Nov. 26, 1957 N. J. ROCHE 2,814,689

DIFFERENTIAL PRESSURE SWITCH

Filed April 25, 1955 2 Sheets-Sheet 1

FIG. 1

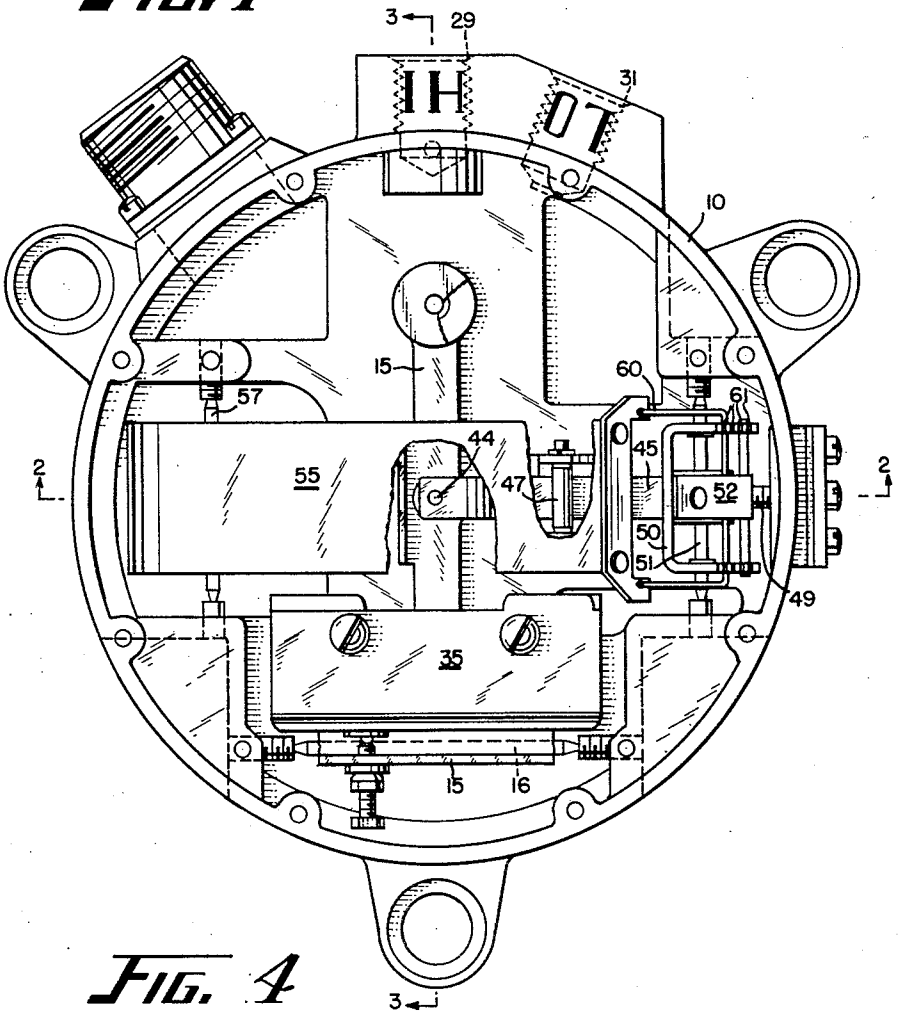
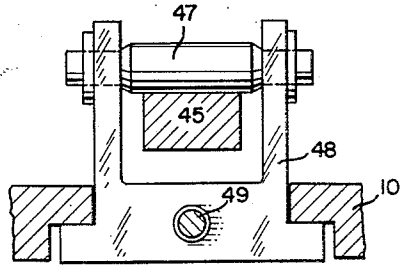


