

[54] **DOUBLE-HYDRAULIC ACTUATOR**

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[51] **Int. Cl.**..... **F15b 11/16; F15b 13/06**

[58] **Field of Search** **91/411, 411 A, 413, 363 A, 91/412, 384; 137/637.1**

[56] **References Cited**

UNITED STATES PATENTS

2,597,419	5/1952	Westbury.....	91/363 A
2,947,285	8/1960	Baltus et al.....	91/387
3,272,062	9/1966	Flippo et al.....	91/411 A
3,338,139	8/1967	Wood.....	91/411 A
3,426,650	2/1969	Jenney.....	91/363 A

FOREIGN PATENTS OR APPLICATIONS

670,352	4/1952	United Kingdom.....	91/412
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[57] **ABSTRACT**

Control for a tandem connected, redundant servo motor system. The tandem connected servo motors are each provided with a suitable control valve and independent pressure fluid supplies therethrough. A single control linkage is provided for both control valves and said linkage is connected to each valve by mechanically over-rideable means so that if one valve sticks the other can still be operated. Means are provided normally holding energizing pressure on a selected first motor and off the second motor, said means being responsive to an over-riding of said over-rideable means to reverse the pressure conditions on the motors. By making the normal conditions of said means partially dependent upon the existence of the main supply pressure, same can be caused to turn on the auxiliary supply pressure upon failure of the main supply pressure.

