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(54) **A self-contained electro-hydraulic bidirectional rotary actuator unit**

(57) A self-contained electro-hydraulic bidirectional rotary actuator unit (1) adapted for limited arc actuation of an object, e.g. adapted for quarter turn actuation of a valve, e.g. a pipeline valve. The unit comprises a hydraulic rotary actuator with a rack and a pinion meshing with a rack and supported on a rotary shaft (9) in the cylinder housing (2). The unit further comprises a bidirectional hydraulic pump (15) and an electric motor (20) connected to the pump housing and driving the pump.

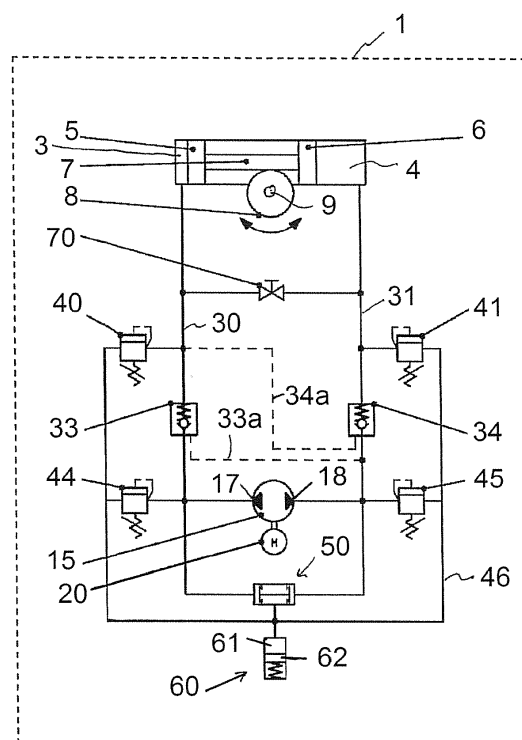


Fig. 3

Description

[0001] The present invention relates to a self-contained electro-hydraulic bidirectional rotary actuator unit adapted for limited arc actuation of an object. For example the unit is adapted for quarter turn actuation, e.g. of a valve, e.g. of a pipeline valve.

[0002] In the field of valve actuation it is often required to provide a significant torque in order to turn a stem of the valve over a limited angle, e.g. over a quarter turn. For example a butterfly valve requires such actuation. Similar limited arc motion at significant torque is also required for other objects like ventilation flaps, doors, etc.

[0003] For example in US 3605409 a self-contained electro-hydraulic bidirectional rotary actuator unit adapted for limited arc actuation of an object is disclosed. This known unit is highly complex, primarily in view of its hydraulic circuit. The actuator has a gear casing housing the pinion, which casing also acts as a hydraulic fluid tank wherein hydraulic fluid is present with an air filled head above the fluid. External tubing connects each cylinder to the electric motor driven pump.

[0004] It is an object of the present invention to provide a unit that is simple in construction, compact, and is mostly maintenance free.

[0005] The present invention provides a self-contained electro-hydraulic bidirectional rotary actuator unit according to claim 1.

[0006] The inventive unit, due to the absence of air in the hydraulic circuit, can be mounted in any desired orientation. For example the unit can be mounted above a valve, below a valve, or with the unit mainly in vertical orientation.

[0007] Due to the absence of air in the hydraulic circuit, the hydraulic fluid may be a biodegradable hydraulic fluid. The absence of air warrants that the biodegradable fluid will not deteriorate due to oxidation.

[0008] The thermal pressure relief valves are set in practice to open at such a pressure that no damage is done to any seals, e.g. around the pistons, so that no leakage will occur in case of the unit becoming very hot, e.g. when exposed to the sun. For example the opening pressure of these valves is set at about 300 bars.

[0009] In a preferred embodiment an additional pressure relief valve is connected to the first duct and an additional pressure relief valve is connected to the second duct. Each of these additional pressure relief valves is connected to the low pressure duct, and each of these additional pressure relief valves is embodied to open at a hydraulic pressure in the respective first or second duct which is significantly below the hydraulic pressure at which the respective first and second thermal expansion pressure relief valves open. In practice this means that the additional pressure relief valves act to govern the maximum torque that can be caused by means of the unit, and the thermal expansion relief valves act as a safeguard in case of excessive pressure built-up due to overheating of the unit.