FIG. 4



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FIG. 2

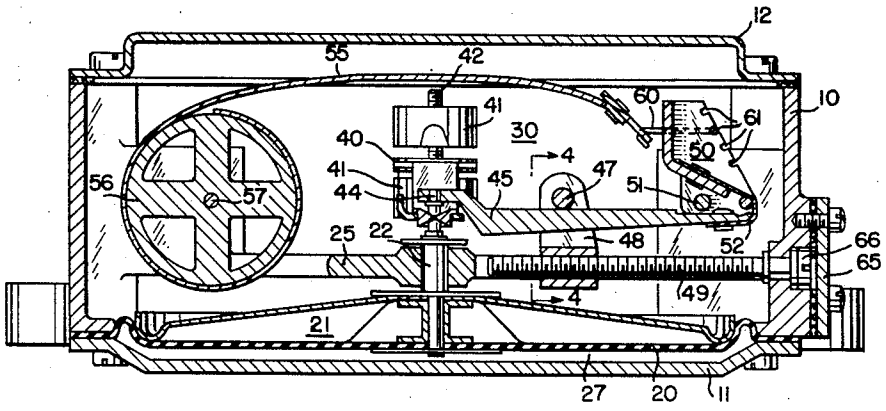


FIG. 3

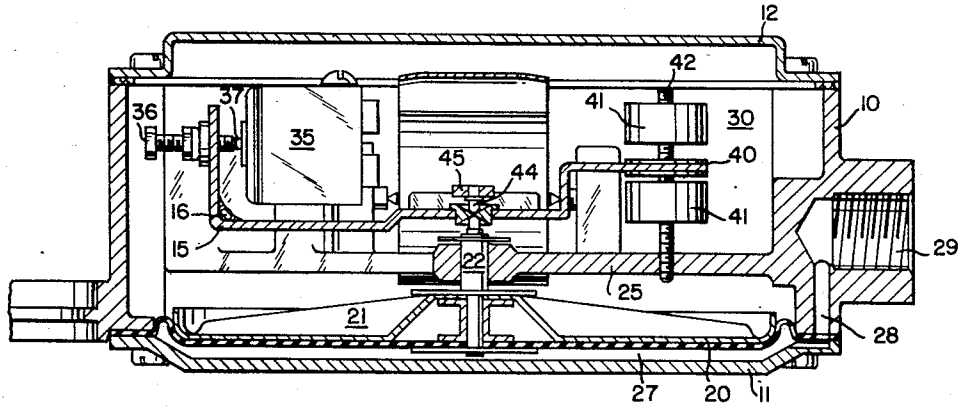
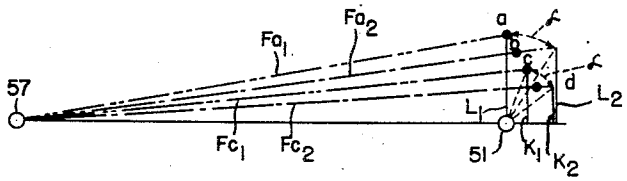


FIG. 5



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DIFFERENTIAL PRESSURE SWITCH

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9 Claims. (Cl. 200—83)

This invention relates to differential pressure switches for use in low pressure applications and adaptable to respond to a wide range of low pressures. This switch has particular adaptability for aircraft use. The embodiment of my invention shown has universal application over the low pressure range from approximately 1" water to 30" water. The novel features of this control device permit covering this wide range and at the same time having extremely low differential over the entire range.

Therefore, one of the objects of my invention is to provide a differential pressure switch with a wide pressure range.

Another object of my invention is to provide a differential pressure switch having low differential over a wide operating pressure range.

Yet another object of my invention is to have a differential pressure switch with the above features that is rugged, small in size, light in weight, and inexpensive to manufacture.

These and other objects of the present invention will readily become apparent as the following description is read in light of the accompanying drawings in which:

Figure 1 is a plan view of a differential pressure switch embodying my invention with the cover removed;

Figure 2 is a section taken along lines 2—2 in Figure 1, looking in the direction of the arrows;

Figure 3 is a section taken along lines 3—3 in Figure 1, looking in the direction of the arrows;

Figure 4 is a section taken along lines 4—4 in Figure 2, looking in the direction of the arrows;

Figure 5 is a diagram representing the lines of force of the spring means and lever system of Figure 2.

In the drawings is shown a casing 10 having a bottom cover 11 and a top cover 12. A lever 15 is pivoted in casing 10 by a pivot pin 16 which is cemented or welded to lever 15. A flexible diaphragm 20 is mounted at the bottom of casing 10 and held in place by bottom cover plate 11. A pressure plate 21 bears on diaphragm 20 and has a post 22 extending from the center thereof which bears on lever 15. A portion 25 of casing 10 has a suitable opening to receive post 22 while allowing axial movement of post 22 in casing 10.

The space 27 between diaphragm 20 and cover 11 is connected by a passageway 28 to a pressure connection 29, and space 27 forms the high pressure side of the differential sensing mechanism. The portion of the casing above pressure plate 21 and enclosed by cover 12 forms a chamber 30 which is the low side of the differential sensing mechanism. A pressure connection 31 opens directly into chamber 30 through the side of casing 10.

