

Nov. 25, 1941.

P. F. K. ERBGUTH

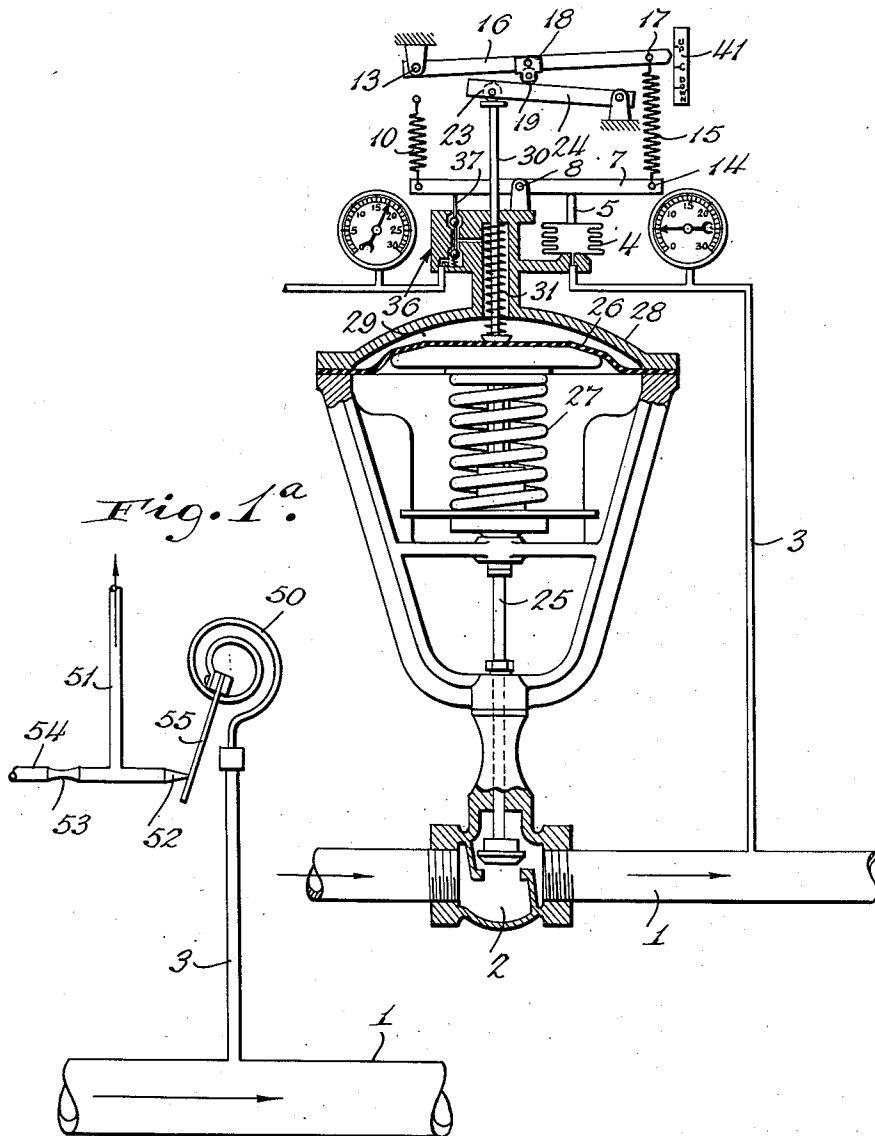
2,264,262

VALVE POSITIONER

Filed April 9, 1940

2 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

Fig. 3.

