Sept. 25, 1962 A. V. C. DAVIS 3,056,004

SENSITIVE PRESSURE SWITCH

Filed Aug. 10, 1959

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Fig. 3.

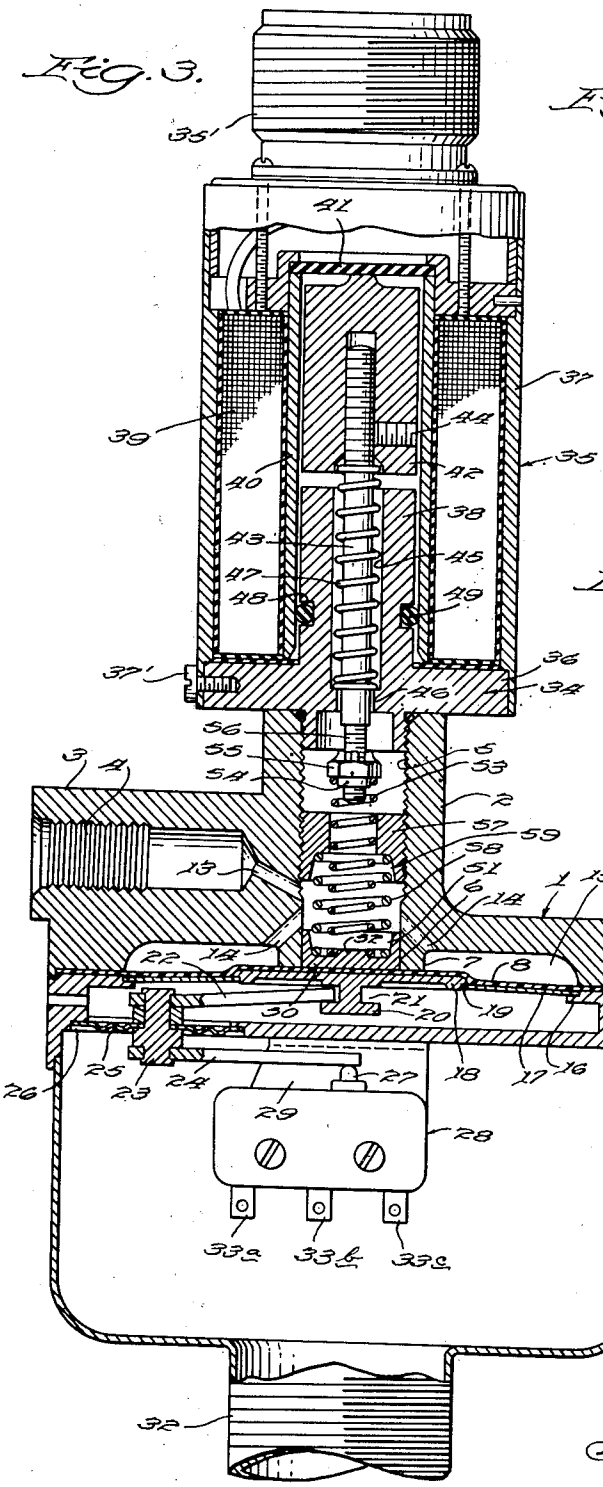



Fig. 1.

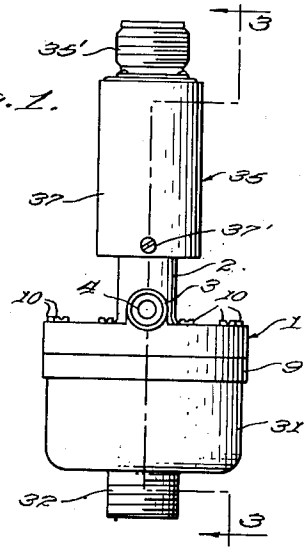



Fig. 2.

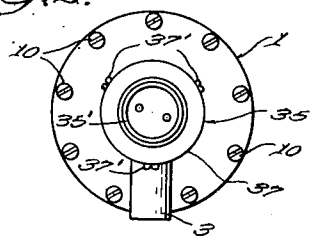
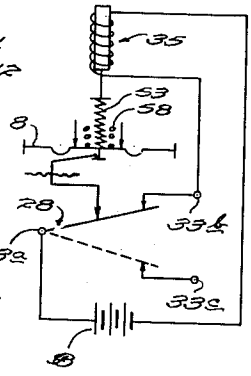



Fig. 4.




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Fig. 6.

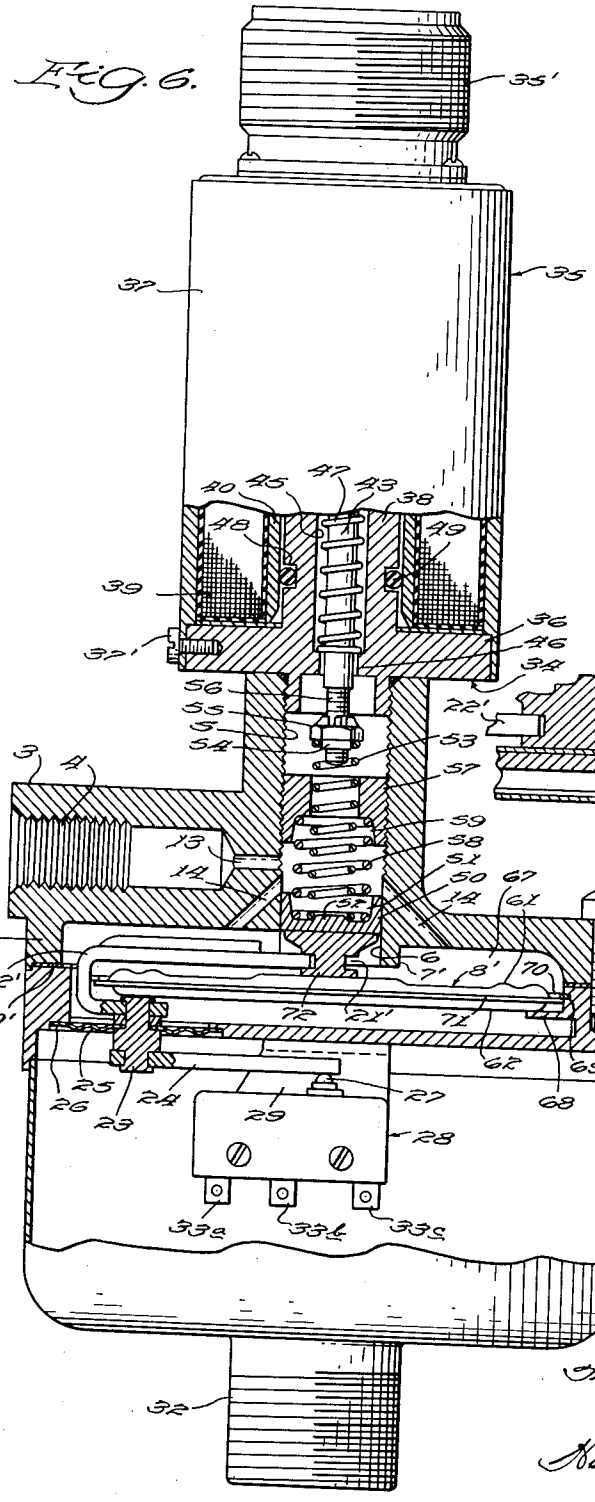



Fig. 5.

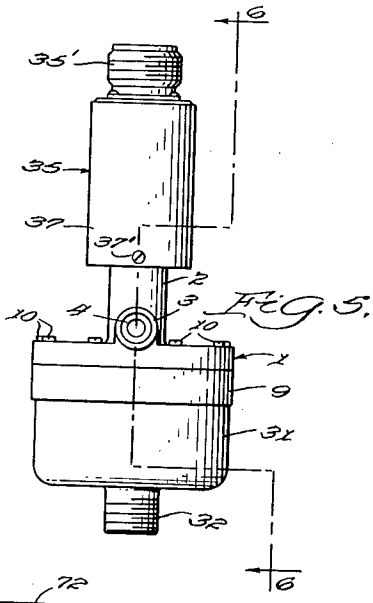



Fig. 8.

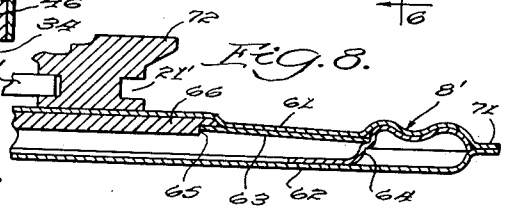
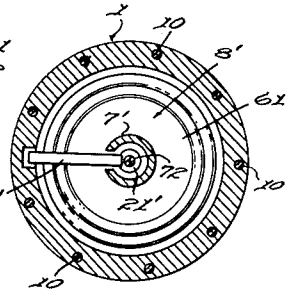



Fig. 7.




