United States Patent

[11] 3,571,540

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[54] RESILIENT REED TYPE ACTUATOR MECHANISM
23 Claims, 11 Drawing Figs.

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[51] Int. Cl. H01h 13/36
[50] Field of Search ..... 200/67 (D), 67 (D1), 67 (D2), (Cursory)

[56] References Cited

UNITED STATES PATENTS

2,583,756	1/1952	Wahlberg	200/670(UX)
2,659,238	11/1953	Martin	200/67D(UX)
2,373,681	4/1945	Heikes	200/67D2(UX)
3,032,623	5/1962	Ball, Jr.	200/67D2(UX)
3,094,594	6/1963	Watson	200/67D(UX)
3,142,741	7/1964	Bury	200/67D(UX)
3,415,962	12/1968	Krieger	200/67D(UX)

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ABSTRACT: An actuator mechanism includes a chamber with one end portion of an elongated resilient reed member disposed therein. The reed member is pivotally but nonshiftably associated with the chamber at its point of entry therein to facilitate sealing of the chamber from the external environment. Overcenter or toggle means are provided for yieldably maintaining the one end portion of the reed member in either of two spaced positions. Several preferred arrangements are disclosed for effecting a crisp, toggle action on angular displacement of the one reed end portion between its spaced positions irrespective of the rate of movement of the remaining reed end portion. A variation of the above construction which is especially well suited for use as a miniature electrical switch is also disclosed.

