through the housing **82.** A portion of the first conduit **50** extends through the cylinder block **12.** First conduit **50** extends from the respective cylinder conduit **48** through the cylinder block **12**. A first conduit path **50A** of the first conduit **50** extends through the cylinder block **12** to the housing **82.** The first conduit **50** extends to the at least one directional system **56.** A second conduit path **50B** extends through the housing **72** to the first control valve **58.** A first annular groove **50E** is interposed between the first and second conduit path **50A** and **50B.** The first annular groove **50E** is defined in the housing **72.**

[0048] The first conduit **50** extends from the first control valve **58** back to the cylinder block **12.** A third conduit path **50C** extends through the housing **82** to the cylinder block **12.** The first conduit **50** extends through the cylinder block **12** to the port plate **14.** A fourth conduit path **50D** extends through the cylinder block **12** to the port plate **14.** A second annular groove **50F** is interposed between the third and fourth conduit path **50C** and **50D.** The second annular groove **50F** defined in the housing **82.** Sealing gaskets (not shown) are interposed between the first and second annular groove **50E** and **50F,** the housing **82** and the cylinder block **12.**

[0049] The second conduit **52** extends through the housing **82.** A first conduit channel **52A** of the second conduit **52** extends from the first control valve **58** to the second control valve **60.** A second conduit channel **52B** of the second conduit **52** extends from the second control valve **60** to the accumulator **54** (not shown).

[0050] A first pilot line **64** extends through the housing **82** from the first control valve **58** to the pilot valve **62** (not shown). The second control valve **60** is connected to the first pilot line **64** through the second pilot line **66** (not shown).

[0051] Fig. 6 illustrates the device **10** as a bent-axis type axial piston hydraulic device. Device **10** comprises a housing **82.** A rotor **86** is coupled to the housing **72.** The rotor **86** is adapted to bed to a drive shaft or to a driven shaft (not shown). The rotor **86** is rotatably supported by the housing **82** around a second rotation axis **B** inclined in respect of the first rotation axis **A.** The port plate **14** is coupled to the housing **82.** In an embodiment, the at least one directional system **56 is** coupled to the

housing **82.** In a further embodiment, a plurality of directional systems **56** are coupled to the housing **82.** The cylinder block **12** is rotatably supported in the housing **82.** Pistons **28** are movably positioned in the respective cylinders **26.** Pistons **28** are coupled to the rotor **86.** Cylinder conduits **48** extend from the base **36** of respective cylinders **26.**

[0052] The first conduit **50** extends from the cylinder block **12** through the housing **72.** A portion of the first conduit **50** extends through the cylinder block **12.** First conduit **50** extends from the respective cylinder conduit **48** through the cylinder block **12.** A first conduit path **50A** of the first conduit **50** extends through the cylinder block **12** to the housing **82.** The first conduit **50** extends to the at least one directional system **56.** A second conduit path **50B** extends through the housing **82** to the first control valve **58.** A first annular groove **50E** is interposed between the first and second conduit path **50A** and **50B.** The first annular groove **50E** is defined in the housing **72.**

[0053] The first conduit **50** extends from the first control valve **58** back to the cylinder block **12.** A third conduit path **50C** extends through the housing **82** to the cylinder block **12.** The first conduit **50** extends through the cylinder block **12** to the port plate **14.** A fourth conduit path **50D** extends through the cylinder block **12** to the port plate **14.** A second annular groove **50F** is interposed between the third and fourth conduit path **50C** and **50D.** The second annular groove **50F** defined in the housing **82.** Sealing gaskets (not shown) are interposed between the first and second annular groove **50E** and **50F,** the housing **82** and the cylinder block **12.**

[0054] The second conduit **52** extends through the housing **82.** A first conduit channel **52A** of the second conduit **52** extends from the first control valve **58** to the second control valve **60.** A second conduit channel **52B** of the second conduit **52** extends from the second control valve **60** to the accumulator **54** (not shown).

[0055] A first pilot line **64** extends through the housing **82** from the first control valve **58** to the pilot valve **62** (not shown). The second control valve **60** is connected to the first pilot line **64** through the second pilot line **66** (not shown).

