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(54) Refundant hydraulic actuator, particularly for an aircraft servocontrol

(57) A redundant hydraulic actuator (1) having two hydraulic cylinders (2, 3), each having a body (4, 5) and a rod (7, 8) having a piston (38, 44) sliding in sealed manner in the body (4, 5), and wherein the bodies (4, 5) of the two cylinders (2, 3) are connected rigidly to a first connecting member (6) of the actuator (1), and the rods of the cylinders (7, 8) are connected rigidly to a second connecting member (9) of the actuator (1); the bodies (4, 5) of the two cylinders (2, 3) being coaxial with each other and inserted one inside the other.

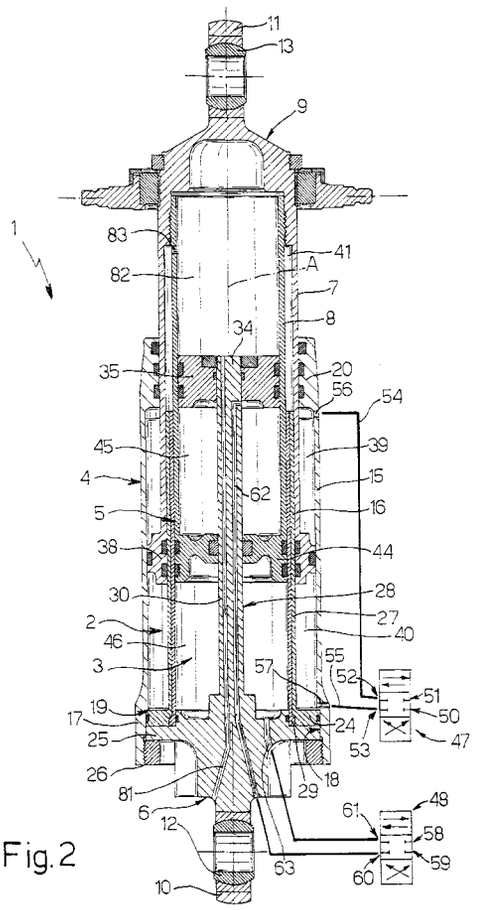

Fig. 2

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Description

[0001] The present invention relates to a redundant hydraulic actuator, particularly for an aircraft servocontrol.

[0002] As is known, in certain safety engineering applications, such as aircraft hydraulic controls, redundant actuators are used comprising two (or more) hydraulic cylinders, each with a respective independent hydraulic circuit, so that, in the event one of the cylinders or hydraulic circuits breaks down, the other cylinder is capable of operating, thus ensuring efficient control.

[0003] A typical example of the use of redundant actuators is in helicopter flight controls, to which the following description refers purely by way of example.

[0004] Known redundant actuators are typically of two types: with parallel-body cylinders and series-body cylinders.

[0005] In the parallel-body solution, the cylinder bodies are side by side and parallel and fixed to a first actuator attachment; and the ends of the rods are connected to a second actuator assembly attachment, along the centerline between the rods. This solution is relatively compact axially, but transversely bulky. Moreover, each of the rods is offset with respect to the actuator attachments, which produces bending moments on the rods in the event of asymmetrical loads being exerted by each cylinder, e.g. due to differing performance of the relative valves and, obviously, in the event one of the two cylinders breaks down. The presence of bending moments calls for oversizing the rods, bodies and attachments structurally; friction and wear on the seals are increased; and, finally, the temperature gradients between the bodies and attachments, due to the even considerable difference between the oil temperature and that of the outside atmosphere, result in transverse loads which further aggravate the seal friction and wear problems.

[0006] In the series-body solution, the bodies of the two cylinders have a common axis and are located end to end and adjacent to each other; and the actuator has a common rod having two pistons sliding inside the respective bodies. Though not subject to bending moments, this solution is axially bulky and therefore cannot be used in applications calling for a small distance between the attachments.