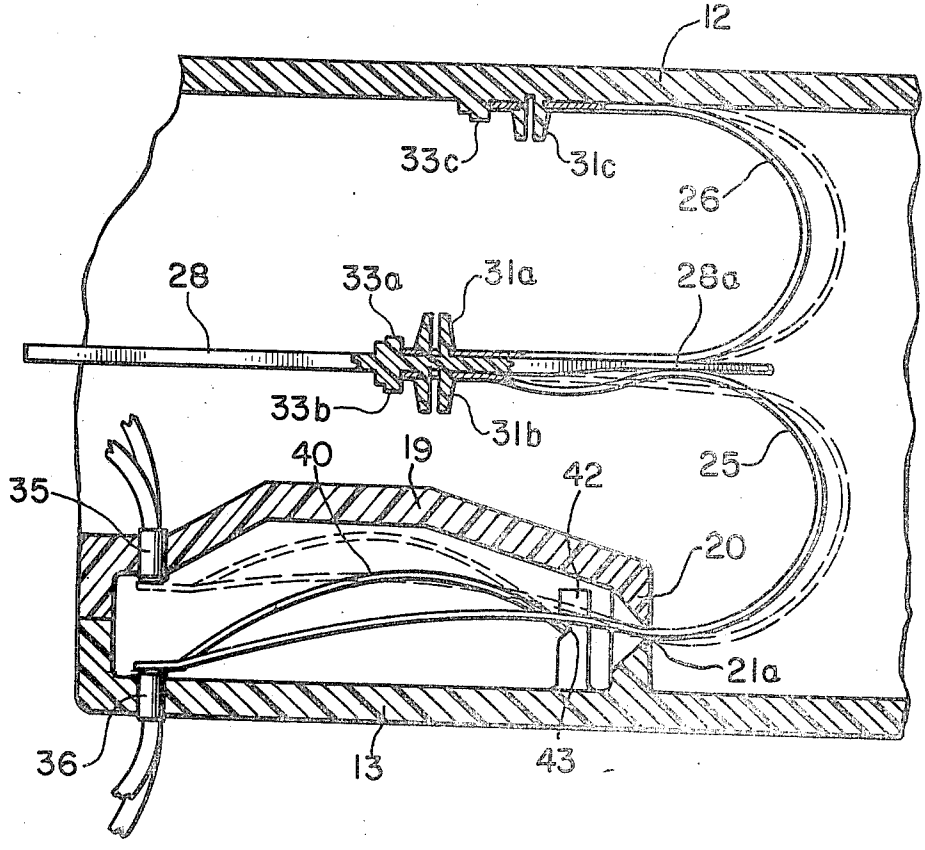


FIG. 1

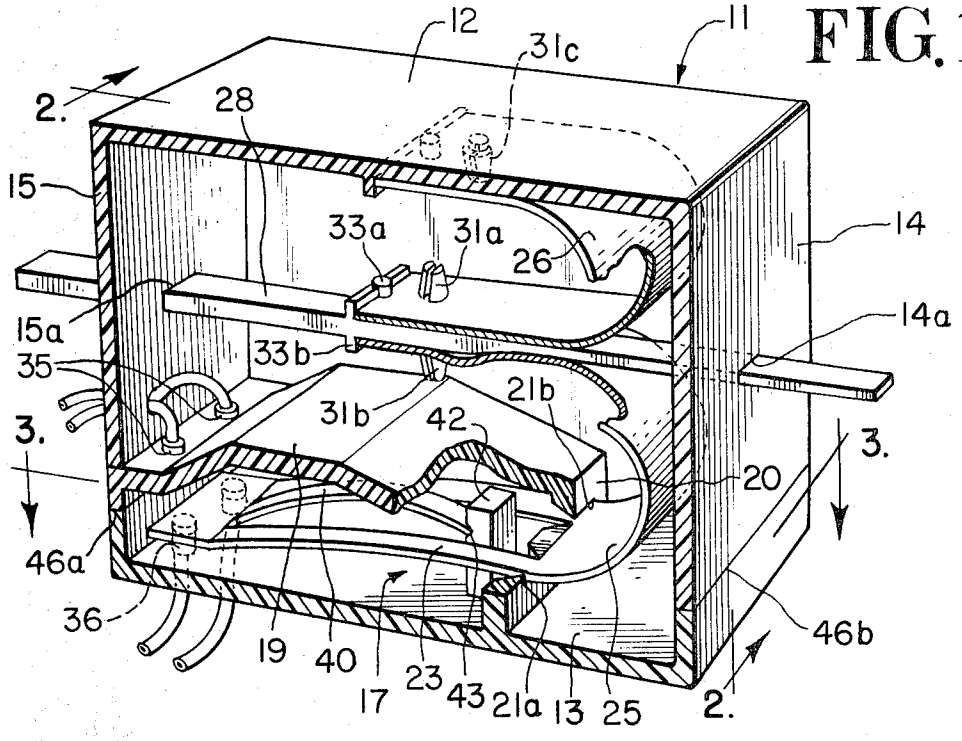
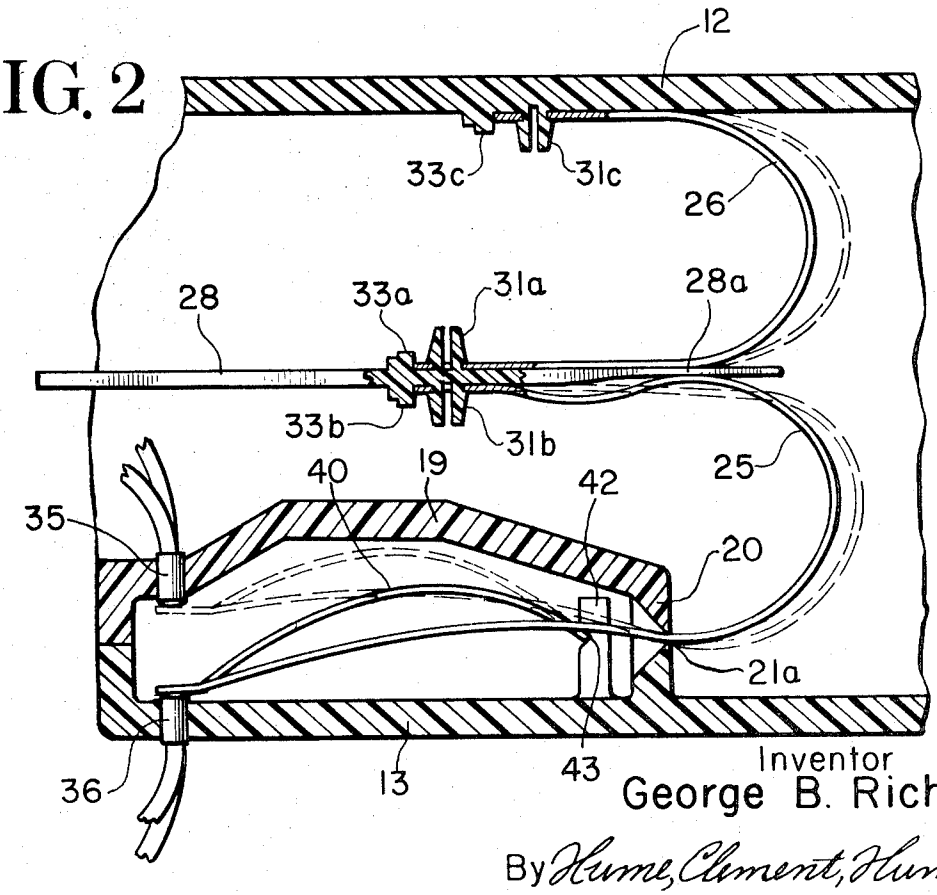


