July 5, 1949. C. D. CHIDGEY 2,475,445

SERVOMOTOR WITH ROTARY INPUT AND RECTILINEAR OUTPUT

Filed Nov. 16, 1946 3 Sheets-Sheet 1

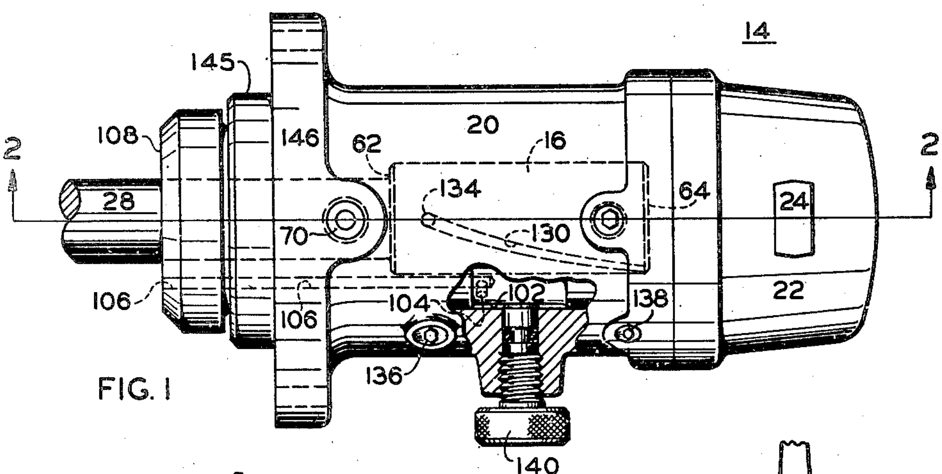

FIG. 1

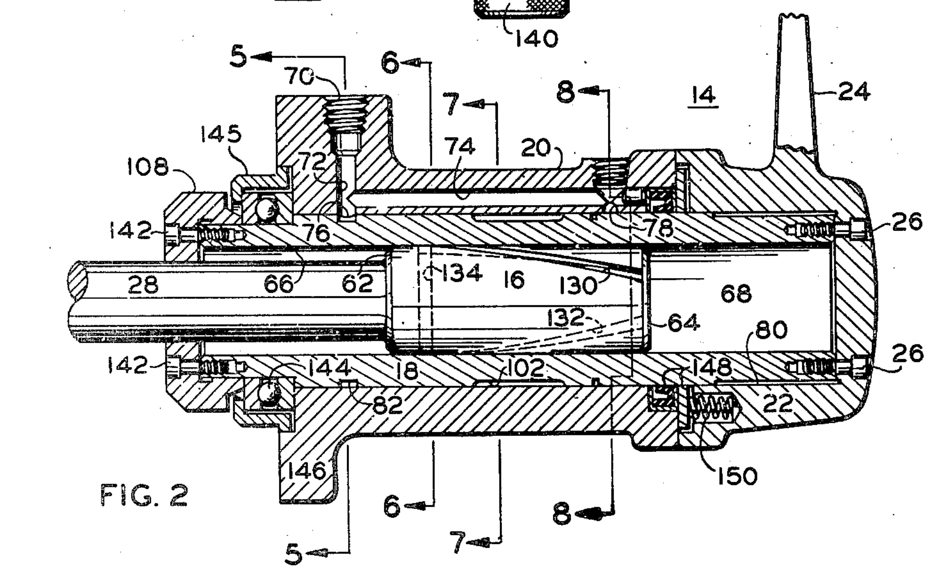

FIG. 2

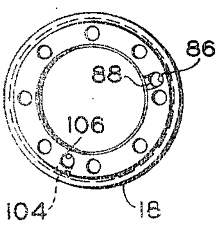

FIG. 3

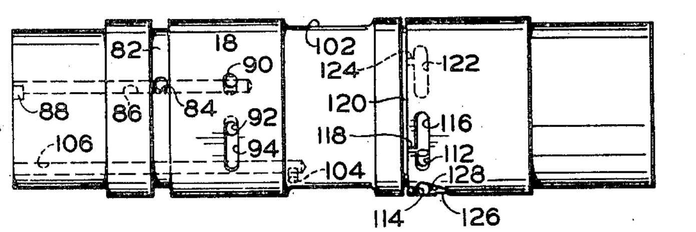

FIG. 4

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July 5, 1949. C. D. CHIDGEY 2,475,445

