United States Patent [15] **3,683,968**
Akeley [45] **Aug. 15, 1972**

[54] **REVERSE-ACTING RELAY VALVE**

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[22] Filed: **June 1, 1970**
[21] Appl. No.: **42,377**

[52] **U.S. Cl.**................................**137/625.66,** 137/84
[51] **Int. Cl.**..**F16k 31/365**
[58] **Field of Search**.........137/82, 85, 625.66, 625.27

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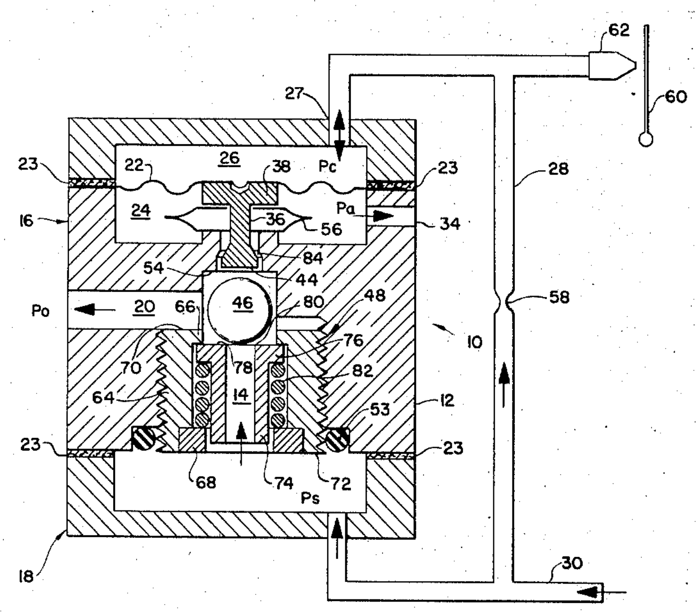
[57] **ABSTRACT**

A reverse-acting relay valve which employs a pressure responsive diaphragm driving an operably related pin. The pin contacts a throttling ball, moving it up and down as the diaphragm moves up and down. The diaphragm moves down with an increase in pressure and up with a decrease in pressure. Movement of the ball in the downward direction is limited by a supply seat, and movement of the ball in the upward direction is limited by an exhaust seat. When the ball is in its downward position, thus resting on the supply seat, flow through the relay is cut off. When the ball is in its upward position, thus against the exhaust seat, flow through the relay is at its greatest. When the ball is between the supply seat and the exhaust seat, some flow through the relay passes through the exhaust seat to a vent.

2 Claims, 3 Drawing Figures



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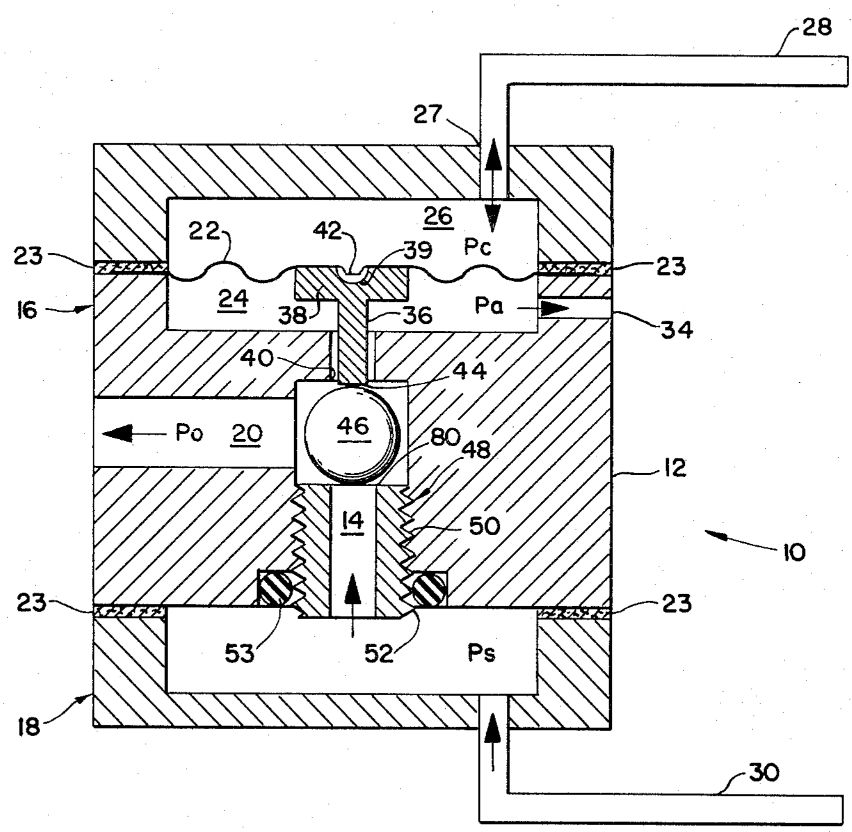