[0007] Moreover, the bodies share a common part, any breakdown of which would make both cylinders inoperative.

[0008] It is an object of the present invention to provide a redundant actuator designed to solve the aforementioned problems typically associated with known actuators.

[0009] According to the present invention, there is provided an actuator assembly as claimed in Claim 1.

[0010] A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a view in perspective of an actuator in accordance with the present invention;

Figure 2 shows an axial section of the Figure 1 actuator;

Figure 3 shows a schematic, partly sectioned side view of a detail of the Figure 1 actuator;

Figure 4 shows a schematic, partly sectioned plan view of the Figure 3 detail.

[0011] Number 1 in Figures 1 and 2 indicates as a whole a redundant servocontrolled hydraulic actuator for operating the flight controls of an aircraft, and in particular for transmitting and amplifying control forces from the joystick to the oscillating plate of a helicopter.

[0012] Actuator 1 substantially comprises a first and a second hydraulic cylinder 2, 3 having respective bodies 4, 5 parallel to each other and fixed rigidly to a first end connecting member 6 of the actuator, and respective rods 7, 8 fixed to a second end connecting member 9 of the actuator.

[0013] Connecting members 6, 9 of actuator 1 are connected respectively to a fixed constraint on the helicopter (not shown) and to the oscillating plate of the helicopter; for which purpose, connecting members 6, 9 have respective end eyes 10, 11 having respective swivels 12, 13.

[0014] According to the present invention, bodies 4, 5 of cylinders 2, 3 are coaxial and inserted one inside the other.

[0015] More specifically, body 4 of first cylinder 2 has an annular cross section and is defined by an outer sleeve 15 and an inner sleeve 16 of axis A. Outer sleeve 15 comprises a wider bottom end 17 defining an inner seat 18 forming a shoulder 19 facing first connecting member 6; and an inner top flange forming a top head 20 of first cylinder 2.

[0016] Inner sleeve 16 comprises an outer radial end flange, which forms a bottom head 24 of first cylinder 2, is housed inside seat 18, and is locked axially between shoulder 19 and a flange 25 forming part of second connecting member 9 of actuator 1. Flange 25 is in turn locked inside seat 18 by an annular ring nut 26 screwed into the seat.

[0017] Body 5 of second cylinder 3 has an annular cross section and is defined by an outer sleeve 27 and an inner sleeve 28 of axis A. Outer sleeve 27 is positioned contacting inner sleeve 16 of body 4 so as to substantially form, with sleeve 16, one solid, double-layered, cylindrical wall, and comprises at the bottom end an outer flange 29 locked axially between flanges 24 and 25.

[0018] Inner sleeve 28 is defined by the lateral surface of a central cylindrical rod 30 of axis A, which projects integrally from connecting member 6 of actuator 1, and has a free end 34 extending axially beyond sleeves 16 and 27 and supporting a top head 35 of second cylinder 3.

[0019] Rod 7 of first cylinder 2 is tubular, projects in-

tegrally from connecting member 9, and slides telescopically and in sealed manner between inner sleeve 16 and top head 20. At its free end, rod 7 forms an annular piston 38, which slides in sealed manner between outer sleeve 15 and inner sleeve 16, so as to define, with outer and inner sleeves 15, 16 and respectively with top head 20 and bottom head 24, a top chamber 39 and a bottom chamber 40 of first cylinder 2.

[0020] Rod 8 of second cylinder 3 is tubular, is fixed in projecting manner to connecting member 9, is housed coaxially inside rod 7 with which it defines an annular chamber 41, and slides telescopically and in sealed manner between outer sleeve 27 and top head 35 of second cylinder 3. At its free end, rod 8 forms internally an annular piston 44, which slides in sealed manner between outer sleeve 27 and inner sleeve 28, so as to define, with outer and inner sleeves 27, 28 and respectively with top head 35 and flange 25 defining a bottom head of second cylinder 3, a top chamber 45 and a bottom chamber 46 of second cylinder 3.