[0010] In an embodiment the additional pressure relief valves are set to open at a hydraulic pressure that is between 50 and 125 bars below the opening pressure of the thermal expansion pressure relief valves, e.g. said additional pressure relief valves being embodied to open at a pressure between 150 and 225 bars.

[0011] In an embodiment the hydraulic circuit comprises a manually operable relief valve interconnecting, when opened manually, the first and second ducts between the respective pilot-operated check valve and respective hydraulic cylinder. This allows direct displacement of hydraulic fluid from the one cylinder to the other as the pinion, and thereby the rack, is moved by external force. For example the pinion shaft has a protruding portion with parallel faces adapted to apply a wrench on the pinion shaft in order to rotate the pinion shaft in an emergency, e.g. loss of electric power or failure of the motor and/or pump.

[0012] In an embodiment the accumulator comprises a bore and a spring loaded piston therein defining the variable volume chamber, e.g. said accumulator being formed in the pump housing.

[0013] In an embodiment the electric motor is arranged parallel to an axis through the linearly aligned first and second cylinders.

[0014] In an embodiment the pump housing is bolted onto a lateral side of the cylinder housing. Preferably the electric motor is located along said same lateral side of the cylinder housing.

[0015] In an embodiment the first and second thermal expansion relief valves are arranged in the cylinder housing, and the pilot-operated check valves and - if present - the additional pressure relief valves are arranged in the pump housing.

[0016] In an embodiment the pump is a radial piston pump.

[0017] In an embodiment the shaft supporting the pinion is further provided with an angle limiter member providing two abutment faces at a defined angular spacing relative to the shaft axis, wherein the cylinder housing is provided with two threaded bores each having threaded angle adjuster rod therein, each adjuster rod being engageable by one of said abutment faces to determine an angular limit position of the pinion shaft, wherein screwing an angle adjuster rod into or out of the corresponding threaded bore adjusts the angular limit position relative to the cylinder housing.

[0018] In an embodiment the cylinder housing is a rectangular aluminum block and the first and second cylinders are formed by one circular bore extending between opposed end faces of the block, wherein the bore is closed at each end thereof by an end cap having one or more sealing rings thereon.

[0019] The invention also relates to the combination of a unit as described herein and a valve, e.g. a pipeline valve, a valve stem of the valve being connected to the pinion shaft.

[0020] The invention will now be described with refer-

ence to the drawings. In the drawings:

Fig. 1 shows, partly as wire frame view, an example of an actuator unit according to the invention;

Fig. 2 shows the unit of figure 1,

Fig. 3 shows a hydraulic diagram of the unit of figure 1,

Fig. 4 shows the unit of figure 1.

[0021] With reference to the drawings an example of a self-contained electro-hydraulic bidirectional rotary actuator unit 1 adapted for limited arc actuation of an object will be discussed. For example the unit 1 is adapted for quarter turn actuation of a valve, e.g. a pipeline valve.

[0022] The unit 1 comprises a hydraulic rotary actuator with a cylinder housing 2 having two linearly aligned, opposed, single-acting first and second hydraulic cylinders 3, 4 therein.

[0023] In the depicted example the housing 2 is a rectangular aluminum block. The first and second cylinders 3, 4 are formed by one circular bore extending between opposed end faces of the block. The bore is closed at each end thereof by an end cap 3a, 4a having one or more sealing rings thereon, which end caps defined the bottom of the respective cylinder 3, 4.

[0024] Each cylinder is provided with a piston 5, 6 that sealingly fits in the bore in the housing 2. These two aligned pistons 5, 6 are interconnected by a rod 7 that forms a toothed rack.