FIG. 1

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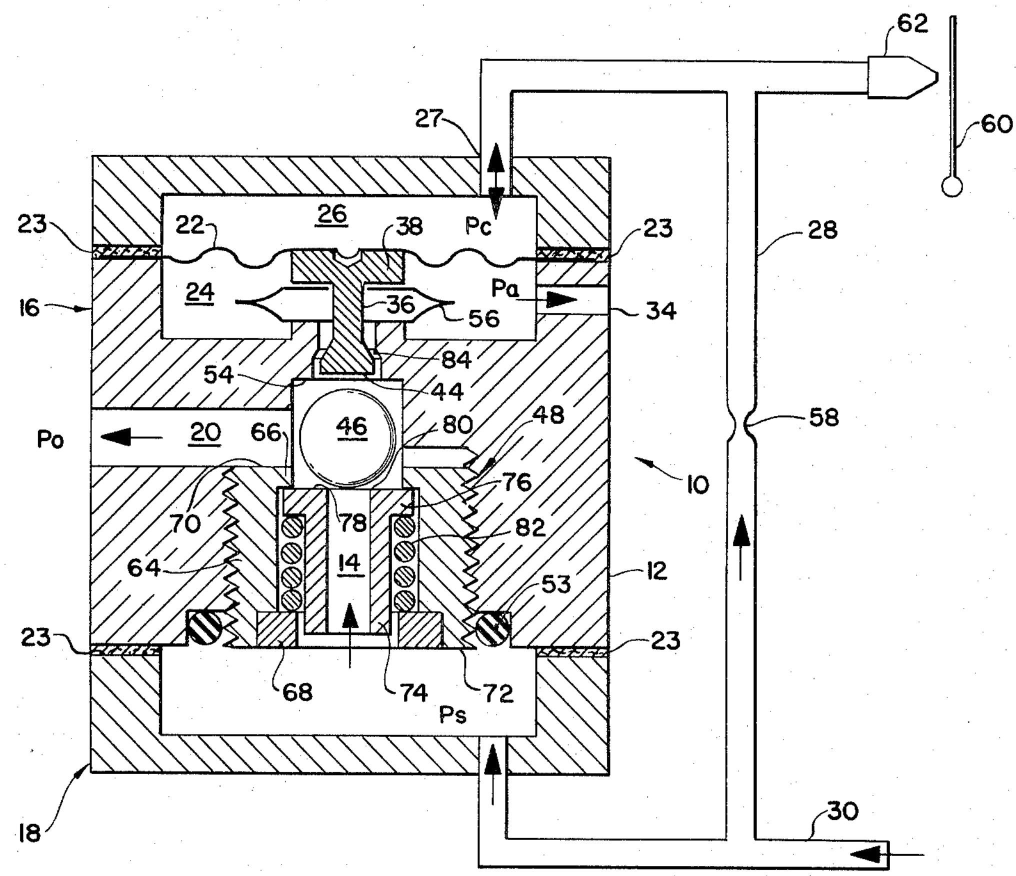

