



Europäisches Patentamt
European Patent Office
Office européen des brevets



Publication number:

0 564 950 A1

12

EUROPEAN PATENT APPLICATION

21 Application number: **93105167.6**

51 Int. Cl.⁵: **F15B 15/08, F15B 11/06**

22 Date of filing: **29.03.93**

30 Priority: **10.04.92 IT MI920889**

43 Date of publication of application:
13.10.93 Bulletin 93/41

84 Designated Contracting States:
AT CH DE ES FR GB LI NL SE

71 Applicant: **UNIVER S.p.A.**
Via Eraclito No. 31
I-20128 Milano(IT)

72 Inventor: **Migliori, Luciano**
Residenza del Sagitario T 29/1,
Via F.lli Cervi
Milano 2 (Milano)(IT)

74 Representative: **Coloberti, Luigi**
Via E. de Amicis No. 25
I-20123 Milano (IT)

54 **Programmable rotary actuator.**

57 A pneumatically programmable rotary actuator has a casing (10) for a rotatably supported output shaft (16) having a pinion (15) drivingly connected to a first fluid pressure actuated rack and piston unit (11, 15); self-balanced hydraulic control means are provided to control the speed of rotation of the output shaft (16) in a programmable manner. The hydraulic control means comprises a double acting pumping device (30, 31) provided with a second rack and piston unit (14) operatively connected to the pinion member (15) of the output shaft (16) in which the opposite chambers (32, 33) of said pumping device are connected by a throttling circuit (34) comprising a throttling slide valve (35) provided with a spool member (41) having variable throttling passages (42), and programmably actuated pneumatic control means (46) at one end of the spool member (41) to axially move the same against an elastically yieldable biasing member (45) at the opposite end of the same spool (41).

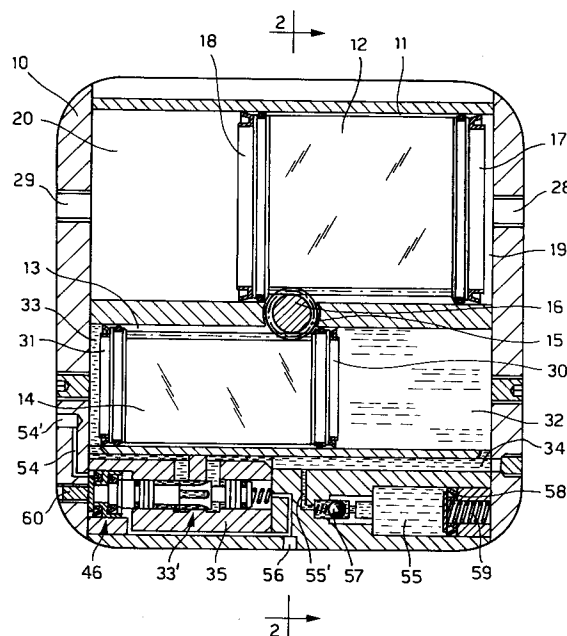


FIG. 1

EP 0 564 950 A1

The present invention relates to a programmable rotary pneumatic actuator in accordance with the preamble of the main claim, of the type comprising a double-acting rack and piston unit which engage a central pinion connected to a driven shaft of the actuator; hydraulic control means are provided to control the movement of the piston unit.

Twin-rack rotary pneumatic actuators are known for example from "Fluid Power Handbook & Directory 1986-87", pp. A/36 and A/37 and DE-A-2,228,570; these actuators are mainly used to convert the reciprocating movements of opposing rack and piston units into the alternate rotary movement of a shaft. Rack-and-pinion rotary actuators of the abovementioned kind are particularly useful for heavy-duty applications since they are able to withstand large loads, while maintaining a high degree of efficiency for most of their travel. From DE-A-2,228,570 it is also known to provide a throttling ball valve member inside a chamber of the piston unit to damping the movement at one end of the stroke.

However, in the case where extremely precise control of the speeds and accelerations of the actuator is required, for example in order to move and position a load or a component during a manufacturing process using robotized systems, it is not recommended or feasible at all to use the current rotary pneumatic actuators not only because of the impossibility of varying and controlling their operation according to variable work requirements, but also because of their poor positioning accuracy due to the compressibility or elastic behaviour of the operating fluid.

Furthermore, in the case of rotary actuators of the rack-and-pinion type currently known, there is no possibility of controlling and programming the working speeds, accelerations and load stoppage positions.

