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Worden

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[54] **POWER AND SPEED CONTROL FOR DOUBLE-ACTING CYLINDER-AND-PISTON MOTOR**

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[52] **U.S. Cl.** **137/625.65**, 91/427, 91/453, 91/459, 137/596.17

[51] **Int. Cl.** **F15b 13/044**

[58] **Field of Search** 91/427, 453, 446, 91/454, 457, 459, 275, 361, 367; 137/627.5, 636, 625.65, 596.17, 595; 338/135, 167; 251/137

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[57] **ABSTRACT**

This specification discloses a controller for working fluid for a cylinder-and-piston motor. The controller has valve means that supply fluid at a rate of flow proportional to the force used to actuate the valve means and regardless of the pressure of the working fluid. Motor speed is thus made proportional to force supplied to the controller. For a double-acting motor, different valve means for opposite ends of the cylinder are operated by different ends of a rocker arm that can be actuated by different solenoids or by a manual lever override. Pressure of the working fluid can be made adjustable.

11 Claims, 3 Drawing Figures

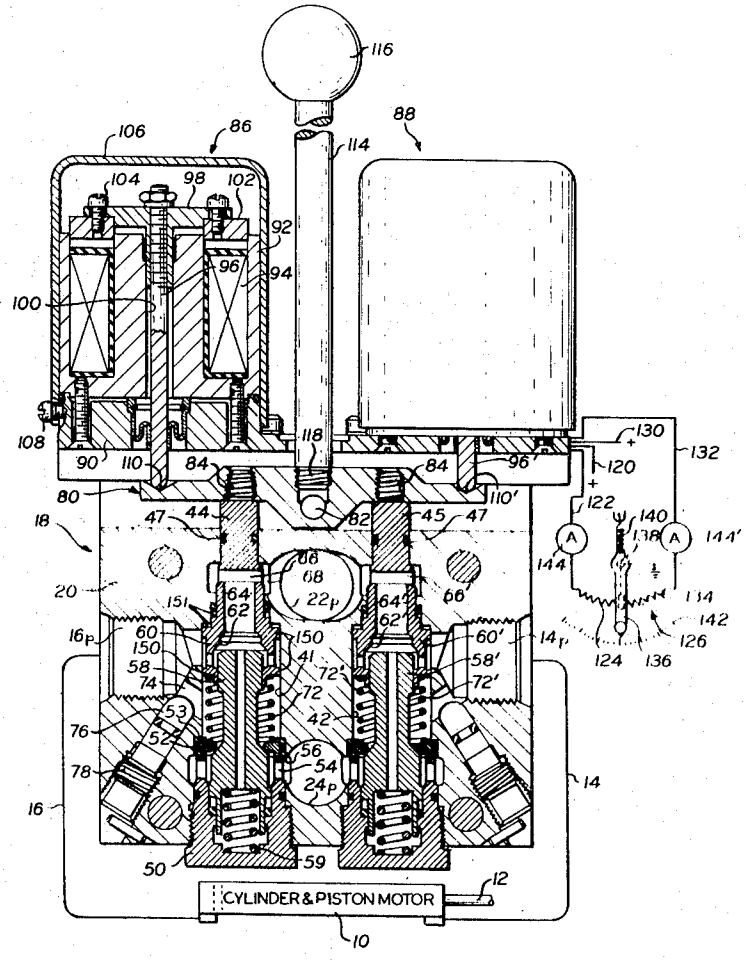


FIG. 1.

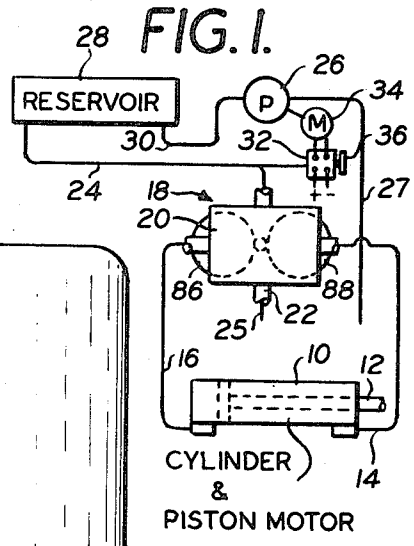


FIG. 2.

FIG. 3.