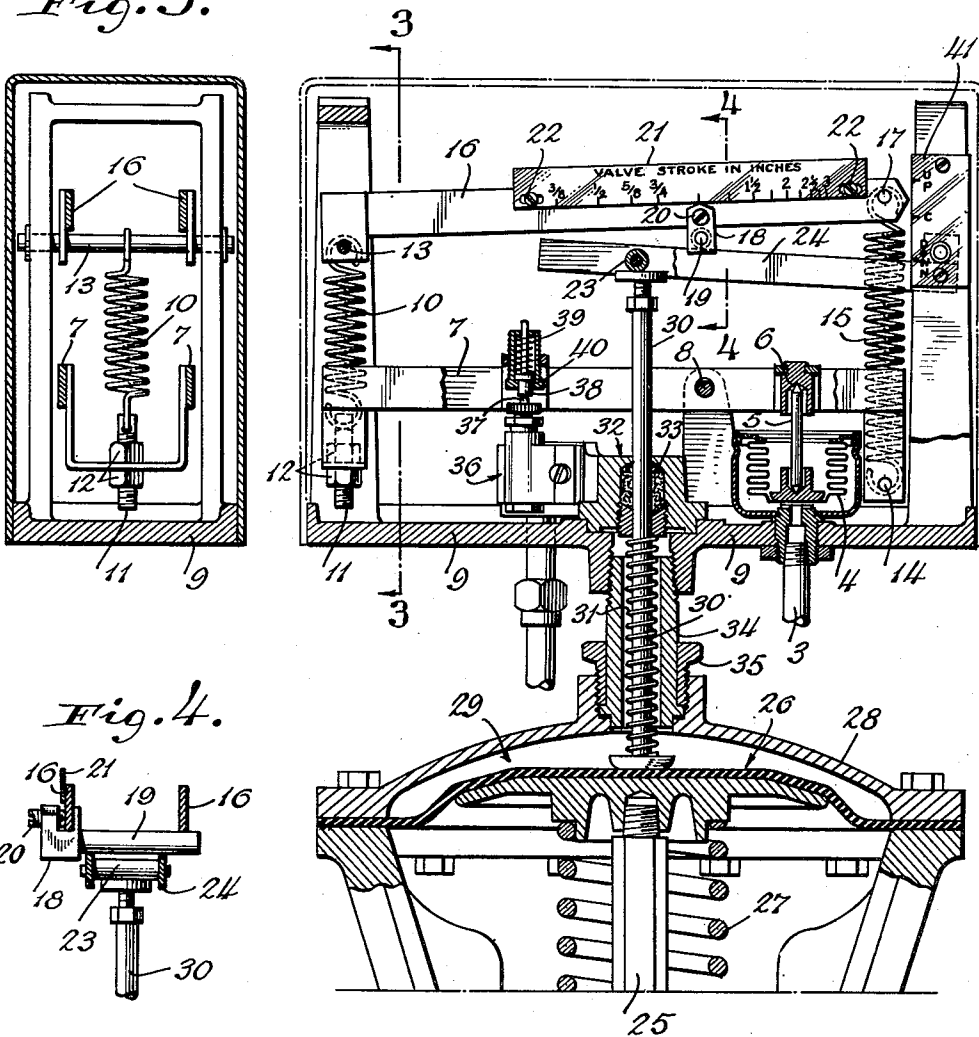


Fig. 4.

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VALVE POSITIONER

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6 Claims. (Cl. 50—10)

This invention relates generally to improvements in control systems which embody a valve or similar mechanism operated by a servomotor. It relates in particular to devices in which a throttling proportional or corresponding relation exists between the position of the servomotor and that of a member or the value of a force or other physical condition.

In particular, it relates to pneumatically controlled and operated devices in which air pressure is used as the medium for operating the servomotor.

A principal object of the invention is to provide an improved apparatus for positioning a main control valve in precise correspondence with the value of a pressure which is an independent variable.

A related object is to provide a comparatively simple device in which the width and position of the throttling range in the controlling range may be readily adjusted and yet with a minimum of friction and backlash.

A further object is to provide an assemblage which is readily attachable to existing valve actuating diaphragm tops without introducing uncertainties.

A particular object is to provide sub-combinations of elements in such general assemblage as will have sub-uses in general servomotor application.