Hydraulic damping systems for controlling the travel of moving components are generally known from GB-A-2,131,096, EP-A- 0,077,597, FR-A-1,380,955 and DE-A-2,944,471, and applied as additional parts to conventional linear actuators; however, none of these known systems has been devised or proposed as a structurally and functionally integrative part of a rack-type rotary actuator, to allow programmable control of the working speeds and travel of the said actuator, making the use of the same pressure fluid to operate the actuator or the control system thereof.

Therefore, the general object of the present invention is to provide a rack-type rotary actuator which makes use of compressed air to operate the actuator and a hydraulic control system suitably integrated with the pneumatic actuating part, so as to control the working and travel of the actuator in a

programmable manner.

A further object of the present invention is to provide a rotary actuator of the abovementioned type with inertial control device, by means of which it is possible to micrometrically adjust the working speeds and accelerations, namely to obtain varying speed conditions by means of a self-balanced hydraulic circuit, forming an integral part of the actuator.

Yet another object of the present invention is to provide a rotary actuator as referred to above, provided with a safety braking device which can be activated to lock the actuator in a safety position.

Yet another object is to provide a rotary actuator able to provide a high degree of positioning precision, of the order of a few hundredths of degree, thereby making the actuator particularly reliable for use in robotized systems.

These and other objects of present invention can be obtained by a programmable pneumatic rotary actuator, comprising a self-balanced hydraulic circuit for controlling and adjusting the travel and the speed of the actuator in accordance with the characteristic features of the main claim.

The present invention, will be further illustrated hereinbelow with reference to a preferred embodiment of a programmable pneumatic rotary actuator, in accordance with the accompanying drawings, in which:

- Fig. 1 is a cross-sectional view of the rotary actuator;
- Fig. 2 is a cross-sectional view along the line 2-2 of Figure 1;
- Fig. 3 is an enlarged detail of the programmable valve device forming part of the hydraulic control circuit, shown in a first operating condition;
- Fig. 4 is a view similar to that of Figure 3, in a second operating condition;
- Fig. 5 is a functional diagram of the actuator and the respective control circuit.

As shown in Figures 1 and 2, the rotary actuator according to the present invention substantially comprises a hollow body or casing 10 having, respectively, a first cylindrical bore 11 for the reciprocate sliding movement of a first rack and piston unit, as well as a second cylindrical bore 13 for the sliding of a second rack and piston unit provided with racks 12 and 14 engaging on the opposite sides of a central pinion 15 integral with or connected to an output shaft 16 of the actuator.

The first rack 12, also called actuating rack, constitutes part of a double acting first rack and piston unit comprising two pistons 17 and 18 which are reciprocable inside respective cylindrical chambers 19, 20 supplied with pressurised air by an external source, via inlet ports 28 and 29.

In a substantially corresponding manner, the second rack 14, also called control rack constitutes part of a second rack and piston pumping unit comprising pistons 30 and 31 which are reciprocable inside respective cylindrical chambers 32 and 33 forming part of a fluid pressure actuated hydraulic control device of the actuator, as described hereinbelow.

The hydraulic control device is in the form of a closed circuit comprising the hydraulic chambers 32 and 33 of the second rack and piston unit in which said chambers are connected to or communicate with each other via a branched path 34; the path 34 comprises a valving device 33' for controlling the flow of a hydraulic fluid, in turn adjusted by a differential-action pneumatic control device, shown in detail in Figs. 3 and 4 of the accompanying drawings.

In particular, as shown, the valve-type control device comprises a hydraulic distributor body 35 formed with an axial bore inside which a spool and piston unit or valve element 36 slides.

The body 35 of the distributor is formed with two radial passages 37, 38 to place the two separate sections of the branched duct 34 in communication with two internal annular chambers 39, 40 of the valving device 33' which are axially spaced from one another, in correspondence with each of two restricted portions 36' and 36'' of the spool or valve element 36, having smaller diameters.

Between the two restricted portions 36' and 36'', the spool 36 has a cylindrical core or spool 41 provided with a set of longitudinal passages 42 having constant width and a gradually decreasing depth towards the annular chamber 40 of the device; the passages 42 at the other end open out towards the other chamber 39. The shape of the passages 42 has been suitably designed with a first part having a gradually increases depth so as to cause, during a first portion of the travel of the spool 36, a gradual variation in the flow cross-section of the fluid, such as to allow a proportional control of the speed of the actuator, as well as a second part with a constant cross-section for the remaining portion of the spool travel, by means of which it is possible to obtain a rapid incremental variation of the flow rate suitable for bringing the actuator rapidly up to its maximum working speed.