8 Claims, 3 Drawing Figures

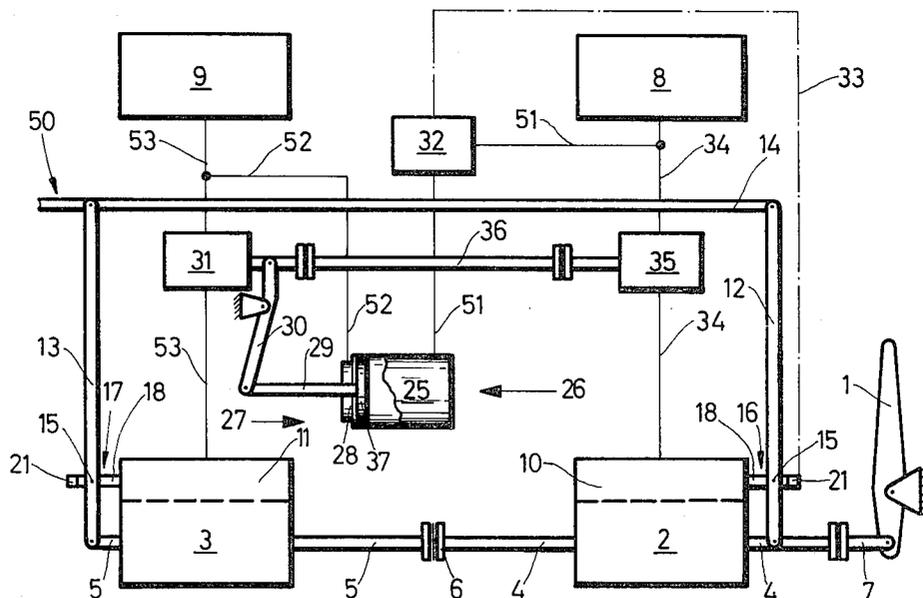


Fig. 1

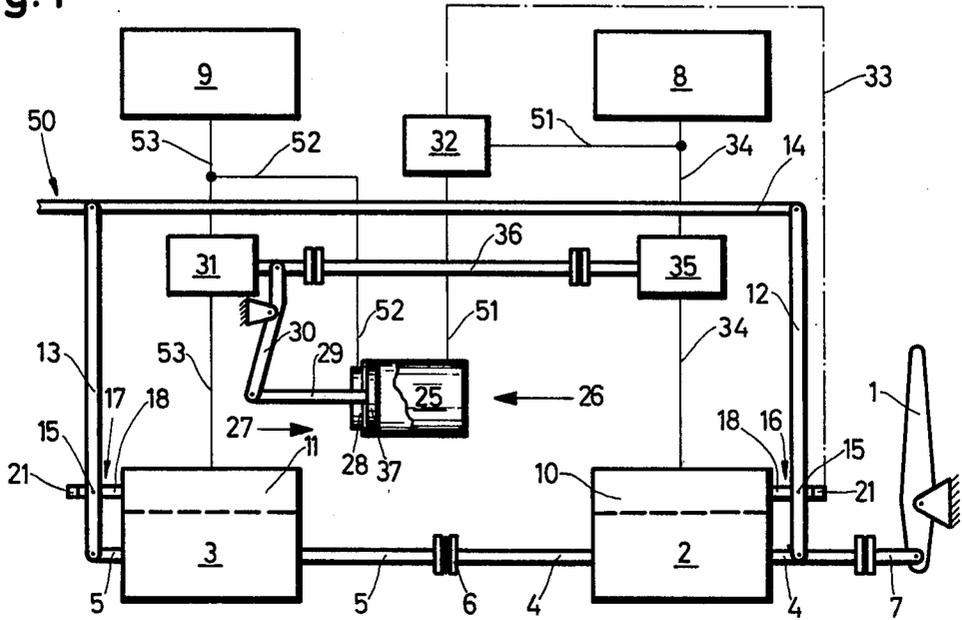


Fig. 2

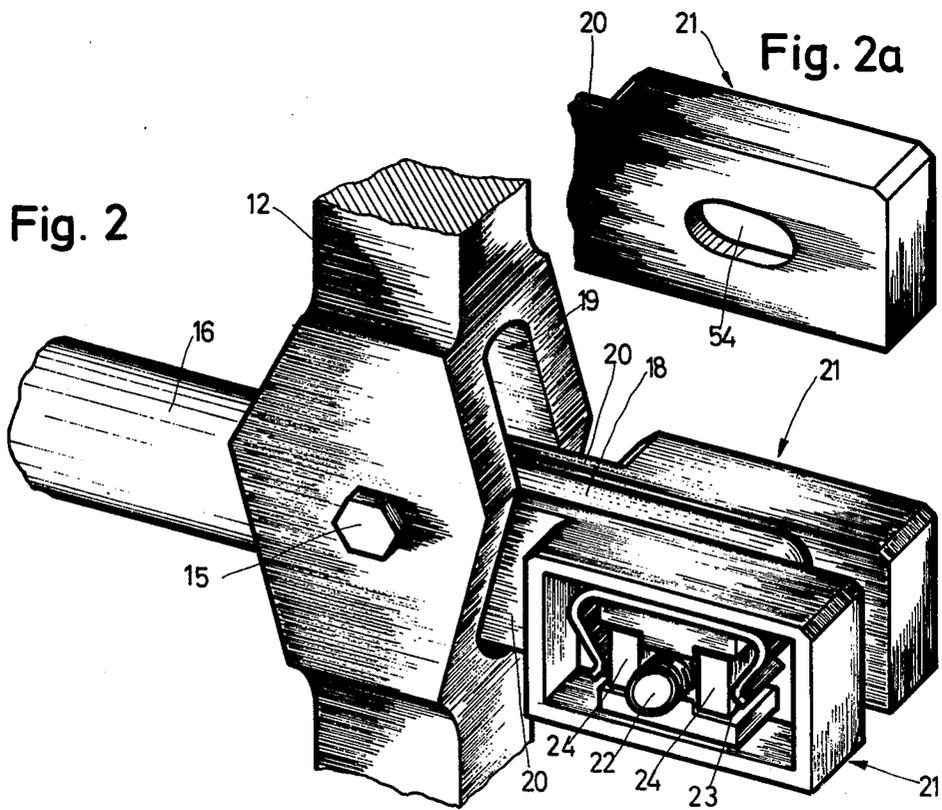


Fig. 2a

DOUBLE-HYDRAULIC ACTUATOR

Hydraulic actuators, particularly those for controls of air and spacecraft, must be constructed redundantly for reasons of safety, that is, at least in duplicate, so that in case one (as the main) drive breaks down at least one second (auxiliary) drive is able to automatically take over the function of the first one. However, this objective cannot be fulfilled merely by mechanically coupling two so-called "simple" hydraulic actuators with the same output and by permitting same to operate a common output member.

Thus, for example in one known arrangement (German Offenlegungsschrift No. 1 426 480) wherein two tandem connected servo motors are simultaneously hydraulically active and the control valves or control valve pistons thereof are coupled mechanically on both sides, additional switching devices are provided in the hydraulic control circuits so that a breakdown of an electric control circuit does not result in a blocking of the control valve pistons and thus result in a total breakdown of the entire actuator. Because of the mechanical coupling of the control valve pistons, it is however, not possible to avoid a total breakdown of the system upon a blocking of one valve member, as due to binding or seizing of the parts. In view of this, further measures are needed if one does not want to dispense all together with a mechanical coupling of the control valve pistons, which dispensing is not possible in the case of this tandem actuator.