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POWER AND SPEED CONTROL FOR DOUBLE-ACTING CYLINDER-AND-PISTON MOTOR

RELATED PATENT AND APPLICATION

Cylinder-and-piston motor control means that operate at a speed proportional to the force applied to the valve means that control the supply of working fluid are disclosed in Worden U.S. Pat. No. 3,498,411. In that patent, the control is used for a bucket truck, and the invention described in this specification is primarily intended for similar use.

A working fluid flow control valve operated by a solenoid and with the rate of flow proportional to the current supplied to the valve-operating solenoid, is disclosed in Kowalski U.S. Pat. application, Ser. No. 716,619, now U.S. Pat. No. 3,534,770.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention provides a simple and more compact controller for working fluid to and from the cylinder of a double-acting cylinder-and-piston motor. Different valve means are used for the opposite ends of the cylinder, but they are operated by a common motion-transmitting element which is a rocker arm in the preferred embodiment of the invention. Movement of the rocker arm in one direction shifts the valve means into position to supply working fluid to one end of the cylinder and shifts the other valve means into position for exhaust of working fluid from the other end of the cylinder.

The pressure of the working fluid must be high enough to make the motor move against the load to which the motor is connected; and provision is made for increasing the pressure of the working fluid supply. By using proportional flow valves that supply working fluid at a rate which depends upon the force of the actuator of the valves and which is independent of the supply pressure of the working fluid, the speed of the motor is kept proportional to the operating force applied to the valves by their actuators; but the work which can be done by the motor can be increased by increasing the pressure of the working fluid supply.

In the preferred construction, the actuating mechanism is kept simple by using separate single-acting solenoids to move the rocker arm in each direction. The amount of current supplied to each solenoid determines the rate of flow of working fluid to the end of the motor cylinder which that solenoid controls and the consequent rate of movement of the motor when operating in the direction controlled by that solenoid.

A manual override is connected with the rocker arm for moving it in the event that power for the solenoids is interrupted.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

BRIEF DESCRIPTION OF DRAWING

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIG. 1 is a diagrammatic view of a motor and control system made in accordance with this invention;

FIG. 2 is a view, mostly in section, on a greatly enlarged scale, of the valve means shown in FIG. 1; and

FIG. 3 is a detail view showing a portion of the structure of FIG. 2 but with the seat element 60 in the position to which it is moved when the operating solenoid is energized.

DESCRIPTION OF PREFERRED EMBODIMENT

FIG. 1 shows a cylinder-and-piston motor 10 which has a piston rod 12 connected with a load, such as a boom of a bucket truck. The motor 10 has tubing 14 connected with one end of the cylinder and other tubing 16 connected with the other end of the cylinder. The cylinder ends which are connected with the tubing 14 and 16 will be referred to herein as the "right" and "left" ends of the cylinder.

The supply and exhaust of working fluid to and from the motor 10 is controlled by valve means 18. FIG. 1 shows a diagrammatic bottom view of the valve means 18 which will be described in detail in connection with FIG. 2.

For the present, it is sufficient to understand that the valve means 18 includes a housing 20 with passages connected with other tubing 22 and 24. Exhaust working fluid from the motor 10 discharges through the tubing 22 into a sump 25 from which the working fluid is withdrawn by a pump 26 through tubing 27 leading to the inlet of the pump 26. The tubing 24 leads to the outlet end of a reservoir 28. The discharge side of the pump 26 connects with the reservoir through tubing 30. The working fluid in the reservoir 28 is under pressure and this pressure is transmitted to a pressure-operated switch 32 which has a connection with the tubing 24 in which the pressure is equal to that of the reservoir 28. The pressure-operated switch 32 controls the supply of power to a motor 34 which drives the pump 26 and this switch 32 shuts off the power to the pump when the pressure in the reservoir 28 reaches a predetermined limit. The switch 32 has an adjustment 36 for determining the pressure at which it opens the circuit of the motor 34. Such pressure switches are well-known and are commonly used on compressed air and hydraulic systems.

When the valve means 18 are in one position, working fluid flows from the reservoir 28 through the tubing 24, through the valve means 18 and to the left end of the motor 10 through the tubing 16. This moves the piston of the motor 10 and the piston rod 12 toward the right in FIG. 1. At the same time, working fluid flows from the right end of the motor 10 through the tubing 14 and valve means 18, to the sump 25. Whenever additional working fluid is needed in the reservoir 28 to maintain the pressure, the pressure switch 32 causes the motor 34 to drive the pump 26 and to draw working fluid from the sump 25 up the tubing 27 to the motor 26 from which the working fluid is discharged through the tubing 30 to the reservoir 28.