SERVOMOTOR WITH ROTARY INPUT AND RECTILINEAR OUTPUT

Filed Nov. 16, 1946 3 Sheets-Sheet 2

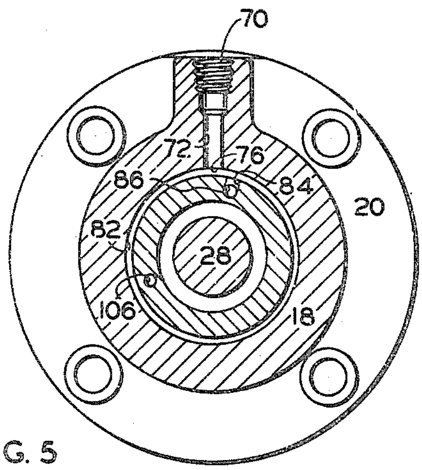

FIG. 5

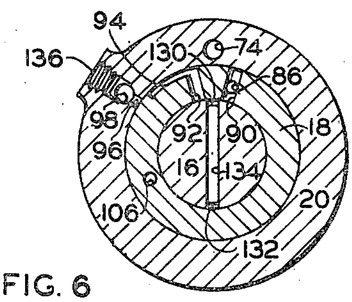

FIG. 6

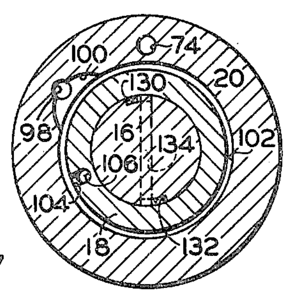

FIG. 7

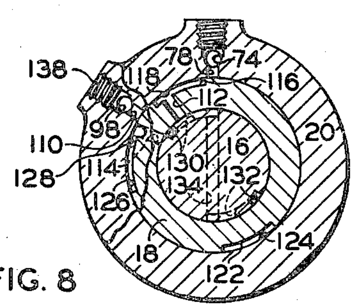

FIG. 8

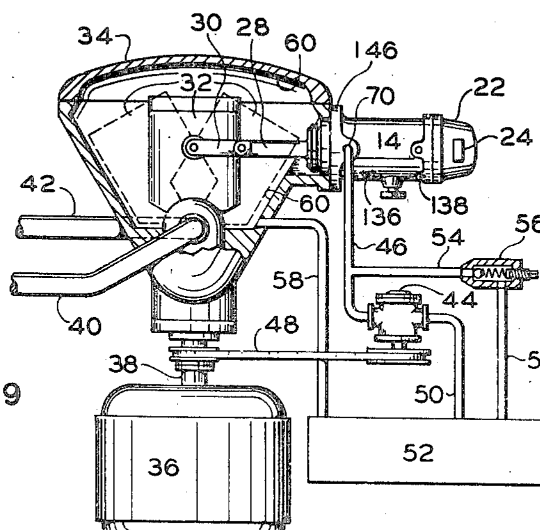

FIG. 9

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SERVOMOTOR WITH ROTARY INPUT AND RECTILINEAR OUTPUT

Filed Nov. 16, 1946 3 Sheets-Sheet 3

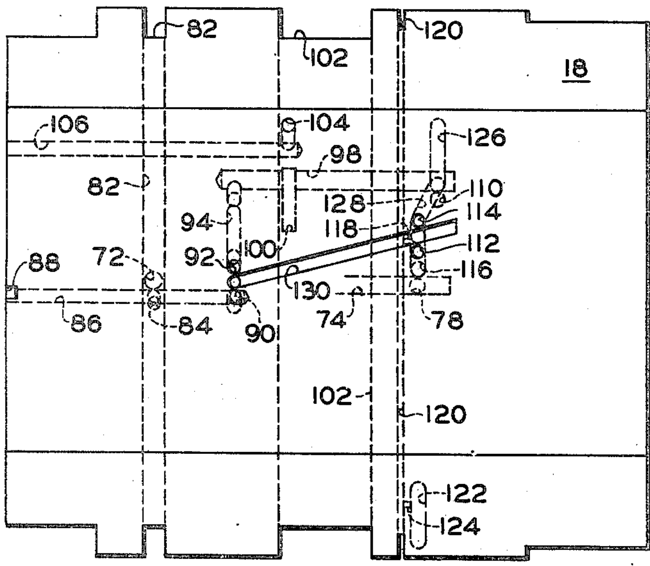

FIG. 10

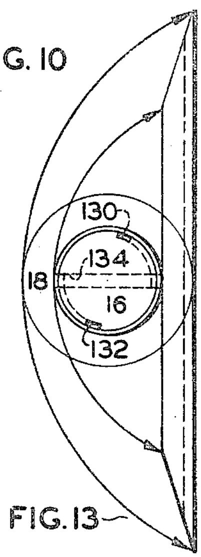

FIG. 13

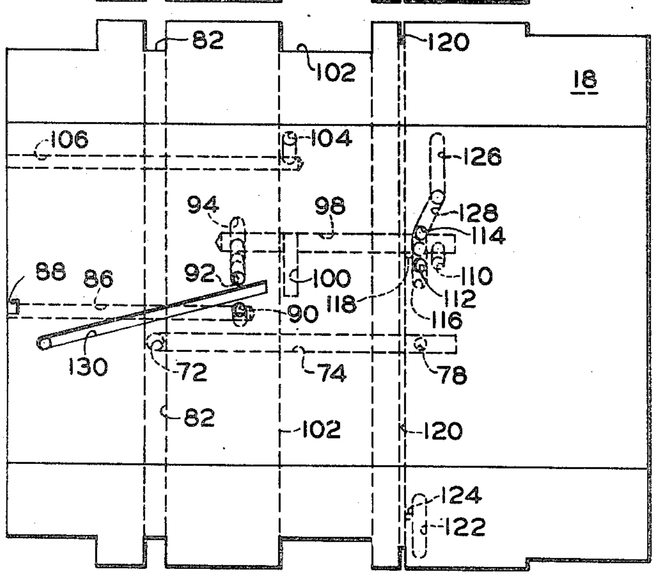

FIG. 11

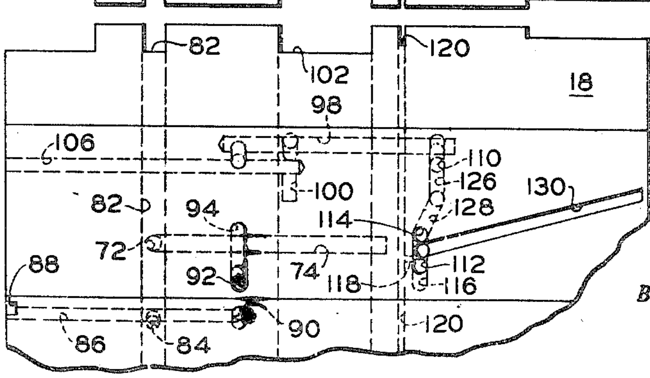

FIG. 12

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SERVOMOTOR WITH ROTARY INPUT AND RECTILINEAR OUTPUT

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Application November 16, 1946, Serial No. 710,361

8 Claims. (Cl. 121—41)

1

This invention relates to power transmissions, particularly to those of the type comprising two or more fluid pressure energy translating devices, one of which may function as a pump and another as a fluid motor.

The invention is particularly concerned with servo-motors of the reciprocating piston type and controls therefor. The general practice in designing servo-motor control circuits is to provide any standard type directional valve for selectively porting operating fluid to either end of the servo-cylinder.

The general object of this invention is to provide a servo-motor in which the directional valve is an integral part of the servo-motor elements.

One of the common types of directional valves employed is the spool or sleeve valve. Such valves are controlled by axial movement of the spool or sleeve.

An object of the proposed invention is to provide a combination spool and sleeve valve in which the valve is controlled by rotary movement of the sleeve.

Servo-circuits employing directional valves normally provide for full strokes of the servo-piston in either direction. When partial movement of the piston is desired, a follow-up control is necessary. In the proposed valve device, the piston travel is initiated by rotation of the sleeve a predetermined distance. When the piston has traveled the selected distance in accordance with the setting of the sleeve, the porting of operating fluid to or from the cylinder is blocked and the piston stops.