FIG. 2



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FIG. 3

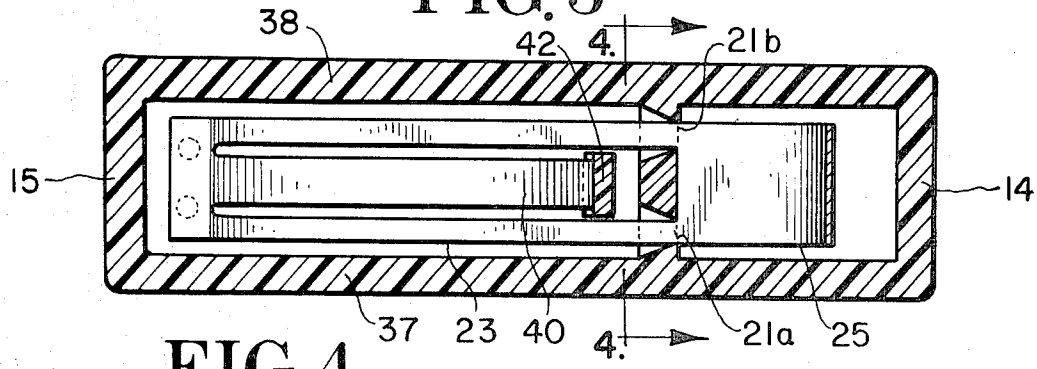


FIG 4

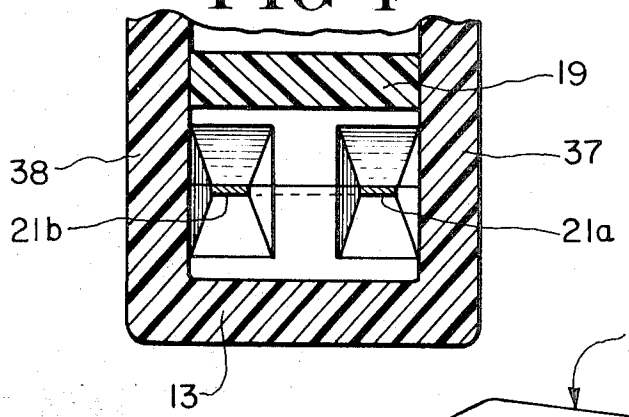


FIG. 6

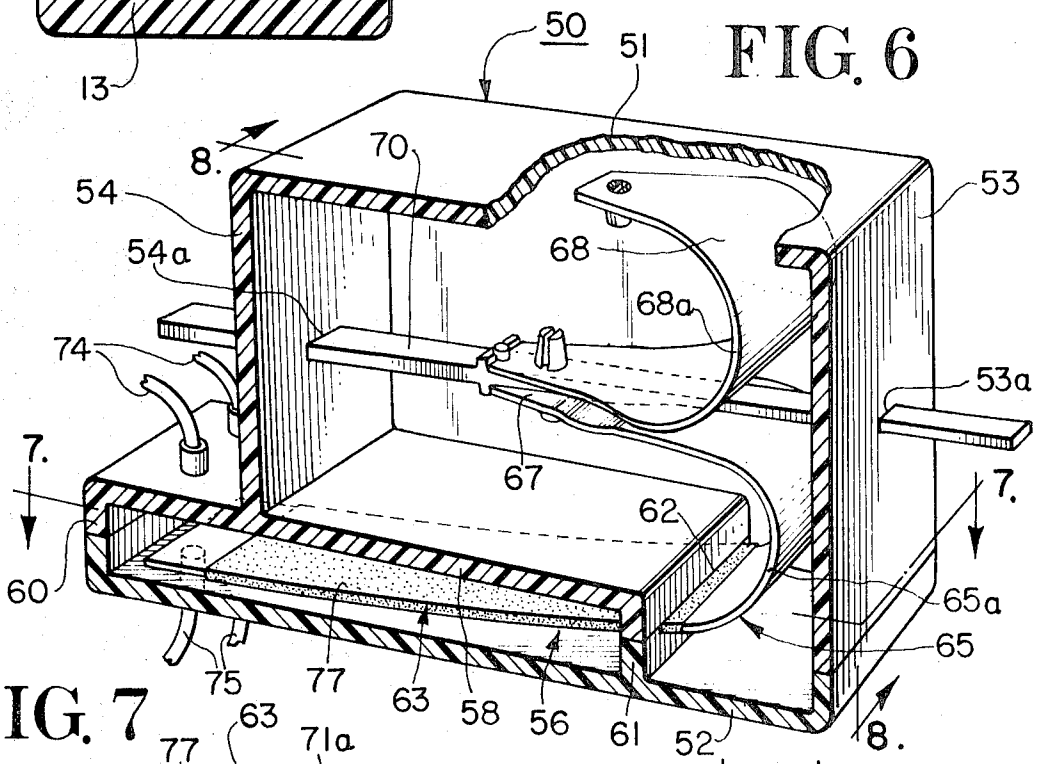
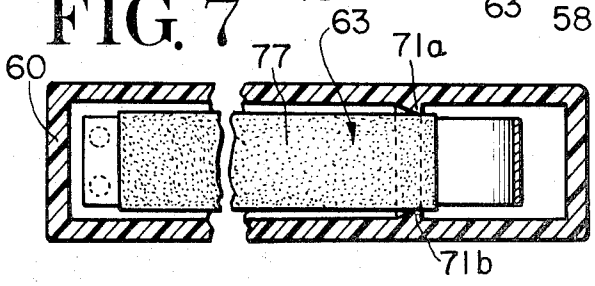
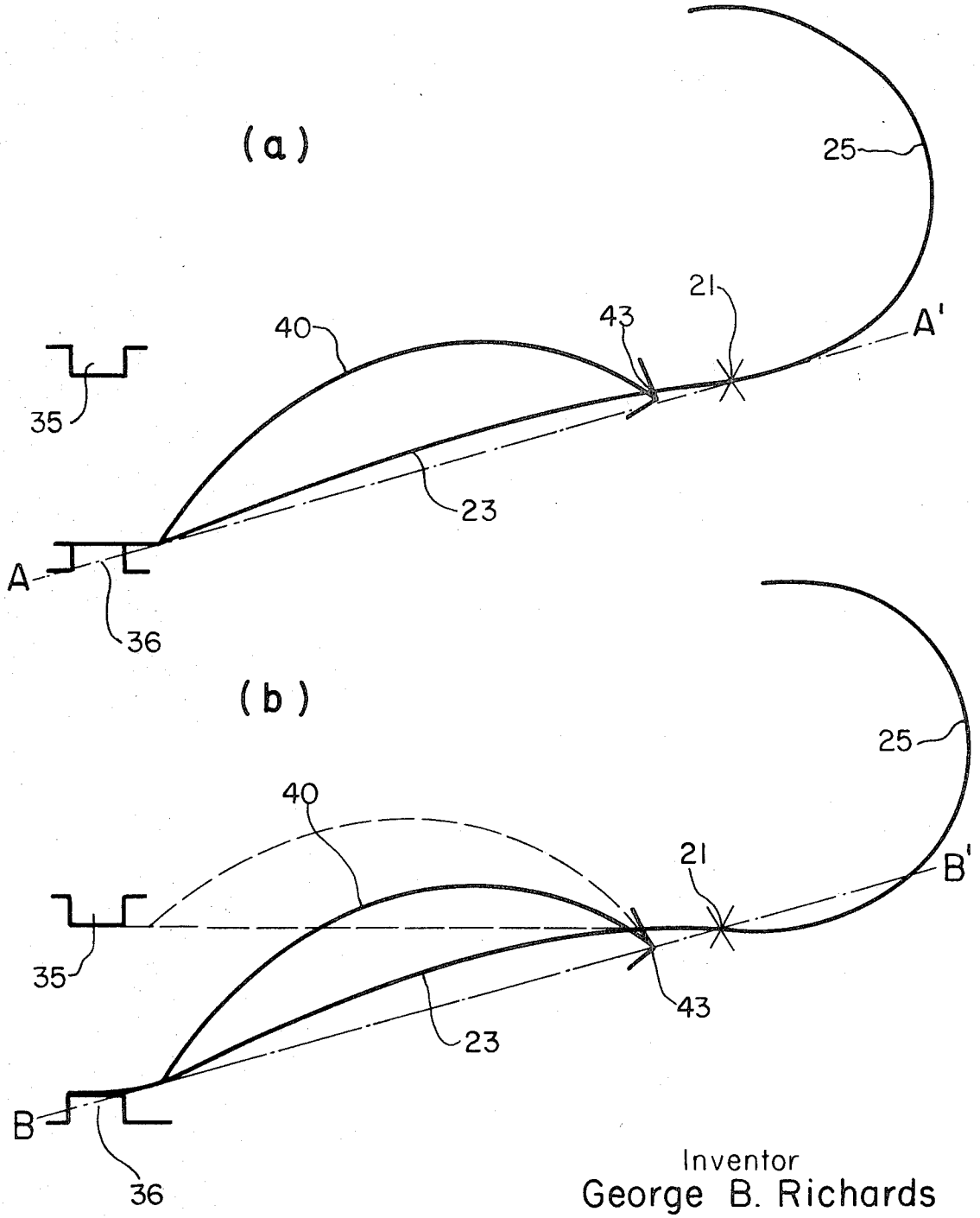