A further problem is that an actuator as above referred to requires, furthermore, an extremely exact adjustment of its coupled control valves which in turn requires a correspondingly great expenditure of effort during manufacture thereof. If control valves of simple servo motors are to be coupled, and thus are designed substantially for use in so-called simple servo-hydraulics, then it is not possible to make symmetric the hydraulic functions of these control valves over their entire control range. Due to the different valve curves (stroke/flow) one must count both on a considerable reduction of the regulating speeds and also on entirely asymmetric pressure relations in the operating cylinder chambers. It has been proven that for this reason operating piston forces can occur which are partly opposed and thus causes the effective actuating force of the drive to be at least materially reduced.

The purpose of the invention is to produce a double-hydraulic actuator which remains operative when one of its mechanically coupled control valves or control valve pistons becomes inoperative or when an energy supply breaks down.

A further purpose is to produce an actuator which no longer requires the hydraulic functions of the control valves to be symmetrical and which will not become inoperative. Upon the occurrence of a blocking, or seizing as has already been mentioned, for example, a sticking of a control valve piston.

Starting from a double-hydraulic actuator with at least two mechanically coupled servo motors in which also the piston rods of the control valves, with which a change-over device is associated, are coupled, it is suggested with respect thereto according to the invention, first to provide between each control valve piston rod and a member which transmits its control signals a positive connection which limits the control forces and, second, a change-over device which consists substan-

tially of a switching element which selectively switches to render hydraulically active either the one or the other servo motor.

Thus such an actuator does not deal with a so-called "true" double-hydraulic, but instead, with two coupled servo motors of which only one works on a common output member while the other one moves along in a pressureless manner as a standby. For this purpose, no further rigid connections are required directly between the servo motors aside from an operating piston rod coupling of the common type of construction and a linkage which provides the coupling of the control valve piston rods. It is understood that in this arrangement the aforementioned members which transmit control signals are structural parts of the control linkage but the chosen positive connections between those members and the control valve piston rods permit (namely during blocking of a control valve piston) an "overriding" of same. Thus, the second, or operative, valve piston can then always be easily actuated. Because of this concept, only insignificantly greater control forces must be produced than are normally required for operating of the control valve pistons.

In order to effect an automatic changing from the failing to the operative servo motor, the aforementioned switching element is in active engagement with at least one of the positive connections, advantageously with the one of the control valve piston rod of the servo motor which serves as main drive.

A differential cylinder can be provided as switching element, which cylinder on the piston side is loaded by the supply pressure of the first servo motor and on the piston rod side (annular chamber) by the supply pressure of the second servo motor, whereby its piston rod actively engages a shut-off device for the pressure source which supplies the second servo motor. Aside from an automatic changing over during a blocking of a control valve piston, this arrangement has the advantage that the differential cylinder also in case of a breakdown of a hydraulic energy circuit, preferably the main servo motor, automatically switches to a hydraulically active condition the second (auxiliary) servo motor which has been moving along on stand-by.

A further important advantage exists in that in such an actuator servo motors can also be used which are designed substantially only for so-called simple servo-hydraulics. Since during operation only one of the servo motors is hydraulically active, adjustment of its control valves is no longer needed when the operation changes. The adjustment which is common in the manufacture of the (single) motors, as has already been mentioned, is completely sufficient.

Thus the servo motors are also in case of operation breakdown or damage easily and individually replaceable. At the same time this tends to solve the problem of quickly installing double-hydraulic actuators where needed and to adjust same to the respective requirements (actuating forces and the like). This problem exists particularly in carrying out projects of the air and space flight especially, during the testing phase.

The invention and further developments of same are discussed more in detail hereinafter in connection with one exemplary embodiment, as illustrated in the drawing, in which:

FIG. 1 is a schematic view of a control in which only one mechanical linkage is provided for transmitting of control signals to a double-hydraulic actuator.

FIG. 2 is a perspective view of details of the connection between a control valve piston rod and a structural part of the linkage according to FIG. 1 and

FIG. 2a is a partial view of a detail according to FIG. 2.

A control surface 1, for example an elevator of an aircraft, can be pivoted by two mechanically coupled servo motors 2 and 3 which are provided therefore with operating cylinders having piston rods 4 and 5 extending therethrough. The latter are axially fixedly connected by a coupling 6 of the usual type of construction, for example a connecting rod coupling; and they are radially movable, within limits, in order to compensate for angle errors and the like. The servo motors 2 and 3 are simple servo motors with an equal output and they actuate a common output member such as a linkage 7 which is connected to the control surface 1 and to new power piston rod 4 of the servo motor 2 which is used as a main drive. However, of the servo motors 2 or 3, which are connected to a separate pressure source 8 or 9 only one is constantly hydraulically active while the second one follows in readiness but without pressure thereon. This will be discussed more in detail below.