A snap acting switch 35 of the plunger actuated type is mounted in casing 10. A screw 36 adjustably mounted in the left end of lever 15, as seen in Figure 3, bears on the actuator plunger 37 of switch 35 (and determines the on or off position of switch 35). An armature 40 is formed at the right end of lever 15 and is positioned between two permanent magnets 41 adjustably mounted in casing 10 on a screw 42.

The left end 44, of a second lever 45, as seen in Figures 1, 2 and 3, bears on lever 15 in line with post 22. The lever 45 is pivoted on a roller fulcrum 47 carried by a carriage 48 which is guided in the casing 10 for movement lengthwise of the lever. The position of fulcrum 48 may be adjusted by a screw 49 as will hereinafter appear. A bell crank lever 50 is pivoted in casing 10 on a pivot pin 51, and has a horizontally extending arm which is attached to the right end of lever 45 by a flexible strap 52.

A Negator spring 55 is mounted in casing 10 on a drum 56 pivoted in casing 10 on a pivot pin 57. On the right end of Negator spring 55 there is attached a U-shaped wire 60 that engages a pair of plurality of notches 61 in lever 50. Negator spring 55 biases lever arm 50 in a counter clockwise direction about pivot 51, this in turn biases lever 45 in a counter clockwise direction about roller fulcrum 47, and results in a downward bias on lever 15 at the point where the left end 44 of lever 45 bears on lever 15. This biases lever 15 clockwise about pivot 16 causing screw 36 to hold plunger 37 in its depressed position.

The switching action occurs when the differential pressure across the diaphragm is large enough so the force on lever 15 through post 22 overcomes the downward bias of lever 45 on lever 15 and lever 15 rotates counter clockwise about pivot 16 moving screw 36 away from plunger 37 and actuating switch 35.

Permanent magnets 41 can be adjusted on screw 42 so as to be in proper relationship with armature 40 of lever 15. The armature will normally be nearer to the lower of the two magnets, which will resist movement of armature 40, when armature 40 moves from the lower magnet, the effect of the lower magnet will decrease at a decreasing rate and the effect of the upper magnet will increase at an increasing rate. The converse of this will be true upon movement of armature 40 from the upper magnet toward the lower magnet. The effect of this on the device is to introduce negative spring rate which will compensate for the spring rate of the snap switch 35 and hence lower the differential of the complete device. The term "negative rate" as it is used here should be defined. The meaning of the term "spring rate" as commonly used is assumed; i. e., the force change due to motion tends to retard the motion. Since this is commonly accepted I shall refer to it hereinafter as positive rate. My concept of negative rate, is, of course, the inverse of positive rate; i. e., the force change due to motion tends to augment the motion.

The differential pressure at which the switching action will occur can be selected by the proper positioning of roller fulcrum 47, which may be accomplished by rotation of screw 49. Removal of a cover 65 allows access to the slotted head 66 of screw 49. In the particular embodiment of my invention from which the drawings were made, a differential pressure of approximately 1" water will actuate the snap switch 35 when the roller fulcrum 47 is near its extreme adjustment to the right of lever 45 and a differential pressure of 30" of water will actuate the snap switch 35 when the roller fulcrum 47 is near its extreme adjustment to the left of lever 45.

Movement of the diaphragm 20 upon an increase in differential pressure will decrease the effective area of the diaphragm, and this will affect the device in the same way as a positive spring rate. The change in the effective moment arm upon clockwise rotation of lever arm 50 will affect the device in the same way as a negative spring rate, which compensates for the positive spring rate effect of the change in area of the diaphragm 20,