FIG. 7



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FIG. 5



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FIG. 8

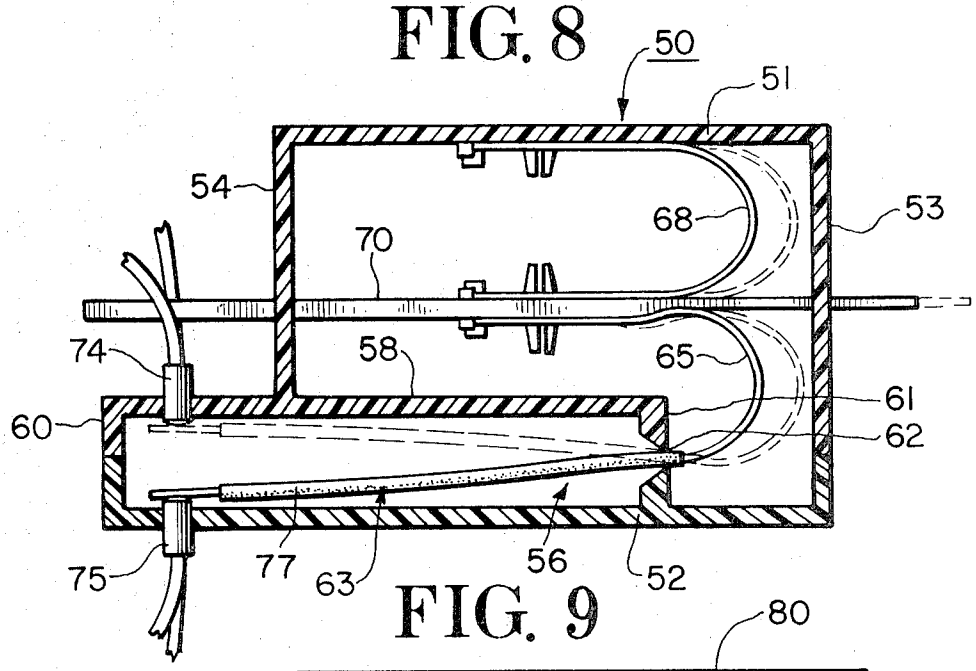


FIG. 9

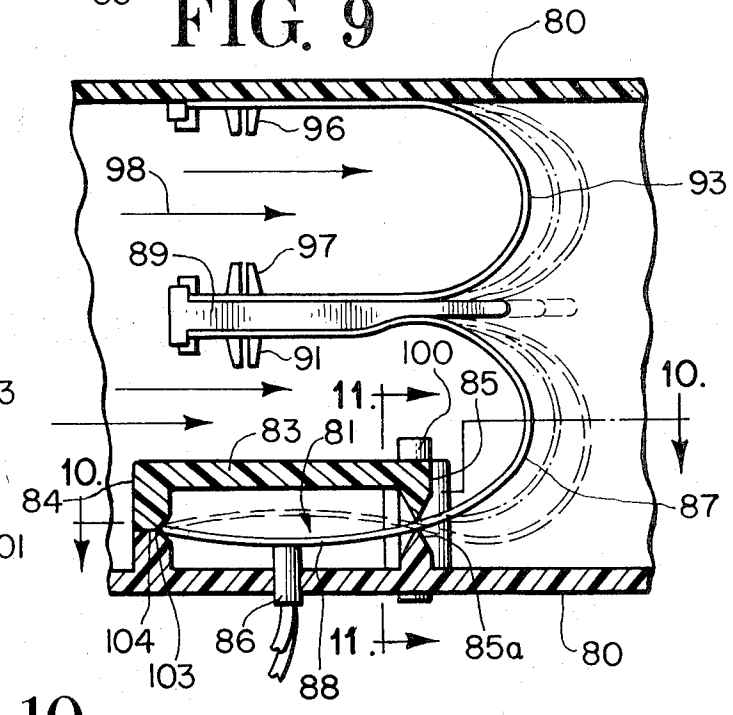


FIG. 11

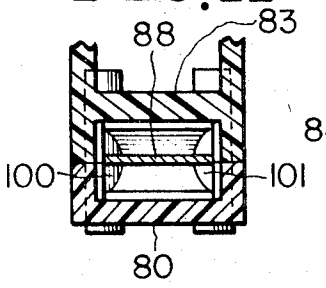
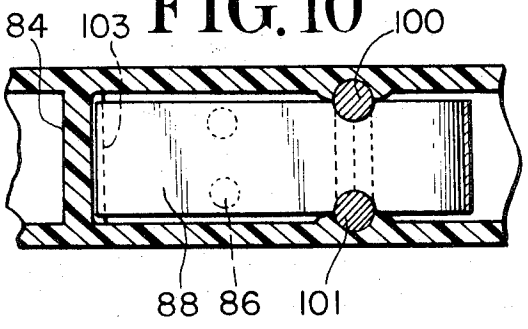


FIG. 10



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RESILIENT REED TYPE ACTUATOR MECHANISM

CROSS REFERENCE TO RELATED APPLICATION

The present application discloses subject matter which is related to that disclosed in a concurrently filed application of the same invention, Ser. No. 665,924 now U.S. Pat. No. 3,467,139.

INTRODUCTION

The present invention lies in the field of actuator mechanisms of the type employing flexible resilient reed members in which one end portion of a reed is displaced to effect a control function in response to an applied force at an opposite reed end portion. The field is further refined to devices in which displacement of the one reed end portion is by virtue of energy translated across an intermediate fulcrum and in which such displacement is always effected with a crisp, toggle or "over-the-center" action.

SUMMARY OF THE INVENTION

The actuator mechanisms of this invention are of an entirely new type from those disclosed in the prior art and permit an end portion of a resilient reed member positioned, for example, within an enclosed and/or sealed chamber to be pivotally deflected, across a fulcrum opening defined at the point of entry of the reed into the chamber, from a first to a second position by motion of the remaining reed end portion positioned outside of the chamber. The one end portion within the chamber may be totally isolated from an outside environment carrying injurious chemicals, volatile gases or fluids and, accordingly, the chamber is capable of entirely waterproof and/or explosion-proof construction. Furthermore, because of the nonshiftable locating of the reed, sealing of the chamber is accomplished by means of a simple static seal at that point where the flexible reed enters the chamber thereby obviating necessity for the more complex and unreliable sliding arrangements or the like of the prior art.