The control valves 10 and 11 of the servo motors 2 or 3 are coupled by a linkage in which, as in a parallel-crank mechanism, two two-arm levers 12 or 13 are pivotally connected at one respective end of each thereof by a piston rod 14 and at the other respective ends of each thereof the levers 12 or 13 are each hinged to one of the power piston rods 4 or 5. The piston rod 14 can for example be moved by a control stick which acts on its left end 50. The control valves are of the type having so-called by-pass mechanism (by-pass valve) which operates in response to pressure and act during reduction or failure of supply pressure to close an otherwise free passage for the pressure medium which passage normally is provided between the chambers of the associated operating cylinder. Each lever 12 and 13 is provided with a cap screw 15 which is arranged freely movably in a not illustrated axially elongated slot in the associated control valve piston rod 16 or 17 (coupling part 18). The coupling parts 18 are guided through the associated lever 12 or 13 which has therefore an opening 19 in the zone of its axis of rotation. This is illustrated in FIG. 2 only for the lever 12 with the understanding that corresponding parts are associated with the lever 13, comprise a mirror image thereof and hence need no express illustration. With respect to the piston rod 14, it can, in view of an easier adjustment of the coupled levers 12 and 13, be additionally equipped with the usual screw locks or the like.

The connections for transmitting control forces between the levers 12, 13 and the associated control valve piston rods 16 or 17 are provided at the outer ends of the coupling parts 18. Details of these connections, which are the same in both control valve piston rods 16 and 17, are illustrated in FIG. 2 but only in connection with the control valve piston rod 16 of the main servo motor 2. According to such figure the aforementioned cap screw 15 is used as a pivotal connector for two lever elements 20 which extend on both sides of the coupling part 18. The lever elements 20 are at their outer ends 21 hinged pivotably, and at the same time axially movably, to a further pivot means 22 which is fixedly arranged in the coupling part 18. Each lever element 20 has an elongated slot 54 (FIG. 2a) in which the

pivot 22 abuts after a full control piston stroke in each control direction. To connect the pivot means 22 to the lever elements 20, a clamplike operating (as leaf) spring element 23 is used wherein each spring 23 holds the pivot 22 in the elongated slot of the associated lever element 20 in a central position through movable sliding members 24. The outer ends 21 of the lever elements 20 are for this purpose constructed as bearing housings for these connecting elements (spring elements 23, sliding members 24).

As has already been mentioned, such a positive connection is provided between each lever 12 and 13 and the associated control valve piston rod 16 or 17.

By this arrangement, the coupled levers 12 and 13 can be pivoted relative to the associated power piston rod 4 or 5 even if one of the control valve pistons (not illustrated) is blocked. The spring elements 23 which oppose the respective control forces, in such case permits an axial shifting of whichever of the lever elements 20 is associated with the blocked piston and do so in each control direction. It is understood that this shifting is possible only if the normal control forces are exceeded and that only the spring elements which belong to these lever elements become effective.

A blocked control valve piston thus does not result in blocking the linkage, instead, it is only necessary to produce greater control forces to overcome and override the spring connectors. If the control valve piston of the main servo motor 2 is blocked, then an automatic switch to the second (auxiliary) servo motor 3 or its control valve 11 takes place whereby this motor is switched hydraulically active and the faulty one is depressurized. For this purpose a differential cylinder 25 is provided which is loaded on its piston side 26 through a pressure line 51 by the supply pressure 8 of the main servo motor 2 and on its piston rod side 27 (annular chamber 28) through a pressure line 52 by the supply pressure 9 of the auxiliary servo motor 3. The piston rod 29 of the differential cylinder 25 is thereby in active engagement with a shut-off device 31 which is connected into a supply line 53 which connects the auxiliary servo motor 3 to its pressure source 9. It can be seen (FIG. 1) that this shut-off device 31 does not influence the loading of the annular chamber 28 by the supply pressure of the last-mentioned motor. Furthermore, a shut-off device 32 is connected into the pressure line 51 between the piston side 26 of the differential cylinder 25 and the pressure source 8 which supplies the main servo motor 2, which shut-off device is operable in response to the spring elements 23 of the connection of control valve piston rod 16 and lever 12. This is indicated by the dash-dotted line 33. The shut-off valve 32 can for example be a magnetic valve the circuit of which is closed or opened by a contact which is operated by the aforementioned spring elements 23. Finally, a shut-off device 35 is connected into a supply line 34 which connects the control valve 10 of the main servo motor 2 to its pressure source 8. Said shut-off valve is coupled through a linkage 36 to the first shut-off device 31.