When the valve means is operated into an opposite position, the situation is reversed and working fluid is supplied to the right end of the motor 10 and exhausted from the left end. The apparatus for operating the valve means 18 is not shown in FIG. 1 but will be described in detail in connection with FIG. 2.

The housing 20 has ports connected with the tubing 14, 16, 22 and 24 and these ports are designated by the same reference characters as the tubing but with a letter *p* appended. There are two main valve chambers 41 and 42 in the housing 20 and these valve chambers are preferably parallel to one another. In the upper end of

each of the valve chambers 41 and 42 there are push rods 44 and 45, respectively, extending through the upper wall of the housing 20 and slideable in bearings provided by the walls of the upper ends of the valve chambers 41 and 42. O-rings 47 on the push rods 44 and 45 prevent leakage of working fluid from the valve chambers 41 and 42 along the running clearance between the push rods and the bearing in which they slide.

At the lower end of the valve chamber 41, a plug 50 screws into a counterbore to close the lower end of the valve chamber 41. The plug 50 bottoms against a valve seat 52 and clamps this valve seat 52 against a shoulder 53, in the valve chamber 41. There are radial openings 54 through the sides of the plug 50 for permitting flow of working fluid between the interior of the valve chamber 41 and a circumferential groove 56 which opens into the port 24p.

A valve element 58 is located in the valve chamber 41 and this valve element 58 contacts with the seat 52 when the valve element is in closed position.

The lower end of the valve element 58 slides in the cylindrical center portion of the plug 50 which provides cylindrical bearing surfaces for cylindrical portions of the valve element 58 which are of substantially the same diameter as the cylindrical bearing surfaces. A spring 59, compressed between the valve element 58 and the bottom wall of the plug 50, urges the valve element 58 toward closed position in contact with the seat 52.

There is a movable seat element 60 which is of cylindrical cross section and which slides in the valve chamber 41 as a guide. In the contruction illustrated, this movable seat element 60 is of one-piece construction with the push rod 44 and it has a seat area 62 with which the valve element 58 contacts when the push rod 41 is depressed to close the clearance between the valve element 58 and the seat area 62.

The seat element 60 has a hollow interior passage 64 extending from the seat area 62 to a cross passage 66 which opens into a circumferential clearance 68 that communicates with the port 22p.

The lower end of the movable seat element 60 surrounds the upper end of the valve element 58 and provides a bearing surface on which the movable seat element 60 and the valve element 58 have longitudinal movement with respect to one another. A spring 72 urges the movable seat element 60 upward; this spring 72 being compressed between the upper side of the seat 52 and the lower side of the seat element 60.

There is an orifice 74 leading from the valve chamber 41, at a location between the seat 52 and the movable seat element 60. This orifice 74 communicates with the port 16p. A bleed valve 76 has threads 78 which screw into an opening in the side of the housing 20. This bleed valve 78 can be screwed back and forth to obstruct greater or lesser portions of the area of the orifice 74 for changing the cross section of the orifice.

There is a rocker arm 80 supported by a fulcrum pin 82 from upstanding portions of the housing 20. This rocker arm 80 contacts with upper ends of the push rods 44 and 45. Threaded inserts 84 in the rocker arm 80 provide the actual contact surfaces between the rocker arm and the push rods 44 and 45, and these inserts 84 can be adjusted to control the exact position of the push rods 44 and 45 for any angular position of the rocker arm about its fulcrum 82.

The actuating apparatus for the valve means includes two solenoids, designated generally by the reference characters 86 and 88. Each of these solenoids includes a base 90 attached to the upper end of the housing 20 and a ferrous metal core 92 having a coil 94 to which electric current is supplied to energize the solenoid. The solenoid 86 has a plunger 96 which threads into a holder 98 having a cylindrical portion that slides in a center opening 100 of the core through which the plunger 96 extends. An armature ring 102, secured to the holder 98 by screws 104, is attracted to the coil 94 whenever the coil is energized. The moving parts at the upper end of the solenoid 86 are protected by a cover 106 which has a lower end fitting closely around the base 90 and secured to the base 90 by detachable fastening means such as a screw 108.