Of special advantage in electrical circuit applications, the actuator mechanism of this invention always provides displacement of the one end portion of the reed within the chamber with a crisp, toggle action. Such abrupt switching action is important to avoid destructive electrical arcing and objectionable "teasing" between the reed and the electrical contacts. The sealed chamber may also be filled with an inert gas, such as argon, to further assist in this regard.

One embodiment of this invention utilizes a bowed tongue segment which is affixed to the end portion of the reed within the chamber to provide a reversible biasing force for effecting the aforementioned crisp, toggle switching action and for normally maintaining the reed in firm engagement with the electrical switch contacts. This bowed segment is so arranged that its curvature is not materially altered during shifting of the reed end portion between its contact positions and the switch is accordingly much less susceptible to component fatigue than comparable prior art switches. This construction also provides a wiping of the switch contacts upon switching of the reed end portion.

The actuator mechanism of this invention also provides the advantage of being responsive to simple longitudinal movement of the remaining end portion of the reed between a pair of spaced positions especially, particularly when the reed is flexibly retained in a generally U-shaped configuration. The actuator is insensitive to the rate of application of the actuating force and furthermore switching of the reed end portion within the chamber always occurs abruptly at a predetermined longitudinal position of the remaining reed end portion. The use of a counterbalancing reed member of similar U-shaped contour permits displacement of the reed end portion within the chamber with any preselected actuating force ranging upwardly from an extremely small minimum value which value is a constant over the entire length of travel of the remaining reed end.

Additionally, the total length of travel of the remaining reed end portion may be made relatively long or relatively short, as desired, and the predetermined point along the length of travel at which switching occurs may be selectively located at any position within the extremes of travel to provide a desired symmetrical or nonsymmetrical length of travel versus switching characteristic.

Proper selection of the counterbalanced reeds also permits the longitudinal movement characteristic of the remaining reed end portion to vary over the length of travel from a resisting to an aiding force or vice versa in any manner and with any force magnitudes desired. Thus a monostable switch, for example, may be designed in which the remaining reed end portion always returns to a predetermined longitudinal point when the actuating force is removed.

The various objects of the invention are to provide a new actuator mechanism for achieving the various advantages heretofore and hereinafter expressly stated or implied.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, partly in section, of one preferred embodiment of the actuator mechanism of the present invention;

FIG. 2 is a cross-sectional view taken along line 3–3 of FIG. 1;

FIG. 3 is a sectional view taken along line 3–3 of FIG. 1;

FIG. 4 is a cross section taken along the line 4–4 of FIG. 3;

FIG. 5*a* and 5*b* are schematic representations of a portion of the actuator mechanism of FIG. 1 and are useful in appreciating the operation thereof;

FIG. 6 is a perspective view of a second embodiment of the actuator mechanism of the invention;

FIG. 7 is a sectional view taken along line 7–7 of FIG. 6;

FIG. 8 is a cross-sectional view taken along line 8–8 of FIG. 6;

FIG. 9 is a cross-sectional view of a further embodiment of the present invention;

FIG. 10 is a sectional view taken along line 10–10 of FIG. 9; and

FIG. 11 is a cross-sectional view taken along lines 11–11 of FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, the actuator mechanism there illustrated comprises wall means in the form of a housing generally designated by the reference numeral 11 and including parallel upper and lower wall portions 12 and 13, respectively, which are joined by a pair of transverse end wall sections 14 and 15. Together the four wall portions constitute a frame for supporting the actuator apparatus to be described. As shown, the housing does not include front and back walls and such are not essential; however, such walls may be provided to shield the apparatus from environmental conditions, if desired or necessary. If the housing is to be a fluid-flow conduit or the like, it may be suitably shaped for this purpose. Of course, in this latter instance the end walls 14 and 15 would be deleted and the housing would be in the form of a cylindrical pipe, for example.

The housing 11 is provided with an enclosed chamber 17 mounted on the interior wall portion 13 thereof. The chamber 17 comprises segments of housing walls 13 and 15, an irregularly contoured wall portion 19 spaced inwardly of lower wall 13 and a transverse end closure wall 20; the back wall of the chamber is not visible in FIG. 1 and the front wall has been cut away to facilitate illustration of the actuator apparatus. The end wall 20 includes means defining an opening in the chamber, here actually a pair of spaced colinear fulcrum openings 21*a* and 21*b* which are preferably of a knife-edge contour as shown, for receiving one end portion 23 of a resilient flexible reed member 25 therein. While any springlike material having suitable flexibility, resiliency, and resistance to fatigue and chemical action may be used for the reed 25, it

has been found that a spring steel sold by the Elgin National Watch Corporation under the trade name "Elgiloy" provides excellent results. This alloy has the following chemical composition and physical properties:

Chemical Composition	
Cobalt	40 percent
Chromium	20 percent
Nickel	15 percent
Molybdenum	7 percent
Beryllium	0.04 percent
Carbon	0.15 percent
Iron	Balance

Physical Properties	
Yield strength	280,000 p.s.i.
Ultimate strength	368,000 p.s.i.

The portion of the reed **25** outside of the chamber comprises part of an actuating means adapted for selectively shifting the reed end portion **23** between its angularly spaced positions. In the present embodiment, the reed member **25** is in a bowed, generally U-shaped configuration by locating means which includes a second flexible reed member **26** likewise return bent on itself to lie in a generally U-shaped configuration. The adjacent ends of reeds **25** and **26** are operatively associated with each other such that they are movable longitudinally with respect to the housing **11** from a first to a second position to angularly displace the end portion **23** of the reed **25** within the chamber **17** from a first to a second position.