[0056] In an embodiment, the device **10** is configured to operate as a hydraulic motor. In an alternate embodiment, the device **10** is configured to operate as a pump.

[0057] The skilled person would appreciate that foregoing embodiments may be modified or combined to obtain the piston hydraulic device **10** of the present disclosure.

Industrial Applicability

[0058] This disclosure describes a piston hydraulic device **10** that has individually variable pistons. The piston hydraulic device **10** provides for the discrete variation in fluid displacement. The discrete variation of displacement is enabled without modifying the geometric configuration of the piston hydraulic device **10.** The relative inclination of the various structures such as the swash plate **84** or the housing **82,** are not varied to obtain the variation of displacement. Energy recovery is obtained by means of the directional system **56** that fluidly connects the piston assembly **24** to the accumulator **54.** Energy is stored in the accumulator **54** in the form of pressurised fluid that may be used as required such as to operate a tool.

[0059] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein.

[0060] Where technical features mentioned in any claim are followed by reference signs, the reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, neither the reference signs nor their absence have any limiting effect on the technical features as described above or on the scope of any claim elements.

[0061] One skilled in the art will realise the disclosure may be embodied in other specific forms without departing from the disclosure or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the disclosure described herein. Scope of the invention is thus indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

Claims

1. A piston hydraulic device (10) comprising:

a cylinder block (12) having a plurality of cylinder assemblies (24), the cylinder block (12) being rotatable about a first rotation axis (A) wherein each cylinder assembly (24) comprises a cylinder (26) and a piston (28);
a port plate (14) having a first port (38) and a second port (40);
a plurality of first conduits (50) for connecting a respective cylinder (26) alternately to the first port (38) or the second port (40) relative to the angular position of the cylinder assembly (24) about the first rotation axis (A),

characterized in that the piston hydraulic device (10) further comprises

at least one second conduit (52) connected between at least one first conduit (50) and an accumulator (54);
at least one directional system (56) fluidly con-

nected to at least one first conduit (50) and fluidly connected to the at least one second conduit (52) wherein the at least one directional system (56) is configured to convey return fluid from the cylinder assembly (24) to the port plate (14) in a first operative condition and to divert return fluid from the cylinder assembly (26) to the accumulator (54) in a second operative condition.

2. The piston hydraulic device (10) of claim 1 wherein the at least one directional system (56) is configured to fluidly disconnect the cylinder assembly (24) from the accumulator (54) and to fluidly connect the cylinder assembly (24) to the port plate (14) in the first operative condition.

3. The piston hydraulic device (10) of claims 1 or 2 wherein the at least one directional system (56) is configured to fluidly disconnect the cylinder assembly (24) from the port plate (14) and to fluidly connect the cylinder assembly (24) to the accumulator (54) in the second operative condition at piston (28) retraction.

4. The piston hydraulic device (10) of claims 1, 2 or 3 wherein the at least one directional system (56) comprises a first control valve (58) positioned in the at least one first conduit (50) to control fluid flow between the cylinder assembly (24) and the port plate (14), a second control valve (60) positioned in the at least one second conduit (52) to control fluid flow to the accumulator (54) and a pilot valve (62) fluidly connected to the first and second control valves (58, 60) to control the actuation of the first and second control valves (58, 60).

5. The piston hydraulic device (10) of claim 4 wherein the at least one second conduit (52) is connected to the at least one first conduit (50) between the first control valve (58) and the respective cylinder assembly (24).

6. The piston hydraulic device (10) of claims 4 or 5 wherein the first control valve (58) is actuatable to open in the first operative condition so as to permit fluid to flow between the port plate (14) and the cylinder assembly (24).

7. The piston hydraulic device (10) of claims 4, 5 or 6 wherein the first control valve (58) is actuatable to close in the second operative condition so as to obstruct fluid flow from the cylinder assembly (24) to the port plate (14).

8. The piston hydraulic device (10) of claims 4, 5, 6 or 7 wherein the second control valve (60) is actuatable to close in the first operative condition so as to obstruct fluid flow from the cylinder assembly (24) to the accumulator (54).