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Fig. 12.

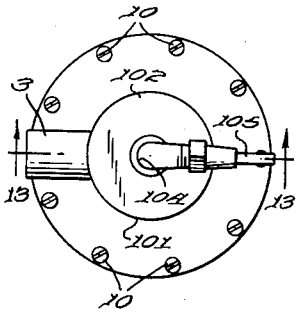



Fig. 9.

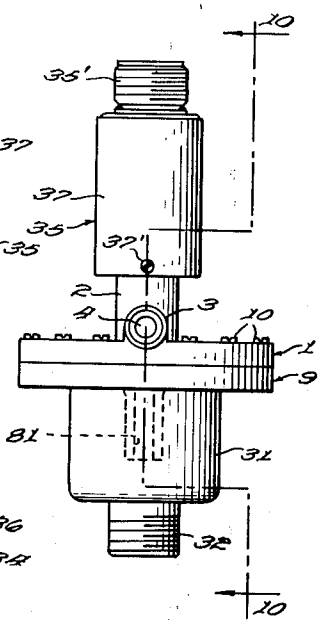






Fig. 10.

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SENSITIVE PRESSURE SWITCH

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Fig. 13.

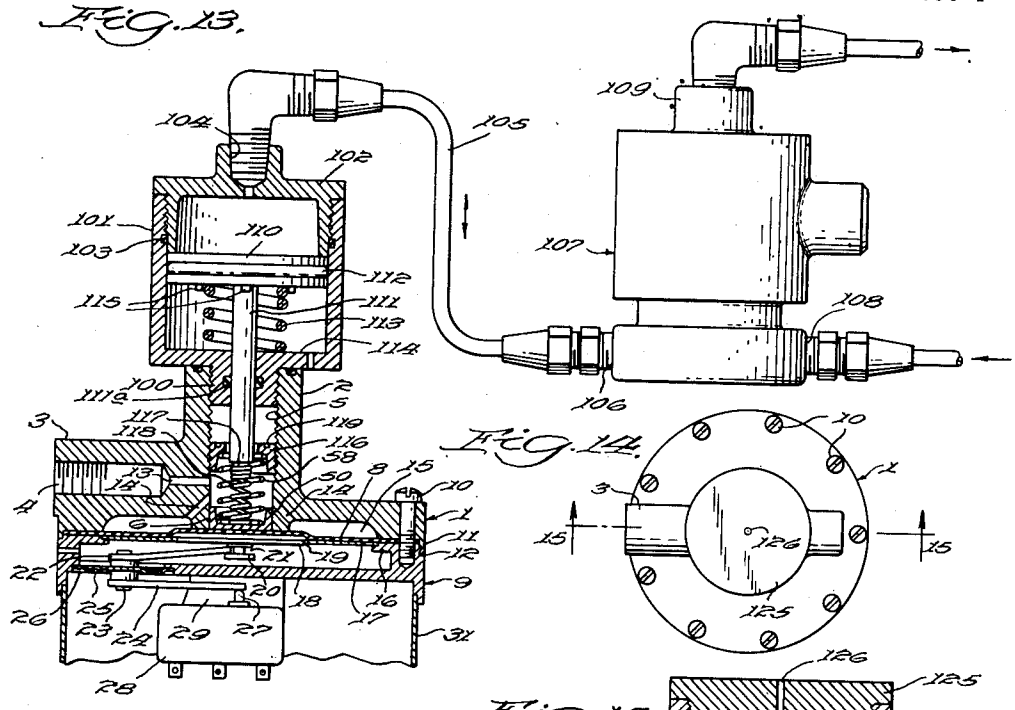



Fig. 14.




Fig. 11.

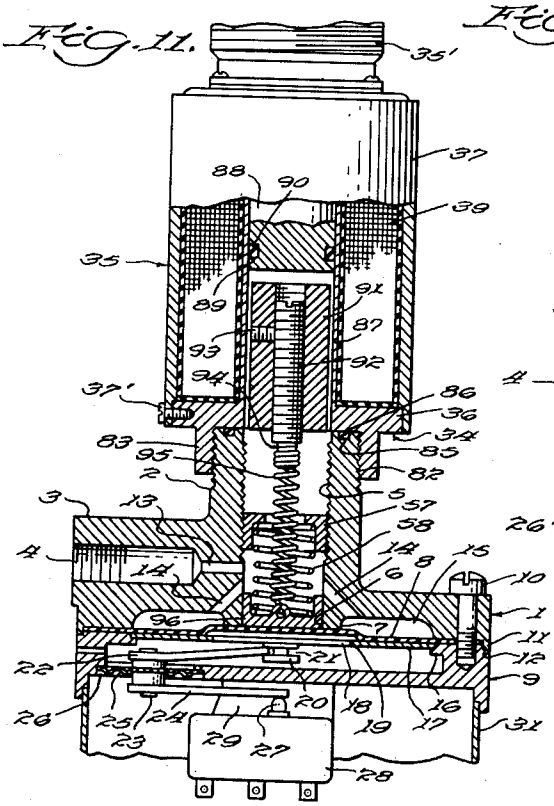
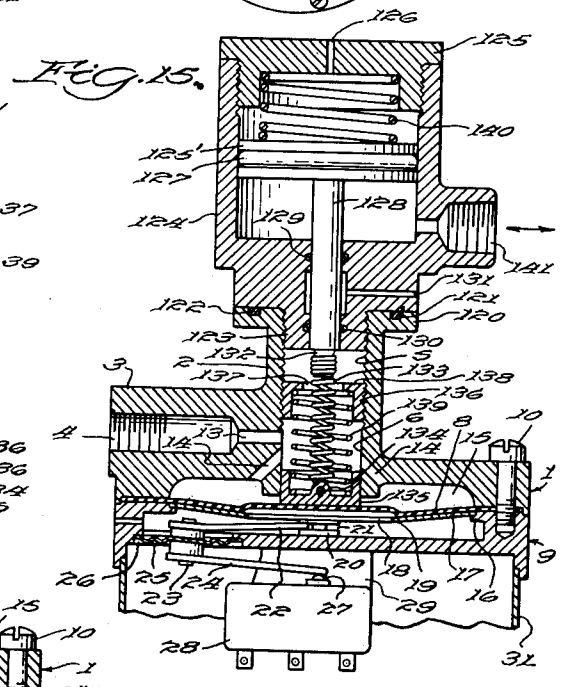



Fig. 15.




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United States Patent Office 3,056,004 Patented Sept. 25, 1962



3,056,004

# SENSITIVE PRESSURE SWITCH

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Filed Aug. 10, 1959, Ser. No. 832,749
39 Claims. (Cl. 200—83)

This invention relates to pressure switches and more particularly to an improved form thereof characterized by extremely small differentials between the greater of two fluid pressures which causes the switches to operate in one direction and the lesser pressure which allows the switch to operate by spring action in the opposite direction.

Commonly, the response of a pressure switch to the greater pressure is termed the "actuation" of the switch and the response to the lower pressure is termed the "re-actuation." Also, commonly, the range or gap between the actuating and re-actuating pressures is known as the "dead band." These terms, having been defined, will be employed in the description of the invention to bring into such description the terminology generally employed in the art to which the invention pertains.

In my prior Patent Number 2,824,919, dated February 25, 1958, there is shown a pressure switch in which the pressure acts on a diaphragm which through a rigid pressure plate and a negative rate spring means such as, for example, a Belleville type spring capable of snap action, yieldingly resists applied pressure. The imposition of pressure of a predetermined magnitude on the diaphragm and pressure plate causes the Belleville spring to partake of snap action, the Belleville spring having such a height to thickness ($h$–$t$) ratio as to partake of snap action, and the snap action, in turn, operates a snap action electric switch. Thereafter, upon a decrease in pressure to a given extent, the power stored in this Belleville spring is released and the diaphragm is returned to its initial position by the return snap action (re-actuation) movement of the Belleville spring and of the switch.

The present invention is directed to and contemplates improved means for making pressure switches having even narrower dead bands than the switches of the said patent. Broadly stated, the principle involved is that of at least partially replacing the energy loss through hysterisis incident to actuation of the switch so that a lesser differential or dead band exists between the actuating and re-actuating pressures.