For a further explanation of the negative spring rate effect of the arrangement of lever 50, Figure 5 is now referred to. An inherent feature of the Negator spring of this arrangement is that it supplies constant force regardless of the amount of its extension. The line of force is from the point of application on the lever 50 to the center of the coil or pivotal axis of the drum 56 as shown in Figure 2. With the point 51 being the pivot point of lever 50 and points *a*, *b*, *c*, and *d* representing the notches in lever 50 the lines of force will be dependent on which notches the U-shaped wire 60 is hooked into. Lines Fa_1 and Fa_2 show the lines of force before and after, respectively, rotation of lever 50 through angle α when U-shaped wire 60 is hooked in notch *a*, and lines Fc_1 and Fc_2 show the lines of force before and after, respectively, rotation of lever 50 through angle α when U-shaped wire 60 is hooked in notch *c*. It can be seen that when U-shaped wire 60 is hooked in notch *a* and lever 50 rotates through angle α, the moment arm corresponding to L_1 becomes smaller and Negator spring 55 has less restraining force on lever 15 through levers 45 and 50. This decrease in effect of Negator spring 55 is the equivalent of negative spring rate on the operation of the device. Also when U-shaped wire 60 is hooked in notch *c* and lever 50 rotates through angle α the moment arm corresponding to K_1 becomes smaller at a greater rate than the moment arm corresponding to L_1 produced when the U-shaped wire 60 is connected to notch *a* and lever 50 rotates through angle α or the ratio of K_1 to K_2 is obviously greater than the ratio of L_1 to L_2. Thus it can be seen that the amount of effective negative spring rate per angular degree of movement of lever 50 introduced in the device is determined according to which of the notches U-shaped wire 60 is connected.

The U-shaped wire 60 will be hooked in one of the notches *a*, *b*, *c*, or *d* at the factory depending upon the specific range of pressures the control device will be used in: notch *a* for the 14 to 30 inches of water range; notch *b* for the 8 to 22 inches of water range; notch *c* for the 4 to 14 inches of water range; and notch *d* for the 1 to 8 inches of water range.

The diaphragm 20 moves the same distance to drive the snap switch 35 through its differential for any of the control point settings for any of the pressure ranges. As the force on lever 15 from the diaphragm 20 is equal to the effective area times the pressure on the diaphragm a greater force results at the higher pressure range. This means that there will also be a greater positive spring rate effect at the higher pressure ranges than at the lower ones due to the same change in effective area of the diaphragm. Therefore the negative spring rate necessary to compensate the positive spring rate due to effective area change on movement of diaphragm 20, is greater at a higher pressure control point than at a lower pressure control point.

The negative spring rate effect, of the Negator spring 55 and lever 50, at lever 15, opposing diaphragm 20, is multiplied by the lever or ratio of lever 45 about roller fulcrum 47. At the high pressure control point the roller fulcrum is near its extreme adjustment to the left of lever 45 and a lever ratio of approximately 5 to 1 exists between the point of application of the Negator spring force through lever 50 and lever 45 to lever 15. At the low pressure control point the effective lever ratio through which the spring acts on the diaphragm is approximately 1 to 5. This means that the rotary movement of lever 50 is considerably greater at the highest pressure control point than at the lowest pressure control point. Therefore the notch *a* is used in the high range of pressures as the smaller negative spring rate per degree of rotation is multiplied by approximately 5, whereas in the low range of pressures notch *d* is used as the higher negative spring rate per degree of rotation is multiplied by approximately ⅕ resulting in a net effect at lever 15 of a higher compensating negative spring rate at the higher pressure range than the lower pressure range. The combined effect of positive rate of the diaphragm and the negative effective spring rate through lever 50 and lever 45 gives substantially the same operating differential at all ranges of operation.

While each notch is at the optimum location for only one setting of the roller fulcrum 47 and ideally an infinite number of locations for the application of the spring force on lever 50 could be provided, for practical purposes the four notches shown provide adequately close adjustment and deviations from optimum meet practical requirements while maintaining desirable simplicity. Therefore, each of the notches 61 is used in its respective range of control point settings with the final field adjustment made by adjusting screw 49.

The use of the magnets to compensate for the spring rate of the snap switch and the Negator spring and lever 50 arrangement to compensate for the spring rate of the effective change in area of the diaphragm upon movement allow the features of a relatively wide range of control point selection, maintaining the lowest possible differential for all of the ranges of control point selection all in one device that is rugged, inexpensive to manufacture, light in weight, and small in size.

Although I have described my invention in my preferred form for carrying my invention into effect, it is to be understood that variations and modifications may be had without departing from the spirit of the invention. I therefore intend to limit the scope of my invention only by the appended claims.