9. The piston hydraulic device (10) of claims 4, 5, 6, 7 or 8 wherein the second control valve (60) is actuatable to open in the second operative condition so as to permit fluid flow from the cylinder assembly (24) to the accumulator (54).

10. The piston hydraulic device (10) of any one of preceding claims 4 to 9 wherein the pilot valve (62) is connected to the first control valve (58) through a first pilot line (64) and the pilot valve (62) is connected to the second control valve (60) through a second pilot line (66) connected to the first pilot line (64).

11. The piston hydraulic device (10) of claim 10 further comprising a third pilot line (88) connects the second control valve (60) to a respective first conduit (50) between the first control valve (58) and the port plate (14).

12. The piston hydraulic device (10) of any one of preceding claims wherein a plurality of directional systems (56) are fluidly connected to the plurality of respective first conduits (50) and fluidly connected to the second conduit (52).

13. The piston hydraulic device (10) of any one of preceding claims wherein the accumulator (54) is fluidly connected to a work tool wherein the fluid connection is controlled by a normally closed valve (78).

14. The piston hydraulic device (10) of any one of preceding claims wherein the device (10) is a bent axis hydraulic device.

15. The piston hydraulic device (10) of any one of preceding claims 1 to 13 wherein the device (10) is a swash plate type hydraulic device.

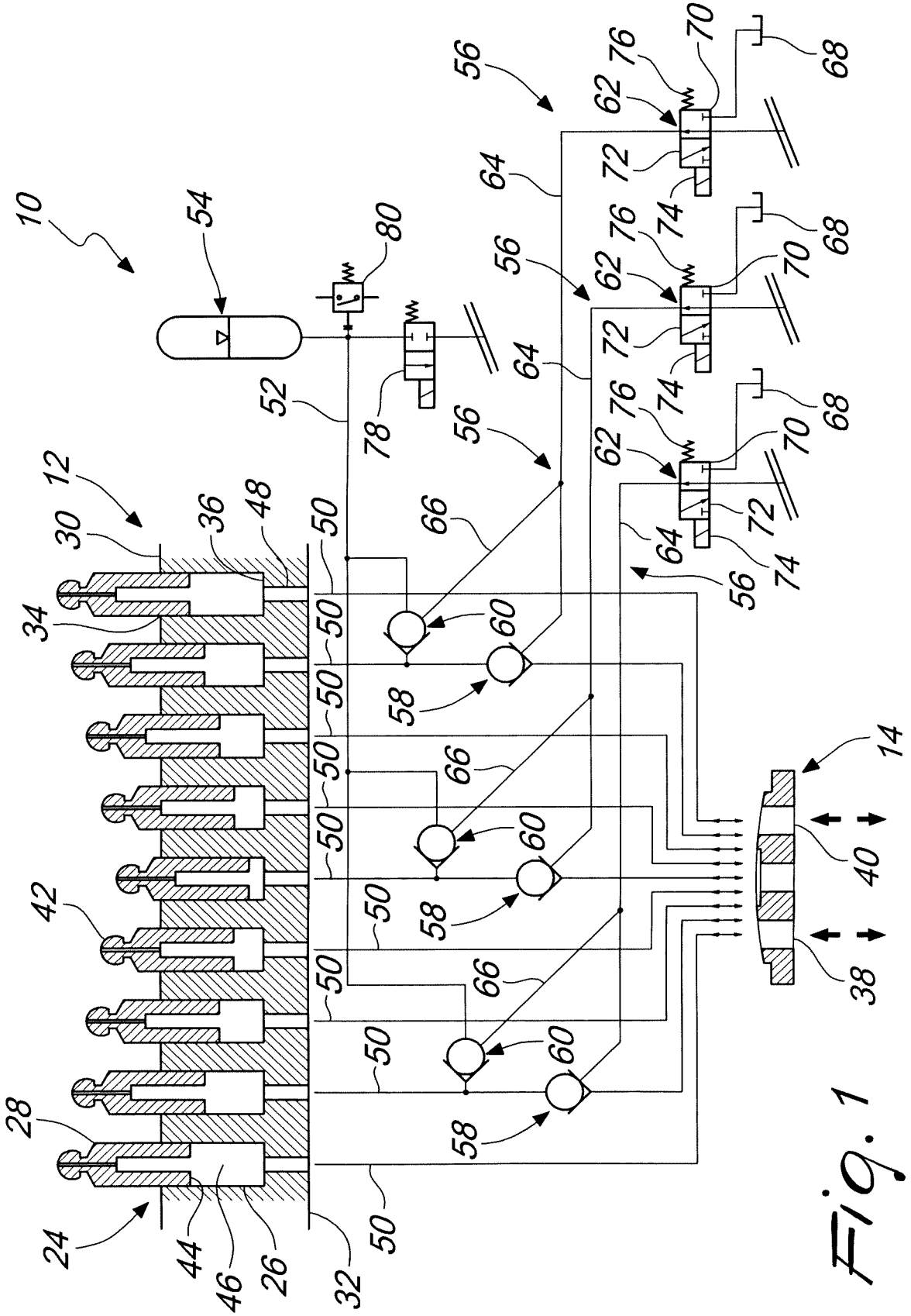
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Fig. 1