Specifically, the reeds **25** and **26** have their adjacent ends affixed to opposite sides of an elongated actuator arm or rod **28** which extends through appropriate guide apertures **14***a* and **15***a* in the end walls **14** and **15** respectively. To facilitate convenient assembly and disassembly of the reeds and actuator arm, tapered yieldable buttons **31***a* and **31***b* are mounted on opposite sides of the actuator arm and are snapped to a positive retaining position through suitable apertures adjacent the ends of the respective reeds. The end of the reed **26**, contiguous to the interior surface of the upper wall, is **12** fastened in like fashion by a yieldable button **31***c* depending from the wall. Abutments **33***a*, **33***b* and **33***c* on the top and bottom surfaces of the actuator and the interior surface of the wall **12**, respectively, are positioned to engage the extreme transverse ends of the respective reeds and to axially align the reeds with the arm **28**.

It will be understood that the reed **26** tends to exert a substantially equal and opposite reaction force on the reed **25** and continues to do so with longitudinal movement of the actuating arm **28**. Such continuous and equal reactionary forces between the reeds **25** and **26** assures that the actuator arm **28** evenly and easily rides in its guiding apertures **14***a* and **15***a* in the opposite walls **14** and **15** and that no binding torque or otherwise wasted energy is incurred during movement of the fastened end of the reed **25** between its first and second longitudinal positions.

Furthermore, the convolutions of the reeds **25** and **26** may be so constructed and their patterns of movement so defined that the reeds offer almost no resistance whatsoever to longitudinal movement of the actuator arm. For instance, with the reeds **25** and **26** of identical, uniform construction and with convolutions of constant equal radius, longitudinal movement of the actuator arm **28** causes portions of the reeds contiguous to the actuator arm to lift directly therefrom and to deflect other segments of the associated reed outwardly; there is no relative sliding movement between the reeds and the actuator arm or housing walls with resulting frictional losses. The radius of the convolution of the reed **26** is held constant with longitudinal movement of the actuator arm because of the precise parallel relationship of the opposed surfaces of the arm **28** and the housing wall **12**. In the case of the reed **25**, such a constant convolution radius is assured by virtue of a contoured surface declivity **28***a* in the actuator arm **28** which declivity effectively compensates for the peculiar movement pattern attributable to the fixing of the reed **25** at the raised fulcrum openings **21***a* and **21***b*. Further arrangements for accommodating required reed support conditions or the like to maintain constant convolution radius are disclosed and claimed in the aforementioned concurrently filed Richards application.

Thus, in the illustrated construction, there is no consumption of energy as a result of longitudinal movement of the actuator arm **28**, but rather a mere translating of potential energy from one segment of each reed to another segment of the corresponding reed with only negligible energy losses due to molecular friction internally of each reed. Greater details of such counterbalanced pressure reed arrangements and preferred constructions are disclosed and claimed in Richards et al. U.S. Pat. No. 3,021,861. Furthermore, the use of various types and arrangements of nonsymmetrical reed elements to effect a continuous and uniform reactive counterbalancing is taught in Richards U.S. Pat. No. 3,230,966 issued Jan. 25, 1966.

Accordingly, although other forms of locating means for the remaining end of reed **25** are possible and perhaps suitable for use in conjunction with the present invention, the arrangements as above described and disclosed in the cited patents are preferred.

Turning now more specifically to a consideration of the chamber **17** and disposition of the end portion **23** of the reed **25** therein, it is seen that electrical contact means extend into the chamber through top and bottom walls thereof. Specifically, the electrical contact means includes a first associated pair of contacts **35** extending through the upper wall **19** of the chamber and a second pair of similar contacts **36** which project through the lower housing wall **13** into the chamber. Each pair of associated contacts is adapted to be selectively bridged by a wide flat terminus of the end portion **23** of the reed **25**; the terminus is shown in engagement with contact pair **36** in FIG. **1**. The end portion **23** of reed **25** is deflectable away from these contacts into engagement with contact pair **35** upon motion of the actuator arm **28** towards the end wall **14** of the housing, as will presently be explained.

The end portion **23** of reed **25** enters the chamber **17** through the two spaced knife-edge fulcrum openings **21***a* and **21***b* which precisely accept spaced legs of the reed; an intermediate portion of wall **20** extends between the legs as a continuous or integral wall portion. Each of the knife-edge openings **21***a* and **21***b* is similar and, as shown in FIG. **2**, the interior surfaces of wall **20** above and below the opening are tapered to intersect the flat outer wall surfaces along knife-edges which define the top and bottom boundaries of the respective openings. Additionally, and as is visible in FIG. **3**, the interior surfaces of wall **20** on opposite lateral sides of each opening are tapered to intersect the exterior surfaces of the wall along vertical knife edges. The overall perspective of the four tapering surfaces which define each knife-edge opening is most clearly depicted in FIG. **4**. It should also be noted from FIGS. **3** and **4** that the front and back walls **37** and **38**, respectively, of chamber **17** are now visible.

Returning now to FIG. **1**, the end portion **23** of the reed **25** enclosed within chamber **17** is provided with an overcenter means comprising a tongue segment **40** having one end secured to or integral with the end portion **23** and a free opposite end. A vertical post member **42**, integral with the lower housing wall **13**, is positioned between the opposite legs of the reed end portion **23** formed by the cutout tongue segment **40**. A horizontal V-shaped recess **43** in the post **42** is provided for pivotally seating the free end of the tongue segment. Tongue

segment 40 is substantially longer than the straight line distance between its fixed end and the seating recess 43 such that the tongue segment is continually maintained in a bowed condition during shifting of the reed end portion 23 between the upper and lower contact pairs 35 and 36, respectively.

In the illustrated embodiment, the tongue segment 40 is formed by a central, partially cutout portion of the reed end portion 23, although the tongue segment 40 may, of course, be a separate segment which is affixed to the reed end portion 23. In this latter case, the reed end portion 23 is provided with a rectangular cutout extending longitudinally from a transverse edge which abuts the outer surface of the wall 20 to an opposite edge located sufficiently to the left of the post 42 to permit unobstructed seating of the tongue in the V-shaped recess 43. In this regard, the expression in the appended claims to the effect that the reed end portion 23 is provided with "a tongue segment having a free end and a secured end" is intended to include both the integral and nonintegral constructions just described.