Therefore, another object of the invention is to provide a servo-valve in which ports and passages in the sleeve and piston cooperate to control the direction and distance of travel of the servo-piston.

Still another object is to provide a servo-valve in which the piston operates to perform a follow-up function and terminate its own travel at any selected position.

The proposed valving device includes a rotatable cylinder or sleeve provided with inlet and outlet ports in combination with a piston containing helical passages adapted to be brought into register with the inlet and outlet ports by rotation of the sleeve. The ports are blocked by the piston body as the helical groove is moved axially out of register with the ports. To carry out the above principle, it is necessary that the ports be adjacent the piston at all times, otherwise, the ports would be in direct communication with the cylinder when the piston moved beyond

2

the ports. Therefore, the limitation of such a valve requires that the piston length be greater than the length of stroke and the cylinder length approximately equal to the sum of the piston and stroke length. In the proposed design, the piston length is less than the length of the stroke and the cylinder length is considerably more than the sum of the two.

Therefore, another object of the invention is to provide a valve of the type described wherein the piston may be shorter than the length of stroke.

To accomplish this, multiple inlet and outlet ports are required and have been located on the internal bore of the cylinder along a helical line similar in form to the passage or groove in the piston. In order to block the inlet and outlet port as the piston moves beyond their location, separate valving means are provided between the cylinder and the body.

Another object of the invention is to provide multiple inlet and outlet ports in the cylinder progressively cooperating with the helical piston groove and blocked by separate valving means when the piston moves out of contact with the ports.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of the present invention is clearly shown.

In the drawings:

Figure 1 is a top plan view of a servo-motor incorporating a preferred form of the invention.

Figure 2 is a section on line 2—2 of Figure 1.

Figure 3 is an end elevation and Figure 4 a plan view of the cylinder or valve sleeve.

Figure 5 is a section on line 5—5 of Figure 2.

Figure 6 is a section on line 6—6 of Figure 2.

Figure 7 is a section on line 7—7 of Figure 2.

Figure 8 is a section on line 8—8 of Figure 2.

Figure 9 is a schematic view of a servo-controlled variable displacement pump.

Figure 10 is a developed view of the internal and external surfaces of the cylinder showing the ports in relation to the piston groove in its central position.

Figures 11 and 12 are similar to Figure 10, but illustrating the helical piston groove in its extreme left and extreme right position, respectively.

Figure 13 is a diagrammatic view of the method employed in developing the illustration in Figures 10, 11 and 12.

The servo-motor 14 comprises a piston 16 reciprocably mounted in a sleeve or cylinder 18 which in turn is rotatably mounted in the body 20. A cap 22, carrying the control lever 24, is fastened to the sleeve 18 by screws 26. The piston 16 is mechanically coupled by rod 28 and link 30 to the yoke 32 of pump 34 (Figure 9). The pump 34 is driven by a prime mover 36 through shaft 38 and is provided with pressure and return conduits 40 and 42 connected to a power transmission not shown. Hydraulic pressure fluid for operating servo 14 is supplied by the auxiliary pump 44 through conduit 46 when driven by belt 48 from the shaft 38. Hydraulic fluid is supplied to pump 44 through suction conduit 50 from tank 52 and excess delivery is relieved through conduit 54 and relief valve 56. The conduit 58 serves as a drain line for the casing 60 of pump 34 and as a discharge or outlet conduit for servo 14 which discharges directly into the pump casing 60.

In variable displacement pumps of the rotary cylinder type employing axially reciprocable pistons mounted in a swinging yoke 32, the position of the yoke 32, either side of the neutral or central position (as illustrated by 32 in dotted line of Figure 9), determines the direction of flow through the conduits 40 and 42. The degree of deflection, either side of the central position, controls the amount of displacement. In other words, with yoke 32 in its extreme left position as shown in dotted lines in Figure 9, the pump is operating maximum capacity and pressure fluid is delivered through conduit 42 and suction is obtained through conduit 40. When the yoke 32 is in its extreme right-hand position as shown in dotted line, it is delivering at maximum capacity, but conduit 42 has become the suction conduit and 40 the pressure conduit of power transmission. When the yoke 32 is in its central or neutral position as shown in Figure 9, the displacement of pump 34 is zero. Therefore, by controlling the position of servo-motor piston 16, the displacement of pump 34 may be selectively varied.