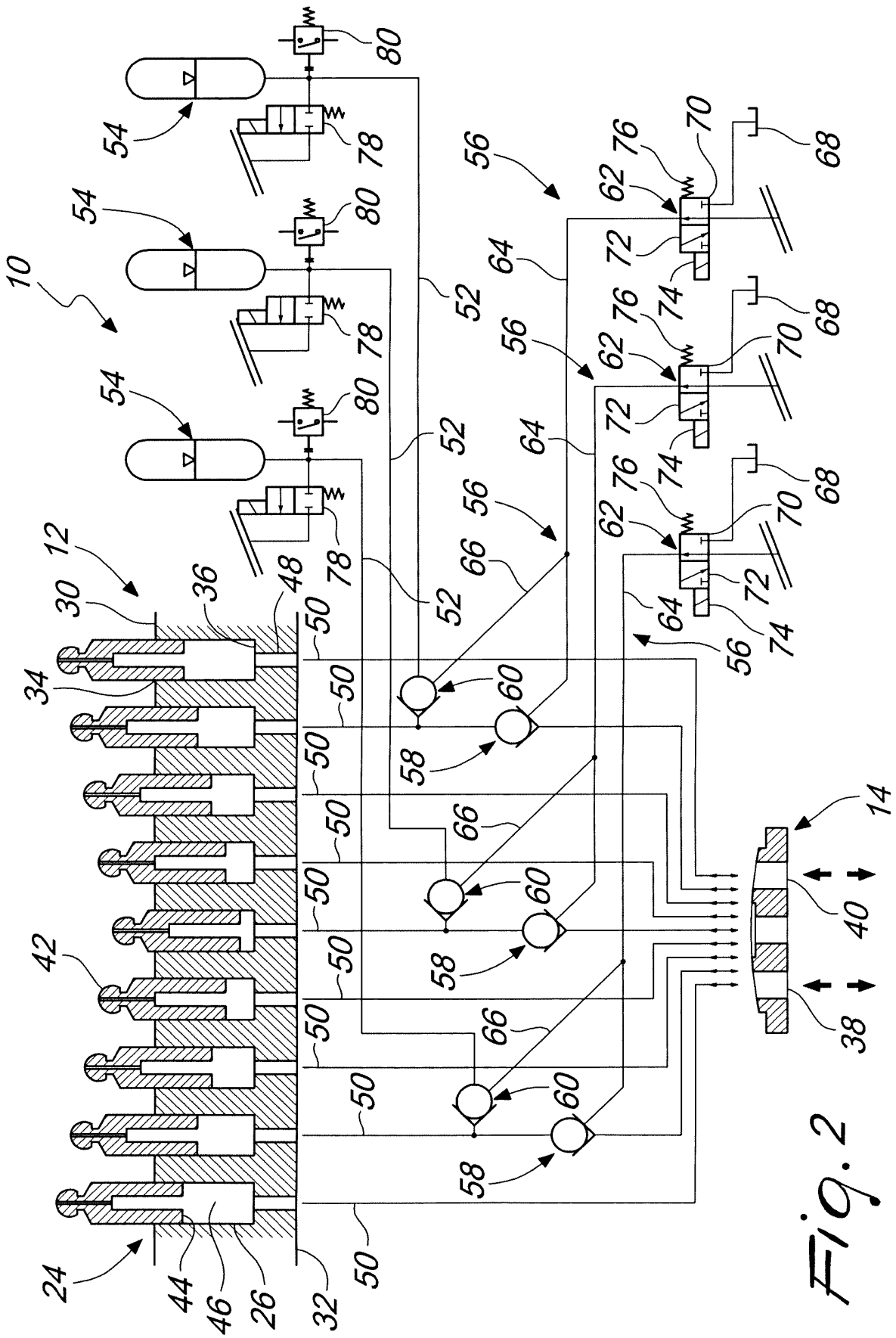
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Fig. 2