The tongue segment 40 exerts a positive biasing force, in proportion to the resiliency of the tongue material and degree of its bowing, which is effective to maintain the terminus of the reed end portion 23 in firm engagement, alternately, with contact pairs 35 and 36 and to assure that shifting of the reed end portion 23 between these contact pairs occurs with a brisk toggle action. The tongue segment 40 furthermore continually exerts a longitudinal biasing force to securely position one transverse edge of the reed cutout in firm contact with that portion of the outer surface of the wall 20 located between the spaced legs of the reed end portion 23. Thus, the reed 25 is maintained in pivotal, but nonshiftable engagement with the fulcrum bearing surface by the described means.

The assembly of the reed end portion 23 within the chamber 17 is facilitated by making the chamber of a bipartite construction. In the illustrated arrangement, both the housing 11 and the chamber 17 are of a molded plastic such as that available from the DuPont Corporation under the trade name "Delrin" and there are at least two mold pieces which are joined, as by gluing, along coplanar mold parting lines 46*a* and 46*b*. The line of the knife-edge openings 21*a* and 21*b* lies in the plane of the mold parting lines 46*a* and 46*b*.

The basic operation of the present embodiment of the invention is understood by reference to FIG. 2 and, in discussing such operation, it is initially assumed that the actuator arm 28 and the associated reed members 25 and 26 are in their first positions indicated by solid lines in the drawing. Thus, the bowed segment 40 exerts a positive biasing force against the integral reed end portion 23 to maintain the terminus of the reed in firm engagement with contact pair 36. Also, in this circumstance, the convolution of reed 25 enters the chamber 17 from slightly above or almost parallel to a plane defined by the knife-edge openings 21*a* and 21*b* and the apex of the recess 43 and, accordingly, the reed convolution does not detract from the biasing force of the segment 40 and, in fact, many contribute slightly to it.

Movement of the actuator arm 28 to the right deflects the convolution of the reed 25 downward and to the right. This action produces a clockwise torque across the knife-edge fulcrum openings which tends to deflect the one reed end portion 23 upward against the biasing influence of the tongue segment 40. When the reed end portion 23 is deflected beyond a critical point, the biasing influence of the tongue segment is abruptly reversed and the reed end portion 23 is abruptly shifted from its solid line position abutting the contacts 36 to its second or dashed line position abutting the contacts 35. Of course, return movement of the actuator arm 28 from its dashed to its solid line position results in operation substantially identical to that already described.

A more exacting understanding of the operation of the actuator mechanism is provided by reference to the semischematic illustrations of FIG. 5 wherein the reference numerals for the structural components of the embodiment of FIGS. 1—4 are retained for clarity of explanation. Specifically, in FIG. 5*a* the actuator reed member 25 is depicted in its first or the solid line position of FIG. 2. Under these circumstances, a line A—A′ drawn between the fulcrum opening 21 and the point of attachment of the tongue segment 40 to the reed end portion 23 lies below the seating axis or apex of the recess 43. Hence, the tongue segment 40 exerts a substantial positive biasing influence to maintain the terminus of the reed end portion in firm engagement with the contacts 36.

Referring now to FIG. 5*b*, the actuator arm for the reed member 25 of FIG. 2 has been displaced to its second or dotted line position. Under these circumstances, the reed reaction force to the right of the fulcrum opening 21 translates a substantial clockwise torque to the reed end portion 23 which torque is effective to bow the reed end portion. This bowing tends to draw the terminus of the reed end portion across the face of the contacts 36 in a wiping action which is of substantial importance for the maintenance of clean contacts. Furthermore, at this point a line B—B′ drawn from the point of attachment of the tongue segment 40 and the reed end portion through the knife-edge opening 21 lies above the V-shaped seating recess 43. The biasing influence of the tongue segment is abruptly reversed at the instant a line drawn between the aforementioned points passes above the seating axis of the recess 43. Hence, the solid line position of FIG. 5*b* is totally unstable and the reed end portion 23 is abruptly snapped to its upper or dotted line position in engagement with contacts 35. Return movement of the actuator reed, of course, provides a switching action similar to that already described.

Since the terminus of the reed end portion 23 is responsive only to whether a critical point has been reached, the switch action is totally insensitive to variations in the rate of movement of the actuator arm and displacement of the reed end portion between its opposed contact positions always occurs at a preselected longitudinal position of the actuator arm. In this regard, the total distance to be traveled by the actuator arm in response to the actuating force may be divided so that equal or desired nonequal parts lie on either side of the preselected longitudinal position to thereby effect a perfectly symmetrical or desired asymmetrical characteristic, respectively, for the switching action.

Furthermore, the force with which the terminus of the reed end portion 23 is biased into engagement with the respective contact pairs and the rate at which it is shifted therebetween is solely a function of the force exerted by the bowed tongue segment 40. The aforesaid biasing force is in turn exclusively dependent upon the stiffness and degree of bowing of the tongue segment which parameters are readily selected to conform to any predetermined specifications.

The end portion 23 of the reed may be made responsive to relatively slight longitudinal movement of the actuator arm 28 or a relatively large movement of this arm, as desired. For instance, if the initial position of the actuator arm 28 is selected such that switching is imminent, a relatively slight movement of the actuator arm will effect displacement of the reed end portion between the contacts while a more remote initial position requires a correspondingly longer movement of the arm 28 to cause switching. Establishment of such an initial position does not materially affect the biasing force of the tongue segment 40 as the magnitude of the biasing force is dependent substantially only on whether the previously discussed line lies above or below the seating line of the V-shaped recess and not its proximity with respect thereto.

The end portion 23 of the reed is made even more sensitive to movement of the actuator arm by a judicious selection of the reed material. For instance, if the reed, or at least the portion extending across the fulcrum, is made of a relatively rigid material, then downward movement of the convolution external to the chamber 17 will result in the reed end portion being moved upwardly in direct proportion to this downward movement. On the other hand, if the segment of the reed lying across the fulcrum is made of a highly flexible material, a much greater downward movement of the convolution will be

required to deflect the point of attachment of the reed end portion and the tongue segment upwardly the required distance. Thus, the actuator arm 28 must be moved a correspondingly greater longitudinal distance.