[0025] The cylinder housing 2 supports a pinion 8 that meshes with the rack on the rod 7. The pinion is supported on a rotary shaft 9 in the cylinder housing 2. This shaft 9 has an output end 10 that is adapted for connection to an object to be rotated about a limited arc. Here the output end 10 has a blind hole into which a stem, e.g. a valve stem, can be inserted.

[0026] The unit 1 further comprises a bidirectional hydraulic pump 15, here a radial piston pump, having a pump housing 16. The pump housing is an aluminum block that is bolted, e.g. by bolt 17, directly onto a lateral side of the cylinder housing 2.

[0027] The unit 1 also comprises an electric motor 20 that is connected to the pump housing and drives the pump 15.

[0028] The hydraulic circuit of the unit 1 comprises ducts that are provided in the pump housing 16 and the cylinder housing 2. As the pump housing 16 is connected directly to the cylinder housing 2 any hydraulic fluid ducts in the pump housing 16 and cylinder housing 2 interconnect directly without intermediate tubing.

[0029] The bidirectional hydraulic radial piston pump 15 has a first pump port 17 and a second pump port 18. In operation of the unit, one port acts as pressure port and discharges pressurized hydraulic fluid into the connected first or second duct and the other as suction port depending on the rotation direction of the electric motor 20.

[0030] The hydraulic circuit comprises a first duct 30

connecting the first pump port 17 through the pump housing and the cylinder housing to the first cylinder 3. A second duct 31 through the pump housing and the cylinder housing connects the second pump port 18 to the second cylinder 4.

[0031] A first pilot operated check valve 33 is arranged in the first duct 30. A second pilot operated check valve 34 is arranged in the second duct 31. Each of these pilot operated check valves has a pilot line 33a, 34a to the other of said first and second ducts 30, 31, so that the one check valve opens if the other duct is used to supply pressurized hydraulic fluid to one cylinder and hydraulic fluid can flow out of the other cylinder via the opened pilot-operated check valve. In the example show the pilot line 33a connects to the duct 31 between the pump port 18 and the check valve 34. The other pilot line 34a connects to the duct 30 between the check valve 34 and the cylinder 3. In an alternative embodiment the line 34a connects to the duct 30 between the pump port 17 and the check valve 33, which may be done to achieve a more rapid closing action of the check valve 34 upon stopping of the pump, e.g. halfway through actuation of a pipeline valve. In the latter embodiment an additional manually operable relief valve, in addition to valve 70, may be provided for between a pilot line 33a, 34a on the one hand and a high pressure duct between the check valve and a cylinder on the other hand. This allows for opening of a check valve and will then render one of the valves 44, 45 active to limit the actual fluid pressure, e.g. if any imbalance is present between the two cylinders.

[0032] A first thermal expansion pressure relief valve 40 is connected to the first duct 30, between the first pilot-operated check valve 34 and the first cylinder 3 as this part of the duct 30 is effectively sealed by the check valve 34 during standstill of the shaft 9 of the unit 1. Thermal effects may then cause the trapped hydraulic fluid to develop an excessive pressure, potentially causing leakage, e.g. along the piston of the respective cylinder, which is now prevented due to the valve 40.

[0033] Similarly a second thermal expansion pressure relief valve 41 is connected to the second duct 31 between the second pilot-operated check valve 34 and the second cylinder 4.

[0034] The hydraulic circuit further comprises a low pressure duct 46 to which these first and second thermal expansion pressure relief valves 40, 41 each connect, such that upon opening of one or both of said thermal expansion pressure relief valves 40, 41 due to thermal expansion hydraulic fluid is relieved from the respective first or second duct into this low pressure duct 46.

[0035] The hydraulic circuit further comprises a suction shuttle valve 50, which is arranged between this low pressure duct 46 on the one hand and each of the first and second pump ports 17, 18 on the other hand. This suction shuttle valve 50 is adapted to allow the suction port to retrieve hydraulic fluid from the low pressure duct 46 and separates the actual pressure port of the pump 15 from the low pressure duct 46.