The lower end of the plunger 96 contacts with the rocker arm 80 in a recess 110 in the top surface of the rocker arm in alignment with the plunger 96.

A plunger 96' of the solenoid 88 has similar contact with the rocker arm in a recess 110' at the opposite end of the rocker arm from the plunger 96. The solenoid 88 is preferably of the same construction with the solenoid 86 and no sectional view of it is necessary for a complete understanding of this invention.

A lever 114 has a knob handle 116 at its upper end and has screw threads 118 at its lower end which screw into a threaded socket in the center of the rocker arm 80. There is enough distance between the solenoids 86 and 88 to permit the lever 114 to be rocked angularly about the axis of the fulcrum 82 for manually operating the rocker arm 80 if there is an interruption in the current supply for the solenoids 86 and 88.

The solenoid 86 has one side of its coil 94 connected with a power supply line 120 and the other side of its coil connected by a conductor 122 to contacts 124 of a potentiometer 126 through which the conductor 122 is grounded.

The solenoid 88 has its coil connected on one side with a power line 130, which may be the same power line as the power line 120; and has its other side connected by a conductor 132 with contacts 134 of the potentiometer 126.

The potentiometer 126 has a manually operated control lever 136 which swings about a pivot 138 and which is normally held in a center neutral position by a spring 140. In this neutral position the potentiometer does not touch any of the contacts 124 or 134 and thus leaves the circuits of both solenoids 86 and 88 open.

Movement of the potentiometer control lever 136 to the left in FIG. 2 supplies a small amount of current to the solenoid 86. If the lever 136 is moved clockwise and further to the left across the contacts 124, the resistance of the potentiometer decreases and the current supplied to the solenoid 86 increases so that the solenoid exerts a greater downward pressure through the plunger 96 against the rocker arm 80 to thrust the push rod 44 downward and to operate the valve means in a manner which will be explained.

Conversely, movement of the potentiometer control lever 136 from its neutral position toward the right in FIG. 2 supplies current to the solenoid 88 in increasing amounts if the lever 136 moves counter-clockwise across the contacts 134.

The potentiometer 126 can be provided with graduations 142 to indicate the extent to which the lever 136 has been moved and these graduations can be cali-

brated to indicate force applied by the solenoids or to indicate flow of the working fluid through the valve means; this flow being proportional to the force applied by the solenoids, as will be explained.

Since the current supplied by the potentiometer **126** will vary with the voltage on the power lines **120** and **130**, a more accurate designation of the force applied by the solenoids **86** and **88**, and the resulting flow of working fluid through the valve means, can be obtained by using read-out devices such as ammeters **144** and **144'**, connected in series with the solenoids **86** and **88**, respectively. These ammeters can be graduated to indicate force applied by the solenoids or to indicate flow of working fluid through the valve means.

The valve means associated with the valve chamber **42** is the same as that already described in connection with the valve chamber **41** and corresponding parts are indicated by the same reference characters with a prime appended.

The operation of the valve means is as follows:

With no current supplied to either of the solenoids **86** or **88**, the rocker arm **80** is held in a neutral mid position by the balanced upward thrust of the springs **72** and **72'**.

Both of the valve elements **58** and **58'** are in closed position against their seats **52** and **52'**, respectively, and flow of working fluid under pressure from the port **24***p* is shut off. Thus no working fluid is supplied to either end of the motor cylinder.

When the solenoid **86** is energized, it pushes the rocker arm **80** down at one end and the other end of the rocker arm rises and pushes the plunger **96'**, upward, there being no substantial resistance against such upward movement of the plunger **96'** when the solenoid **88** is not energized.

This movement of the rocker arm **80** counterclockwise on its fulcrum **82** thrusts the push rod **44** downward so that the movable seat element **60** brings the seat area **62** in contact with the valve element **58** and further downward movement of the push rod **44** moves the valve element **58** away from the valve seat **52** and thus shifts the valve element **58** into open position so that working fluid under pressure flows across the valve seat **52** and into the valve chamber **41** above the seat **52**. From the valve chamber **41**, this working fluid under pressure flows through the orifices **74** into the port **16**p and through the tubing **16** to the left end of the cylinder-and-piston motor **10**. The working fluid under pressure acts against the piston of the motor **10** and moves the piston rod **12** toward the right against whatever load is connected with the piston rod **12**.