[0021] Rods 7 and 8 form in between an annular chamber 41.

[0022] Cylinders 2, 3 are controlled by respective known distributors 47, 48 shown schematically in Figure 2 and housed in a valve body 50 (Figure 1) fixed to the outside of outer sleeve 15 of first cylinder 2.

[0023] Distributors 47, 48 are four-way, three-position, closed-center, continuously positioned types.

[0024] Distributor 47 has a supply port 50, a discharge port 51, and two work ports 52, 53 connected respectively to top and bottom chambers 39, 40 of first cylinder 2 by respective conduits 54, 55. More specifically, conduits 54, 55 are connected to respective openings 56, 57 formed in outer sleeve 15 of first cylinder 2, close to respective heads 20, 24.

[0025] Similarly, distributor 48 has a supply port 58, a discharge port 59, and two work ports 60, 61 connected respectively to top and bottom chambers 45, 46 of second cylinder 3 by respective conduits 62, 63 formed through rod 30 and connecting member 6 and through flange 25 of connecting member 6 respectively.

[0026] A vent and drain conduit 81 formed through rod 30 and connecting member 6 connects to the outside atmosphere a top chamber 82 formed in sleeve 28 of second cylinder 3 and extending between top head 35 of second cylinder 3 and top connecting member 9. Rod 8 has one or more vent and drain holes 83 connecting to chamber 82 a top end of chamber 41 between rods 7 and 8.

[0027] Distributors 47, 48 have respective known movable slide valves 64, 65 (Figures 3 and 4) for defining the port connection modes of the respective distributors and the useful flow sections. The slide valves are housed in valve body 50, are movable axially along respective axes B, C parallel to each other and to axis A of actuator 1, and are controlled in parallel by a feedback control assembly 66 shown schematically in Figures 3 and 4.

[0028] Assembly 66 substantially comprises an input lever 70 connected to a control member 72 shown partly in Figure 3 and forming part of a manual control chain not shown; two feedback rods 73 connecting top connecting member 9 to input lever 70; and two control levers 74 for transmitting control loads from input lever 70 to slide valves 64, 65 of distributors 47, 48.

[0029] More specifically, input lever 70 is substantially U-shaped, and comprises a central attachment 75 hinged to control member 72, and two parallel arms 76 on opposite sides of valve body 50. Each arm 76 has a free end 77 connected to a bottom end 78 of a respective feedback rod 73 by a hinge 79 having an axis D perpendicular to axis A. Rods 73 have respective top ends 80 hinged to connecting member 9.

[0030] Levers 74 are located on opposite sides of valve body 50, to which they are hinged by respective pins 86 having a common axis E parallel to axis D and perpendicular to axes A, B and C. Pins 86 are connected rigidly to, so as to rotate with, levers 74, and, inside valve body 50, are connected to respective cranks 87, 88 parallel to each other and extending radially from respective pins 86 towards respective slide valves 64, 65 of distributors 47, 48. Cranks 87, 88 are connected to slide valves 64, 65 by respective spherical joints 89 permitting relative slide in the direction of the crank axes, so as to form a crank mechanism for converting the rotation of pins 86, i.e. of levers 74, into simultaneous axial translation of slide valves 64, 65.

[0031] Levers 74 are hinged to respective arms 76 of input lever 70 by respective pins 85 having an axis F parallel to axis E and located on the opposite side of axis E to axis D.

[0032] Operation of actuator 1 will now be described as of a balance condition in which actuator 1 is stationary in a given position and both distributors 47, 48 are in the center position.