Another object is to provide a valve positioner of such rugged construction that an operator can even stand on it without damaging the device or affecting its working. A related object is to provide a construction in which the working parts are kept clean and dry. A like object is to provide a construction in which the valve positioner can be turned to any desired angular position with respect to the top cover of the valve. A further object is to provide working parts of strong and yet light construction in an arrangement in which they are held together in a manner to avoid backlash to avoid the bad effects of inertia, and to maintain the working parts in their proper relationships even in the face of abnormal conditions.

A further object is to provide a valve positioner of such high sensitivity that it will operate the valve from fully closed to fully open with less than a 10th of an inch mercury difference of change of the governing pressure and so that a departure of the valve position from correspondence of as little as a thousandth of an inch will result in the application of the full operating pressure to the servomotor. A further object is

to provide a construction which permits a ready adjustment of sensitivity and throttling range, which will operate without binding and be very rigid, and in which each of the working parts is accessible without interference from any other parts.

The particular object of the invention is to provide a relay, or pilot valve of a type which has considerable capacity, mounted directly upon the stuffing box and connected with the pressure chamber for the main diaphragm in such a manner as to eliminate time lag.

A further object is to provide a valve positioner which can be removed or replaced without disturbing the diaphragm top cover. A like object is to provide an arrangement in which the relay pilot valve is actuated by a means which cannot injure the pilot valve.

Another object is the provision of improved adjusting means for altering the range of the stroke of the servomotor within very wide limits and with a scale in which there is a general inverse or semi-logarithmic relation between the position of the adjusting means and the value of the stroke set by such means.

Still another object is the provision of a balanced spring-and-lever arrangement in which the operating parts are accessible and the adjustments for the position and width of the throttling range are conveniently separated for convenience in assembly and testing and yet in which the several parts are spring-biased into operative relation without risk of binding. A related object is the provision of an arrangement in which the several parts operate freely and to best advantage as regards attaining the higher "accuracy of control" or the minimum departure from the desired correspondence.

Other objects of the invention will appear to those skilled in the art from the accompanying drawings and specification, in which are illustrated and described several embodiments of the invention; it being my intention to claim all that I have disclosed which is new and useful.

In the figures, wherein like characters of reference indicate like parts throughout, Fig. 1 is a general diagrammatic front elevation, partially in section, of an illustrative embodiment of the invention as applied to the pressure control of a plant; Fig. 1a shows the preferred modification of a portion of the device of Fig. 1 so that, instead of being directly governed by the pressure in the plant, the control is in accordance with an air pressure which in turn is made to correspond with that of the plant; and Fig. 2 is a view

generally similar to Fig. 1 of the valve positioner itself; and Figs. 3 and 4 are vertical sections along lines 3—3 and 4—4 of Fig. 2, looking toward the left in said figure.

A brief general description of the drawings may be helpful. They show a valve positioner for a horizontal pipe for a plant whose pressure, e. g., is to be controlled by a main control valve. This pressure tends to move an expansible bellows to a corresponding position. A lever, the lowest of three generally horizontal levers, is balanced by two springs and takes up a position within a very narrow range corresponding to that of the bellows to position a relay air pilot valve for the main valve in either a floating or a proportional relation with the plant pressure. One of the springs is stressed through the remaining two levers in proportion to the valve travel, its constant of proportionality being adjustable at will and so that the amount of adjustment for a given change in valve travel is larger for small than for large valve openings. The other spring is adjustably secured to a fixed point so that the position of the operating range of the travel may be readily shifted as desired. The whole assemblage is mounted upon the diaphragm top so that the position of the valve positioner is taken directly from that of the face of the diaphragm; the arrangement used in which the valve actuator is on top of the valve which the diaphragm actuates eliminating exposed mechanical connections. The bellows of the air positioner is ordinarily connected to the relay pressure pipe from air pilot which varies in accordance with the physical condition e. g., pressure as shown, temperature or the like. Alternatively, the bellows may be connected directly to the space in which the pressure is to be maintained, it being merely necessary to provide a bellows-and-spring arrangement suitable for the pressure.