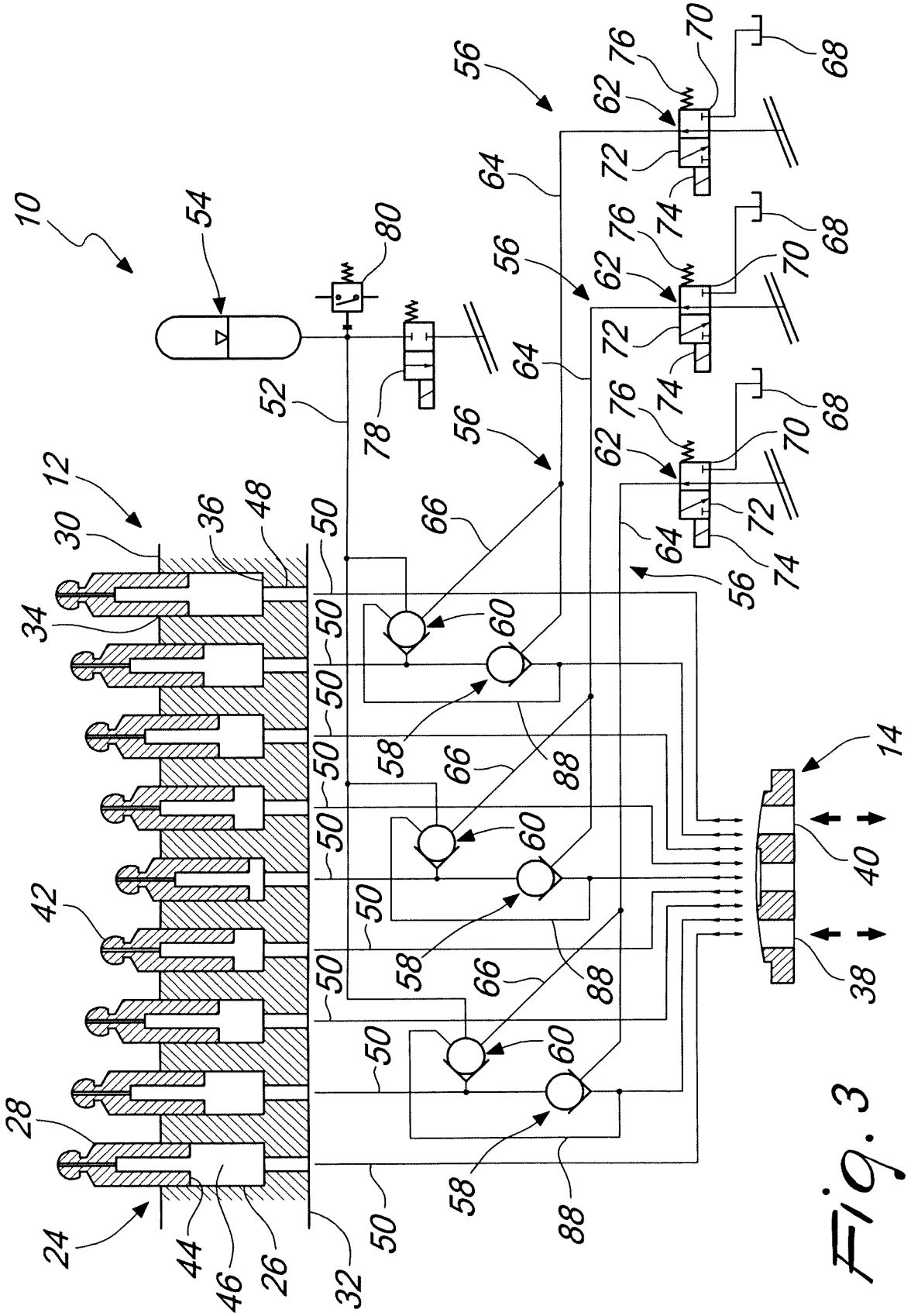
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Fig. 3