[0033] In response to manual control of the joystick, control member 72 transmits motion to input lever 70 so as to rotate it in one direction or the other about axis D and so move pins 85 and therefore levers 74, which rotate with respective pins 86 about axis E to move slide valves 64, 65 of distributors 46, 47 from the center position into such a position as to activate cylinders 2, 3 in the required direction and achieve a given target position. The movement of rods 7, 8 of the two cylinders, and hence of connecting member 9 with respect to connecting member 6, is fed back by rods 73 to input lever 70, which rotates levers 74 in the opposite direction to the control direction; when the position of connecting member 9 corresponds with the manual control target, i.e. in the absence of a position error, levers 74 restore slide valves 64, 65 of distributors 46, 47 to the center position to restore the actuator to a new balance position.

[0034] Feedback control assembly 66 is capable of reacting to external disturbance loads to maintain the desired position of cylinders 2, 3. That is, in response to

a disturbance load, rods 7, 8 tend to shift from the balance position; which shift is transmitted by feedback rods 73 to input lever 70, which, via levers 74, shifts slide valves 64, 65 of distributors 46, 47 from the center position, thus producing a difference in pressure between the chambers of cylinders 2, 3 and hence such a reaction as to withstand the load.

[0035] Cylinders 2 and 3 operate in parallel but fully independently of each other. In the event one of cylinders 2, 3 breaks down due to a mechanical fault on either the cylinder itself or the relative distributor 46, 47, the other cylinder is capable of ensuring operation of the actuator.

[0036] The advantages of actuator 1 according to the present invention will be clear from the foregoing description.

[0037] The coaxial arrangement of cylinders 2, 3 makes for an axial size of actuator 1 comparable with that of known parallel-body actuators, but with none of the attendant drawbacks. That is, the actuator is also radially compact, and the rods are subjected to purely axial loads in any operating condition.

[0038] Moreover, the preferred embodiment described has safety characteristics designed to ensure maximum reliability of the actuator. In particular, the inner sleeve 16 of first cylinder 2 and the outer sleeve 27 of second cylinder 3 - which, from the functional standpoint could be integrated into one part - are in the form of separate components, so that bodies 4, 5 of cylinders 2, 3 are fully independent structurally, thus preventing any cracks from spreading from one body to the other.

[0039] Finally, vent conduit 81 provides for detecting any otherwise invisible oil leakage from the cylinders to chambers 41 and 82, and so enabling appropriate steps to be taken immediately.

[0040] Clearly, changes may be made to actuator 1 as described herein without, however, departing from the scope of the accompanying Claims.

[0041] In particular, distributors 46, 47 may be replaced with solenoid valves; feedback may be electric as opposed to mechanical, e.g. by means of a position transducer housed in rod 30; and the feedback system may be dispensed with if open-loop control is sufficient.

[0042] Safety conditions permitting, inner sleeve 16 of first cylinder 2 and outer sleeve 27 of second cylinder 3 may be integrated into one component.

[0043] Finally, chambers 82 and 41 may be drained differently. In particular, sleeve 28 may be a separate tubular member fitted about rod 30, and conduit 81 may be replaced by surface grooves on rod 30; and holes 83 may be replaced by channels formed between sleeves 16 and 27 and through connecting member 6 to drain chamber 41 independently of chamber 82.

Claims

1. A redundant hydraulic actuator (1) comprising:

a first hydraulic cylinder (2) having a first body (4) and a first rod having a piston (38) sliding in sealed manner inside said first body (4);

a second hydraulic cylinder (3) having a second body (5) and a second rod (8) having a piston (44) sliding in said second body (5);

first connecting means (6) connected rigidly to said first and second body (4, 5) of said cylinders (2, 3);

second connecting means (9) connected rigidly to said first and second rod (7, 8) ;

said first and second cylinder (2, 3) being activated in parallel to move said second connecting means (9) with respect to said first connecting means (6);

characterized in that said first body (4) and said second body (5) are coaxial with each other; and **in that** said second body (5) is housed inside the first body (4).

2. An actuator as claimed in Claim 1, **characterized in that** said bodies (4, 5) and said pistons (38, 44) have annular sections.

3. An actuator as claimed in Claim 1 or 2, **characterized in that** said first and said second body (4, 5) are defined radially by respective pairs of substantially cylindrical sleeves (15, 16; 27, 28) coaxial with one another and projecting from said first connecting means (6).