Referring to Fig. 1, horizontal pipe 1 contains a vertical main control valve 2. Pressure pipe 3 connects pipe 1 with a fixed end of bellows 4 which is diagrammatically shown in Fig. 1 as of the internal pressure-type and in Figs. 2 and 3, as preferably made of the external pressure type. While either may be used, the external pressure type is preferred as the better adapted for use in the arrangement of the device as keeping the walls of the bellows under tension so that they do not tend to buckle and collapse. In either case, the lower end of vertical rod 5 bears against a cup bearing in the movable end of bellows 4 and moves with the latter. The upper end of rod 5 bears against a movable fulcrum cup bearing 6 of compound lever 7 which is pivotally mounted upon pivot pin 8 which is affixed in base plate 9 to which is also secured the fixed end of bellows 4. The left-hand end, in Figs. 1 and 2, of lever 7 is adjustably connected with the lower end of tension spring 10 by the threaded bolt 11 which has a threaded shank that passes through a slightly larger unthreaded hole near the end of compound lever 7 and is provided with the adjusting and locking nuts 12. The upper end of spring 10 is connected to a pin 13 which is affixed to the base plate 9. The right-hand end of lever 7 carries a pin 14 to which the lower end of tension spring 15 is hooked. The upper lever 16 is simple and uses pin 13 as a fixed pivot at its left-hand end and its right-hand end carries a pin 17 over which the upper end of spring 15 is hooked. This lever also carries an adjustable carriage 18 for a fulcrum pin 19 which is

readily movable along the lever 16 to set the desired throttling range, locking screw 20 being provided to secure this carriage in its last-set position. This lever also carries a graduated scale 21 adjacent the path of the carriage 18 which scale is adjustably secured to this lever by screws 22, the cooperating holes in this scale being longitudinally slotted to provide for the setting of the scale to a calibrating position in which the scale's graduations substantially agree with the value indicated by a cooperating index on the upper side of carriage 18. Fulcrum pin 19 bears against the top surface of and at least approximately horizontal simple lever 24 which is pivoted at its right-hand end and carries pivotally mounted roller 23 near its left-hand end.

The valve 2 is actuated through stem 25 by diaphragm 26 downwardly and by spring 27 upwardly. The diaphragm cover plate 28 clamps the peripheral edges of diaphragm 26 to form an air-pressure chamber 29.

Within pressure chamber 29 and above diaphragm 26 are located vertical pusher rod 30 and its compression spring 31 which is of such a strength that it biases rod 30 to abut the adjacent surface of diaphragm 25 even though the valve be installed in an inverted position instead of upright as shown and even though there be considerable frictional opposition to the movement of rod 30. Vertical rod 30 passes through a stuffing box 32 containing sealing packing 33.

Base plate 9 is connected with the top cover plate 28 by nipple 34 which is provided at its lower end with a circular shoulder which is adapted to bear against a corresponding gasketed portion of cover plate 28. Externally threaded coupling nut member 35 engages the other face of the shoulder of nipple 34 to secure nipple 34 in a position substantially coaxial with valve stem 25 but leaving it free to turn when coupling nut 35 is loosened. The inside diameter of nipple 34 is sufficiently large so as to provide clearance for spring 31 for pusher rod 30.

Mounted on the side of the stuffing box 32 is the relay air valve 36, stem 37 of which is operable by bumper 38 which is normally forced by spring 39 into engagement with shoulder 40, the height of which is adjustable. The arrangement of the bumper is such that a counter-clockwise movement of lever 7 beyond proper limits cannot possibly injure air relay valve 36. The lower end of bolt 11 fetches up on the top of the base plate 9 at one limit of travel, the adjustment of bolt 11 being relatively slight and only enough to calibrate for departures of individual springs 10 from their intended standard value.