FIG. 2

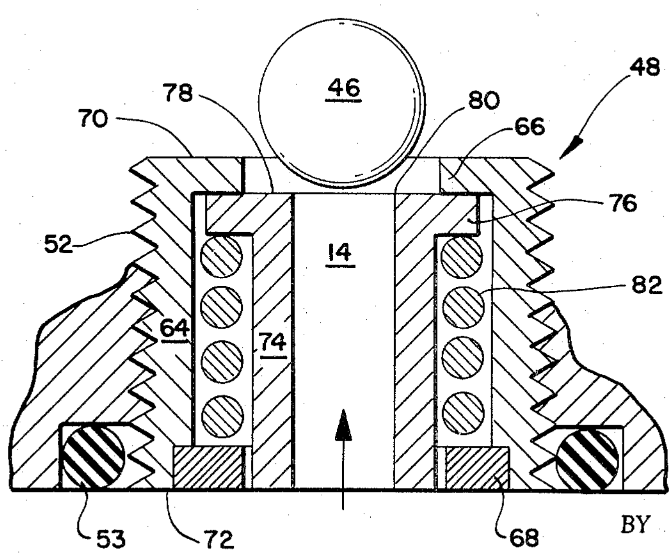

FIG. 3

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REVERSE-ACTING RELAY VALVE

BACKGROUND OF THE INVENTION

The instant invention relates to reverse-acting relays or pneumatic amplifiers.

The instant invention is particularly applicable to pneumatic control systems. Industrial pneumatic control systems and devices commonly operate over a 3–15 pounds per square inch pressure range, although some special systems use other pressure ranges. Signals are usually transmitted through relatively small bore tubing, with lengths varying from a few feet up to 2,000 feet or more. Pneumatic indicators, controllers and transmitters typically have receiving end volumes up to approximately 5 cubic inches. Diaphragm or piston valve motors frequently have receiving end volumes ranging from about 100 to about 6,000 cubic inches equivalent volume. The system usually must respond to small relatively weak signals of a few tenths of a pound per square inch or less.

Various manufacturers have different mechanical approaches to the problem, but the basic idea remains the same. The pneumatic relay produces a relatively strong output in the 3 to 15 pounds per square inch range in response to the relatively weak input signal, for example from a measured variable. The receiver, in turn, translates these pressure signals into movement of an indicator or recorder or controller mechanism.

SUMMARY OF THE INVENTION

It is an object of the instant invention to provide a pneumatic relay valve or amplifier wherein the bleed rate and gain and capacity of the relay valve can be adjusted as desired. Advantageously, the relay valve according to the instant invention shows improved stability and lower hysteresis in a smaller sized unit than conventional relay valves.

According to the instant invention a reverse-acting relay valve is provided which includes a hollow housing and a partition having a centrally exposed bore therein positioned so as to divide the housing into a first and a second section. The bore provides communication between the two sections and an output passage extending outwardly from the bore through the housing. A pressure responsive diaphragm is positioned in the first section to divide it into two sub-sections, a first sub-section proximal the partition and a second sub-section distal the partition. Means connect the distal sub-section to a fluid input and means also connect a fluid supply to the second section. Means are provided to vent the proximal sub-section to the atmosphere. A pin is operably related at one end to the diaphragm and extends therefrom through the proximal sub-section into the bore on one side of the output passage. An exhaust seat is provided in the surface of the bore between the output passage and the proximal sub-section. A throttling ball is positioned in the bore below the exhaust seat and is adapted to seat against the exhaust seat in the bore and to close communication between the proximal sub-section and the output passage and second section when the diaphragm flexes in one direction due to a decrease in pressure in the distal sub-section relative to the pressure in the proximal sub-section and to open communication when the diaphragm flexes in the other direction. A supply seat is positioned in the bore between the second section and the output passage and is adapted for the ball to seat against, closing communication with the second section, when the pin extends into the bore to the fullest position pushing the ball against the supply seat due to an increase in pressure in the distal sub-section relative to the pressure in the proximal sub-section. Means are provided for adjusting the distance between the supply and exhaust seats, whereby the bleed rate and gain and capacity of the relay are controlled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view with parts shown in section of a reverse-acting relay valve according to the instant invention.

FIG. 2 is a schematic view with parts shown in section of another embodiment of the instant invention.

FIG. 3 is an enlargement of the supply seat of the embodiment shown in FIG. 2.