The spool 42 has at its right-hand end, as viewed in Figure 3, a plug head 43 which extends into the cylindrical bore 44 of the distributor 35, in which a biasing spring 45 is housed; the spring opposes with a gradual action the forward thrust movement imparted to the spool by a differential-action pneumatic control device, denoted in its entirety by 46, at the opposite end of the spool 36.

More precisely, the differential-action pneumatic control device 46 comprises a main and a sec-

ondary piston elements acting separately and in succession; the secondary piston element 47 is provided on an extension of reduced diameter of a cylindrical head 48 of the spool which protrudes into a piston chamber 49 at one end of the body 35 of the distributor. The piston 47 has a diameter smaller than the internal diameter of the chamber 49 so as to form a kind of plunging piston.

The piston 47 is moreover slidable inside a movable chamber provided by a cylindrical cup 50 freely sliding inside the piston chamber 49; the cup 50 has a cylindrical neck 51 of reduced diameter which, together with a gasket 52, defines the main piston of larger diameter, sliding inside the chamber 49. This second piston, or more precisely the inner bottom surface of the cylindrical cup 51, rests against the end of the spool 36 which supports the secondary piston 47; furthermore, the bottom of the cup 50 is formed with an axial passage 53 which opens out on both sides so as to communicate both chamber 49 and movable chamber inside the cup members 50 with an inlet port 54 supplying compressed air.

The chamber 49, on the side opposite to that supply duct 54, and the chamber 44 of the biasing spring, are further connected via respective ducts to a venting opening 56. Suitable sealing gaskets keep the hydraulic control circuits of the actuator separate from the pneumatic control circuit of the valving device.

As schematically shown in Figure 1, the hydraulic circuit is furthermore connected to a fluid accumulator in the body 10 comprising a chamber 55 containing hydraulic fluid under pressure, the chamber 55 communicates via a duct 55' and a unidirectional check valve 57, with the branched duct 34 of the hydraulic control device of the actuator. Inside the chamber 55 there is provided a piston 58 constantly urged by a preloaded spring 59 so as to keep the hydraulic fluid at a constant predetermined pressure sufficient to compensate for any losses in the hydraulic control circuit.

In the figures, 60 denotes moreover a stop member which is adjustable, for example by means of screwing, and which can be suitably adjusted so as to vary the end position of the spool 36 and hence the minimum aperture for the fluid flow through the valve element in the absence of pressurised air supply inside the pneumatic control device 46.

As shown in cross-sectional view of Figure 2, the actuator is furtherly provided with a passive-action safety brake; by means of this brake it is possible to achieve a high degree of precision for the stoppage position of the actuator shaft 16 and consequently a high degree of positioning accuracy for a moving load or mechanical component, which can be calculated to the order of one hundredth of

degree.

In the example shown, the safety brake is pneumatically operated; substantially it comprises a first locking member 61, integral with the shaft 16 of the actuator, as well as a second locking member 62 which is constantly biased so as to engage frontally with the former, by means of cup springs or equivalent biasing means 63 arranged between the locking element 62 and an inner wall of the body 10 which separates the safety brake 61, 62 from the chamber 64 of a pneumatic cylinder, the piston 65 of which is connected to the stop member 62.

The shaft 16 of the actuator is furthermore connected to a signal generator or encoder 66 by means of a gear reducer 67 comprising a set of toothed gears to provide a high reduction ratio so as to obtain a high rotational ratio between the shaft 16 of the actuator and the shaft of the electrical signal generator 66, consequently the output of a few tens of thousands of pulses per revolution.