Accordingly, it is an object of the present invention to provide a pressure switch having means, including negative rate spring means, effective to impose a bias on a pressure responsive means which responds to predetermined changes in applied fluid pressure with snap action, the bias being of such magnitude that when modifyingly applied to the pressure imposed load, a very slight change in the fluid pressure will effect the deflection of the pressure responsive means with at least a portion of the said modifyingly applied load then being rendered idle until the switch is returned through re-actuation pressure to its former position.

Another object of the invention is to provide a pressure actuated switch embodying the above-stated principle of the application of a bias on a pressure responsive element of the switch in the direction of movement incident to actuation thereof and in which the said bias is provided by electro-magnetic means.

A further object of the invention is to provide a pressure actuated switch embodying the above-stated principle of the application of a bias thereon in the direction of movement incident to actuation thereof in which the said bias is provided by a pressure actuated means other



than that to which the switch responds for its pressure responsive action.

Still another object of the invention is to provide a pressure switch including a solenoid having the moving element thereof (usually the armature) arranged to supply a modifying bias on the pressure responsive means of a snap action pressure switch which is in addition to the load applied thereon by an actuating fluid pressure.

A still further object of the invention is to provide means in a snap action pressure switch which includes a pressure responsive element and mechanism actuated thereby for operation of a snap switch and embodying means for applying a modifying bias thereon to reduce the width of the dead band between the actuating and re-actuating pressures and in which the bias applying means comprises a piston and a cylinder together with an electro-magnetic valve means for admitting pressure to the piston in an amount sufficient to apply the desired bias to the pressure responsive switch actuating element of the pressure switch mechanism.

A still further object of the invention is the provision in a snap action pressure switch having a pressure responsive diaphragm of means for providing an added loading to the diaphragm and in the same direction as the pressure load applied thereon, said loading being applied only during the actuating cycle or movement of the switch.

A still further object of the invention is to provide a pressure responsive switch with a solenoid and armature operative during one cycle of switch operation (actuation or re-actuation) to apply an added load to the pressure responsive element of the switch.

With the foregoing objects in view, together with such other objects and advantages as may subsequently appear, the invention resides in the parts, and in the construction, combination and arrangement of parts described, by way of example, in the following specification of certain presently preferred embodiments of the invention, reference being had to the accompanying drawings which form a part of said specification and in which drawings FIGS. 1 through 11 illustrate the application of the principles of the invention to various forms of pressure switches through the use of a solenoid and in which:

FIGS. 1 through 11 illustrate a first embodiment of the invention in which:

FIG. 1 is a side elevation of a pressure switch embodying the present invention,

FIG. 2 is a top plan view of the pressure switch shown in FIG. 1,

FIG. 3 is a greatly enlarged sectional view taken on the staggered line **3—3** of FIG. 1,

FIG. 4 is a circuit diagram of the electrical portion of the pressure switch,

FIG. 5 is a side elevational view of a second form of the first embodiment of the invention,

FIG. 6 is an enlarged view in partial medial section taken on the staggered line **6—6** of FIG. 5,

FIG. 7 is a reduced scale, transverse sectional view taken on the line **7—7** of FIG. 6,

FIG. 8 is a greatly enlarged, fragmentary sectional view of the aneroid element shown in FIGS. 6 and 7,

FIG. 9 is a side elevational view of a third form of the first embodiment of the invention,

FIG. 10 is a greatly enlarged view in partial medial section of the pressure switch shown in FIG. 9, the view being taken on the staggered line **10—10** of said FIG. 9,

FIG. 11 is a slightly reduced scale, medial, sectional view of a pressure switch generally similar to that shown in FIG. 3 except for the employment of a solenoid which, upon energization, affects the bias on the pressure responsive switch actuator through a tension spring,

FIGS. 12 through 15 constitute a second embodiment

of the invention and illustrate the application of the principles of the invention by the use of fluid pressure as a biasing means for the pressure responsive switch actuator and in which:

FIG. 12 is a top plan view of one form of the said second embodiment of the invention,

FIG. 13 is a sectional view taken on the line 13—13 of FIG. 12,

FIG. 14 is a top plan view of a second form of the said second embodiment of the invention, and

FIG. 15 is a sectional view taken on the line 15—15 of FIG. 14.

Referring first to FIGS. 1 through 4, the device there shown comprises a base **1** of generally circular outline having an axially extending sleeve portion **2**; said axial portion having a laterally extending boss **3** containing a threaded port **4** for connection to a source of pressure. The sleeve portion **2** is hollow and is internally threaded from the outer end thereof to a point adjacent the inner face of the body member as at **5** and terminates at the inner face of the body member in a smooth bore portion **6**.

The inner end of the bore **6** is surrounded by an annular wall portion **7** serving as an abutment and stop member for a diaphragm **8** the peripheral edge of which is clamped between the adjacent faces of the base **1** and the cap member **9** by a series of screws **10**. Preferably, for alignment purposes, the base **1** is provided with an annular bead **11** engaging a corresponding annular recess **12** in the mating face of the cap member **9**. A passage **13** connects the inlet port **4** with the axial bore extending through the member **2** and passages **14, 14** connect said bore with the space **15** extending between the outer periphery of the annular wall **7** and the juncture of the member **1** with the diaphragm at the outer edge thereof. Accordingly, fluid pressure entering through the inlet port will pass through the passage **13** and into the bores **5** and **6** and thence through the passages **14, 14** will impinge upon the diaphragm **8** to urge it in a direction away from the adjacent inner face of the base member **1**.

To effect snap type actuation and re-actuation of the diaphragm, the cap member **9** has an annular ledge **16** disposed adjacent to the diaphragm engaging face and on which rests the outer dameter of a Belleville spring **17**, the spring having an $h:t$ ratio of not less than about 1.4:1 so that a portion of its movement has a negative rate. The opening constituting the inner diameter of the Belleville spring is filled by a plug element **18** having a shoulder **19** engaging the face of the Belleville spring opposite the face engaging the ledge **16**. The diaphragm **8** lies directly upon the Belleville spring and upon the exposed face of the plug element **18**. At its center, the plug element is provided with an axially extending boss **20** having an annular groove **21** extending around it. The groove is engaged by the free end of an arm **22** of a rock member assembly including a connecting rivet element **23**, a second arm **24** extending generally parallel to but spaced from the arm **23** and a resilient, corrugated, thin metal disk **25** surrounding and secured to the rivet element **23** at about the midlength thereof and having its outer peripheral edge disposed and secured by soldering or brazing in a circular recess **26** comprising an opening in the wall of the cap element **9**; the resilient disk **25** serving in effect, as a hinge element whereby movements of the diaphragm and consequently of the Belleville spring and plug element are transmitted through the rock frame to the plunger **27** of an electric switch **28** mounted on a bracket **29** carried by the cap member **9**. A cover **31** secured to the outer face of the cap member **9** serves to enclose the switch and said cover may terminate either in a grommet or in appropriate socket type electrical connecting means such as at **32'** which is connected within the cover to the switch terminals as, for example, the terminals **33***a*, **33***b* and **33***c* of the switch **28**.

Threadedly engaging the outer end of the threaded portion **5** of the sleeve member **2** is the base member **34** of a solenoid assembly generally indicated at **35**; said solenoid having a socket means **35'** for electrical connection to a source of energy. The base member **34** includes a laterally extending flange **36** supporting a cylindrical cover **37** secured thereto by screws **37'** and also includes an axially extending Pole piece **38** disposed within the solenoid winding **39** for about half the length of the winding. The winding is mounted on a sleeve **40** having one end resting on the flange **36** the opposite end being closed by a plug element **41**. Freely slidably mounted within the tube **40** is the armature **42** formed of paramagnetic material and which is internally threaded and threadedly secured to the end of a rod **43** and locked thereon by a setscrew **44**. The rod **43** extends through an axial bore **45** in the boss **38** and is guided by a reduced diameter concentric bore **46** at the outer face of the flange **36**. A compression spring **47** extending between the shoulder formed by the bores **45** and **46** and the end of the armature **42** tends to urge the armature outwardly in the sleeve **40** and away from the adjacent end of the boss **38**.

The outer face of the Pole piece **38** is provided with a circumferential groove **48** in which an O-ring **49** is seated and which engages the inner face of the tube or sleeve **40**.