[0036] The hydraulic circuit further comprises an accumulator 60 having a spring loaded variable hydraulic chamber 61 connecting to the low pressure duct 46. This accumulator absorbs changes in hydraulic fluid volume due to thermal expansion.

[0037] The hydraulic circuit is completely filled with hydraulic fluid and is devoid of air.

[0038] As is a preferred optional feature of the unit, an additional pressure relief valve 44 is connected to the first duct 30 and an additional pressure relief valve 45 is connected to the second duct 31. These additional pressure relief valves 44, 45 are each connected to the low pressure duct 46.

[0039] Each of these additional pressure relief valves 44, 45 is embodied to open at a hydraulic pressure in the respective first or second duct 30, 31 which is significantly below the hydraulic pressure at which the first and second thermal expansion pressure relief valves 40, 41 open.

[0040] For example, in a practical application, these additional pressure relief valves 44, 45 are set to open at a hydraulic pressure that is between 50 and 125 bars below the opening pressure of the thermal expansion pressure relief valves 40, 41. For example these additional pressure relief valves are set to open at a pressure between 150 and 225 bars.

[0041] As is a preferred optional feature the hydraulic circuit comprises a manually operable relief valve 70 interconnecting, when opened manually, the first and second ducts 30, 31 between the respective pilot-operated check valve 33, 34 and the respective hydraulic cylinder 3, 4 so that hydraulic fluid may flow directly from the one cylinder into the other cylinder. For example the shaft 9 is provided with a protrusion 9b outside the housing 2 which may e.g. have parallel faces to be engaged by a wrench.

[0042] As is preferred the accumulator 60 comprises a bore and a spring loaded piston 62 therein defining the variable volume chamber 61. Here the accumulator is formed in the pump housing 16, in the alternative one could arrange the accumulator within the cylinder housing 2. A metallic spring is preferred to load the piston 62, but in an alternative a gas spring may be provided.

[0043] The volume of the chamber 61 can be very small, e.g. as small as 1.5 cc.

[0044] In view of a compact design the electric motor 20 is arranged alongside a lateral side of the cylinder housing 2, parallel to an axis through the linearly aligned first and second cylinders 3, 4. The pump housing 16 is bolted onto the same lateral side of the cylinder housing 2.

[0045] In the depicted example the first and second thermal expansion relief valves 40, 41 are arranged in the cylinder housing 2. The pilot-operated check valves 33, 34 and the additional pressure relief valves 44, 45 are arranged in the pump housing 16.

[0046] In the depicted example the shaft 9 supporting the pinion 8 is further provided with an angle limiter member 80 providing two abutment faces 81, 82 at a defined

angular spacing relative to the shaft axis. The cylinder housing is provided with two threaded bores 83, 84 each having a threaded angle adjuster rod 85, 86 therein. Each adjuster rod is with its inner end engageable by one of the abutment faces in order to determine an angular limit position of the pinion shaft 9. By screwing an angle adjuster rod 85, 86 into or out of the corresponding threaded bore the angular limit position relative to the cylinder housing is adjusted.

Claims

1. A self-contained electro-hydraulic bidirectional rotary actuator unit (1) adapted for limited arc actuation of an object, e.g. adapted for quarter turn actuation of a valve, e.g. a pipeline valve, wherein the unit comprises:

- a hydraulic rotary actuator comprising a cylinder housing (2) with two linearly aligned, opposed, single-acting first and second hydraulic cylinders (3,4), each cylinder being provided with a piston (5,6), said pistons being interconnected by a rod (7) forming a rack, the cylinder housing supporting a pinion (8) meshing with said rack and being supported on a rotary shaft (9) in the cylinder housing, the shaft having an output end (10) adapted for connection to an object to be rotated about a limited arc ,
 - a bidirectional hydraulic pump (15) having a pump housing (16),
 - an electric motor (20) connected to the pump housing and driving the pump,
- wherein a hydraulic circuit comprising ducts is provided in the pump housing (16) and the cylinder housing (2), the pump housing being connected to the cylinder housing and any ducts in said pump housing and cylinder housing interconnecting directly without intermediate tubing, wherein the hydraulic pump (15) has a first pump port (17) and a second pump port (18), one port acting as pressure port and the other as suction port depending on the rotation direction of the electric motor (20),
- wherein the hydraulic circuit comprises a first duct (30) connecting the first pump port (17) through the pump housing and the cylinder housing to the first cylinder (3), and a second duct (31) connecting the second pump port (18) through the pump housing and the cylinder housing to the second cylinder (4), and wherein a first pilot operated check valve (33) is arranged in the first duct (30), and wherein a second pilot operated check valve (34) is arranged in the second duct (31), each of said pilot operated check valves having a pilot line (33a, 34a) to the other of said first and second ducts