In all Figures, the same reference numerals have been applied to corresponding parts.

DETAILED DESCRIPTION

Referring to FIG. 1 it may be seen that the reverse-acting relay valve of the instant invention includes a hollow housing indicated generally at 10. A central section 12 of housing 10 having a centrally disposed bore 14 therein is positioned so as to act as a partition and divide the housing into a first section 16 and a second section 18. Bore 14 provides communication between the two sections, 16 and 18, and an output passage 20 extending outwardly from bore 14 through housing 10. A pressure responsive diaphragm 22 is sealed in position as by gasket 23 in first section 16 to divide it into two sub-sections, a first or proximal sub-section 24 proximal partition 12 and a second or distal sub-section 26 distal partition 12. Means such as access 27 and line 28 connect distal sub-section 26 to a source of fluid input pressure not shown. Means such as supply line 30 connect a fluid supply to second section 18. Means such as vent opening 34 vent proximal sub-section 24 to the atmosphere. A second gasket 23 seals second section 18 to partition 12.

Pin 36 is operably related at one end 38, shown as of an enlarged T-shaped cross section, to diaphragm 22 and extends therefrom through proximal sub-section 24 into bore 14 on one side of output passage 20. End 38 has a dimple 39 therein which mates with a bump 4 on diaphragm 22 to center pin 36. An exhaust seat indicated generally at 40 is provided in the surface of bore 14 between output passage 20 and proximal sub-section 24. A throttling ball 46 is positioned in bore 14 below exhaust seat 40 and the other end 44 of pin 36 and is adapted to seat against exhaust seat 40 in bore 14 and to close communication between proximal sub-section 24 and output passage 20 and second section 18 when diaphragm 22 flexes in one direction (the upward direction as shown) due to a decrease in pressure (P_c) in the distal sub-section 26 relative to the pressure (P_a) in proximal sub-section 24 and to open communication when diaphragm 22 flexes in the other direction.

A supply seat indicated generally at 48 is positioned in bore 14 between second section 18 and output passage 20 and has a seating surface 80 adapted for ball 46 to seat against, closing communication with second section 18 when pin 36 extends into bore 14 to the fullest position pushing ball **46** against seating surface **80** of supply seat **48** due to an increase in pressure in distal sub-section **26** relative to the pressure in proximal sub-section **24**. Means such as coacting screw threads **50** and **52** are provided on the surface of bore **14** and supply seat **48** for adjusting the distance between supply seat **48** and exhaust seat **40**. In this way the full travel of ball **46** can be adjusted to achieve a desired gain or bleed rate. O-ring **53** provides a seal and mechanical locking action between supply seat **48** and bore **14**. Ball **46** moves in bore **14** between exhaust seat **40** and supply seat **48** in response to input pressure P_c to provide output pressure P_o proportional to input pressure P_c.

In the embodiment shown in FIG. 2 a spring bias element **56** is positioned between end **38** of pin **36**, which is in contact with diaphragm **22**, and partition **12**. Spring bias element **56** adds a force bias to the natural spring action of the diaphragm. A restrictor **58** is provided in line **28**, which is connected to line **30**, so that the pressure P_c in distal sub-section **26** is less than but related to the input pressure P_s in fluid supply line **30** and second section **18**. The pressure P_c in distal sub-section **26** is further controlled by a flapper **60** acting on nozzle valve **62**. The position of flapper **60** may be determined by a measuring system or set in other appropriate manners and controls the escape of fluid, e.g., air, through nozzle **62** to maintain P_c at a desired level.

In the embodiment shown in FIG. 2, and referring to FIG. 3 where it may be seen more clearly, supply seat **48** is shown as an assembly including an outer sleeve **64** adjustably positioned in bore **14** and having inwardly extending shoulders **66** at end **70** extending into bore **14** (its inner end) and **68** at its outer end **72**. An inner sleeve **74** having an outwardly extending shoulder **76** at its inner end **78** is positioned with shoulder **76** between shoulders **66** and **68** of outer sleeve **64** so that inner sleeve **74** can slide relative to outer sleeve **64**. Seating surface **80** is provided on inner end **78** of inner sleeve **74**. Spring biasing means **82** are positioned between shoulder **68**, shown formed by a ring staked into outer sleeve **64**, and shoulder **76** at the inner end **78** of inner sleeve **74** for biasing inner sleeve **74** toward shoulder **66**. If desired, an O-ring **53** may be used to hold the supply seat **48** assembly in position after it has been adjusted. This arrangement makes the position of seating surface **80** adjustable under the force exerted thereupon by ball **46** and makes possible the utilization of further travel of ball **46** to achieve the highest possible exhaust capacity through exhaust seat **40** when needed.