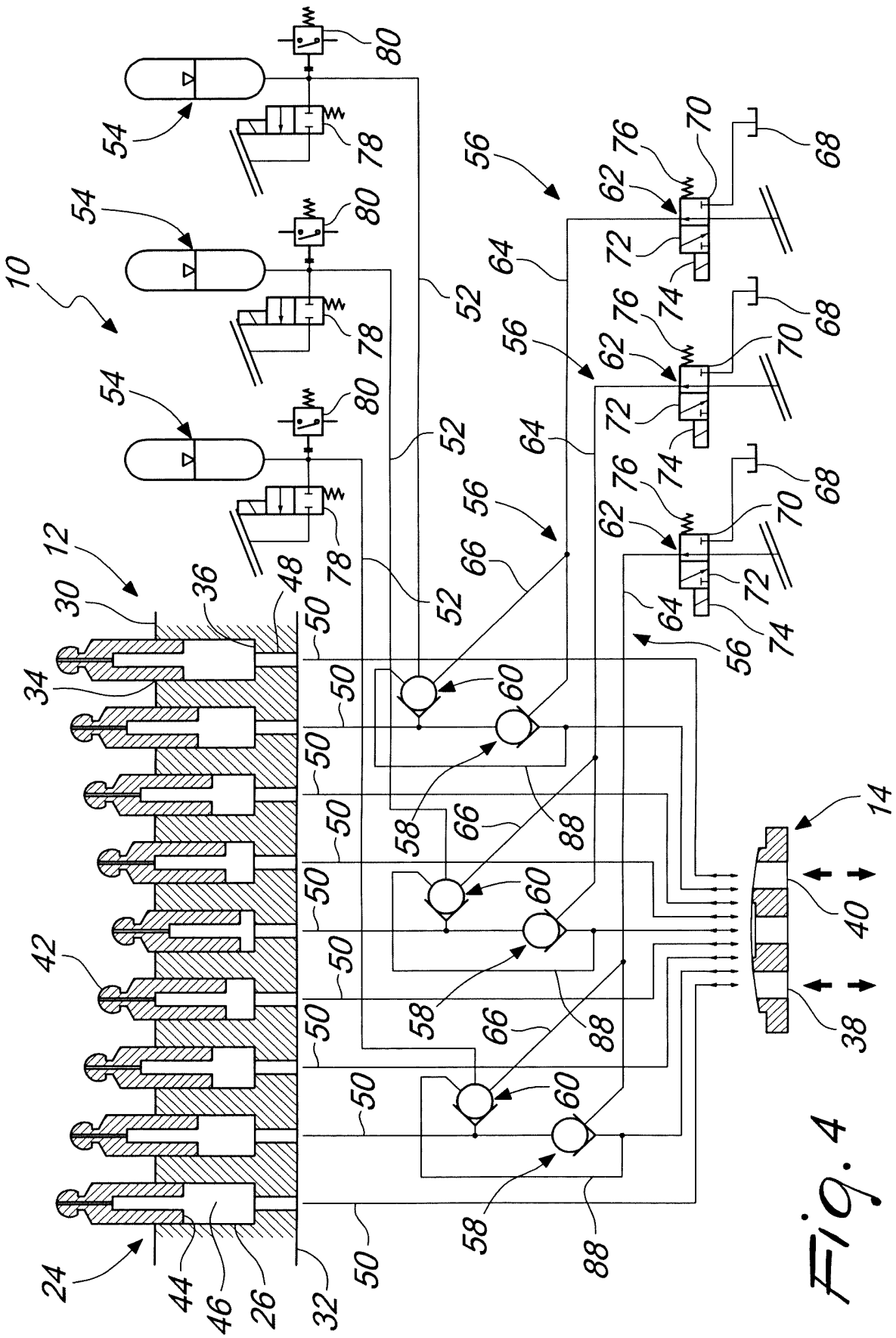
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Fig. 4