- (30,31),
 wherein a first thermal expansion pressure relief valve (40) is connected to the first duct (30), between the first pilot-operated check valve (34) and the first cylinder (3),
 and wherein a second thermal expansion pressure relief valve (41) is connected to the second duct (31) between the second pilot-operated check valve (34) and the second cylinder (4),
 and wherein the hydraulic circuit comprises a low pressure duct (46) to which said first and second thermal expansion pressure relief valves (40, 41) each connect, such that upon opening of one or both of said thermal expansion pressure relief valves (40, 41) due to thermal expansion hydraulic fluid is relieved from said respective first or second duct into said low pressure duct (46),
 wherein the hydraulic circuit comprises a suction shuttle valve (50), which is arranged between said low pressure duct (45) on the one hand and each of said first and second pump ports (17, 18) on the other hand, said suction shuttle valve (50) being adapted to allow the suction port to retrieve hydraulic fluid from said low pressure duct and separating the pressure port from the low pressure duct,
 wherein the hydraulic circuit comprises an accumulator (60) having a spring loaded variable hydraulic chamber (61) connecting to the low pressure duct (46), said accumulator absorbing changes in hydraulic fluid volume due to thermal expansion,
 and wherein the hydraulic circuit is completely filled with hydraulic fluid and is devoid of air.
2. Unit according to claim 1, wherein an additional pressure relief valve (44) is connected to the first duct (30), and wherein an additional pressure relief valve (45) is connected to the second duct (31), and wherein each of said additional pressure relief valves (44,45) are connected to said low pressure duct, and wherein each of said additional pressure relief valves (44,45) are embodied to open at a hydraulic pressure in said respective first or second duct (30,31) which is significantly below the hydraulic pressure at which said first and second thermal expansion pressure relief valves (40,41) open.
 3. Unit according to claim 2, wherein said additional pressure relief valves (44,45) are set to open at a hydraulic pressure that is between 50 and 125 bars below the opening pressure of the thermal expansion pressure relief valves (40,41), e.g. said additional pressure relief valves being embodied to open at a pressure between 150 and 225 bars.
 4. Unit according to one or more of the preceding claims, wherein the hydraulic circuit comprises a manually operable relief valve (70) interconnecting, when opened manually, the first and second ducts (30,31) between the respective pilot-operated check valve (33,34) and the respective hydraulic cylinder (3,4).
 5. Unit according to one or more of the preceding claims, wherein the accumulator (60) comprises a bore and a spring loaded piston (62) therein defining the variable volume chamber (61), e.g. said accumulator being formed in the pump housing (16).
 6. Unit according to one or more of the preceding claims, wherein the electric motor (20) is arranged parallel to an axis through the linearly aligned first and second cylinders (3,4).
 7. Unit according to one or more of the preceding claims, wherein the pump housing (16) is bolted onto a lateral side of the cylinder housing (2).
 8. Unit according to one or more of the preceding claims, wherein the first and second thermal expansion relief valves (40,41) are arranged in the cylinder housing (2), and wherein the pilot-operated check valves (33,34) and - if present - the additional pressure relief valves (44,45) are arranged in the pump housing (16).
 9. Unit according to one or more the preceding claims, wherein the pump (15) is a radial piston pump.
 10. Unit according to one or more of the preceding claims, wherein the shaft (9) supporting the pinion (8) is further provided with an angle limiter member (80) providing two abutment faces (81,82) at a defined angular spacing relative to the shaft axis, and wherein the cylinder housing is provided with two threaded bores (83,84) each having threaded angle adjuster rod (85,86) therein, each adjuster rod being engageable by one of said abutment faces to determine an angular limit position of the pinion shaft, wherein screwing an angle adjuster rod into or out of the corresponding threaded bore adjusts the angular limit position relative to the cylinder housing.
 11. Unit according to one or more of the preceding claims, wherein the cylinder housing (2) is a rectangular aluminum block and wherein the first and second cylinders (3, 4) are formed by one circular bore extending between opposed end faces of the block, wherein the bore is closed at each end thereof by an end cap (3a, 4a) having one or more sealing rings thereon.
 12. In combination a unit according to one or more of the preceding claims and a valve, e.g. a pipeline valve.