Figure 5 of the accompanying drawings shows finally the control apparatus for the actuator described above. As can be noted in said figure, the inlets 28, 29, 54' and 56 for supplying pressurised air to the chambers of the actuator operating pistons are connected to a pressurised fluid source 68 by means of a distributor 68', the solenoid valves of which are suitably connected to the outlets of a CPU or programmable logic processing unit 69 which receives at its inlet side the control signals emitted by the encoder or generator 66, indicating the direction and speed of rotation of the actuator shaft 16. In this way, by programming the supply times for the pressurised air to the two chambers of the rack and piston unit 12, i.e. by programming the position and the instants when the valve device 33 is activated, by means of the supply of pressurised air to the pneumatic control device 46, as well as the instant when the locking braking device 61, 62 is activated, by means of operation of the respective pneumatic control device 65, it is possible to control and vary the rotational travel and speed of the shaft 16 micrometrically, between a low speed value and a high value within a gradually variable range, and a maximum value greater than the preceding ones; this is obtained for example with a first pressure control signal at the inlet 54 for positioning the spool 36 in the condition of Figure 3, for pressures in the chamber 49 variable gradually within a preset range of values, while the maximum value of the working speed can be obtained with the spool operating condition shown in Fig 4 for an extreme pressure value in the chamber 49. In fact, since the spool 36 is hydraulically balanced, during the first adjusting portion of the spool stroke, the passages 42 allow the hydraulic fluid to gradually circulate at a rate proportional to

the position of the spool itself; it is obvious that in this way it is possible to control and program the displacement speed of the rack and piston unit 12 and hence the speed of rotation of the shaft 16 of the actuator in a gradually variable manner and in proportion to the values of the pressurised air supplied to the pneumatic device 46 controlling the spool 36, lying within a predefined range, for example between 0 and 4 Atm. This gradual adjustment is possible in that displacement of the spool 36 initially is effected by the main piston 52 of the sliding cup 50, which has a larger area. When the cup 50 reaches the end of its travel, against the right-hand wall of the chamber 49, the second piston 47 which receives pressurised air via the axial passage 53 in the said cup 50 is operated. In view of the smaller area of this second piston, once a pressure threshold has been exceeded, for example 5 Atm, higher than the maximum preset pressure value for operation of the first piston, the spool 36 is pushed forwards completely, bringing the largest cross-section of the passages 42 into communication with the passage 38. In this way, it is possible to achieve the maximum speed of rotation of the actuator shaft. The supply of pressurised air to the two chambers 19 and 20 may be periodically reversed and each time the shaft 16 reaches a predetermined angular position, the program stored in the CPU 69 will command stoppage of the actuator and activation of the brake 61, 62 so as to ensure stable and extremely precise positioning of the shaft 16 within very small tolerances.

It is understood that the above description and illustrations with reference to the accompanying drawings have been provided purely by way of example of a preferred embodiment of a pneumatic rotary actuator according to the invention.

Claims

1. A pneumatically programmable rotary actuator comprising a casing (10), a control shaft (16) rotatably supported by the casing (10), fluid pressure actuated rack and piston unit (11) drivingly connected to reciprocate said control shaft (16), and hydraulic control means (14, 34, 35) to control the rotational speed of the shaft (16) of the actuator, characterised in that said hydraulic control means comprises a double acting pumping device having rack and piston pumping unit (14, 30, 31) reciprocable within axially aligned hydraulic chambers (32, 33), said rack and piston pumping unit (14, 30, 31) being drivingly connected to said control shaft (16); a closed circuit (34) branched off from said hydraulic chambers (32, 33) said closed circuit (34) comprising a valving device (33') having a slidable throttling member (41), and

programmably actuable pneumatic control means (46) at one end of the throttling member (41) acting against the biasing of a spring member (45) provided at the opposite end of the throttling member (41) of the valving device.

2. A pneumatically programmable rotary actuator according to Claim 1, characterised by comprising a pneumatically actuable locking device (65') for the control shaft 16 of the actuator, said locking device (65') comprising first locking member (61) rotatably supported by the control shaft (16) and second locking member (62) slidably supported in respect to the first locking member (61) of the device, and pneumatically actuable control means (65) to engage and disengage said locking members (61, 62).
3. A pneumatically programmable rotary actuator according to Claim 1, characterised in that said control shaft (16) is connected to an electric signal generator (66), via a gear reducer unit (67).
4. A pneumatically programmable rotary actuator according to the preceding claims, characterised in that the locking device (65'), the associated pneumatic control means 65, the signal generator (66) and the gear reducer unit (67) are removably arranged in a housing inside the casing (10) of the actuator.
5. A pneumatically programmable rotary actuator according to Claim 1, characterised in that the control chambers (19, 20) of the rack and piston unit (11), the pneumatic control means (65) for the shaft locking device (65') and the pneumatic control means (46) for the throttling member of the valving device (33') are connectable to a pressurised-fluid source via solenoid valves (68'), said solenoid valves (68') and said signal generator (66) being connected to a programmable logic control unit (69).
6. A pneumatically programmable rotary actuator according to Claim 1, characterised in that said valving device comprises a hydraulic distributor (35) provided with said closed circuit (34) between the hydraulic chambers (32, 33) of the rack and piston pumping unit (14, 30, 31), said distributor (35) having first and second annular chambers (39, 40) spaced apart and communicating with said closed circuit (34) of the pumping unit mentioned above; an axially sliding valve element inside said distributor, said valve element comprising a spool

member (41) having longitudinal passages (42) for the hydraulic fluid, said passages (42) opening towards the abovementioned annular chambers (39, 40) and piston means (34, 43) connected to the spool member (41) to balance the hydraulic thrust on opposite side of the spool member (41).