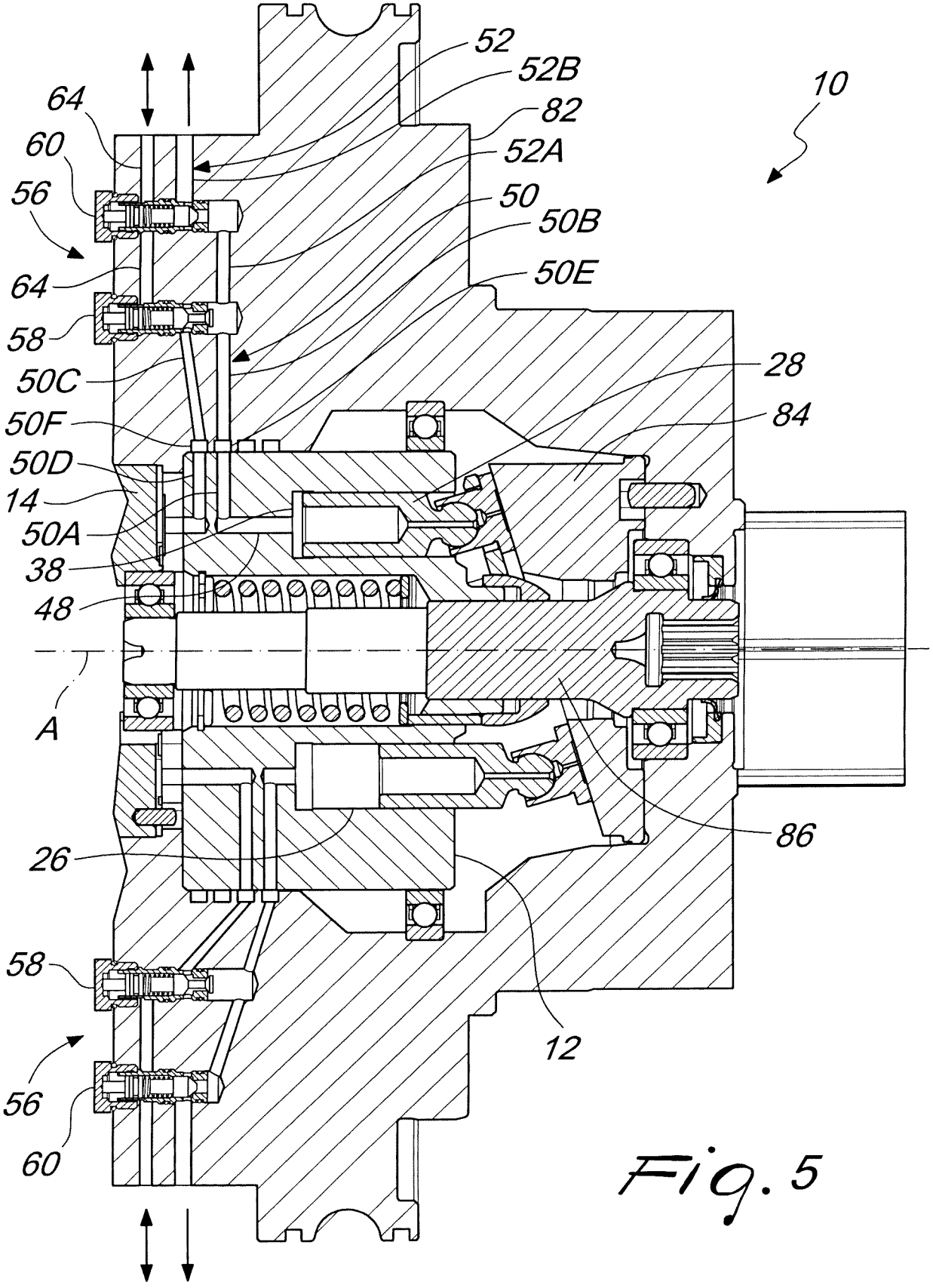
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Fig. 5