I claim as my invention:

1. Spring rate compensation apparatus comprising: a support member; a lever pivotally connected to said support member; condition sensing means including a force output member having a positive spring rate with increases in the magnitude of the condition sensed, the force output member of said sensing means operatively associated with a first portion of said lever removed from the pivot point thereof for applying a force thereto; and spring means associated with a second portion of said lever removed from the pivot point thereof and having an effective negative spring rate with increases in the magnitude of the condition sensed by said sensing means, said spring means being arranged to apply a force to the second portion of said lever with the resulting moment opposing the moment due to the force applied by said sensing means, a decrease in moment resulting from the force due to said spring means accompanying an increase in moment resulting from an increase in force due to said sensing means.

2. A differential pressure switch comprising: a casing; a mechanical linkage including a first lever; an adjustable fulcrum for said first lever in said casing; a diaphragm having a spring rate of deflection for sensing differential pressure mounted in said casing; said diaphragm applying a force to the first end of said first lever as a function of the differential pressure sensed by said diaphragm; a second lever of said mechanical linkage pivoted in said casing, said second lever being pivotally attached to the second end of said first lever; spring means for applying a force to said second lever and hence to said first lever opposing the force applied to said first lever by said diaphragm, a plurality of places for applying the force of said spring means to said second lever; the effective moment arm of said second lever decreasing upon pivotal movement thereof due to increases in pressure differential with a resultant decreasing effective force being applied to said first lever, said change in effective force on said first lever effectively compensating the spring rate of deflection of said diaphragm; a selection of a plurality of available different forces and spring rates to oppose the differential pressure on said diaphragm due to said plurality of points for application of the force of said spring means on said second lever and said adjustable fulcrum of said first lever; said spring means normally biasing said second and

first levers to a first position, said levers pivoting to a second position upon the moment arising due to a differential pressure at said diaphragm being greater than the moment arising due to the opposing force of said spring means; and switch means actuated by a portion of said mechanical linkage upon pivotal movement of said levers between the first and second positions thereof.

3. A differential pressure switch comprising: a casing; a mechanical linkage including a first lever; an adjustable fulcrum for said first lever in said casing; a diaphragm having a spring rate of deflection for sensing differential pressure mounted in said casing, said diaphragm applying a force to the first end of said first lever as a function of the differential pressure sensed by said diaphragm; a second lever of said mechanical linkage pivoted in said casing, said second lever being pivotally attached to the second end of said first lever; spring means for applying a force to said second lever and hence to said first lever opposing the force applied to said first lever by said diaphragm; the effective moment arm of said second lever varying upon pivoted movement thereof, said change in effective moment arm of said second lever resulting in varying the effective force acting in opposition to movement of said diaphragm and thereby effectively compensating the spring rate of deflection of said diaphragm; said second lever comprising two interconnected substantially triangular parallel arms having a plurality of notches along parallel edges thereof and having the pivot point of said second lever in the corner of said parallel arms opposite said edges with said plurality of notches, said pivotal attachment of said second lever to said first lever being at a corner of said parallel arms adjacent said notch edges of said parallel arms, a U-shaped wire attached to one end of said spring means cooperating with said notches in said second lever, a different effective force differential per degree of rotation of said second lever for each of said notches used to apply an effective force to said second lever; said spring means normally biasing said second and first levers to a first position, said levers pivoting to a second position upon the moment arising due to a differential pressure of said diaphragm being greater than the moment arising due to the opposing force of said spring means; and switch means actuated by a portion of said mechanical linkage upon pivotal movement of said levers between the first and second positions thereof.

4. A differential pressure switch comprising: a casing; a mechanical linkage including a first lever; an adjustable fulcrum for said first lever in said casing; a diaphragm having a spring rate of deflection for sensing differential pressure mounted in said casing, said diaphragm applying force to a portion of said first lever removed from said adjustable fulcrum; a second lever of said mechanical linkage pivoted in said casing, said second lever actively cooperating with said first lever; spring means for applying a force to said second lever and hence to said first lever opposing the force applied to said first lever by said diaphragm; pivotal motion of said second lever effectively changing the length of the moment arm upon which said spring means operates thereby varying the effective force on said first lever, said change in effective force on said first lever effectively compensating the spring rate of deflection of said diaphragm; said spring means normally biasing said second and first levers to a first position, said levers pivoting to a second position upon the moment arising due to a differential pressure of said diaphragm being greater than the moment arising due to the opposing force on said first lever from said spring means; and switch means actuated by a portion of said mechanical linkage upon pivotal movement of said levers between the first and second positions thereof.

5. A differential pressure switch comprising: a casing; a mechanical linkage including a first lever; an adjustable fulcrum for said first lever in said casing; a diaphragm having a spring rate of deflection for sensing differential

pressure mounted in said casing, said diaphragm applying a force to a first portion of said first lever removed from said adjustable fulcrum as a function of the differential pressure sensed by said diaphragm; a second lever of said mechanical linkage pivoted in said casing, said second lever being pivotally attached to a second portion of said first lever; spring means for applying a force to said second lever and hence to said first lever opposing the force applied to said first lever by said diaphragm; the effective length of the force transmitting lever arm of said second lever changing upon pivotal movement of said second lever arm, a change in effective force resulting from said changing effective length opposing movement of said diaphragm, said change in effective force compensating the spring rate of deflection of said diaphragm, the amount of said change in effective length of the force transmitting lever arm of said second lever per degree of rotation being different for different points of application of said spring means to said second lever arm; said spring means normally biasing said second and first levers to a first position, said levers pivoting to a second position upon the moment arising due to a differential pressure in said diaphragm being greater than the moment arising due to the opposing force on said first lever from said spring means; and switch means actuated by a portion of said mechanical linkage upon pivotal movement of said first lever between the first and second position thereof.

6. Spring rate compensation apparatus comprising: condition sensing means having a spring rate of deflection for producing a force as a function of the condition sensed; balancing means for providing a force opposing the force produced by said condition sensing means; a mechanical linkage including first and second interrelated levers, the force provided by said condition sensing means being applied to said first lever, the force provided by said balancing means being applied to said second lever, said forces being applied to said levers so as to be in opposition to each other; pivotal movement of said second lever as a result of change in the condition sensed by said condition sensing means changing the effective moment arm of said second lever resulting in a varying effective force being applied to said first lever, an adjustable fulcrum for varying the lever ratio of said first lever, a plurality of places for attaching said balancing means to said second lever with the resulting effective force upon pivotal movement of said second lever arm different for each place of attachment, the spring rate deflection of said condition sensing means being effectively compensated by the change in effective force upon pivotal movement of said second lever.

7. Spring rate compensation apparatus comprising: a linkage; a condition sensing means having a spring rate of deflection for applying a force to a first portion of said linkage as a function of the condition sensed; and balancing means for applying a force to a second portion of said linkage opposing the force produced by said condition sensing means; said linkage providing an effective spring rate upon movement thereof compensating for the spring rate of said condition sensing means; a first adjusting means included in said linkage for varying the force of said balancing means opposing the force of said condition sensing means, a second adjusting means included in said linkage for varying said compensating spring rate.

8. A pressure responsive device comprising a casing, a diaphragm in said casing moveable in response to differential pressure, a switch having a predetermined motion requirement to move through its operating differential, means operatively connecting said diaphragm and said switch, a lever having a first end positioned by said diaphragm, a pivot for said lever in said casing engaging said lever intermediate its ends and adjustable lengthwise of said lever, a member pivoted in said casing, means connecting the second end of said lever and said member causing pivotal movement of said member proportional

to the displacement of the second end of said lever, and a spring connected between said member and said casing and biasing said member in a direction to oppose movement of said diaphragm due to an increase in pressure differential, said spring being connected to said member at a point so that as said diaphragm moves due to an increase in pressure differential the effective lever arm through which said spring acts on said member will decrease.

9. A pressure responsive device comprising a casing, a pressure sensing means in said casing, a switch, means connecting said pressure sensing means and said switch for operation thereby, a lever having a first end positioned by said pressure sensing means, a pivot engaging said lever so as to provide pivotal motion of said lever, said pivot being adjustable lengthwise of said lever, a member pivoted in said casing, means connecting said member and the second end of said lever causing pivotal motion of said member proportional to the displacement of the second end of said lever, a spring connected between said

member and said casing to bias said member in a direction to oppose movement of said pressure sensing means, said spring being connected to said member at a point so that as said diaphragm moves due to an increase in pressure differential, the effective lever arm through which said spring acts on said member will decrease, and means for varying the point of connection between said spring and said member to vary the extent of reduction in effective lever arm as said member moves through a predetermined angle.

References Cited in the file of this patent

UNITED STATES PATENTS

2,337,001	Ray	Dec. 14, 1943
2,339,847	Ellison	Jan. 25, 1944
2,586,972	McKenzie	Feb. 26, 1952
2,615,102	McMath	Oct. 21, 1952
2,647,743	Cook	Aug. 4, 1953