4. An actuator as claimed in Claim 3, **characterized in that** an inner sleeve (16) of said first body (4) and an outer sleeve (27) of said second body (5) contact each other radially to substantially form a solid wall.

5. An actuator as claimed in one of Claims 2 to 4, **characterized in that** said first connecting means (6) comprise a flange (25) from which said sleeves (15, 16; 27, 28) of said bodies (4, 5) extend, and which defines a first head of said second body (5).

6. An actuator as claimed in one of the foregoing Claims, **characterized by** comprising an axial rod (30) projecting axially from said first connecting means (6) and supporting a second head (35) of said second body (5) opposite said first connecting means (6).

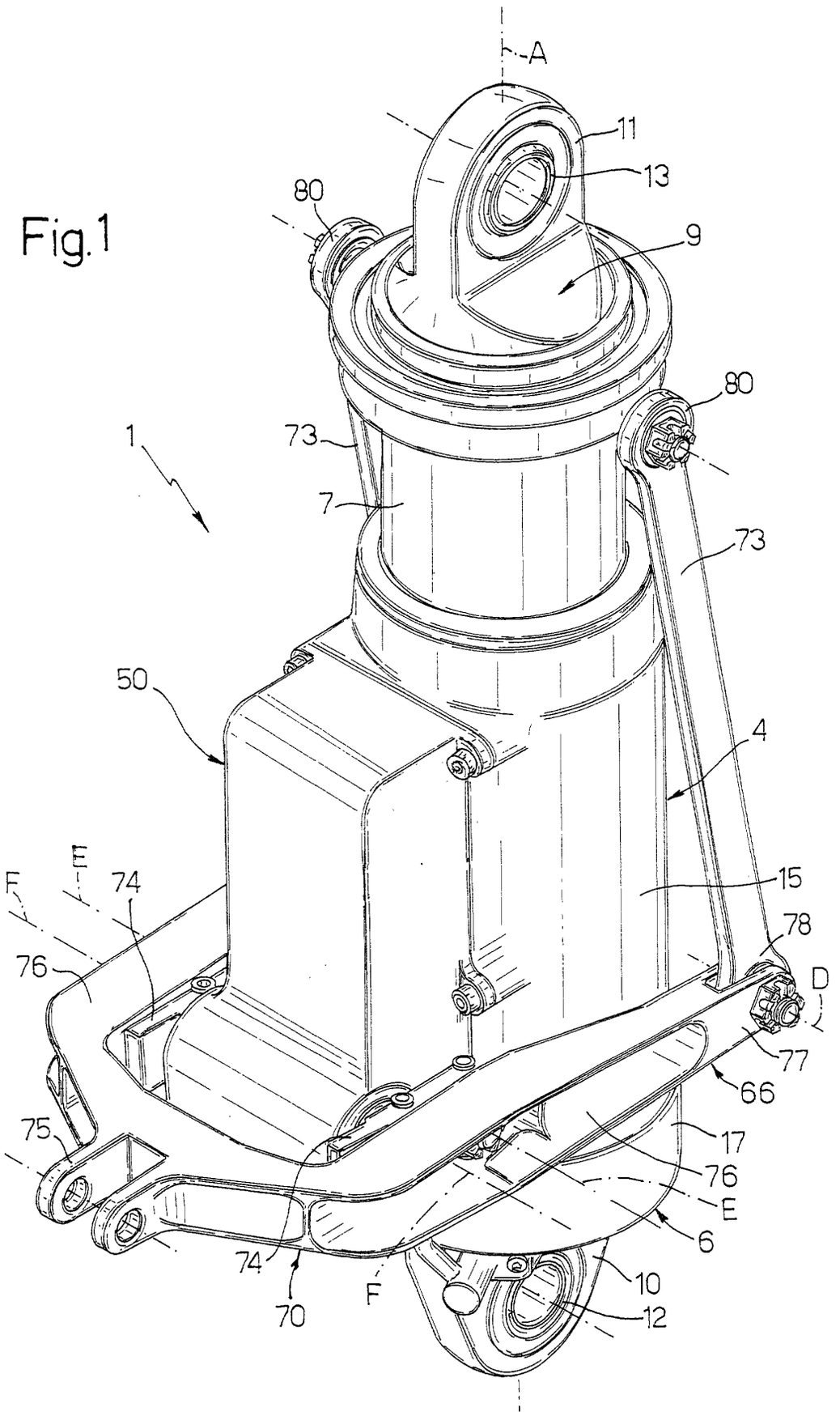
7. An actuator as claimed in Claim 6, **characterized in that** said second rod (8) defines radially a chamber (82) extending between said second head (35) of said second body (5) and said second connecting means (9); said chamber (82) being connected to the outside by a vent conduit (81) formed through said axial rod (30) and said first connecting means (6).