The servo-piston 16 is a differential reciprocating piston type having a rod end 62 and head end 64 exposed to pressure in working chambers 66 and 68, respectively, of the cylinder 18. Pressure conduit 46 communicates with servo-body 20 at connection 70 which is further connected by means of passages 72 and 74 to pressure ports 76 and 78 on the internal bore 80 on body 20 (Figure 2). Port 76 communicates with annular groove 82 in cylinder 18 which in turn connects by means of radial passage 84 to axial passage 86. Axial passage 86 communicates at one end with the working chamber 66 and the rod end of servo-piston 16 by means of radial passage 88 and at the other end with inlet port 90 of cylinder 18.

Adjacent the inlet port 90 is an outlet or discharge port 92 which is connected to the peripheral slot 94 in cylinder 18. Tank slot 94 may be rotated into communication with outlet port 96 of body 20 (see Figure 6) and thereby connected by passage 98 to slot 100 (Figure 7). Slot 100 opens into annular tank groove 102 which is connected to the pump case 60 and tank 52 by means of radial passage 104 and axial passage 106 in the sleeve 18. Axial tank passage 98 extends beyond slot 100 to connect with tank port 110 in body 20.

A second set of control ports is located in cylinder 18 at a point nearer the head end working chamber 68. It comprises the inlet or pressure port 112 and the outlet or tank port 114

(Figure 8). Inlet port 112 connects through peripheral slot 116 which in turn is connected by passage 118 (Figure 4) to annular groove 120 and to pressure balancing slot 122 through passage 124. Outlet port 114 is connected to peripheral slot 126 by means of diagonal slot 128 (Figure 10).

Servo-piston 16 is provided with two identical helical grooves 130 and 132 interconnected by radial passage 134. The helical grooves extend from a point in the piston periphery adjacent the rod end 62 to the head end 64 and communicate with the head end working chamber 68 of cylinder 18.

The body 20 is drilled and plugged at 136 and 138 in order to form outlet ports 96 and 110, respectively, connected with axial passage 98. A set screw 140 is threaded through body 20 and adapted to bottom against the annular groove 102 (Figure 1) for the purpose of locking the cylinder 18 in rotation and fixing the servo position thereby maintaining constant pump delivery. Sealing ring 108 (Figure 2) is fixed to the cylinder 18 by machine screw 142 and supports the bearing 144 in the retainer 145. The servo-motor 14 is fastened to the pump casing 60 by means of bolts through flange 146. Between the cap 22 and body 20, a suitable hydraulic packing 148 is provided which is urged into position by spring 150.

In operation, the starting position is illustrated in Figures 1 to 10 inclusive. The pump yoke is shown in its neutral position in Figure 9 and the relative position of cylinder 18 and piston 16 together with the porting arrangement are illustrated in the other figures.

The helical groove 130 is diagrammatically shown positioned between the inlet ports 90 and 112 and the outlet ports 92 and 114 in Figure 10. The cross-sectional view shown in Figures 6 and 8 illustrate the same condition. If the inlet ports 90 and 112 in Figure 10 were moved upwardly into communication with helical groove 130 (similar to rotating cylinder 18 counterlockwise in Figures 6 and 8) then pressure fluid would be directed to working chamber 68 against the head of the piston 16. At the same time, operating pressure fluid is constantly present in the rod end 62 or working chamber 66 as communicated thereto by passage 72, port 76, annular groove 82, passages 84, 86 and 88. However, piston 16 being provided with differential areas, equal pressure in both chambers 66 and 68 will move the piston 16 to the left.

As the piston moves to the left, the helical groove will tend to move away from inlet ports 90 and 112. When the travel is sufficient to block communication between the pressure ports 90 and 112 and the helical groove 130, no further travel of the piston will be permitted. However, if the sleeve or cylinder 18 is rotated still further, the piston 16 will continue its travel in the same direction so long as the inlet ports 90 and 112 are in communication with the helical groove.