Referring to Fig. 4, the top of pusher rod 30 is in the form of a flat disc on which roller 23 rests, the arrangement being such that pusher rod 30 is not pushed bindingly sideways due to the slight horizontal component movement of roller 23 as lever 24 rises and falls. In Fig. 3, a vertical adjustment of bolt 11 is shown and also the fact that the lower end of said bolt acts as a stop against the upper surface of base plate 9 to limit the counter clockwise travel (Fig. 2) of lever 7. Fig. 4 also shows that pin 19 is rigidly attached to carriage 18, which considerably simplifies the construction and also provides a much stronger working part than if this were a roller such as 23. In practice, stud fulcrum pin 19 has proved to be entirely satisfactory and superior to an end-supported roller which involves a lighter and more complicated construction.

The operation of the device of Fig. 1 is as fol-

lows: Normally the position of bellows 4 corresponds with the pressure in the main pipe, to a plant which pressure is commonly referred to as the plant pressure and is independently variable with time. In equilibrium, the positions of lever 7 and stem 37 of relay valve 36 correspond with the plant pressure. For correspondence between the position of stem 25 of valve 2 and the pressure in bellows 4, the position of stem 25 must be carried through pusher rod 30, roller 23, pin 19, adjustable carriage 18, and pin 17 on the right hand end of lever 16 (Fig. 1) to position the upper end of spring 15 which is correspondingly tensioned. Lever 7 balances upon pivot pin 8 so that the several forces exerted upon it by the bellows 4, strong spring 15 and weak spring 10 are in equilibrium to produce a position of lever 7 in which bumper 38 positions relay valve stem 37 at a position which corresponds with the pressure in bellows 4. The frictional forces that can possibly act upon lever 7 are small since its only useful work is the positioning of stem 37 of the small relay air valve 36 and the large forces due to bellows 4 and the latter's opposing spring 15 are taken by knife-edges in effect. Also fulcrum pin 8 rolls against the bottom of its hole which is made appreciably larger than pin 8 so that a knife-edge action is obtained.

However, in practical operation, the packing 33 of stuffing box 32 may bind slightly or the packing of the main valve 2 may bind excessively so that large operating forces are required. Assuming that the pressure in bellows 4 is not echoed by a corresponding position of stem 25 of main valve 2, a small departure, e. g., around a thousandth of an inch, from the corresponding position will produce an upset in the equilibrium of lever 7 since strong spring 15 will be incorrectly tensioned with the result that the sensitive lever 7 will be unbalanced to a position in which stem 37 of air valve 36 is positioned to an effectively different position from that which corresponds with the pressure in bellows 4.

Air valve 36 is preferably of a type which has such a large capacity that a relatively slight movement of valve stem 25 of main valve 2 will cause a full variation of the air pressure controlled by relay valve 36. The standard working range of the positioner is ordinarily from 2 to 14 lbs. per sq. in. relative to the atmosphere. Spring 10 is relatively weak and is adjusted by bolt 11 and nuts 12 to change the working range from say, 4 to 16 lbs. per sq. in. to the standard range. The relative strengths of springs 10 and 15 result from the fact that they are at least roughly in inverse proportion to the lengths of the arm of lever 7 to which they are attached, bellows 4 ordinarily having a relatively slight but appreciable spring-effect.

The scale 21 is located with its minimum valve stroke graduation nearly in line with pusher rod 30 and the large-valve-stroke end of the scale is distant therefrom and also away from the pivot 13 of lever 16, the resultant arrangement being such that a general inverse or logarithmic spacing of the graduations is obtained, thus permitting the valve stroke to be set with substantially equal accuracy on a percentage basis throughout the scale. The vertical movement of this lever 16 may be conveniently checked against a vertical scale 41 which is mounted on base plate 9 adjacent the right hand end of lever 16 (Fig. 2).