7. A pneumatically programmable rotary actuator according to Claim 1, characterised in that said pneumatic control means for the throttling member (41) comprises independent first and second piston members (47, 52) having different thrust areas and sequentially acting on the throttling member (41) of the valving device.
8. A pneumatically programmable rotary actuator according to Claim 7, characterised in that said pneumatic control means for the throttling member (41) comprises a first cup-shaped piston member (50) freely slidable inside a chamber (49), said first piston member (50) having an axial bore (53), and a second piston member (47) connected to the throttling member (41), said second piston member (47) being slidable provided within the cup-shaped piston member, (50), the axial bore in the cup-shaped piston member defining an air passage between said chamber (49) and the inside of the cup-shaped piston member (52), and plug means on said second piston member (47) to close said axial bore (53) in the cup-shaped piston member (52) mentioned above.
9. A pneumatically programmable rotary actuator according to Claim 8, characterised in that the stroke of said throttling member (41) and said second piston member (47), is greater than the stroke of said first piston member (52).
10. A pneumatically programmable rotary actuator according to Claim 1, characterised by comprising a fluid accumulator chamber (55) for accumulating a quantity of a pressurised hydraulic fluid, said accumulator chamber being connected to said closed circuit (34) via a check valve, said accumulator chamber (55) comprising a piston member (58) and biasing means acting on said piston member (58) for maintaining the pressure of the hydraulic liquid in the accumulator chamber (55) at a substantially constant value.
11. A pneumatically programmable rotary actuator according to Claim 8, characterised by comprising adjustable stop means (60) protruding into said chamber for the first cup-shaped pis-

ton member (50) of said pneumatic control means.