Only one of the two mechanically coupled shut-off devices 31 and 35, for example spool valves, is open while the other one blocks or vice versa. If for example the third shut-off device 35 is open and thus the main servo motor 2 is energized, the pressure medium supply to the auxiliary servo motor 3 or its control valve 11 is blocked through the first shut-off device 31. At the

same time the second de-energized (and thus open) shut-off device 32 assures that the piston 37 of the differential cylinder 25 is in its appropriate limit position, that is it is in the extended position which is illustrated in FIG. 1. This results from equal supply pressure in that the force which acts onto the larger piston surface from the supply pressure of the main servo motor 2 is greater than the force (supply pressure auxiliary motor 31) which acts on the smaller annular surface. Thus in this position also the piston 37 keeps the first shut-off device 31 closed.

If the control valve piston of the main servo motor 2 is blocked, the piston 37 of the differential cylinder 25 is automatically retracted, that is, it assumes the second limit position as soon as the spring 23 of that control valve piston is overcome. This causes the auxiliary servo motor 3 to become hydraulically energized and the main servo motor 2 to become depressurized. More in detail, the yielding of the respective spring elements 23, which yielding occurs upon blocking of a control valve piston, causes a blocking of the second shut-off device 32 after which only the annular chamber 28 of the differential cylinder 25 is pressurized, namely, by the supply pressure of the auxiliary servo motor 3. In the second not illustrated limit position of the piston 37, the first shut off device 31 is now opened through the bent lever 30 and the third shut-off device 35 is, because of its mechanical coupling (linkage 36) to the first one, now closed. Thus, the power piston of the main servo motor 2 is prevented from getting into a locked condition.

Accordingly the auxiliary servo motor 3, whose control valve 11 (particular the piston thereof) has the same position as that of the main servo motor 2, can take over automatically the driving function when the other is inoperative. To identify the blocked control valve piston, one only needs to connect a signalling device to the second shut-off device 32. Thus, if this device is not energized and greater forces than usual must be produced for the control; then this indicates a blocking of the control valve 11 of the auxiliary servo motor 3.

If the supply pressure of the main servo motor 2 is inoperative, the auxiliary servo motor 3 is switched automatically to a pressurized condition since again the pressure on the greater piston surface of the differential cylinder 25 is lacking and the piston 37, when it changes into its second limit position, opens the first shut-off device 31 through its piston rod 29 and the bent lever 30.

It is noted that the described arrangement is not limited to a double hydraulic drive with two simple servo motors. In place of these motors, for example, motors can also be used in which three similar operating cylinders are arranged parallel to one another and are provided with a common valve unit. Such servo motors are usually used for controlling the rotor blades of rotary-wing aircraft. In such case it will be understood that then at least the aforescribed linkage is constructed in triplicate.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The combination in a redundant fluid actuator system of at least two separate and separably operated servomotors, each of said servomotors having a first piston rod mounted for reciprocal movement and a control

valve for controlling the movement of said first piston rods, each of said control valves having a second piston rod thereon, means for mechanically coupling each of said first piston rods together, a common control member for controlling both of said servomotors, said common control member including means for mechanically coupling said common control member to each of said first piston rods, means for preventing the operation of one of said servomotors while permitting an operation of the other of said servomotors, and means for effecting a change-over in operation from one of said servomotors to the other of said servomotors, said change-over means including means defining a resilient connection between each of said second piston rods and said common control member and switching means for effecting said change-over responsive to flexing of said resilient connection due to a force being applied thereto by said common control member which exceeds a predetermined limit caused when one of said second piston rods becomes blocked due to a malfunctioning thereof, and resilient connection also being sufficiently rigid to effect a movement of said second piston rods by said common control member without a flexing of said resilient connection, said movement being permitted when said second piston rods are freely movable.

2. The combination according to claim 1, wherein said common control member comprises a pair of levers and pivot connection means thereon positioned adjacent one end and intermediate the ends of each of said pair of levers, said second piston rods being connected to said common control member at said intermediate position whereby a movement of the other end of said control member in one direction will effect a movement of said second piston rods in said direction.