8. An actuator as claimed in any one of the foregoing Claims, **characterized in that** said cylinders (2, 3) are controlled by respective independent distributors (47, 48).

9. An actuator as claimed in Claim 8, **characterized in that** said distributors (47, 48) are controlled mechanically; and by comprising a feedback control assembly (66) for parallel controlling respective slide valves (64, 65) of said distributors (47, 48) in response to a load received from manual control means (72).

10. An actuator as claimed in Claim 9, **characterized in that** said control assembly (66) comprises an input lever (70) connected to said manual control means (72); at least one feedback member (73) connected to said second connecting means (9) and to said input lever (70) to transmit to said input lever (70) a feedback load correlated to the position of said second connecting means (9); and transmission means (74, 86, 87, 88) interposed between said input lever (70) and said slide valves (64, 65) to move said slide valves (64, 65) in response to a position error of said second connecting means (9) with respect to a target position imposed by said manual control means (72).

Fig.1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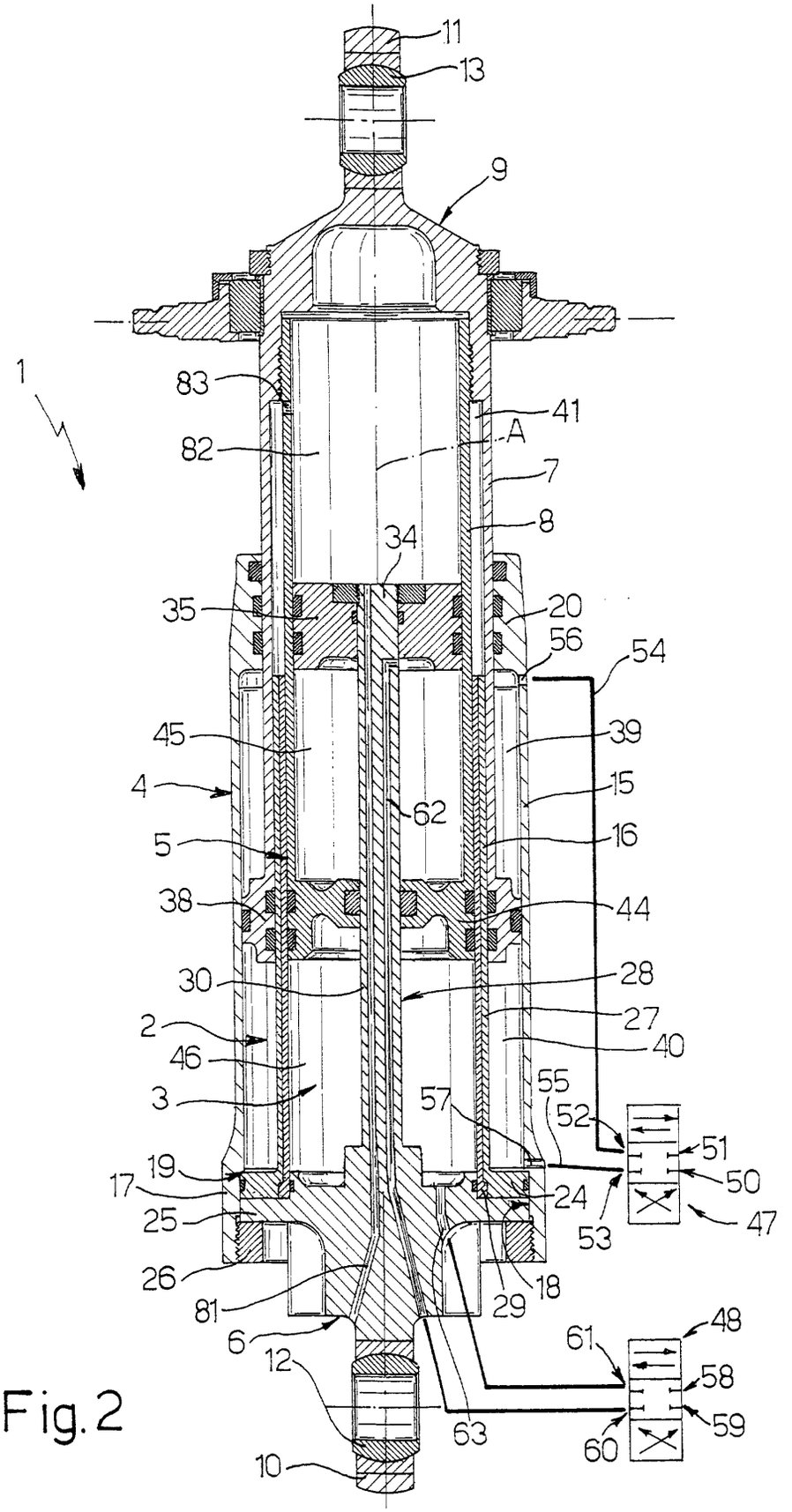
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Fig. 2

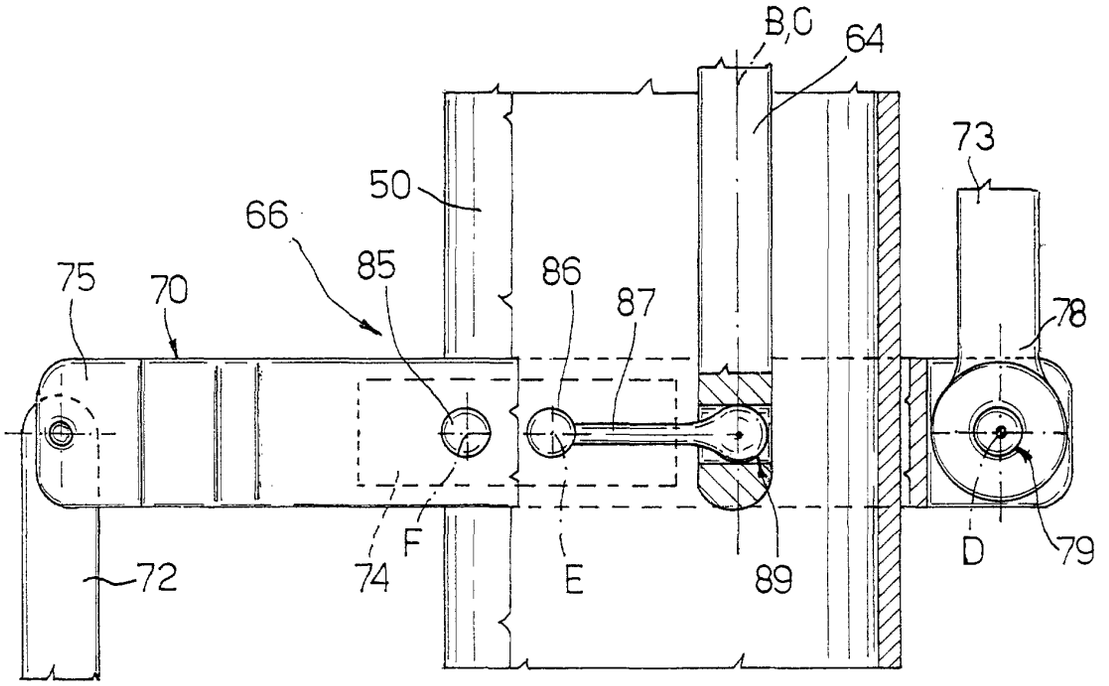
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Fig. 3