The bore **6** in the base member **1** slidably accommodates a plug element **50** the face of which rests upon the diaphragm **8**. The opposite face of the plug element **50** contains a cylindrical recess **51** interrupted at its center by a cylindrical boss **52**. A compression spring **53** has one end thereof surrounding and positioned by the boss **52** and said spring thence extends axially of the bore **5** and the opposite end thereof engages a shoulder **54** on a nut **55** carried by the threaded end **56** of the rod **43**. Threadedly mounted in the threaded bore **5** of the sleeve **2** is an abutment element **57** having an axial bore extending therethrough through which the spring **53** extends. The outer periphery of the recess **51** in the plug **50** engages and positions one end of a second compression spring **58** the opposite end of which engages a cylindrical recess **59** in the adjacent face of the plug element **57**. Thus both of these springs, **53** and **58**, apply loads to the plug element **50** and hence to the diaphragm and Belleville spring while the opposite ends of these springs are separately adjustable, the spring **53** being adjusted for the imposed load by re-positioning of the nut **55** on the rod **43** and the load exerted by the spring **58** being determined by the position of the abutment element **57** in the threaded bore **5**.

It is to be noted that the pressure fluid media entering the port **4** reaches the interior of the bore **6** through the passage **13** and thence through the passages **14, 14** and exerts its pressure against the diaphragm **8**. The pressure also will extend through the adjusting nut **57** and thence through the bore **46** enter the sleeve **40** of the solenoid, escape from the solenoid being prevented by the gasket **49**. Thus, the pressure entirely surrounds the armature **42** and the static pressure thereon is balanced, and thus having no effect upon the movement of the armature. However, the rate of movement of the armature is retarded by the presence of the fluid and this damps the armature sufficiently to prevent overtravel when the solenoid is energized.

Referring now to FIG. 4 there is shown diagrammatically a general arrangement of the pressure switch and its biasing means, the diagram illustrating the device in the position shown in FIG. 3. In this view, the solenoid **35** is energized applying its bias through the spring **53** to the diaphragm in addition to that of the spring **58** and the Belleville spring and in addition to the pressure load thereon. The switch **28** is closed in the direction connecting the solenoid to the source of energy represented at B. When the accumulated pressure effects snap action of the Belleville spring, the switch **28** is actuated to connect another contact and disconnect the current to the

solenoid. The changed position of the switch actuates whatever pressure control means is connected to be actuated at that time, to, for example, stop the pump means which has been responsible for the increase in pressure or whatever other devices may be employed to achieve that result. This continues until the pressure has decreased sufficiently to permit the Belleville spring 17 to return to its normal position by snap action or, in other words, to "re-actuate." Thus it is that when the switch has re-actuated and returned to its normal position it is then subjected to a predetermined extent of bias in the direction in which it is intended to actuate so that an extremely small increase in pressure is all that is required to cause it to actuate. Accordingly, the "dead band" is thus reduced to a great extent below that which could be otherwise achieved. It will be seen that thus relieving the additional pre-load applied by the solenoid when actuation has taken place enables the re-actuation to occur at a pressure decrease which is extremely close to the pressure which caused the initial actuation of the switch. Alternatively, the solenoid coil might, in some installations of the pressure switch, be connected to the switch contact 33*c*, as will be hereinafter shown, and it is equally possible that in some installations the pressure controlling means might be connected to whichever one of the contacts, 33*b* or 33*c*, was connected to the solenoid, dependent upon the requirements of the system in which the pressure switch is employed. For this reason the diagram shown in FIG. 4 is to be regarded as representative of one type of installation only. It will also be appreciated that any plunger operated switch, whether single or double throw, or single or multiple pole, may be substituted for the switch illustrated so long as it is capable of actuation and re-actuation by the pressure responsive means and that this applies to all embodiments of the invention.

Referring next to the invention shown in FIGS. 5 through 8, all corresponding parts which have been previously described have been given the same numbers as applied in the preceding figures and, if referred to at all, will be referred to only incidentally. In these figures, the switch actuator comprises an aneroid capsule indicated at 8'. This form of the invention is intended for use as a vacuum responsive switch or as an altitude responsive switch, it being arranged to respond by snap action to some predetermined pressure less than, say, sea level atmospheric pressure.

The aneroid cell 8' is a hollow disk-like cell formed of slightly cupped thin metal disks 61 and 62 which are secured together by soldering or welding around their edges. As an incident to the manufacture of the cell, the air is evacuated therefrom to a desired extent which, usually, is as nearly completely as possible and may either be a complete vacuum or a partial vacuum dependent upon the degree of temperature compensation required. The members 61 and 62 are normally urged away from each other by a Belleville spring 63 disposed within the cell and having its outer edge seated on a ring 64 adjacent the rim of the member 61, said ring having an edge forming a shoulder to center the Belleville spring thereon and to keep the edge of the Belleville spring from contacting the thin, very flexible metal comprising the cell walls. The inner diameter of the Belleville spring 63 engages a shoulder 65 formed in the periphery of a plug element 66 extending through the opening in the Belleville spring and resting upon and forming a support for the central portion of the cell wall 61.

In this form of the invention, the base 1 and cap member 9 are secured together by screws 10 in the usual manner but a gasket 10' is substituted for the diaphragm shown in the first form of the invention. The opposed end faces of the base 1 and cap 9 thus form an enclosed chamber 67 which is connected to the source of pressure to which the cell responds through the passages 14, 14, the bore 6, the passage 13, and the port 4. The cap member 9 includes



an annular ledge 68 disposed inwardly of the end face thereof upon which the wall member 62 of the aneroid is mounted. The inner periphery of the cap member 9 adjacent the end face thereof is provided with an annular groove 69 in which a snap ring 70 is seated resting upon the rim 71 formed by the closing seam of the aneroid cell to hold the cell firmly seated on the ledge 68. Fixed to the outer surface of the central portion of the cell wall member 61 is a stud element 72 having an annular groove 21' formed therein in which the arm 22' of the rock frame 23 is engaged. The rock frame includes, as in the first form of the invention, an arm 24 connected to the arm 22' by a rivet element 23 and a resilient disk element 25 secures the rock frame in a circular recess 26 in the cap element 9, the rock frame arm 24 actuating the plunger 27 of a switch 28 carried by a bracket 29 mounted on the outer surface of the cap member 9. Outwardly, beyond the annular groove 21', the stud member 72 includes a larger diameter portion which engages the end face of the plug element 50. It is to be noted that the rock frame arm 22' extends radially away from the groove 21' thence extends around the edge of the aneroid cell and thence radially back toward the axial line of the pressure cell for a short distance at which point it is connected to the rivet element 23. The ledge 68 is interrupted to provide a gap through which bent portion of the arm 22' may extend past the edge of the aneroid cell to the opposite side thereof. Likewise, the end of the snap ring are separated sufficiently to complement this gap. Additionally, the end wall 7' surrounding the end of the bore 6 adjacent the cell containing cavity 67 is provided with a radially extending gap to afford clearance for the free end of the arm 22' as it is moved by the action of the cell 8'. The end of this annular wall also serves as a stop element to limit the outward movement of the cell wall 61.

Assuming that the device is to be used as a switch which is responsive to some given altitude condition, the port 4 is connected to or left open to atmosphere. At sea level and up to some predetermined altitude the air pressure then within the cavity 67 would maintain the aneroid cell collapsed. When the pressure in the cavity 67 was reduced to some predetermined extent by reason of increased altitude, the Belleville spring would snap to the position shown in FIG. 8 with consequent movement of the rock frame and actuation of the switch. Such movement would correspond to the re-actuation portion of the cycle of the first described invention and as an incident thereto the solenoid would be energized to apply a bias to the pressure cell in opposition to the Belleville spring within the cell or capsule 8' until such time as through descent or other conditions the pressure in the cavity 67 increased to a point at which the opposition thereto by the Belleville spring is overcome and the Belleville spring moved by snap action allowing the aneroid cell to collapse with consequent actuating movement of the rock frame and of the switch 28. A switch of this character would be useful, for example, in cabin pressure maintaining systems or in any other aircraft system in which the indication of a given altitude or of a given atmospheric pressure less than sea level was essential. It is believed to be obvious that even though the Belleville springs used in the aneroid cells may vary some in individual characteristics, suitable adjustment of the load imposed by the solenoid through the springs 53 and 58 can compensate for such differences so that through appropriate adjustments a series of switches having Belleville springs of different characteristics enclosed within the capsule can be brought into adjustment for actuation and re-actuation in a uniform manner for a given set of pressure conditions. The bias imposed in one direction by the solenoid acts to replace the work lost to the operation of the switch and the hysterisis of the parts and thus narrows the "dead band" of the switch so that it will actuate and re-actuate at very close differences in pressures.

Referring next to the form of the first embodiment of the invention shown in FIGS. 9 and 10, again, all parts disclosed which are similar to parts described in detail in preceding figures have been given the same numbers and will be referred to only incidentally in the description of this form.