The usual arrangement includes modification of Fig. 1 to include a means for converting a plant condition into a corresponding air pressure. Such means for use in connection with

the arrangement of Fig. 1 is shown in Fig. 1a in which pressure pipe 1 is carried to the fixed stem of bourdon 50 instead of to bellows 4 as in Fig. 1. In the modified arrangement, bellows 4 is connected by pressure pipe 51 to nozzle 52 which allows leakage of air to the atmosphere. Pipe 51 is supplied through throttling restriction 53 in air supply pipe 54. Bourdon tube 50 has its free end connected to a flapper 55 which it operates relative to nozzle 52 to provide a leak which varies in proportion to, and in correspondence with, the pressure in the main pipe 1.

The operation of the device of Fig. 1 when modified as shown in Fig. 1a is as before for the valve positioner itself. Fig. 1a is a highly diagrammatical showing of a well known device such as that shown in Best Patent 1,837,377. The interposition of a flapper 55 movable relative to nozzle 52 merely sets up changes in pressure in pipe 51 and in bellows 4 which correspond with those in main pipe 1 and hence with the pressure of the plant to which pipe 1 is attached, assuming that friction losses are negligible. In other words, this modification substitutes an air pressure of convenient pressure range for the plant pressure. Also, it may be described to substitute air for fluid in pipe 1, which may be a dirty fluid or one which is for some other reason unsuitable for use in bellows 4.

The meaning of the terms including "valve positioner" as used herein, in the appended claims, may be further clarified by the following reference to the device disclosed by way of example as an air-operated embodiment. In this embodiment, a main control valve 2 has a movable stem 25 which is to be positioned in accurate correspondence with the value of a fluid pressure in line 3, such fluid pressure being either that in a plant whose pressure it is desired to regulate as in Fig. 1 or a corresponding pressure which is set up, e. g., by the usual flapper-and-nozzle of Fig. 1a. If no valve positioner be employed, the fluid pressure to be regulated acts directly upon the diaphragm 26 which actuates valve stem 25 against the opposing force of its spring 27 and appreciable errors in the position of stem 25 may occur due to the mechanical friction acting upon the valve stem 25. However, to avoid such errors, what is known in this art as a valve positioner may be attached to the valve so that an error of the position of its stem 25 will directly affect the position of an additional pilot valve 36 so that the force due to the full pressure of an auxiliary fluid is made available upon a slight sticking of the valve stem instead of a force which is directly proportional to the ratio of the error to the total travel of the main valve. While a main valve has been shown by way of example as the final controlled element, the invention claimed is in the added "positioner" and hence is not restricted to the use of such a positioner with a valve or even to the use of fluid as the auxiliary power source since any other final movable element or auxiliary power source may be obviously utilized as long as the movement of the final movable element is converted into a corresponding force, the variable to be regulated is likewise converted into a second corresponding force, and the positioning of the final element is governed by the relative values of the two forces.

The terms and expressions which I have employed are used as terms of description and not of limitation, and I have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various

modifications are possible within the scope of the invention claimed.

I claim:

1. A positioner for a pneumatically operated main valve the position of which is to be governed by a fluid pressure which acts upon a diaphragm which positions the valve, comprising, in combination, a pusher rod which has one end adapted to detachably abut a face of the diaphragm and the other end having a flat face normal to the end of the rod, a spring for holding said rod in operative connection with said diaphragm, a first lever having a fulcrum at a distance from the axis of the rod and arranged to swing through a small angle near the perpendicular to said axis and carrying a roller having a pivot substantially parallel to said fulcrum, said roller being disposed on said first lever to be in the path of said flat end face, a second lever generally parallel to said first lever and having a fulcrum on the opposite side of said axis from that first mentioned and movable in substantially the same plane as said first lever, the carriage of said lever including a stud adapted to abut said first lever, a third lever of at least approximately the same length as said second lever and having a fulcrum for positioning it to operate in substantially the same plane as first and second levers and to be generally parallel therewith, a balancing spring connecting adjacent ends of said second and third levers, a bellows operatively connected to said third lever near the point of connection of a said balancing spring and also remote from said third lever fulcrum, a second balancing spring having one end fixed and the other end adjustably connected with the portion of said third lever at a point also remote from its said fulcrum and effective to oppose the first mentioned spring, a bumper which is biased into engagement with said lever in one direction and free to be moved against the bias through a limited extent in the other direction, a relay air valve positionable by said bumper, and a stuffing box for said pusher rod for preventing leakage around the pusher rod from a space of which said diaphragm forms one wall, said stuffing box being constructed to connect said relay valve directly with said space and to mount said air valve.