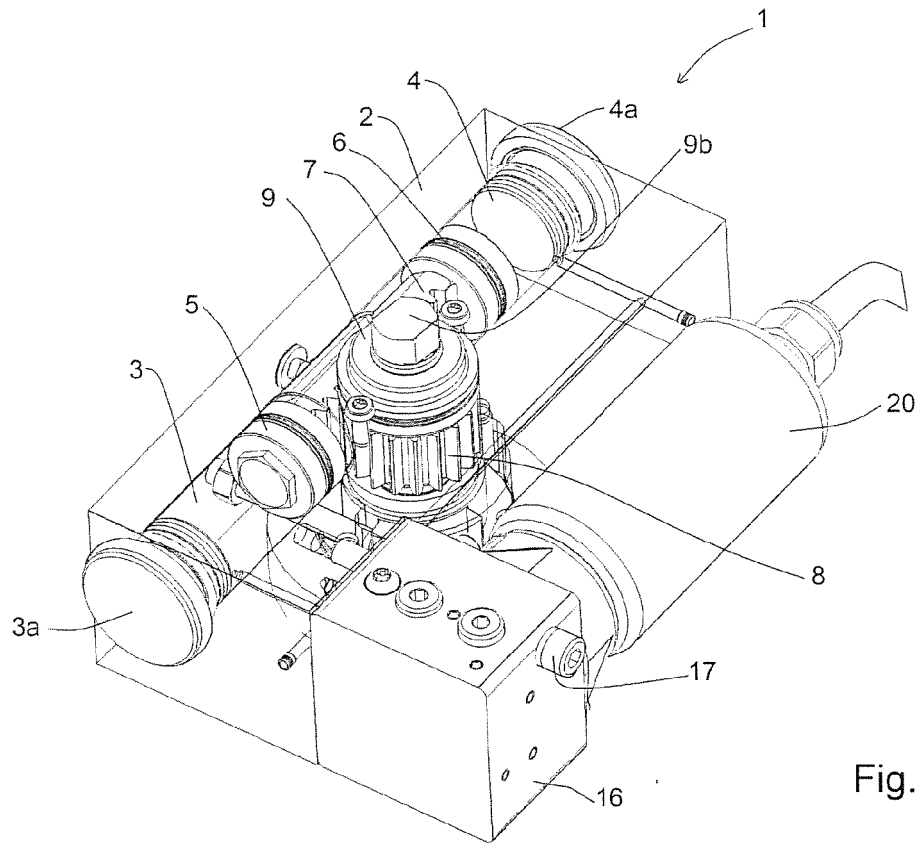


Fig. 1

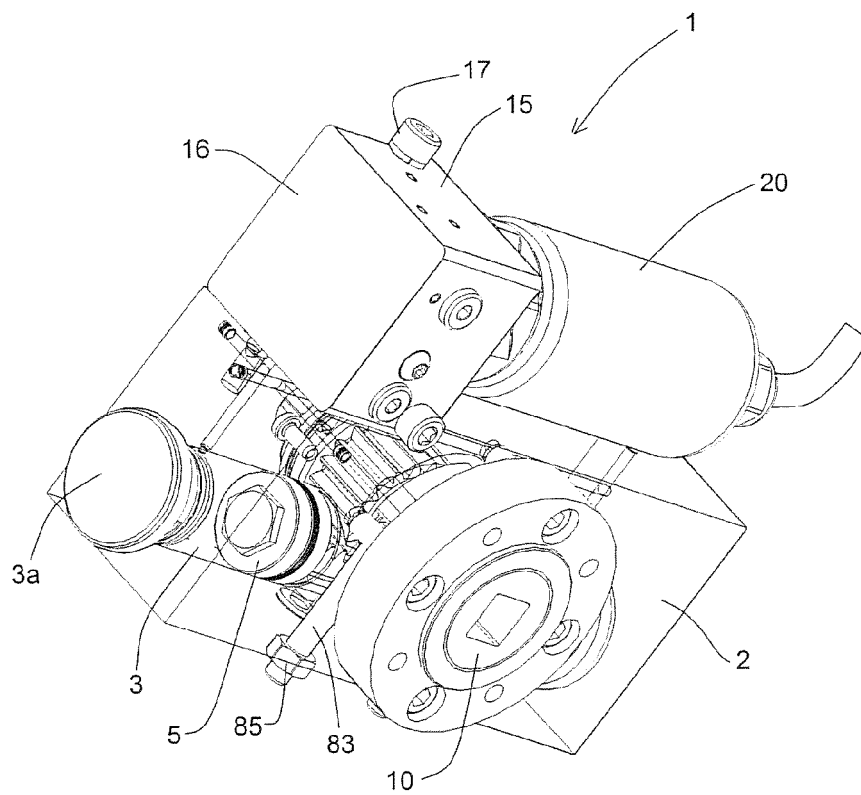


Fig. 2