The pressure responsive actuator here comprises the diaphragm 8'' having its periphery clamped between the adjacent faces of the base member 1 and cap member 9 in the same manner as in FIGS. 1 through 4. The diaphragm, however, lies closely against the end face of the base member 1 and this base member is provided with a series of radially extending grooves 73 leading from the discharge ends of the passages 14, 14 and intersecting a series of annular grooves 74 disposed concentrically with each other about the axial line of the bore 6. The grooves 73 and 74 serve to distribute the pressure evenly over the surface of the diaphragm. The diaphragm is normally held pressed against the end face of the base member 1 by a rigid pressure plate 75 which is of substantially the same diameter as the free area of the diaphragm 8''. The pressure plate carries an annular shoulder 76 which engages the inner diameter of a Belleville spring 77, the outer periphery of which is mounted in a shoulder 78 formed in a circular rim or wall 79 on the inner face of the cap member 9. The pressure plate 75 on the side opposite the diaphragm additionally carries an axially projecting stud element 80 having the annular groove 21 formed therein for reception of the arm 22 of the rock frame which includes the connecting rivet 23, the arm 24, the resilient disk 25 anchored in the recess 26 in the cap member 9, the free end of the arm 24 serving to operate the plunger 27 of a switch 28 carried by the bracket 29. Additionally, the cap member 9 carries a port 81 which communicates with the interior of the cap member 9 at the side of the diaphragm opposite that which is in communication with the port 4, the diaphragm forming a flexible partition interposed between the ports 4 and 81. When the port 81 is also connected to a source of pressure, the pressure switch acts in response to pressure differentials between the sources of pressure to which the ports 81 and 4 are, respectively, connected. In this connection, it will be appreciated that other illustrated forms of the invention can similarly be provided with a second port on the opposite side of the diaphragm for service as differential pressure switches.

The operation of this form of switch is believed to be obvious from the description of the two preceding embodiments of the invention. Normally, the switch is in the position shown in section in FIG. 10 in which position the solenoid is energized and is applying its load to the diaphragm in addition to the pressure entering through the port 4 which is opposed by the Belleville spring 77 and the pressure entering through the port 81. When the pressure entering through the port 4 in addition to the bias imposed by the solenoid and the spring 58 overcomes the resistance of the Belleville spring and the said opposing pressure, the spring moves with snap action until the surface of the pressure plate 75 engages the outer end of the annular wall 79, the wall thus, in addition to serving as an anchor for the outer periphery of the Belleville spring, acting also as a stop member to limit the movement of the pressure plate. Actuation of the switch 28 will connect one circuit and disconnect another including the de-energization of the solenoid as previously described in connection with the first form of the invention. When the pressure on the side of the diaphragm supplied through the port 4 decreases to a predetermined extent the Belleville spring will partake of its re-actuation movement, returning to the position shown in FIG. 10, and, of course, re-energizing the solenoid. For those uses in which a differential between two pressure sources is unnecessary, the port 81 may be left disconnected and thus open to atmosphere whereupon said port will act merely as the necessary breather to permit the free actuation of the diaphragm and the pressure plate in response to the pressure conditions affecting it through the port 4.

It will be understood that when the solenoid is disabled, the spring 47 will move the armature and the rod 43 away from the diaphragm releasing the load imposed thereon by the spring 53, thus reducing the load reduction deriving from pressure reduction to which the diaphragm will respond by snap action. The same consideration is, of course, true with respect to the aneroid cell or capsule which is the pressure responsive actuating means in the second form of the first embodiment of the invention, the disabling of the armature and release of the spring 47 and 53 serving likewise to reduce the amount of pressure on the exterior of the aneroid cell enabling it to respond to a lesser increase in applied fluid pressure. It will be understood that the adjustment of the spring 58 corresponds generally to the adjustment to compensate for differences in switch response and inherent differences in seemingly identical Belleville springs as discussed in detail in my said prior patent. The present invention is, therefore, directed particularly to the means of imposing an additional load on the Belleville spring element of the switch which acts in addition to the actuating pressure and thus, being adjustable, permits the actuating pressure to be adjusted within a very close limit with respect to the re-actuating pressure.

FIG. 11 illustrates the point that the solenoid previously described need not be one which applies a push upon the switch actuator but may also apply its bias additively, where desired, by exerting a pull upon the primary bias producing means through a tension spring. In this figure, all parts which are the same as shown in FIG. 3 and which operate in the same manner have been given the same numbers as applied in FIG. 3. The sleeve 2 of the base 1 is additionally externally threaded as at 82 and is engaged by the depending internally threaded sleeve portion 83 of the solenoid base 34. The end of the sleeve portion 2 is provided with an annular groove 85 in which an O-ring gasket 86 is seated to prevent leakage of fluid between the solenoid base 34 and the sleeve 2. The solenoid base 34 includes an integral sleeve portion 87 which extends through the solenoid and the pole piece 88 at the outer end of this sleeve is provided with a groove 89 containing an O-ring gasket 90 to prevent fluid leakage out of the outer end of the solenoid. The solenoid armature 91 is loosely mounted within the end of the sleeve 87 adjacent to the base 34 and carries an axially disposed screw threaded pin 92 secured in adjusted position therein by a set screw 93. The screw 92 extends into the bore 5 beyond the end of the armature 91 and carries a screw threaded portion 94 engaged by one end of a tension spring 95 which extends axially along the bore 5 and engages a plug member 96 in the lower end of the bore 6 the outer end of which engages the diaphragm 8 and the said plug member being urged against the diaphragm in opposition to the spring 95 by the compression spring 58 reacting between the plug member 96 and the abutment sleeve member 57.

Normally, the full force of the spring 58 is exerted through the plug member 96 against the diaphragm 8 and the Belleville spring 17. This, however, is opposed by the tension exerted thereon through the energized solenoid with the resultant pull exerted by the armature through the tension spring 95 on the plug member in opposition to the spring 58. Thus the energization of the solenoid can reduce the effect of the spring 58 to a point at which the diaphragm can respond to applied pressure at a very slight change from that which caused the diaphragm and Belleville spring to operate in the opposite direction.

Finally, considering FIGS. 12, 13, 14 and 15, it is shown that instead of a solenoid for applying the added bias to the pressure responsive actuator of the switch, fluid pressure may be employed. As in previous figures, similar

parts have been given the same numbers as in previously described figures.

In the form shown in FIGS. 12 and 13, the threaded portion 5 of the sleeve 2 is engaged at its outer end by the externally threaded neck 100 of a cylinder 101 with an interposed gasket 101*a*, the outer end of which is internally threaded and is closed by a cap 102 and sealed by a gasket 103 interposed between the cap member and the cylinder wall. The cap member in turn is provided with an internally threaded port 104 connected by a line 105 to the port 106 of a solenoid operated three-way valve 107 of a type available on the open market, said valve also having an inlet port 108 and a discharge port 109.

Slidingly mounted in the cylinder 101 is a piston rod 111 extending therefrom through the threaded neck 100 and a sealing gasket 111*a* carried thereby. A gasket 112 seated in a peripheral groove in the piston engages the side wall of the cylinder to effect a seal therewith. A compression spring 113 surrounding the piston rod 111 extends between the inner face of the cylinder 114 and the adjacent face of the piston 110 and operates to oppose the effect of pressure on the piston entering through the port 104, a series of lugs 115 on the face of the piston engaged by the spring 113 serving to position the spring co-axially with respect to the piston rod 111. The distal end of the piston rod 111 is spaced from the plug 50 and terminates in a reduced, diametric threaded end 117 engaged by one end of a compression spring 118, the other end of the spring engaging the plug 50.

In addition to the pressure imposed load on the plug 50 through the piston rod 111, further load is supplied through the spring 58 extending between the plug 50 and an adjustable abutment member 116 threadedly engaging the threaded portion 5 of the base member 1, said member having an axial bore therein through which the piston rod 111 reciprocates and said bore being provided with a peripheral groove in which a gasket 117 is seated to prevent leakage therethrough. A series of holes in the outer face of the abutment member 116 as indicated at 119 provides means for engagement with the abutment member by a spanner wrench for insertion, removal and adjustment of the abutment member.