3. The combination according to claim 2, wherein said pivot connection means adjacent said one end of said pair of levers is connected to said mechanically coupled first piston rods of said servomotors.

4. The combination according to claim 1, including first and second pressure source means for supplying pressurized gas to each of said control valves controlling said servomotors, respectively;

wherein said change-over valve means further includes first means for effecting a maintaining of one of said control valves in fluid communication with said first pressure source means in response to the fluid pressure in said first pressure source means and for producing a signal in response to a drop in said gas pressure and wherein said means for preventing the operation of one of said servomotors while permitting an operation of the other of said servomotors includes second means for effecting a shut off of the pressurized fluid supply to said one of said control valves in response to said signal and for simultaneously connecting said second pressure source means to the other of said control valves.

5. The combination according to claim 1, including first and second pressure source means for supplying pressurized fluid to each of said control valves controlling said servomotors, respectively;

wherein said change-over means further includes first means for effecting a maintaining of one of said control valves in fluid communication with said first pressure source means in response to said switching means and for producing a signal in re-

sponse to said flexing of said resilient connection beyond said predetermined limit and wherein said means for preventing the operation of one of said servomotors while permitting an operation of the other of said servomotors includes second means for effecting a shut off of the pressurized fluid supply to said one of said control valves in response to said signal and for simultaneously connecting said second pressure source means to the other of said control valves, and said first means including a shut-off valve and differential pressure responsive actuator means.

6. The combination according to claim 1, wherein said resilient connection means comprises a pair of lever elements pivotally secured at one end to each of said second piston rods and said control member, each of said levers having means defining an elongated slot-like opening therethrough, the longitudinal axis intersecting the axis of said pivot connection to the respective one of said second piston rods, pin means secured to said second piston rod and received in said elongated slot-like opening, said pin means being longitudinally slidable in said elongated slot-like opening and leaf spring means for resiliently maintaining said pin means in an approximate centrally located position in said elongated slot-like opening whereby a relative movement between said second piston rod and said levers will be resisted by said leaf spring means.

7. The combination according to claim 6, including sliding members engaging said pin means on opposite sides thereof, said leaf spring means engaging oppositely facing sides of said sliding members to resiliently maintain said pin means in said central position.

8. The combination in a redundant fluid actuator system of at least two separate and separably operated servomotors, each of said servomotors having a first piston rod mounted for reciprocal movement and a control valve for controlling the movement of said first piston rods, each of said control valves having a second piston rod thereon, means for mechanically coupling each of said first piston rods together, a common control member for controlling both of said servomotors, said common control member including means for mechanically coupling said common control member to each of said first piston rods, means for preventing the operation of one of said servomotors while permitting an operation

of the other of said servomotors and means for effecting a change-over in operation from one of said servomotors to the other of said servomotors, at least two pressure source means for supplying pressurized fluid to each of said control valves controlling said servomotors, respectively, said means for effecting said change-over including means defining a resilient connection between each of said second piston rods and said common control member and switching means for effecting said change-over responsive to flexing of said resilient connection due to a force being applied thereto by said common control member which exceeds a predetermined limit caused when one of said second piston rods becomes blocked due to a malfunctioning thereof, said resilient connection also being sufficiently rigid to effect a movement of said second piston rods by said common control member without a flexing of said resilient connection, said movement being permitted when said second piston rods are freely movable, valve means for producing a signal in response to a flexing of said resilient connection and said means for effecting a change-over further including pressure differential valve means connected in circuit with both of said pressure source means and said valve means for effecting a shut off of the pressurized fluid supply to one of said control valves in response to said signal and for simultaneously connecting said second pressure source means to the other of said control valves, said pressure differential valve means including a cylinder having a reciprocable piston mounted therein and a rod connected to said piston and movable therewith and wherein said means for preventing the operation of one of said servomotors while permitting an operation of the other of said servomotors includes first and second valves connected in circuit with said supply of pressurized fluid and each controlling the supply of pressurized fluid to said control valves, said first and second valves each having a control rod thereon which is mechanically coupled to the other and simultaneously operable in response to a movement of said piston to effect said shut off of said pressurized fluid supply to one of said control valves and to simultaneously connect said second pressure source means to the other of said control valves.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3 878 764 Dated April 22, 1975

Inventor(s) Hans Zech

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 21; change "and resilient" to --said resilient--.
line 42; change "gas" to --fluid--.
line 44; delete "valve".
line 50; change "gas" to --fluid--.

Signed and Sealed this

sixteenth Day of September 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks