May 27, 1958 H. LANGSTROTH 2,836,671

FLUID ACTUATED SWITCH

Filed Nov. 18, 1954 2 Sheets-Sheet 1

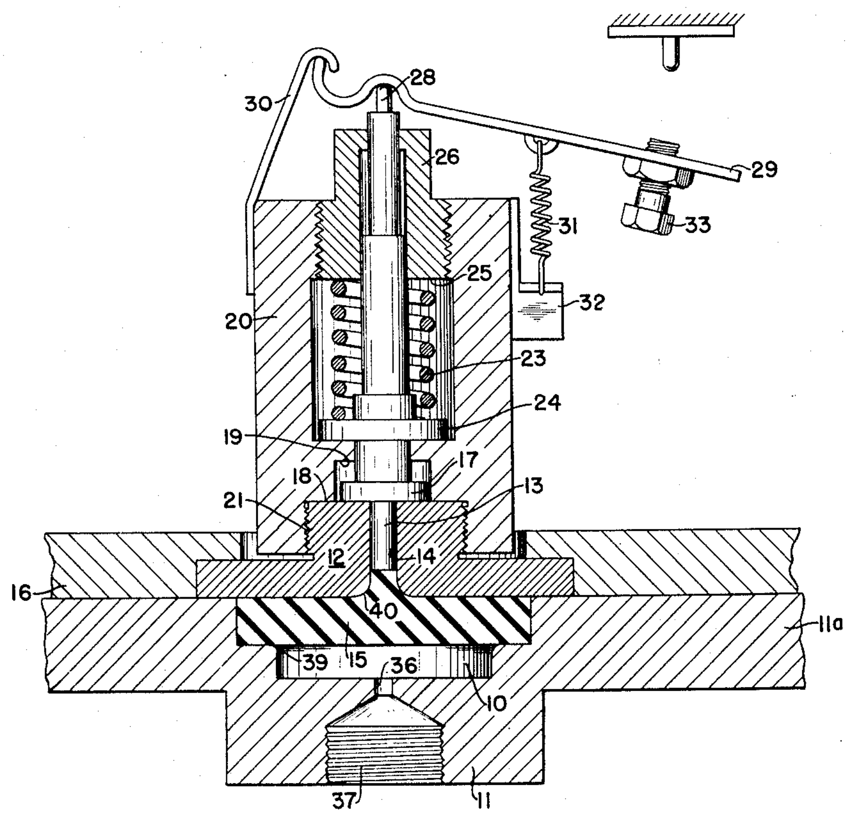

FIG. 1

INVENTOR.
HALL LANGSTROTH
BY Pennie Edmonds Morton Barrows & Taylor
ATTORNEYS

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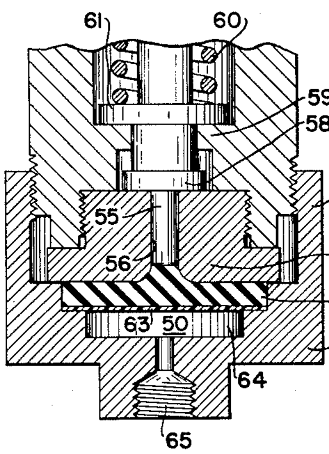

FIG. 2

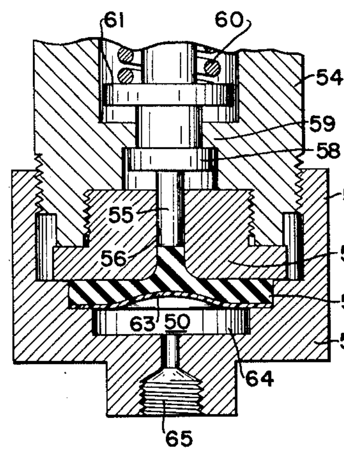

FIG. 3

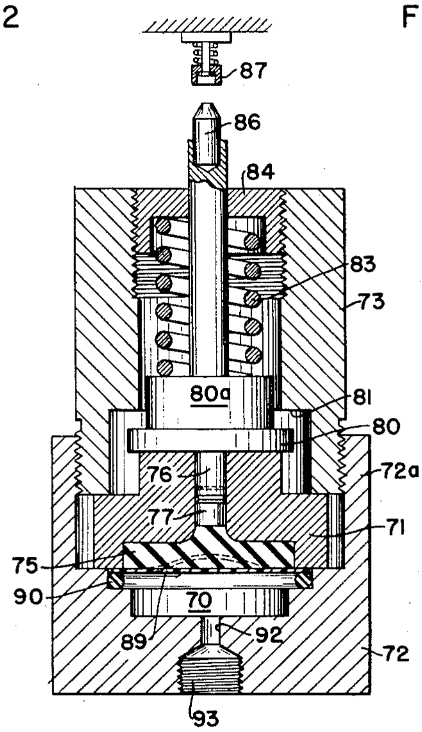

FIG. 4

INVENTOR.
HALL LANGSTROTH
BY Pennie Edmonds Morton Barrows & Taylor
ATTORNEYS

United States Patent Office

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FLUID ACTUATED SWITCH

Hall Langstroth, Riverside, Conn.

Application November 18, 1954, Serial No. 469,812

2 Claims. (Cl. 200—83)

This invention concerns an improved piston-type pressure sensitive switch which is fluid actuated. More specifically, this invention concerns a pressure sensitive switch which will operate at very high fluid pressures within a small range of pressure tolerances.

Fluid pressure control systems have become widely used in recent years and are becoming increasingly important. In the course of the use and development of such systems, applications for higher and higher fluid pressures have been discovered. As development of high pressure systems has progressed, it has become apparent that various components suitable for use in relatively low pressure fluid systems are not satisfactory for use at such higher levels of pressure. In particular, fluid actuated switches which have been useful at lower pressures have not proved satisfactory in pressure ranges of 3,000 pounds per square inch and higher. Most conventional fluid actuated switches fail at even lower pressure levels, and even those which do not fail frequently have a materially shortened operating life.

Various types of switches have been employed at high pressures in place of the switches using resilient diaphragms. For example, structures employing flexible metallic diaphragms have been employed. Most of these substitute structures have disadvantages. In the case of the flexible metallic diaphragm switches, the diaphragms often lose their resiliency and take a permanent set, thus becoming inaccurate. In addition, the brazed joints or seams fail after a period of flexing. Other possible types of substitute switches have been objectionable for various reasons, but in general the objection is to their tendency to fail at high temperatures.

In view of the unsatisfactory nature of the fluid actuated switches currently available for high pressure application, there has been much research devoted to the fluid pressure sensitive switch field. In addition to developing a switch able to withstand high pressures, it has been the hope of researchers to create a switch which will be useful at both extremely high and extremely low temperatures. Other researchers have sought a switch which may be actuated by oil and other chemical substances which normally attack rubber. The switch of the present invention is capable of resisting high pressures and is adaptable for use at extremes of temperature or for use with normally destructive chemical fluids.

As pointed out in my application Serial No. 388,749, filed October 28, 1953, relating to a novel Fluid Actuated Switch, at certain low and moderately high pressure levels, switches employing a flexible diaphragm composed of resilient fluid-tight material, such as rubber, have been widely employed. At relatively high pressures, however, the fluid-tight diaphragms have ruptured. My observations indicate that the two main causes of this diaphragm failure are a shearing and pinching. Actually, the pinching is just a particular kind of shearing of the diaphragm material. In the case of simple shearing, the diaphragm may be directly cut or sheared against solid switch parts,

and particularly against the end of the actuating piston itself. In the case of pinching, however, shearing does not take place until the material of the diaphragm has flowed or been otherwise moved into a crevice between relatively movable parts which are then subjected to relative movement. Pinching is a particularly serious problem in the region between the piston and the walls of the hole through the solid walls of the fluid containing chamber.

The switch of the present invention is useful at higher pressures than prior art switches despite the fact that it employs a fluid tight flexible diaphragm. The diaphragm of the present invention, like diaphragms used in the prior art low pressure applications, functions in two capacities, to wit: it provides a fluid tight barrier and it provides an actuating means for opertaing the switch. It is not necessary to employ a special material which has high tensile strength and shear resistance for the diaphragm. In fact, any ordinary flexible resilient, noncompressible material, such as India rubber, may be employed for general applications. This diaphragm material is prevented from shearing by careful shaping and arrangement of switch parts to avoid sharp corners and edges and to avoid crevices between relatively movable parts. Crevices into which the diaphragm material might flow, be pinched and shear are avoided by providing very close tolerances between relatively movable members.

More specifically, the pressure sensitive switch of the present invention comprises a chamber having bounding walls for containing the fluid under high pressure. A piston extends into a first opening in one of the bounding walls and is so mounted that it has limited movement. A second opening is provided in another of the bounding walls of the chamber in order to permit the entry of the fluid. Then a deformable, resilient, noncompressible diaphragm is arranged in the chamber across the first opening and held in place against the chamber bounding walls in order to form a fluid tight barrier. This barrier prevents the flow of fluid through said first opening. The chamber walls are so formed that they present a smooth and essentially continuous surface to that surface of the diaphragm which is adjacent the piston. Preferably, the end of the piston nearest the diaphragm does not extend into the chamber, but lies within a bounding wall. Thus, this end of the piston is always recessed from the general surface level of the bounding wall. The chamber wall presents a smooth and essentially continuous surface to the diaphragm, and in the preferred form of the invention the diaphragm extends into the opening in the wall and into contact with the end of the piston. The piston is made to fit the first opening to extremely close tolerances so that there is no opportunity for the diaphragm material to flow between the piston and the bounding wall in the region of the first opening.

For a better understanding of the present invention, reference is made to the accompanying drawings which may be referred to as follows:

Fig. 1 illustrates in vertical section a form of the present invention which will find general application in fluid pressure systems.

Fig. 2 illustrates a modified form of the switch of the present invention also shown in vertical section.

Fig. 3 illustrates the structure of Fig. 2 in the position it assumes after actuation.

Fig. 4 illustrates another modification of the switch of the present invention which is useful in applications where the fluid might have an undesirable chemical effect on the material of the resilient diaphragm.

Referring to Fig. 1, it will be observed that the switch has a chamber **10** having bounding walls formed by metallic members **11** and **12**. A piston member **13** extends into an opening **14** (hereafter called the first opening) in the metallic bounding wall **12**. The piston does not extend clear through the bounding wall but is terminated relatively closer to the chamber than to the outside of the bounding wall.

The piston is preferably terminated in a square surface generally perpendicular to the elements of the cylindrical bore or opening **14** in which the piston rides. "Square end" will be understood to mean that the end of the piston might be slightly concave. In any event, the square end of the piston at its closest approach to the chamber is recessed from all regions of the opening **14** which are curved or contoured to prevent cutting of the diaphragm.

Within the chamber, a deformable, resilient, noncompressible diaphragm **15** is arranged across the first opening **14** and held in place against chamber wall **12** in a manner which will hereafter be described. The diaphragm is preferably of suitable form to also contact the end of piston **13**, even though the piston is recessed within member **12**. The diaphragm **15** provides a fluid tight barrier which will prevent the flow of fluid through the first opening **14**. The chamber walls **11** and **12** which contact the diaphragm are made smooth and essentially continuous in those areas which contact the surface of the diaphragm.

The piston **13** by virtue of its exact fit within first opening **14** is confined to linear movement. A radial flange **17** on the piston is arranged to be enclosed by shoulders **18** and **19** in order to limit the amount of linear motion permitted the piston. Shoulder **18** is preferably formed as part of the bounding wall **12**. Shoulder **19** is preferably the bottom surface of a radial flange extending inwardly from generally tubular housing member **20**. The housing member **20** and the metallic bounding wall member **12** are advantageously made threadably engageable at a junction **21** in order to fix the shoulders **18** and **19** relative to one another to enclose flange **17**.

Pressure is supplied the piston **13** in order to urge it downward toward the flexible diaphragm **15**. This pressure is advantageously supplied by a coil spring **23**. The coil spring may be made to extend between some portion of the piston such as second radial flange **24** on the piston and some portion or extension of housing member **20**, such as sleeve closure member **26**. Sleeve closure member **26** is advantageously engaged within housing **20** in such a manner that its axial position may be adjusted in order to increase or decrease the effective pressure of coil spring **23** which is exerted upon piston **13**. Sleeve closure member **26** may be provided with portions which snugly engage the piston **13** in order to preserve its axial alignment within housing **20** and first opening **14**.

The remote end **28** of piston **13** is made to contact lever arm **29**. When the switch is actuated, force is exerted by the end **28** of piston **13** upon the lever arm against a fulcrum provided by bracket hook **30**, which force causes rotation about this fulcrum. In rotating, the relative light return spring **31** which extends between lever arm **29** and a mounting tab **32** on housing **20** is extended. A contact member **33** is provided at the end of lever arm **29**. This contact member is adjustable, in that it is a screw, so that it is possible for the lever arm contact to be adjusted to engage fixed contact **34** at various lever arm levels. Electrically a circuit may be completed, for example, by connecting the terminals of the circuit respectively to the lever arm contact **33** and to the fixed contact **34**.

Referring again to the chamber **10**, a second opening is provided, this time in metallic bounding wall **11** in order to afford actuating fluid access to the chamber. The fluid system may be coupled to the switch using the enlarged threaded portion **37** adjacent the second opening **36**.

All surfaces which contact the resilient diaphragm should be relatively smooth and continuous. Even the corners between adjacent portions of metallic bounding wall **11** against which the diaphragm is not ordinarily forced should be rounded in order to be certain to prevent the shear of the flexible diaphragm **15** at the high pressures involved. However, it is essential that all surfaces against which the diaphragm will be forced by fluid pressure be smooth and that all edges and corners be rounded. In particular, it is essential that the corner **40** between the interior surface of bounding wall **12** and the sidewalls of hole **14** be rounded and made quite smooth. It is quite difficult to state in absolute terms the specific amount of rounding which is required. This amount will obviously vary with the diaphragm material used and the amount of pressure employed. However, on conventional silicone rubber materials having a durometer hardness reading on the Shore A scale of between 30 and 60, a minimum radius of curvature of 0.015 inch is necessary. A greater radius in the order of $\frac{1}{32}$ inch is preferred and will give more consistently satisfactory results in the pressure range of from 3,000 to 10,000 pounds per square inch.

In addition to keeping the radius of curvature of shoulders, edges and corners relatively large and keeping the surfaces bounded by the resilient diaphragm smooth, it is extremely important to keep the clearance between moving parts, and particularly between the piston **13** and the first opening **14** sufficiently small that it is impossible for the diaphragm to flow into the crevice between these relatively movable members. It has been found that for materials having a durometer hardness reading on the Shore A scale between 30 and 60 for pressures between 3,000 and 10,000 pounds per square inch, the clearance should preferably be no more than .0005 inch. If the limitations on the structure described are followed for the conditions specified, there will be no opportunity for shear, pinching or abrasion which would otherwise cause wear and deterioration of the diaphragm.

As previously mentioned, it will be noted that the diaphragm in this case is preferably essentially a flat disc with an axial protrusion which preferably smoothly conforms to the surface of wall member **12**, the first opening **14** and the end of piston **13**. The end of piston **13** should be made perfectly square for best results although it might be slightly concave, and it should preferably be recessed at its point of nearest approach to the chamber, a distance just slightly larger than the radius of the shoulder between the interior bounding wall and the hole. The smaller the clearance between the end of the piston and the walls of the chamber, the less the opportunity for pinching the diaphragm therebetween. It has been found that pistons having approximately $\frac{1}{8}$ inch diameter are preferable in order to reduce the total amount of force applied to the end of the piston and yet have sufficient area for accurate actuation.

In the course of actuation of the switch of the present invention, fluid is caused to flow into the chamber **10** through second opening **36**. The increasing pressure tends to force the diaphragm **15** against the end of piston **13** and urge it upward. However, the coil spring **23** which bears against the piston determines the amount of force which is necessary to actuate the switch and the piston will not move upward until the amount of force supplied by coil spring **23** is counterbalanced and overcome. When the amount of fluid pressure exceeds the amount of spring pressure, the diaphragm **15** will be deformed upward into first opening **14** and the piston will be urged upward causing lever arm **29** to move upward. Contact **33** on lever arm **29** will then be able to contact fixed contact **34** and complete the electrical circuit involved.

It should be mentioned that in the actuation of the switch, the diaphragm is not compressed but is merely deformed. Compression is, practically speaking, not possible with solid materials such as rubber, etc. However, under the very high pressures involved, for all practical purposes the diaphragm **15** resembles a fluid substance and behaves in very much the same way a contained fluid would behave.

Referring now to Figs. 2 and 3 the structures illustrated are modified forms of the switch of the present invention. The switch illustrated differs in ony minor respects from the switch structure shown in Fig. 1 and accordingly only partial views of the structure are shown. In this case, the chamber **50** is bounded by metallic bounding walls **51** and **52**. These metallic bounding walls are advantageously castings which are arranged to cooperate with one another in such a manner as to support flexible resilient diaphragm **53** therebetween. Members **51** and **52** are held together by a pair of threaded joints. The first threaded joint is between housing member **54** and wall member **52**. The second joint is between housing member **54** and wall member **51**. Wall member **51** in this case is provided with a tubular extension **51*a***, the inside edge of which is threaded in order to engage threads on housing member **54**. As in the structure of Fig. 1 a piston member **55** extends through an axially positioned opening **56** in bounding wall **52**. The opening **56** will in this modified structure be referred to as the first opening.

The piston is provided with a radially extending flange **58** which is enclosed between housing member **54** and bounding wall member **52** and more specifically between radially inward extending flange **59** on the housing and the top of bounding wall **52**. A spring member **60** exerts pressure on the radial flange **61** of the piston in much the same manner as pressure is applied in the structure of Fig. 1.

In this case, the chamber **50** does not have the diaphragm **53** as one of its fluid containing walls. Instead, an intermediate layer **63** of material which may be selected to resist chemical attack is employed between the diaphragm and the chamber. As in the previous case, fluid is permitted entry through second opening **64** and wall member **51** and the fluid system supplying the fluid pressure may be coupled to the switch adjacent said opening by engagement with threaded portion **65**.

Comparison of Figs. 2 and 3 will illustrate the operation of the switch. Specifically, as fluid is introduced into chamber **50** through the second opening **64** the pressure increases until the force of the spring **60** is overcome. At this point, the piston will be able to move upward and away from the chamber **50**. The fluid will produce this upward movement by a deformation of the diaphragm **53** which is accomplished by a flexing of the sheet of protective material **63**. In other respects the operation of the switch is essentially the same as the operation of the switch illustrated in Fig. 1.

The material of the protective sheet **63** may be composed of nylon, Kel F and a variety of other inert plastic materials. Use of such material with substances such as oil will prevent the attack of the rubber composing the diaphragm by the oil or other materials.

It should also be noted that the position of the switch shown in Fig. 3 is its uppermost position since the radial flange **58** of piston **55** is prevented from moving further by shoulder **59**. At this point, the flexible diaphragm has reached its point of maximum deformity except that in the structure shown, it is possible for a limited amount of deformation to occur in the small space existing between members **52** and **51**. Since shoulders over which the diaphragm material flows are rounded in accordance with the provisions of the present invention, the opportunity for damage to the diaphragm is quite remote.

Referring now to Fig. 4, still another form of the present invention is illustrated. In this case, the chamber **70** is bounded by metallic boundary walls **71** and **72**. As in the case of the Fig. 2 and 3 structure, the bounding

walls are held together by their respective threaded engagement with housing member **73**. Housing member **73** has its inside diameter threaded for engagement with bounding wall member **71**, its outer wall at the same end is threaded for engagement with tubular extension **72*a*** of bounding wall member **72**. These pieces may all be placed together in threaded engagement with flexible diaphragm **75** and its associated parts and piston member **76** and its associated parts in position.

The piston **76** in this case is not a one-piece member, but is composed of two active portions, the portion which contacts the axially extending portion of the diaphragm here designated **77** is relatively short and provides what may be described as a floating action. This piece may be carefully machined to effect the necessary close clearances without making the balance of the piston **76** to the same precision.

This structure differs somewhat from the previously described structures in that the limitation of movement is accomplished in a slightly different manner. In this case, the piston **76** is provided with a radially extending flange **80** which, as in previous cases, rests against the top of metallic bounding wall member **12**, which limits its movement toward the chamber. Contrary to the previous cases, however, there is no flange on housing member **73**. Instead, the radial flange **80** extends outwardly sufficiently far to oppose a shoulder **81** on the housing **73**. Pressure is exerted by spring member **83** on block member **80*a*** which rests atop radially extending flange **80**. Spring member **83** is held in place by end cap **84** which is threadably engaged so that an adjustment of spring pressure may be obtained. The end cap **84** also provides a precision aperture through which the end of piston **76** penetrates in snug engagement therewith. The relatively snug engagement permits accuracy in maintaining alignment of the piston. In this instance, a directly actuated switch is provided with one contact **86** in the end of piston **76** and the other fixed contact **87** mounted directly opposite thereto and spaced away a distance comparable to that which the piston moves. A small amount of light spring pressure may be provided to fixed contact **87** to assure good contact between the two contact members **86** and **87**.

In this instance a sheet of chemically inert, resilient material **89** is employed in much the same way and for much the same reasons that it was employed in the structures of Figs. 2 and 3. However, it is contemplated that the protection afforded the diaphragm by the constructions of Figs. 2 and 3 may not be adequate when highly caustic or otherwise destructive chemicals are employed as the fluid for actuating the switch. When such chemicals are employed, it is advisable also to employ a resilient toroidal ring **90** of the same material as the sheet **89** to insure that none of the destructive chemical reaches the rubber diaphragm. Though it has not been shown, it is possible and might be advisable when using highly destructive chemical materials to provide a coating of some inert plastic material over the whole bounding wall of the chamber **70**.

It should be pointed out that the switches illustrated in Figs. 2–4 are probably unsatisfactory for cold temperature applications at temperatures in the order of −65° F. However, switches of the type illustrated in Fig. 1 employing normal industrial rubber or neoprene may be employed at such low temperature levels. Of course, the fluid employed in this instance should not be oil or any other chemical material which will cause destruction of the rubber diaphragm if long life is expected. With chemically inactive fluids, the structure of Fig. 1 is useful over an extremely wide range of temperatures without materially affecting the accuracy of the switch.

It is possible to change the sensitivity of any of the various switches described by employing different types of diaphragm materials as well as by adjustment of the spring. Different types of diaphragm materials will, however, vary the accuracy of the switch more severely than will variation of spring fulcrums. In this connection it should be pointed out that most of the inert materials which may be employed to protect the rubber diaphragm are of harder, less flexible consistency than is the rubber diaphragm and accordingly will present a relatively harder, less flexible surface to the fluid. As a consequence the switch structure of the type of Fig. 1 is ordinarily more sensitive than the modified forms of the switch described. However, any of the other possible varieties may be made extremely sensitive so that it will respond at the desired pressure within very close tolerances despite the high pressures encountered.

Various modifications in the structures described specifically herein are possible and will occur to those skilled in the art. All such modifications within the scope of the claims are intended to be within the scope of the present invention.

I claim:

1. A pressure sensitive switch comprising a chamber having bounding walls, a piston having a square end extending into a first opening in the bounding walls and snugly accommodated within the first opening so that its end nearest the chamber is always recessed within the first opening away from the general surface level of the bounding walls and the smooth contoured region of the first opening at said bounding wall, opposed stops on the piston and on said walls to limit movement in the direction of extension through the opening, a second opening in the bounding walls of the chamber permitting the entry of fluid, a deformable, resilient, non-compressible diaphragm arranged in the chamber across the first opening held in place against the chamber bounding walls adjacent said first opening to form a fluid tight barrier and extending into the opening in the wall into contact with the bottom of the piston, a smooth and essentially continuous surface being presented at all positions of the piston to that surface of the diaphragm which is adjacent the piston.

2. A structure as described in claim 1 in which the surface of the diaphragm remote from the piston is bounded by a resilient material of harder durometer reading than the diaphragm.

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