When the solenoid valve 107 is energized fluid pressure will reach the interior of the cylinder 101 through the line 105 and the pressure load thus imposed on the piston, less the opposition thereto by the springs 58, 113 and 117, will be added to that imposed by the springs 58 and the actuating pressure imposed on the diaphragm 8 through the port 4. When this combined load through increase of the actuating pressure reaches some predetermined point, the load thus imposed will cause the Belleville spring to deflect with a snap action and resultant actuation of the switch 28. The circuit diagram for the electric circuit would be similar to that shown in FIG. 4 and upon such actuation of the Belleville spring and switch, the solenoid valve 107 would be de-energized, whereupon, the fluid would be returned through the line 105 by the action of the spring 113 on the piston 110, the fluid thence leaving the valve through the outlet port 109 thereof, it being understood that when the valve is energized the port 106 is connected with the inlet port 108 and that when it is de-energized the port 106 is connected with the discharge port 109. When the pressure through the port 104 has decreased to a predetermined degree, the Belleville spring and diaphragm will react by the snap action of the Belleville spring and return to the position shown in FIG. 13. Such reactuation will, of course, re-energize the solenoid valve 107 with the resultant imposition of the bias on the pressure responsive actuator by the piston 110. It will thus be apparent that the operation is exactly the same as though the cylinder 101 and its associated piston and springs were a solenoid.

Referring finally to FIGS. 14 and 15, the sleeve 2 of the base 1 terminates at its outer end in a lateral flange 120 having an annular groove in 121 in the outer face thereof containing a gasket 122. The outer end of the internally threaded portion 5 of the sleeve 2 is engaged by the externally threaded end 123 of a cylinder 124. The outer end of the cylinder 124 is internally threaded and is closed by a screw cap 125 having a breather hole 126 therein. Reciprocably mounted in the cylinder 124 is a piston 125' having a peripheral groove containing a gasket element 127 engaging the cylinder wall. The piston 126 is carried by a piston rod 128 extending through the end wall of the cylinder where it is engaged by spaced O-ring gaskets 129 and 130, there being an open space between the bearing portions containing these gaskets with which a breather hole 131 communicates. Below the threaded end of the cylinder 124 the piston rod 128 terminates in a reduced diameter threaded portion 132 to which one end of a tension spring 133 is connected. The other end of the tension spring 133 is connected to an eyelet 134 formed as an integral part of a plug element 135 slidably mounted in the bore 6 of the base member 1. Also threadedly mounted in the threaded portion 5 of the sleeve member 2 is an abutment member 136 having an axial opening 137 therein through which the spring 133 extends, said abutment member also having a shoulder 138 serving as an abutment for one end of a compression spring 139 which surrounds and extends co-axially with the spring 133 and which, at its outer end, engages the plug member 135. A compression spring 140 extends between the cap member 125 and the outer end of the piston tending to move the piston toward the plug member 135. A port 141 opens into the space between the piston and the end of the cylinder through which the piston rod extends, said port being adapted to be connected to a three-way valve such as the valve 107 shown in FIG. 13 and in the same manner as illustrated in that figure.

It will be appreciated that the structure here disclosed illustrates the point that the fluid pressure form of biasing means for a pressure switch can operate additively through a tension spring as well as through a compression spring in the same manner that the solenoid may operate through a tension spring as illustrated in FIG. 11. Generally, a pressure switch thus made would normally be in the position shown in FIG. 15, that is, with the Belleville spring in the position shown in that figure and with the plug element 135 projecting out of the bore 6. The solenoid valve would be energized and pressure fluid would be in the cylinder tending to urge the piston 126 against the loads thereon imposed by the spring 140 and the spring 133, the latter being opposed by the initial loading of the spring 139. When the pressure on the switch actuating means entering through the port 4 decreased to a predetermined extent the Belleville spring would actuate and in turn effect actuation of the switch 28 and which as in the previously described embodiments of the invention, in addition to whatever other functions were produced by current control by the switch, would de-energize the solenoid valve allowing the spring 140 to move the piston toward the opposite end of the cylinder with incidental discharge of pressure fluid out of the port 141 and through the discharge port of the solenoid valve.

While in the foregoing specification there have been described and illustrated certain presently preferred embodiments of the invention, it is not to be inferred therefrom that the invention is intended to be limited to such embodiments, and it will be understood that the invention includes as well, all such changes and modifications in the parts and in the construction, combination and arrangement of parts as shall come within the purview of the appended claims.

I claim:

1. In a pressure switch, a frame structure including a fluid pressure receiving chamber and means for connecting said chamber with a source of fluid pressure, a switch mechanism carried by said frame structure and including snap action contact making and breaking devices, a

member forming a wall of said chamber movably responsive to fluid pressure variations therein, means translating pressure responsive movements of said member into snap action movements of said switch mechanism, spring means having at least a decreasing rate constantly operative to apply a bias on said member to yieldingly oppose fluid pressure in said chamber; said spring means and said member being subject to hysteresis losses incident to the pressure responsive movements thereof, and means for increasing the sensitivity of said switch to pressure changes including devices acting on said member and operative by a power source externally of said pressure switch to yieldingly and at least partially offset those hysteresis losses of said spring means and said member which occur incident to movements thereof responsive to increasing pressure in said chamber.

2. A pressure switch as claimed in claim 1 in which said devices include a solenoid having a coil connected to a source of electrical energy, an armature and a train of mechanism extending therefrom to said member, and means for connecting said coil to the source of energy only during the times said member and spring means are to be subjected to switch actuating movement in response to a pressure increase.

3. A pressure switch as claimed in claim 1 in which said devices include a cylinder connected to a source of fluid pressure, a piston in said cylinder positioned to be subjected to pressure therein, spring means operative to cause said piston to yieldingly oppose pressure in said cylinder, a train of mechanism extending between said piston and said member and valve means operative to admit pressure to said cylinder only during the times said member and said spring means are to be subjected to switch actuating movement in response to a pressure increase.

4. In a pressure switch, a frame structure including a fluid pressure receiving chamber and means for connecting said chamber with a source of fluid pressure, a switch mechanism carried by said frame structure and including snap action contact making and breaking devices, a member forming a wall of said chamber movably responsive to fluid pressure variations therein, means translating pressure responsive movements of said member into snap action movements of said switch mechanism, spring means having at least a decreasing rate constantly operative to apply a bias on said member to yieldingly oppose fluid pressure in said chamber; said spring means and said member being subject to hysteresis losses incident to the pressure responsive movements thereof, and means for increasing the sensitivity of said switch to pressure changes including devices acting on said member and operative by a power source externally of said pressure switch to at least partially offset those hysteresis losses of said spring means and said member which occur incident to movements thereof responsive to decreasing pressure in said chamber.

5. A pressure switch as claimed in claim 4 in which said devices include a solenoid having a coil connected to a source of electrical energy, an armature and a train of mechanism extending therefrom to said member, and means for connecting said coil to the source of energy only during the times said member and spring means are to be subjected to switch actuating movement in response to a pressure decrease.

6. A pressure switch as claimed in claim 4 in which said devices include a cylinder connected to source of fluid pressure, a piston in said cylinder positioned to be subjected to pressure therein, spring means operative to cause said piston to yieldingly oppose pressure in said cylinder, a train of mechanism extending between said piston and said member and valve means operative to admit pressure to said cylinder only during the times said member and said spring means are to be subjected to switch actuating movement in response to a pressure decrease.

7. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions and switch actuating means operably associated with said switch mechanism and correspondingly movable between two positions; said actuating means including, a member movably responsive to fluid pressure imposed on the surface thereof, means affording the connection of said pressure switch to a source of fluid pressure with resultant imposition of fluid pressure on said surface of said member, and means engaging said member and yieldingly opposing the force of fluid pressure on said member and devices effective to increase the sensitivity of said yielding means to pressure changes yieldingly engaging said yielding means and operative by said engagement to reduce the pressure opposing bias on said member when said switch actuating means is in a predetermined one of said two positions to a greater extent than when said switch actuating means is in its other position.

8. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions and switch actuating means operably associated with said switch mechanism and correspondingly movable between two positions; said actuating means including, a member movably responsive to fluid pressure imposed on the surface thereof, means affording the connection of said pressure switch to a source of fluid pressure with resultant imposition of fluid pressure on said surface of said member, and means engaging said member and yieldingly opposing the force of fluid pressure on said member and including devices controlled by said switch mechanism effective to increase the sensitivity of said yielding means to pressure changes yieldingly engaging said yielding means and operative by said engagement to reduce the pressure opposing bias on said member when said switch actuating means is in a predetermined one of said two positions to a greater extent than when said switch actuating means is in its other position.

9. A pressure switch as claimed in claim 8 in which said devices include a solenoid controlled by said switch mechanism and having devices interposed between the armature thereof and said member effective to yieldingly additively oppose the bias on said member exerted by said first-named fluid pressure force opposing means.

10. A pressure switch as claimed in claim 8 in which said devices include a pressure responsive cylinder and piston means and yieldingly devices interposed between said piston and said member, and controlling means for said cylinder and piston including a valve controlled by said switch mechanism.

11. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, switch actuating means separately movable by snap action operably associated with said switch mechanism and correspondingly movable between two positions; said actuating means including a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting said member to fluid pressure, pressure opposing means engaging said member and imposing a yielding bias thereon including a spring having a negative rate, and means for increasing the sensitivity of said switch actuating means to pressure changes including auxiliary devices yieldably modifying the bias imposed on said member by said pressure opposing means when said switch actuating means is in a predetermined one of said two positions.

12. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, switch actuating means separately movable by snap action operably associated with said switch mechanism including a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting said member to fluid pressure, pressure opposing means engaging and imposing a yielding bias on said member including a spring having a negative rate and means for

increasing the sensitivity of said pressure opposing means to pressure changes including devices yieldably engaging said member and effective to decrease the bias imposed on said member by said pressure opposing means when said switch is in a predetermined one of said two positions.

13. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, switch actuating means separately movable by snap action operably associated with said switch mechanism including a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting said member to fluid pressure, pressure opposing means engaging and imposing a yielding bias on said member including a spring having a negative rate and means for increasing the sensitivity of said pressure opposing means to pressure changes including devices yieldably engaging said member effective to increase the bias imposed on said member by said pressure opposing means when said switch is in a predetermined one of said two positions.

14. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, switch actuating means separately movable by snap action operably associated with said switch mechanism including a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting said member to fluid pressure, pressure opposing means engaging and imposing a yielding bias on said member, and other means yieldably engaging said member effective to decrease the bias imposed on said member by said pressure opposing means when said switch is in a predetermined one of said two positions and to increase the said bias when the switch is in its other position.

15. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, switch actuating means separately and correspondingly movable by snap action between two positions operably associated with said switch mechanism and including, a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting a face of said member to fluid pressure, pressure opposing means engaging another portion of said member and imposing a yielding, pressure-opposing bias thereon including a spring member having at least a decreasing rate, and means controlled by said switch actuating means additionally yieldably engaging said member effective to partially oppose the pressure-opposing bias on said member when said switch actuating means is moved to a predetermined one of said two positions by movement of said member.

16. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, and switch actuating means separately and correspondingly movable by snap action between two positions operably associated with said switch mechanism and including, a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting a face of said member to fluid pressure, pressure opposing means engaging another portion of said member and imposing a yielding, pressure-opposing bias thereon including a spring member having at least a decreasing rate, and means controlled by said switch actuating means additionally yieldably engaging said member effective to increase the pressure-opposing bias on said member when said switch actuating means is moved to a predetermined one of said two positions by movement of said member.

17. In a pressure switch, a switch mechanism movable with inherent snap action in either direction between two positions, and switch actuating means separately movable by snap action operably associated with said switch mechanism and including, a member movably responsive to the force of fluid pressure imposed thereon, means for subjecting a face of said member to fluid pressure, pressure opposing means engaging another portion of said member and imposing a yielding, pressure-opposing bias thereon including a spring member having a least a decreasing rate, and means controlled by said switch mechanism additionally yieldably engaging said member effective to partially oppose the pressure-opposing bias on said member when said switch mechanism is in a predetermined one of said two positions and to increase the said bias when said switch mechanism is in the other of said two positions.

18. A pressure responsive switch including a member yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, means including a disc spring engaging and opposing pressure imposed loads on said member normally effective to maintain said member in a position of repose and operative both to permit said member to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said member to return with snap action to its said position of repose upon a drop of at least a predetermined magnitude in the imposed pressure with incident actuation of said switch, and other devices engaging said member and effective, only during the times when said member is in said position of repose, to decrease the extent of pressure opposing bias imposed on said member.

19. A pressure responsive switch including a member, yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, means including a disc spring opposing pressure imposed loads on said member and normally effective to maintain said member in a position of repose and operative both to permit said member to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said member to return with snap action to its said position of repose upon a drop of at least a predetermined magnitude in the imposed pressure with incident actuation of said switch, and other devices effective only during the times when said member is in said position of repose, to partially oppose the force exerted on said member by said disc spring means with resultant reduction in the magnitude of pressure increase required to cause said member to move from its said position of repose.

20. A pressure responsive switch including a member, yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, means including a disc spring engaging and opposing pressure imposed loads on said member and normally effective to maintain said member in a position of repose and operative both to permit said member to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said member to return with snap action to its said position of repose upon a drop of at least a predetermined magnitude in the imposed pressure with incident actuation of said switch, and other devices effective only during the times when said member is in said position of repose to additively combine a force with the force exerted by said pressure on said member in opposition to said disc spring with resultant decrease in the magnitude of pressure change required to cause said disc spring means to be moved by the pressure imposed load thereon.

21. A pressure responsive switch including a frame, a pressure responsive member mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port in said frame affording connection of said cavity with a source of fluid pressure, an electric switch including contact making and breaking mechanism, devices extending between said member and said switch effective to translate pressure responsive movements of said member into movements of the contact making and

breaking mechanism of said switch, means engaging said member and including an over-center spring effective to apply a bias to said member in opposition to the pressure imposed load and normally effective to maintain said member in one position and in response to a pressure imposed load on said member of a predetermined magnitude, to allow said member to overcome said bias and to move with snap action to another position and, in response to a pressure decrease of at least a predetermned magnitude, to allow said means to return said member to its said one position, and other means engaging said member and effective only during the time said member is in said one position, to modify the bias imposed by said first-named means on said member.

22. A pressure responsive switch including a frame, a pressure responsive member mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch including contact making and breaking mechanism, devices extending between said member and said switch effective to translate pressure responsive movements of said member into movements of the contact making and breaking mechanism of said switch, means engaging said member and including an over-center spring effective to apply a bias to said member in opposition to the pressure imposed load and normally effective to maintain said member in one position and in response to a pressure imposed load on said member of a predetermined magnitude to allow said member to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to allow said means to return said member to its said one position, and other means effective only during the times said member is in said one position, to partially oppose the force exerted on said member by said first-named means with resultant reduction in the magnitude of pressure increase required to cause said member to move from its said one position.

23. A pressure responsive switch including a frame, a pressure responsive member mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch including contact making and breaking mechanism, devices extending between said member and said switch effective to translate pressure responsive movements of said member into movements of the contact making and breaking mechanism of said switch, means engaging said member and including an over-center spring effective to apply a bias to said member in opposition to the pressure imposed load and normally effective to maintain said member in one position and in response to a pressure imposed load on said member of a predetermined magnitude to allow said member to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to allow said means to return said member to its said one position, and other means effective, only during the times said member is in said one position, to additively combine a force with the force exerted by said first-named means to oppose a pressure imposed load on said member with resultant decrease in the magnitude of pressure change required to cause said first-named means to move said member in opposition to the pressure imposed load thereon.

24. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a bias to said diaphragm yieldingly opposing fluid pressure in said cavity; said means being effective normally to maintain said diaphragm in one position and in response to an increase in the pressure imposed load on said diaphragm of a predetermined magnitude to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to return said diaphragm to its said one position, and other means effective only during the times said diaphragm is in said one position, to modify the bias imposed by said first-named means on said diaphragm.

25. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a bias to said diaphragm yieldingly opposing fluid pressure in said cavity; said means being effective normally to maintain said diaphragm in one position and in response to an increase in the pressure imposed load on said diaphragm of a predetermined magnitude to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to return said diaphragm to its said one position, and other means effective only during the times said diaphragm is in said one position, to partially oppose the force exerted on said diaphragm by said first-named means with resultant reduction in the magnitude of pressure increase required to cause said diaphragm to move from its said one position.

26. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a bias to said diaphragm yieldingly opposing fluid pressure in said cavity; said means being effective normally to maintain said diaphragm in one position and in response to an increase in the pressure imposed load on said diaphragm of a predetermined magnitude to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to return said diaphragm to its said one position, and other means effective only during the times said diaphragm is in said one position, to additively combine a force with the force exerted by said first-named means to oppose a pressure imposed load on said diaphragm with resultant decrease in the magnitude of pressure change required to cause said first-named means to move said diaphragm in opposition to the pressure imposed load thereon.

27. A pressure responsive switch including a frame, a pressure responsive means carried by said frame including an aneroid cell having a flexible, pressure responsive wall, a relatively inflexible wall, and an over-center spring normally urging said flexible wall outwardly away from said inflexible wall in opposition to atmospheric pressure of a predetermined magnitude less than sea level pressure and effective to cause said flexible wall to move with snap action in response to pressure changes of sufficient magnitude both to overcome and to be overcome by the bias of said over-center spring, and devices effective, only during the times when said flexible wall is moved away from

said inflexible wall, to partially oppose the force exerted on said flexible wall by said over-center spring.