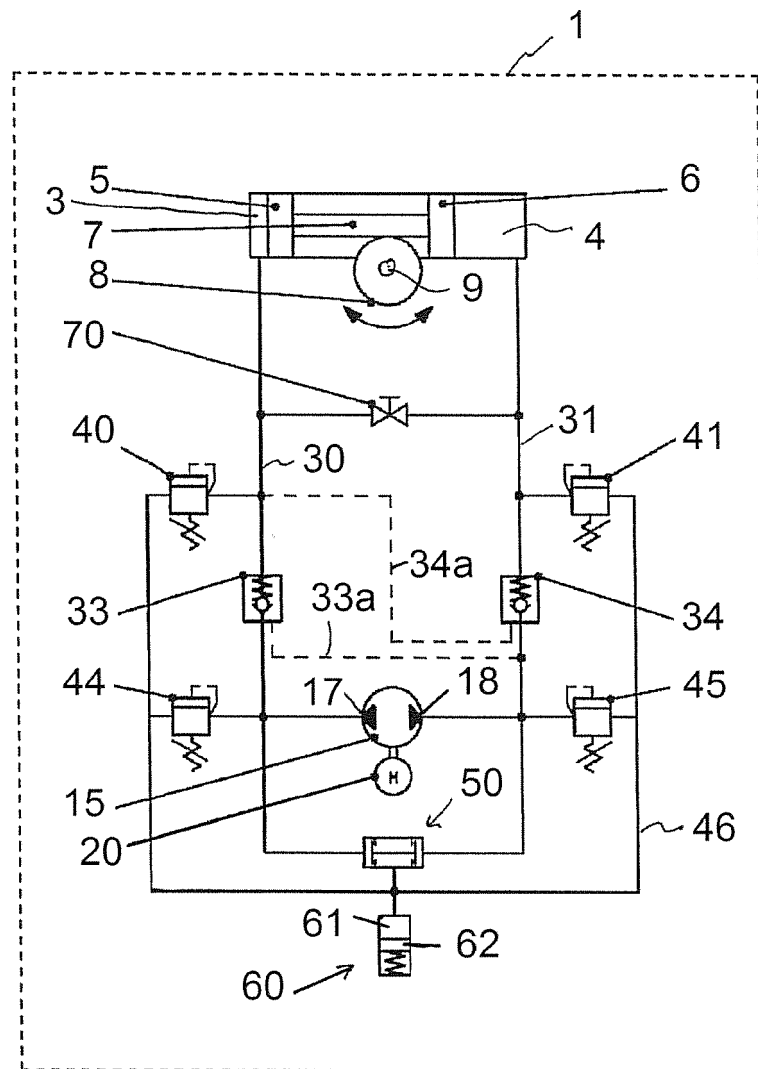


Fig. 3

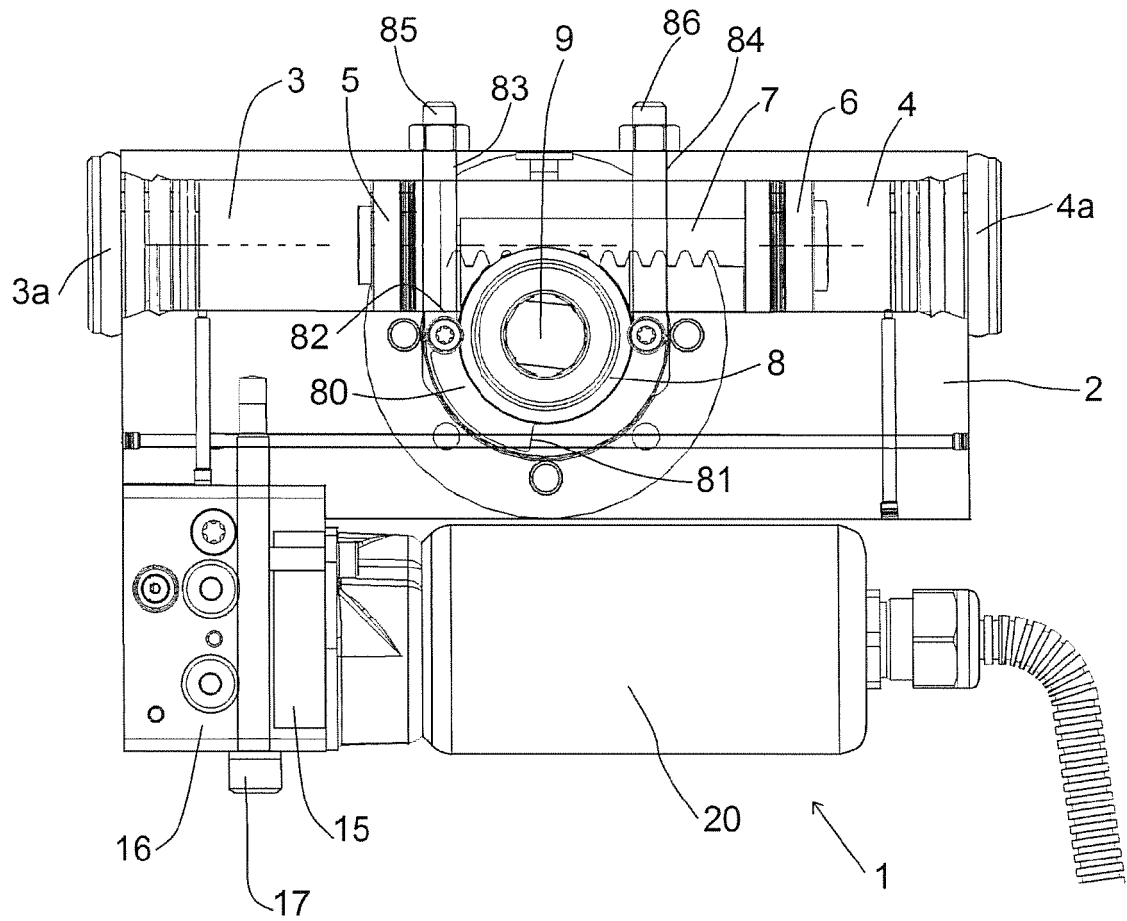


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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