2. A valve positioner for a valve actuated by a fluid pressure actuator including a chamber comprising, in combination, a pusher rod biased into contact with a portion of the valve actuator in said chamber, a first lever oscillatably positionable about its fulcrum by said rod, a second lever and a carriage carried by it and adjustable along it, said second lever being generally operable with said first lever and with its fulcrum at the opposite end from that of said first lever and said carriage being constructed and arranged to operatively connect said levers to move said second lever in an adjustable predetermined proportion with said first lever, a third lever, two balancing springs connected with said third lever to turn the latter, one of said balancing springs connecting the free end of said second lever with one end of said third lever and the other of said balancing springs being connected with the other end of said third lever, means for altering the adjustment of the second mentioned spring to alter the spring force exerted by such spring when the

third lever is substantially balanced, a pressure responsive means for producing a force corresponding with a governing pressure and connected to said third lever to alter the balancing forces upon the latter and a relay valve operable by said third lever and mounted directly upon and directly connected pneumatically with the pressure chamber of the valve actuator.

3. The combination set forth in claim 2 including a bumper which is moved by the third lever positively in the direction away from the relay valve and is spring-urged toward the latter, said relay valve being biased toward the bumper as by the pressure of the relay fluid.

4. A valve positioner for a valve actuated by a servomotor comprising, in combination, a first lever oscillatably positionable about its fulcrum by a movable operation of said valve, a second lever and a carriage carried by it and adjustable along it, said second lever being generally operable with said first lever and with its fulcrum at the opposite end from that of said first lever and said carriage being constructed and arranged to operatively act upon said lever to move the said second lever in an adjustable pneumatic proportion with said first lever, a third lever, two balancing springs connecting with said third lever to turn the latter, one of said balancing springs connecting the free end of said second lever with one end of said third lever and the other of said balancing springs being connected with the other end of said lever, a pressure responsive means for producing a force corresponding with a governing pressure and connected to said third lever to alter the balancing forces upon the latter, and a relay means operable by said third lever governing the operation of said servomotor.

5. The combination set forth in claim 4 in which the second lever includes two generally parallel, flat, thin strips and the carriage includes a stud adapted to abut an adjacent edge of said first lever and a fastening screw as a slot for engaging the edge of one of said strips adjacent said first lever and having a screw for holding said carriage in position on said strip, whereby proportionately movement of the levers is readily adjustable without binding and securable by a single adjusting fastening screw.

6. A positioner, for a servomotor operated element the position of which is to be governed in correspondence with a variable force exerted by a movable member, comprising, in combination, a lever for governing said element and actuated by said member at a point on the lever remote from its fulcrum, two opposing springs connected with said lever to balance the then-value of the stated forces, an adjustable means connecting one of said springs to a fixed point, a second lever having one portion movable with said element and fulcrumed at a fixed point remote from said portion, a third lever at least approximately parallel to said second lever and having a fixed fulcrum and an adjustable fulcrum which coacts with said second lever, said levers having their fixed fulcrums on opposite sides of said adjustable fulcrum and said third and first levers being connected by the other of said springs, and a relay operated in accordance with the position of said third lever to govern the operation of said servomotor.

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