There is a pressure drop through the orifice **74**. The amount of pressure drop depends upon the cross-section of the orifice; that is, upon the adjustment of the needle valve **76**. The pressure drop depends also upon the rate of flow of hydraulic working fluid through the orifice. For any given cross-section of the orifice **74**, the pressure drop is proportional to the rate of flow of the working fluid.

The lower end of the movable seat element **60**, which surrounds the upper end of the valve element **58**, forms a flange **150** which slides in the valve chamber **41** as a piston. This flange piston **150** is exposed on its lower side to the pressure in the valve chamber **41** at the upstream end of the orifice **74**. On its upper side **151**, however, the flange piston **150** is exposed to the working fluid pressure on the downstream side of the orifice **74**. The valve element **58** is in contact with the seat area **62** and no working fluid can escape between the valve element **58** and the seat area **62**.

The pressure differential, therefore, across the flange piston **150** is equal to the pressure drop through the orifice **74** and is proportional to the rate of flow of the working fluid through the orifice. As the rate of flow increases, the pressure drop increases and the greater pressure on the under side of the flange piston **150** pushes the movable seat element **60** and the push rod **44** up against the force of the solenoid **86**. As the movable seat element **60** rises, the spring **59** under the valve element **58** maintains the valve element **58** in contact with the seat area **62** and this causes the valve element to rise and move toward the valve seat **52** so that the rate of flow of working fluid is reduced.

In this way the extent of opening of the valve element **58** and the resulting rate of flow of working fluid to the motor **10** through the tubing **16** adjusts automatically until the downward thrust of the solenoid **86** balances the upward force of the springs **59** and **72**, and the upward pressure differential on the flange piston **150**. The valve means in the valve chamber **41** is, therefore, a proportional flow valve; that is, a valve in which the rate of flow through the valve means is proportional to the force applied to the valve means to open it; the force of the solenoid **86**. The amount of current supplied to the solenoid **86** determines the force that is exerted by the solenoid **86**.

While working fluid is flowing to the motor **10** through the valve chamber **41**, the valve element **58'** in the valve chamber **42** remains in its closed position as shown in FIG. **2** and the movable seat element **60'** is pushed somewhat higher by the spring **72'** because the right side of the rocker arm **80** has been moved higher by the counter clockwise displacement of the rocker arm by the solenoid **86**. Working fluid displaced from the motor **10**, as the motor piston moves toward the right, flows through the tubing **14**, port **14***p*, between the valve element **58'** and the seat area **62'**, through the passage **64'** and cross-passage **66'** to the port **22***p* which leads the exhaust fluid back through the tubing **22(1)** to the sump **25**.

When the motor **10** is to be operated to move the piston and rod **12** toward the left in FIG. **2**, the potentiometer **126** is operated to energize the solenoid **88** and to de-energize the solenoid **86**. This rocks the rocker arm **80** clockwise the depress the pushrod **45** and to let the pushrod **44** move upward. This operates the valve means to produce the opposite effect from that already described and supplies working fluid to the tubing **14** while opening the other tubing **16** to exhaust so that the motor **10** moves its piston and rod **12** to the left.

The preferred embodiment of the invention has been illustrated and described but changes and modifications can be made and some features can be used in different combinations without deviating from the invention as defined in the claims.

What is claimed is:

1. A power and speed control system for a cylinder-and-piston motor including in combination first valve means for controlling the working fluid supply to, and exhaust from, one end of a motor cylinder, second valve means for controlling the supply and exhaust of working fluid for the other end of the motor, a housing in which the first and second valve means are located in generally parallel relation to one another and ori-

ented to move in the same direction for comparable operations, common motion-transmitting means for moving both the first and second valve means in opposite directions when said motion-transmitting means moves in different directions, an electro-magnetic actuator that moves the motion-transmitting means in one direction, a second electro-magnetic actuator that moves the motion-transmitting means in a different direction, each valve means including a valve element for controlling flow of fluid to the motor and another valve element for controlling exhaust flow of fluid from the motor, one of the valve elements of each of said first and second valve means being flow-responsive and having means comprising a restricted passage through which the working fluid supply passes, a movable wall connected to the flow-responsive valve element and movable as a unit therewith, the wall being exposed on opposite sides to the working fluid pressure at the upstream and downstream ends, respectively, of the restricted passage, the upstream pressure being on the side of the movable wall to urge the flow-responsive valve element toward closed position with progressively greater force as the rate of flow through the restricted passage increases whereby the rate of flow of working fluid through the valve means is proportional to the current supplied to the electro-magnetic actuators to hold the respective flow-responsive valve elements in open position, and current control means including a single control lever for regulating a current supply to each of the electro-magnetic actuators, the current control means being adjustable into different positions in accordance with the desired rate of flow of working fluid past the flow-responsive valve elements.