28. A pressure responsive switch as claimed in claim 27 in which said devices comprise a solenoid having an armature, a compression spring interposed between said armature and said flexible wall, said solenoid and armature being so disposed that upon energization of the coil of said solenoid said armature through said compression spring will exert a force against said flexible wall in opposition to the force of said over-center spring but insufficient to overcome the force of said over-center spring until a predetermined amount of atmospheric pressure is exerted on said flexible wall in addition to the force deriving from the armature of the energized solenoid.

29. A pressure responsive switch as claimed in claim 28 in which said switch includes connections operative to energize the coil of said solenoid when said flexible wall is moved outwardly from said inflexible wall by said over-center spring and to de-energize said solenoid when the atmospheric pressure on said flexible wall in addition to the force deriving from the energized solenoid overcomes the bias of said over-center spring.

30. A pressure responsive switch including a member yieldably responsive to imposed fluid pressures, means for subjecting said member to fluid pressure, an electric switch, and devices effective to cause said member to respond to imposed fluid pressure with snap action including over-center spring means operative to bias said member to yieldably oppose pressure imposed loads thereon, said devices including a solenoid having a coil electrically connected to said switch, an armature, and yielding means forming an operative interengagement between said armature and said pressure responsive member; said coil being energized only when said member is in its said position of repose and said solenoid being then effective to activate said armature with resultant modification of the magnitude of pressure imposed load upon said member required to cause said member to move with snap action in opposition to the bias of said over-center spring means.

31. A pressure responsive switch including a member yieldably responsive to imposed fluid pressures, means for subjecting said member to fluid pressure, an electric switch, and devices effective to cause said member to respond to imposed fluid pressure with snap action including over-center spring means operative to bias said member to yieldably oppose pressure imposed loads thereon, and devices including a solenoid having a coil electrically connected to said switch, an armature, and yielding means forming an operative interengagement between said armature and said pressure responsive member; said coil being energized only when said member is in its said position of repose and said solenoid being then effective to partially oppose the force exerted on said member by said over-center spring means with resultant reduction in the magnitude of pressure increase required to cause said member to move from its said position of repose.

32. A pressure responsive switch including a member yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, negative rate spring means opposing pressure imposed loads on said member normally effective to maintain said member in a position of repose and operative both to permit said member to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said member to return with snap action to its said position of repose upon a drop in the imposed pressure of at least a predetermined magnitude with incident actuation of said switch, and other devices effective to modify the magnitude of pressure imposed loads on said member required to cause said member to move from its said position of repose; said other devices including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said pressure responsive member and said piston, and valve means for introducing fluid pressure into said cylinder only during the time said pressure responsive member is in its said position of repose and for relieving said cylinder from pressure at all other times.

33. A pressure responsive switch including a member yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, negative rate spring means opposing pressure imposed loads on said member normally effective to maintain said member in a position of repose and operative both to permit said diaphragm to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said diaphragm to return with snap action to its said position of repose upon a drop in the imposed pressure of at least a predetermined magnitude with incident actuation of said switch, and other devices effective to partially oppose the force exerted on said diaphragm by said negative rate spring means with resultant reduction of the magnitude of pressure increase required to cause said member to move from its said position of repose; said other devices including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said diaphragm and said piston, and means for introducing fluid pressure into said cylinder only during the time said diaphragm is in its said position of repose and for relieving said cylinder from pressure at all other times.

34. A pressure responsive switch including a member yieldably responsive to imposed fluid pressure, means for subjecting said member to fluid pressure, an electric switch, devices conducting pressure responsive movements of said member to actuate said switch, negative rate spring means opposing pressure imposed loads on said member normally effective to maintain said member in a position of repose and operative both to permit said member to move with snap action from its position of repose in response to a predetermined pressure increase and to cause said member to return with snap action to its said position of repose upon a drop of the imposed pressure of at least a predetermined magnitude with incident actuation of said switch, and other devices effective to additively combine a force with the force exerted by said negative rate spring means to oppose a pressure imposed load on said member with resultant decrease in the magnitude of pressure change required to cause said negative rate spring means to move said member in opposition to the pressure imposed load thereon; said other devices including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said pressure responsive member and said piston, and valve means for introducing fluid pressure into said cylinder only during the time said pressure responsive member is in its said position of repose and for relieving said cylinder from pressure at all other times.

35. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means including a negative rate spring effective to apply a yielding, pressure opposing bias on said diaphragm and normally effective to maintain said diaphragm in one position and in response to an increase in the pressure imposed load on said diaphragm of a predetermined magnitude, to allow said diaphragm to overcome said bias and move with snap action to another position and in response to a pressure drop of at least

a predetermined magnitude to allow said over-center spring means to return said diaphragm to its said one position, and other means effective only during the times said diaphragm is in said one position to modify the bias imposed by said over-center spring means on said member; said other means comprising a solenoid, an armature associated with said solenoid, means establishing a yielding interengagement between said armature and said diaphragm and electrical connections extending between the coil of said solenoid and said switch effective to energize said coil only during the time said diaphragm is in its said one position, the energization of said coil being effective to cause said armature acting through said interengaging means to impose a load on said diaphragm in opposition to the bias imposed thereon by said negative rate spring means.

36. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including a negative rate spring effective to apply a yielding, pressure opposing bias on said diaphragm and normally effective to maintain said diaphragm in one position and in response to an increase in the pressure imposed load on said diaphragm of a predetermined magnitude, to allow said diaphragm to overcome said bias and move with snap action to another position and in response to a pressure drop of at least a predetermined magnitude to allow said means to return said diaphragm to its said one position, and other means effective only during the times said diaphragm is in said one position to modify the bias imposed by said first-named means on said member; said other means comprising a solenoid having a coil and an armature, electrical connections extending between said switch and said coil, devices establishing a yielding interengagement between said diaphragm and said armature, said armature and said coil of said solenoid being so constructed and arranged that upon energization of said coil said armature acting through said interengaging devices will additively combine with the force exerted by said first-named means on said diaphragm to oppose a pressure imposed load on said diaphragm with resultant decrease in the magnitude of pressure change required to cause said first-named means to move said diaphragm in opposition to the pressure imposed load thereon.

37. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port in said frame affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a yielding, pressure opposing bias on said diaphragm and normally effective to maintain said diaphragm in one position and in response to an increase of predetermined magnitude in the pressure imposed load on said diaphragm, to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to allow said means to return said diaphragm to its said one position, and other means effective to modify the magnitude of pressure imposed load on said diaphragm required to cause said diaphragm to move from its said one position; said other means including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said diaphragm and said piston, and means for introducing fluid pressure into said cylinder only during the times said diaphragm is in said one position and for relieving said cylinder from pressure at all other times.

38. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port in said frame affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a yielding, pressure opposing bias on said diaphragm and normally effective to maintain said diaphragm in one position and in response to an increase of predetermined magnitude of the pressure imposed load on said diaphragm, to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to allow said means to return said diaphragm to its said one position, and other means effective to partially oppose the force exerted on said diaphragm by said first-named means with resultant reduction in the magnitude of pressure increase required to cause said diaphragm to move from said one position; said other means including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said diaphragm and said piston, and valve means for introducing fluid pressure into said cylinder only during the times said diaphragm is in its said one position and for relieving said cylinder from pressure at all other times.

39. A pressure responsive switch including a frame, a pressure responsive diaphragm mounted on said frame and cooperating therewith to define a pressure fluid receiving cavity, a port in said frame affording connection of said cavity with a source of fluid pressure, an electric switch, devices extending between said diaphragm and said switch effective to translate pressure responsive movements of said diaphragm into contact making and breaking movements of said switch, means engaging said diaphragm and including an over-center spring effective to apply a yielding, pressure opposing bias on said diaphragm and normally effective to maintain said diaphragm in one position and in response to an increase of predetermined magnitude of the pressure imposed load on said diaphragm, to allow said diaphragm to overcome said bias and to move with snap action to another position and, in response to a pressure drop of at least a predetermined magnitude, to allow said means to return said diaphragm to its said one position and other means effective to additively combine a force with the force exerted by said first-named means to oppose pressure imposed load on said diaphragm with resultant decrease in the magnitude of pressure change required to cause said first-named means to move said diaphragm in opposition to the pressure imposed load thereon, said other means including a cylinder, a piston mounted in said cylinder, a train of mechanism establishing a yielding interengagement between said diaphragm and said piston, and valve means for introducing fluid pressure into said cylinder only during the times said diaphragm is in its said one position and for relieving said cylinder from pressure at all other times.

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