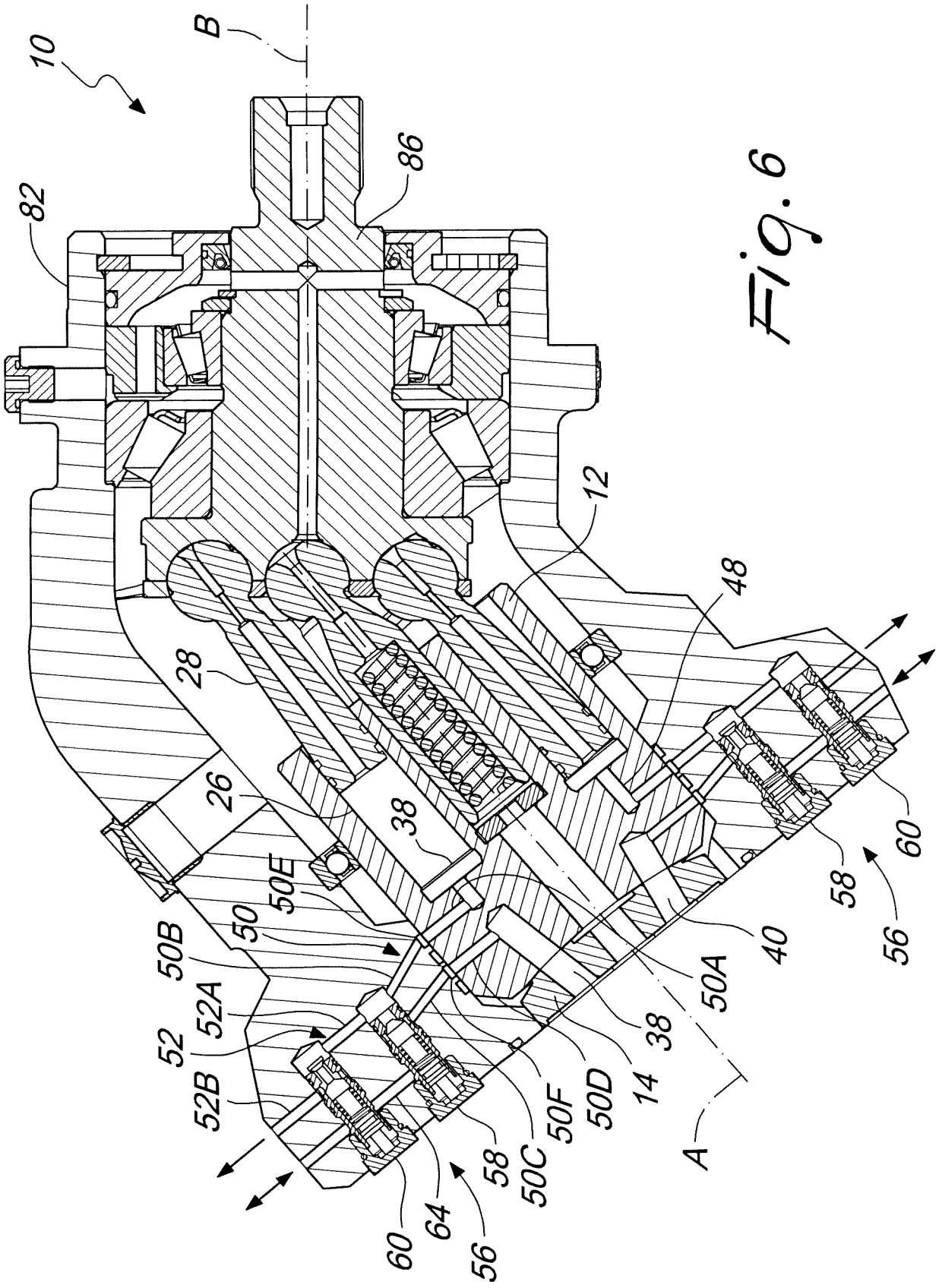
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Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 18 42 5052

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 September 2018	Olona Laglera, C

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