In Figure 10, the helical groove 130 is shown adjacent both sets of inlet and outlet ports. When the piston 16 travels to the left as described above, it will reach a point where the head end 64 moves beyond the inlet and outlet ports 112 and 114. If ports 112 and 114 were the only ports used, the piston travel would stop as soon as the ports were out of contact with the helical groove 130. Therefore, it would be necessary to increase the length of the piston or as has been done in this invention, an additional set of ports was provided separated axially from the first set, The multiple inlet ports or multiple outlet ports are located along a helical line parallel to the helical groove in the piston.

By duplicating the ports, a further difficulty arises for as the piston travels beyond the ports, they would be out of control of the helical groove and provide direct communication to pressure and to tank. In the present design, slots 116 and 126 (Figure 8) have been provided which are rotated out of communication with pressure and tank port 78 and 110, respectively, in the body and thereby block inlet port 112 and outlet port 114 when piston 16 has moved beyond the location as illustrated in Figure 11. When the cylinder or sleeve valve 20 is rotated clockwise, the tank ports 92 and 114 are shifted into communication with the helical groove 130. The working chamber 68 is thus drained by means of helical groove 130, port 92, slot 94, passage 96, passage 98 (Figure 6), passage 100, annular groove 102, radial passage 104, axial passage 106 (Figure 7), pump casing 60, and conduit 58 to tank 52. The above described communication to tank is employed when the servo-piston 16 is in its left position (Figure 11). When in the right end of the cylinder 18, discharge is accomplished by means of helical groove 130, outlet port 114, slots 128 and 126, tank port 110 in the body 20 to axial passage 98 and then by passage 100, etc., to tank as described in the preceding sentence.

When the pressure in working chamber 68 has been relieved to tank, the force on the rod end 62 of piston 16 drives the servo-motor to the right. When the piston 16 has traveled sufficiently to the right to have moved out of contact with inlet and outlet ports 90 and 92, respectively, then the outlet or tank port 92 must be blocked by separate valving means. Since working chamber 66 is constantly under full operating pressure, the uncovering of port 90 by the axial piston travel makes no difference. As to the tank port 92, cylinder 18 with groove 94 is rotated clockwise until tank port 96 in body 20 is blocked (Figure 6).

Helical grooves 130 and 132 in piston 16 are diametrically opposite each other and since they are interconnected by passage 134, pressure in both grooves is equal thereby providing pressure balance. The flow of pressure fluid from or to the chamber 68 may be directly via groove 130 (the shortest and the usual path of flow) or indirectly via groove 130, passage 134, and groove 132.

It will thus be seen that the present invention has provided a servo-motor and follow-up control system in which a graduated rotary operating means may control and axially position the longitudinal movement of a servo-piston with a short length of servo-cylinder. This is accomplished by means of helical grooves in the servo-piston in cooperation with a multiple ported rotatable servo-cylinder provided with passages adapted to be blocked by the servo-motor body at predetermined points.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. A servo-motor control comprising a cylinder provided with a set of inlet and outlet ports on its internal bore, a piston reciprocably mounted in the cylinder and provided with a helical groove in the surface of the piston and adapted to communicate with the cylinder at one end of the piston, means for rotating and angularly displacing the cylinder and piston and selectively connecting the helical groove with the inlet or outlet ports, whereby the piston will travel until the groove is moved axially out of contact with the port, and a second set of inlet and outlet ports in the cylinder axially displaced from the first set for providing a set of ports adjacent the helical groove regardless of the position of the piston in the cylinder.

2. A stroke control for a servo-motor comprising a cylinder rotatively mounted in a housing, a differential servo-piston reciprocably mounted in the cylinder, passages connecting the rod end of the differential piston to a pressure fluid source, inlet and outlet ports on the internal bore of the cylinder in combination with a helical groove in the piston surface communicating with the opposite end of the differential piston, means for rotating the cylinder thereby moving the inlet or outlet port into communication with the groove whereby the piston will travel axially and block communication with the port, and additional inlet and outlet ports spaced axially along the internal bore of the cylinder to provide at least one inlet and one outlet port adjacent the helical groove of the piston during its entire travel.