2. The control system described in claim **1** characterized by the motion-transmitting means including a rocker arm, a pivotal support for the rocker arm intermediate the ends thereof, each of said first and second valve means having a push rod in position to contact with the rocker arm on a different side of the pivotal support for causing the valve means to move in opposite directions as the rocker arm moves angularly about said pivotal support.

3. The control system described in claim **2** characterized by each of the actuators being a solenoid that operates the rocker arm, the solenoid having the motion-transmitting means that contact with the rocker arm on opposite sides of the pivotal support of the rocker arm and further from the pivotal support than are the push rods.

4. The flow control system described in claim **3** characterized by the flow-responsive means of each of the valve means including two chambers connected by the restricted passage through which working fluid flows as it passes through said valve means, the connecting passage being of reduced cross section to provide a substantial pressure drop between said chambers, which drop is substantially proportional to the rate of flow of the working fluid, surfaces on different sides of said movable wall being exposed to pressure in the different chambers.

5. The control system described in claim **4** characterized by working fluid supply means including an adjustable controller for changing the pressure at which working fluid is supplied to the upstream chamber.

6. The control system described in claim **2** characterized by a manually-operated override for the actuators including a lever connected with the rocker arm and movable angularly to impart rocking movement in both directions about said pivotal support of the rocker arm.

7. Control system described in claim **1** characterized by the current control means being movable in opposite directions for supplying the regulated amounts of current to the respective electromagnetic actuators and the resulting rate of flow of working fluid to the motor and speed of operation of the motor.

8. The control system described in claim **7** characterized by the current control means being a potentiometer with a brush having a mid-position and movable in opposite directions from its mid position, means for biasing the brush toward its mid position and for exerting progressively greater force to bring the brush back toward mid position as the displacement of the brush from its mid position is increased, a rheostat for each of the solenoids, one rheostat being on one side of the mid position of the brush and the other rheostat being on the opposite side of the mid position, the brush being selectively movable across the rheostats and each of the rheostats being oriented to increase the current to its solenoid as the brush moves over that rheostat in a direction away from the mid position of the brush.

9. The control system described in claim **1** characterized by each of the valve means including valve elements having two pairs of contacting surfaces that comprise valves of said valve means, a valve chamber in which each of the valve elements move axially to selectively bring the contacting surfaces of the different pairs together or apart, each of the valve chambers having a port communicating with a different end of the cylinder from the other valve chamber, a working fluid supply passage for each chamber, one pair of contacting surfaces controlling flow of working fluid between the cylinder port and the supply passage, and the other pair of contacting surfaces controlling the flow of working fluid between the cylinder port and the exhaust passage, a housing in which both of the valve chambers are located in substantially parallel relation with one another, a working fluid supply header extending through the housing between the two valve chambers and communicating on its opposite sides with the different valve chambers, an exhaust header extending through the housing between the two valve chambers and connected at its opposite sides with the different valve chambers at locations spaced axially of the valve chambers from the working fluid header.

10. The control system described in claim **9** characterized by each of the valve means being open for flow of working fluid to the cylinder by axial pressure in one direction and being opened for exhaust of working fluid from the cylinder by axial pressure in the opposite direction, a spring that applies the axial pressure in the direction that opens the valve means for exhaust, the solenoids supplying the axial pressure in the opposite direction so that the current supplied to the solenoids controls the rate of flow and resulting speed of operation of the motor, the valve means in each housing having a stem extending beyond one end of the housing and comprising part of the motion-transmitting means by which the valve means are operated, the solenoids being located at the end of the housing through which stems extend.

11. The control system described in claim **9** characterized by adjustable valve means in each of said passages of restricted cross-section for changing the cross-section of said passages to change the rate of flow of working fluid for any given actuating force applied to the valve means.

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