Referring again to FIG. 2, end **44** of pin **36** has a frustoconical cross-section. Exhaust seat **40** includes a throttling surface **84** in bore **14** having a taper matching that of frusto-conical end **44** of pin **36**. A shoulder **54** is also part of exhaust seat **40** and is positioned for ball **46** to seat against when diaphragm **22** flexes in one direction due to a decrease in pressure P_c in distal sub-section **26** relative to the pressure P_a in proximal sub-section **24**.

The operation of the reverse-acting relay according to the instant invention may be briefly described. Diaphragm **22** responds to the difference between the pressure P_c in distal sub-section **26**, which may be regarded as the control pressure, and the pressure P_a in proximal sub-section **24** to move pin **36** which contacts throttling ball **46** moving it up and down as diaphragm **22** moves up and down. Diaphragm **22** moves down with an increase in pressure P_c, which, as shown in FIG. 2, may be related to the supply pressure P_s in supply line **30**, and up with a decrease in pressure P_c. Proximal sub-section **24** is vented to atmosphere by vent **34** so that P_a is essentially a constant reference pressure, atmospheric pressure. The movement of ball **46** in the downward direction is limited by supply seat **48** and movement of ball **46** in the upward direction is limited by shoulder **54** on exhaust seat **40**. When ball **46** is in its downward position, resting on supply seat **48**, e.g. the seating surface **80** of supply seat **48**, flow through the relay is cut off. When ball **46** is in its upwardmost position and thus against shoulder **54** and in the FIG. 2 embodiment, end **44** is against throttling surface **84** of exhaust seat **40**, flow through the relay to output passage **20** is at its greatest. When ball **46** is between supply seat **48** and exhaust seat **40**, some fluid passes through exhaust seat **40** and hence out through vent **34**. The position of supply seat **48** is adjustable so that the full travel of ball **46** can be adjusted to achieve a desired gain and bleed rate. The small section of pin **36** achieves large clearance to surface **84** for high demand exhaust capacity and the matching tapers of end **44** and throttling surface **84** center pin **36** in exhaust seat **40** when the ball **46** is seated against shoulder **54** so that pin **36** does not rub and produce hysteresis in the operating range.

The relationship is such that the steady state output pressure P_o in output passage **20** will decrease as P_c in distal sub-section **26** increases. In the normal operating range with P_o varying from 3 to 15 pounds per square inch with a supply pressure P_s equal to 20 pounds per square inch, ball **46** will move only slightly, never seating on either exhaust seat **40** or supply seat **48**. In a typical arrangement, P_c varies from about 3.5 to 3.0 pounds per square inch, and P_o in response thereto varies from 3 to 15 pounds per square inch. This is the general arrangement shown in FIG. 2. If P_c is reduced well below its normal operating range, for example by opening flapper **60**, nozzle valve **62** assembly to the maximum extent, then ball **46** moves against shoulder **54** on exhaust seat **40** and in conjunction with end **44** and throttling surface **84** shuts off the exhaust flow into proximal sub-section **24**. This results in a maximum flow from second section **18**, which is at pressure P_s, the supply pressure, to the output and results in a maximum output pressure P_o. If P_c should increase to well above its normal operating range, ball **46** will seat against supply seat **48** shutting off the supply pressure P_s and increasing the clearance through exhaust seat **40** to achieve the maximum exhaust flow capacity.

The maximum supply and exhaust capacities are functions of total ball **46** travel and hence the adjustability of the position of supply seat **48** can be utilized to adjust the maximum supply and exhaust capacity. The resiliency of the supply seat assembly **48** shown in FIG. 2 can be utilized to achieve the highest possible exhaust capacity when necessary.