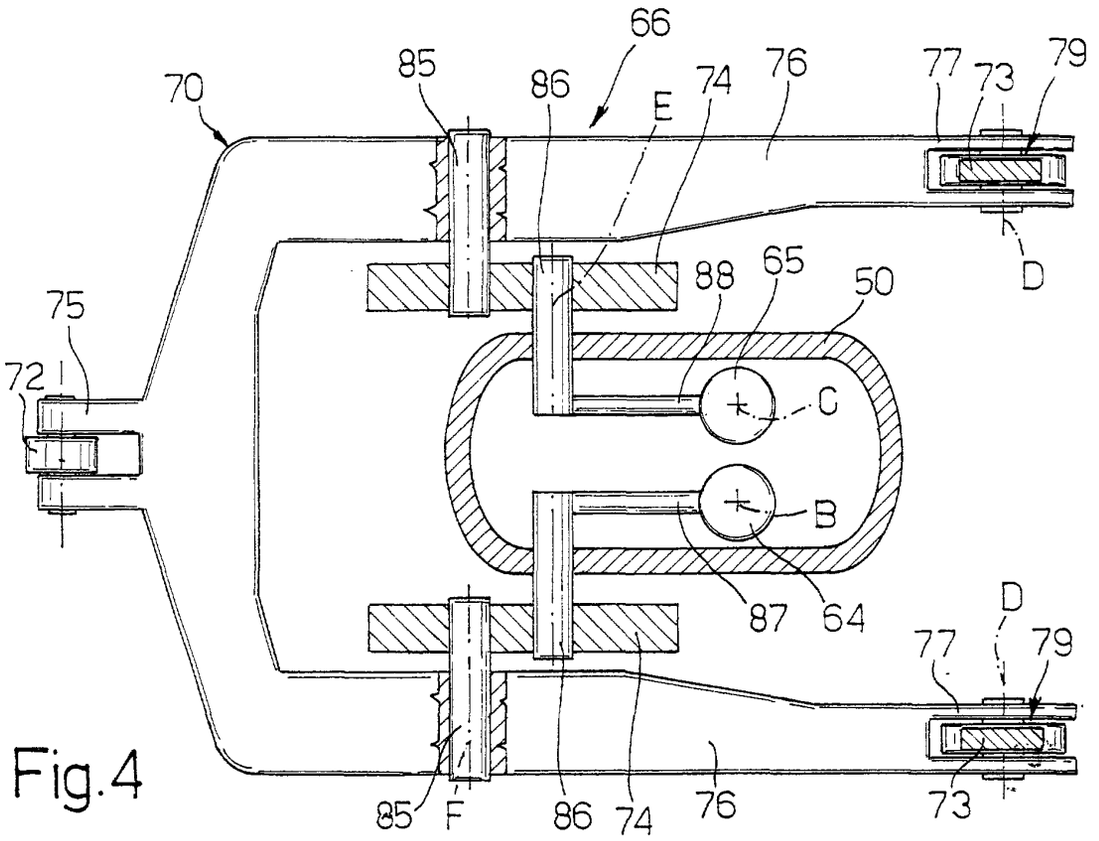
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Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 00 83 0650

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F15B
B64D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	5 February 2001	Staengl, G

CATEGORY OF CITED DOCUMENTS

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