3. A stroke control for a servo-motor comprising a cylinder rotatively mounted in a housing, a differential servo-piston reciprocably mounted in the cylinder, passages connecting the rod end of the differential piston to a pressure fluid source, inlet and outlet ports on the internal bore of the cylinder in combination with a helical groove in the piston surface communicating with the opposite end of the differential piston, means for rotating the cylinder thereby moving the inlet or outlet port into communication with the groove whereby the piston will travel axially and block communication with the port, and additional inlet and outlet ports spaced axially along the internal bore of the cylinder to provide at least one inlet and one outlet port adjacent the helical groove of the piston during its entire travel, the inlet ports and the outlet ports being angularly and axially disposed along a path on the internal bore of the cylinder having a helical form and of the same magnitude as the helical groove.

4. A stroke control for a servo-motor comprising a cylinder rotatively mounted in a housing, a differential servo-piston reciprocably mounted in the cylinder, passages connecting the rod end of the differential piston to a pressure fluid source, inlet and outlet ports on the internal bore of the cylinder in combination with a helical groove in the piston surface communicating with the opposite end of the differential piston, means for rotating the cylinder thereby moving the inlet or outlet port into communication with the groove whereby the piston will travel axially and block communication with the port, additional inlet and outlet ports spaced axially along the internal bore of the cylinder to provide at least one inlet and one outlet port adjacent the helical groove of the piston during its entire travel, and means for blocking the inlet and outlet ports not adjacent the piston when the piston has traveled to a point beyond the ports.

5. A stroke control for a servo-motor comprising a cylinder rotatively mounted in a housing, a differential servo-piston reciprocably mounted in the cylinder, passages connecting the rod end of the differential piston to a pressure fluid source, inlet and outlet ports on the internal bore of the cylinder in combination with a helical

groove in the piston surface communicating with the opposite end of the differential piston, means for rotating the cylinder thereby moving the inlet or outlet port into communication with the groove whereby the piston will travel axially and block communication with the port, additional inlet and outlet ports spaced axially along the internal bore of the cylinder to provide at least one inlet and one outlet port adjacent the helical groove of the piston during its entire travel, and inlet and outlet passages in the housing positioned for communicating with their respective inlet and outlet ports of the cylinder only during that phase of the servo operation during which the respective inlet and outlet ports are in contact with the piston.

6. In a servo-motor, a cylinder element and a piston element reciprocably mounted therein, means for angularly displacing the cylinder and piston by relative rotation, a valving device comprising a helical groove communicating with an operating chamber and located in the surface of one of the elements in combination with a plurality of inlet and outlet ports dispersed along a helical path parallel to the groove in the other element whereby the relative rotation of the elements will selectively connect the operating chamber to at least one of the inlet or outlet ports for driving the piston axially through the cylinder, and valving means for blocking the inlet and outlet ports connected to the operating chamber by means other than the helical groove.

7. In a servo-motor employing a cylinder rotatively positioned in a housing and a reciprocating piston mounted therein and requiring a piston stroke greater than the length of the piston, a plurality of inlet ports located along a helical path on the internal bore of the cylinder, a plurality of outlet ports along a parallel helical path but circumferentially separated from the inlet ports a predetermined distance to form a land therebetween, a helical groove in the surface of the piston extending to one end thereof and having a width approximately equal to the circumferential distance separating the inlet and outlet ports and normally positioned against the land between the inlet and outlet ports when the servo-piston is stopped, and means for rotatively adjusting the relative position of the cylinder and piston to port pressure fluid along the groove to the cylinder.

8. In a servo-motor employing a cylinder rotatively positioned in a housing and a reciprocating piston mounted therein and requiring a piston stroke greater than the length of the piston, a plurality of inlet ports located along a helical path on the internal bore of the cylinder, a plurality of outlet ports along a parallel helical path but circumferentially separated from the inlet ports a predetermined distance to form a land therebetween, a helical groove in the surface of the piston extending to one end thereof and having a width approximately equal to the circumferential distance separating the inlet and outlet ports and normally positioned against the land between the inlet and outlet ports when the servo-piston is stopped, and means for rotatively adjusting the relative position of the cylinder and piston to port pressure fluid along the groove to the cylinder, inlet and outlet ports in the housing adapted to be rotated into communication with the inlet and outlet ports in the cylinder only during the period the cylinder ports are adjacent the piston and capable of porting operating fluid into or out of the helical groove.

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