The embodiment of FIG. 1 is simple to manufacture and, having few parts and large clearances, provides relatively trouble-free service. For most applications it provides a satisfactory combination of performance characteristics. The stiffness of diaphragm **22** and the travel of ball **46** determine the gain of the relay. The bleed rate and supply and exhaust capacity depend upon ball and bore dimensions and the diametrical clearance between pin **36** and seat **40** as well as ball travel adjustment, as is apparent to those skilled in the art. If pin **36** rubs on seat **40** or bore **14**, the resulting friction increases the hysteresis in the relay operation.

The embodiment of FIG. **2** minimizes operating bleed rate without sacrificing supply and exhaust capacity. When the lowest possible bleed rate is required this construction is preferred even though the smaller clearances and increased complexity may make this embodiment more difficult to maintain. Spring **56** adds a force bias to the natural spring action of diaphragm **22**. With this combination the diaphragm stiffness can be reduced to favor optimum linearity of output versus input. Flapper **60**, nozzle valve **62** and flow restrictor **58** are often used with a relay valve in a force-balance instrument such as a force balance differential pressure transmitter. Flow restrictor **58** is usually built into the base of the relay and flapper **60**, nozzle **62** assembly is the position detector which controls the pressure P_c to the relay, whose output pressure P_o feeds a feedback bellows to maintain force balance.

It will be appreciated that the foregoing is only a description of some representative forms of apparatus embodying the principles of the instant invention. This is for illustrative purposes and the instant invention is defined by the claims,

Wherein what is claimed is:

1. A reverse-acting relay valve comprising:

a. a hollow housing;

b. a partition having a centrally disposed bore therein positioned so as to divide the housing into a first and a second section, the bore providing communication between the two sections and an output passage extending outwardly from the bore through the housing;

c. a pressure responsive diaphragm positioned in the first section to divide it into two sub-sections, a first sub-section proximal the partition and a second sub-section distal the partition;

d. means connecting the distal sub-section to a fluid input from a fluid supply;

e. means connecting the fluid supply to the second section;

f. means venting the proximal sub-section to the atmosphere;

g. a pin operably related at one end to the diaphragm and extending therefrom to its other end through the proximal sub-section into the bore on one side of the output passage;

h. an exhaust seat in the surface of the bore between the output passage and the proximal sub-section;

i. a throttling ball positioned in the bore below the exhaust seat and the other end of the pin, unattached to the pin and adapted to seat against the exhaust seat in the bore and to close communication between proximal sub-section and the output passage and second section when the diaphragm flexes in one direction due to a decrease in pressure in the distal sub-section relative to the pressure in the proximal sub-section and to open communication when the diaphragm flexes in the other direction;

j. a supply seat positioned in the bore between the second section and the output passage including an outer sleeve adjustably positioned in the bore and having inwardly extending shoulders at its end extending to the bore and at its outer end, an inner sleeve having an outwardly extending shoulder at its inner end positioned between the shoulders of the outer sleeve so that the inner sleeve can slide relative to the outer sleeve, a seating surface on the inner end of the inner sleeve, and spring biasing means positioned between the shoulder at the outer end of the outer sleeve and the shoulder at the inner end of the inner sleeve for biasing the inner sleeve toward the shoulder at the end of the outer sleeve extending into the bore, said supply seat adapted for the ball to seat against, closing communication with the second section, when the pin extends into the bore to the fullest position pushing the ball against the supply seat due to an increase in pressure in the distal sub-section relative to the pressure in the proximal sub-section; and

k. means for adjusting the distance between the supply and exhaust seats, whereby the gain and capacity of the relay are controlled.

2. The reverse-acting relay of claim **1** wherein the end of the pin extending into the bore has a frustoconical cross section and the exhaust seat comprises a throttling surface in the bore having a taper matching that of the frustoconical ends of the pin, and a shoulder positioned for the ball to seat thereagainst when the diaphragm flexes in one direction due to a decrease in pressure in the distal sub-section relative to the pressure in the proximal sub-section.

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