5

10

15

20

25

30

35

40

45

50

55

6

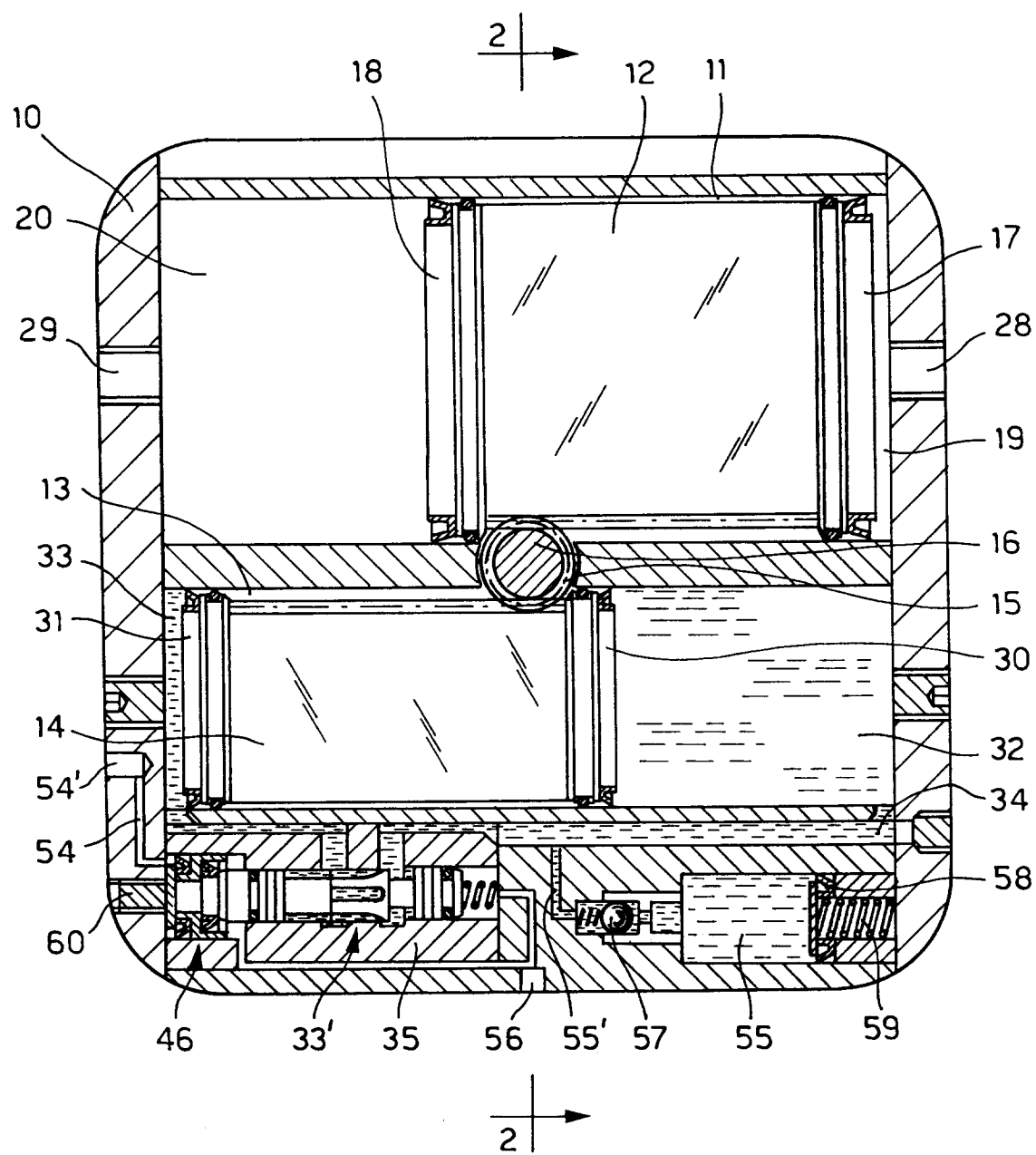


FIG. 1

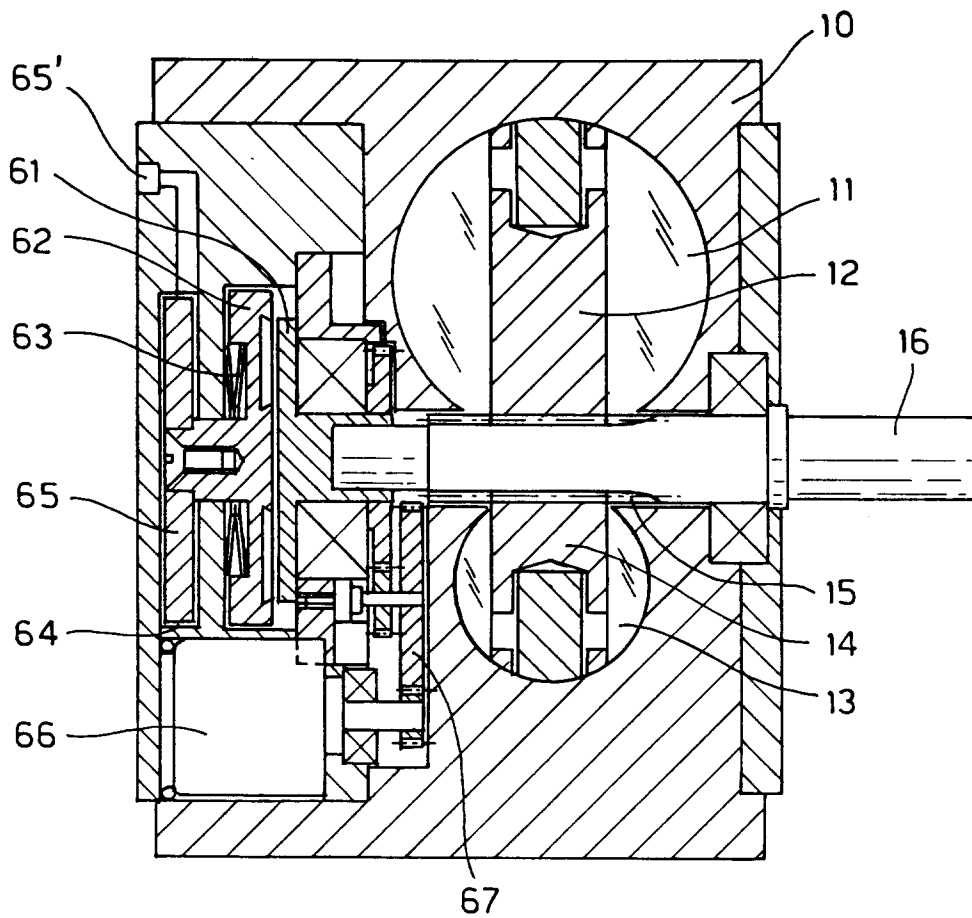


FIG. 2

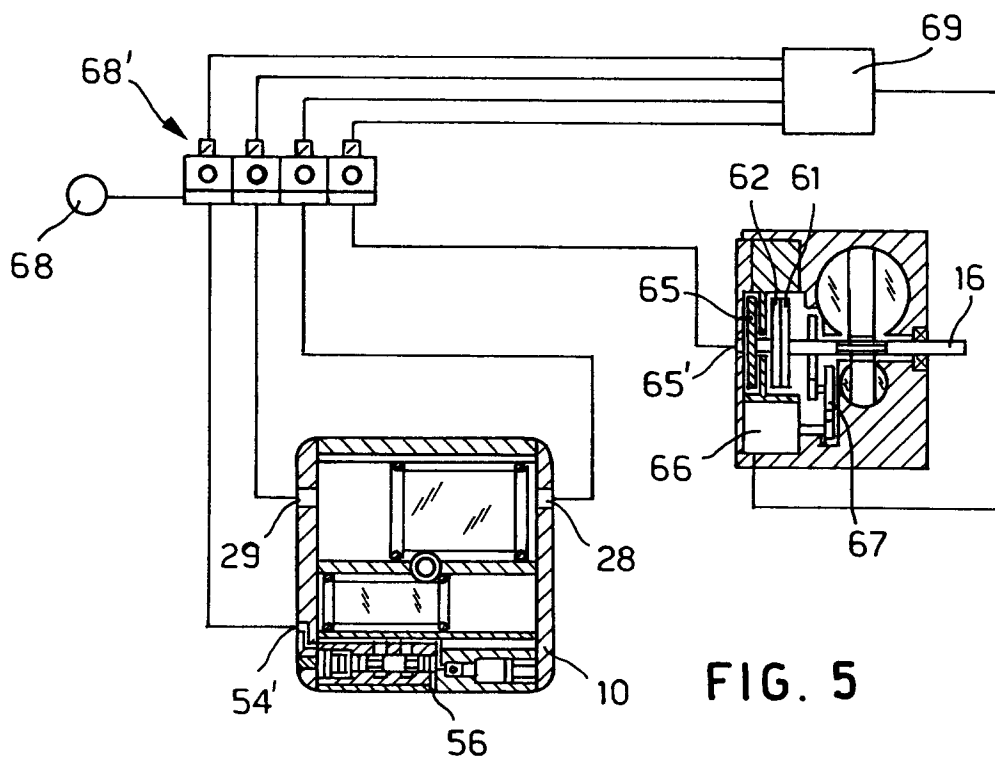


FIG. 5

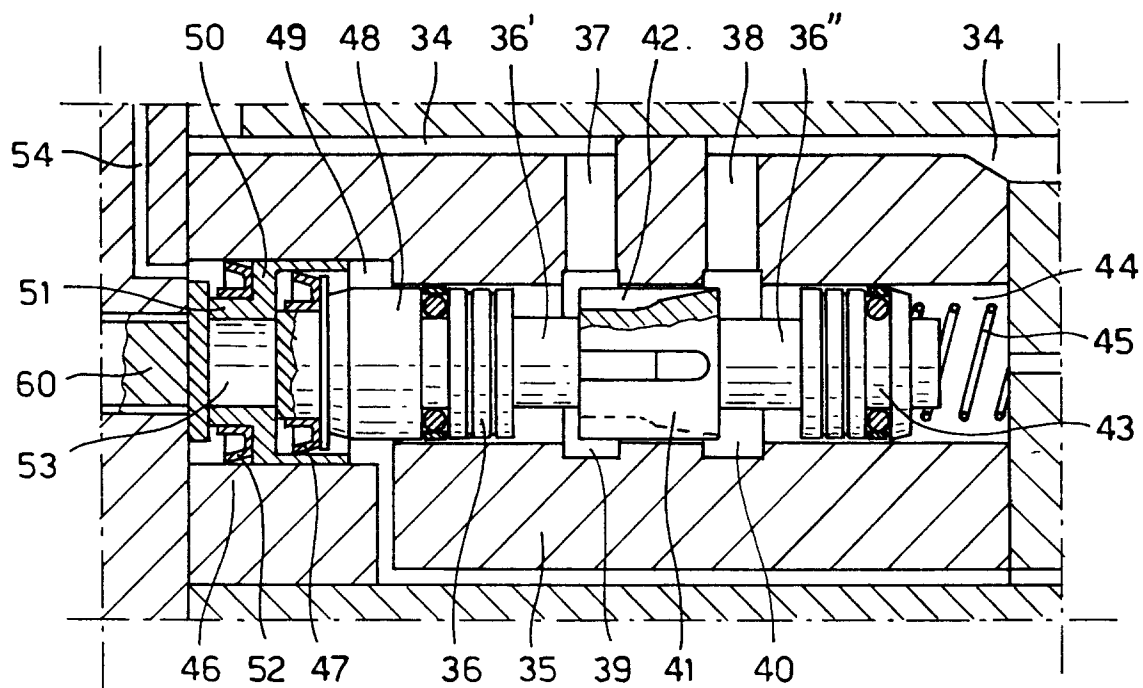


FIG. 3

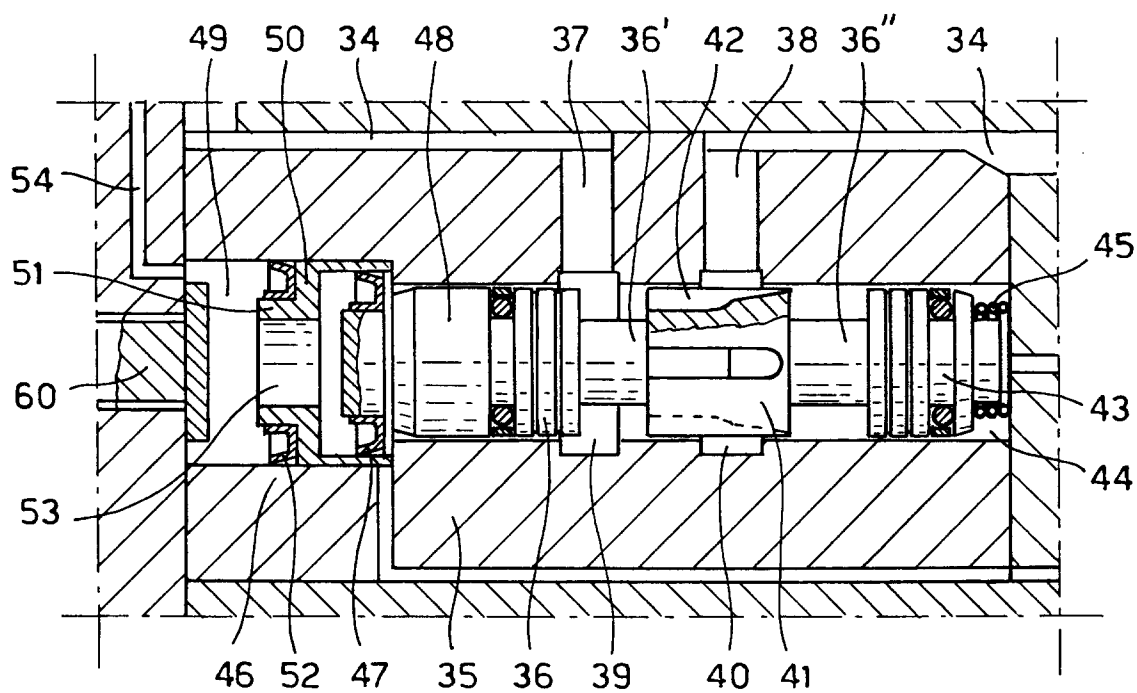


FIG. 4



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 10 5167

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,Y	EP-A-0 481 692 (C & C) * figure 4 * ---	1, 3, 5, 10	F15B15/08 F15B11/06
D,Y	GB-A-2 131 096 (LORD) * the whole document * ---	1, 3, 5, 10	
A	FR-A-1 492 255 (MAIRE) * the whole document * ---	6	
D,A	DE-A-2 228 570 (CHODOS) ---		
D,A	DE-A-2 944 471 (KLOTZ) ---		
D,A	FR-A-1 380 955 (SIHN) ---		
D,A	EP-A-0 077 597 (HUMABO) ---		
A	FR-A-2 274 853 (MESSIER-HISPANO) ---		
A	US-A-2 963 260 (SIRAVO) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F15B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 07 JULY 1993	Examiner KNOPS J.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			