The above-described toggle action of the reed end portion 23 is extremely important in, for instance, electrical switch applications to preclude "teasing" and arcing between the contacts and the switch member, which action results in unsatisfactory and/or unreliable operation of the switch and shortens its useful life. A further important feature is that the curvature of the bowed tongue segment 40 remains substantially constant for all positions of the reed end portion 23 between the contact pairs 35 and 36. Thus, the bowed segment is not subjected to repeated flexing and resultant fatigue. The absence of significant flexing is especially important in electrical circuit applications where the presence of ozone or the like may render the metal brittle and thereby substantially increase the probability of fatigue.

Of course, the bowed segment 40 would experience no flexure whatsoever only if the fulcrum openings 21*a* and 21*b* and were congruent with the V-shaped recess 43. However, for the limited arc of movement experienced by the end of the reed, the actual flexing of the bowed segment 40 is extremely slight with the relative spacing of the recess 43 and the openings 21*a* and 21*b* as illustrated in FIG. 2. This flexing is even further reduced by moving the post 42 nearer the opening 21. The same biasing force in this case is maintained either by lengthening or increasing the stiffness of the tongue segment 40.

In view of the foregoing features, the present embodiment of the invention is also highly attractive for application as a simple miniature electrical switch. In such application, the convolution of the reed 25 to the right of the knife-edge fulcrum openings 21*a* and 21*b* is replaced by a short, straight stub portion of the reed or the like which extends a preselected distance to the right side of the fulcrum. Furthermore, the chamber 17 may, if desired, by replaced by a simple frame for supporting the electrical contacts, the integral post 42 by some equivalent means for pivotally locating the free end of the tongue segment and the knife-edge openings by any suitable fulcrum for permitting translation of energy thereacross to the reed end portion while maintaining the reed member in pivotal, but nonshiftable relation to the fulcrum. In this construction, the stub portion of the reed member constitutes the actuating means and the stub is adapted to coact with the overcenter means formed by the bowed tongue segment 40 and associated structure to selectively shift the reed end portion between its spaced positions.

An alternate embodiment of the present invention is illustrated in FIG. 6. This embodiment is generally similar to that of FIG. 1 and includes a housing 50 having parallel upper and lower walls 51 and 52, respectively, and a pair of opposed end walls 53 and 54. A chamber 56 is formed in conjunction with the bottom wall 52 of the housing by a parallel wall 58, spaced inwardly from the wall 52, and a pair of opposed end closure walls 60 and 61. The end wall 61 includes a central opening 62 for receiving one end portion 63 of an elongated reed member 65 which has its remaining end 67 affixed to the underside of an actuator arm 70. The reed member 65 is retained in pivotal but nonshiftable relation to the fulcrum opening in the chamber by frictional engagement with the chamber walls.

The reed member 65 is again preferably formed of a resilient and flexible metal to permit the reed to be retained in a bowed generally U-shaped configuration as illustrated. The reactive torque of the remaining end 67 of the reed member 65 is counterbalanced by a similar reed member 68 which is also disposed in a generally U-shaped configuration with its opposite ends affixed respectively to the upper housing wall 51 and the actuator arm 70 by means of the tapered button and aperture arrangement previously discussed. The actuator arm 70 is of an elongated construction and extends through opposite guide slots 53*a* and 54*a* in the end walls 53 and 54 respectively.

The reeds 65 and 68 differ from their counterparts of FIG. 1 in that they both increase in width as they approach respective points 65*a* and 68*a* of maximum width intermediate the fixed ends of their respective convolutions. This type of nonuniform construction in which each reed tapers downwardly in width from a midpoint of maximum width is responsible for providing a toggle or "over-the-center" action for this actuator mechanism, as will be explained in detail later herein. A reed member of this type is illustrated in FIG. 4*c* of Richards U.S. Pat. No. 3,259,142, issued Jul. 5, 1966. Again, unlike the first embodiment there is only a singular opening 62 in the end wall 61 and the end portion 63 of the reed within the chamber 56 is not slotted or the like but is a homogenous and continuous extension of the reed 65.

The opening 62 in the wall 61 of the chamber for accepting the end portion 63 of the reed 65 is preferably formed as a knife edge to provide a suitable fulcrum for pivotal deflection of the reed member. Specifically, with reference to FIG. 7, the interior surfaces of the wall 61 on lateral sides of the reed are tapered to meet the outer wall at sharply defined vertical knife edges 71*a* and 71*b*. Similarly, as is visible in FIG. 8, the interior surfaces of the wall 61 above and below the reed 65 taper outwardly to intersect the exterior surfaces of the wall 61 along horizontal, opposed knife edges.

Electrical contact pairs 74 and 75 extend, in sealed relationship, through the lower and upper walls 52 and 58, respectively, of the chamber 56 near the terminus of the reed end portion 63. Each of the contact pairs 74 and 75 is adapted to be selectively bridged by the conductive terminus of the reed to thereby complete an electrical circuit (not shown). That portion of the reed to the right of the terminus is provided with a protective electrically insulative coating 77 which may extend through the knife-edge aperture 62 in end wall 61 to a point exterior of the chamber.

The coating 77, which is accentuated in thickness for convenience of illustration, may be of a resilient rubberlike composition to also aid in maintaining an effective seal at the knife-edge aperture upon repeated movement of the reed between its contact positions. In this connection, it should be understood that proper deflection of the reed across the fulcrum requires that the opening be at least very slightly larger than the thickness of the reed. Alternatively, if it is desired to maintain an airtight seal even with repeated operation of the device, some resiliency must exist at the knife-edge opening either by virtue of the inherent properties of the chamber and/or reed materials or by imposition of a resilient material, such as coating 77, at the opening. In this regard, selection of a coating material of a low durometer rubber or the like, such as No. 40 durometer rubber, provides an efficient and reliable airtight seal at the point of entrance of the reed into the enclosed chamber. The chamber 56 is filled with an inert gas to reduce opportunity for electrical arcing, etc. Thus, the chamber 56 may be made totally waterproof and explosion proof. The foregoing is applicable to all of the embodiments disclosed therein.

The operation of the present embodiment is best understood by reference to FIG. 8 and in explaining such operation it is again initially assumed that the actuator arm 70 and the reeds 65 and 68 are in their solid line positions illustrated in the drawing. In this condition, the end portion 63 of the reed 65 within the chamber is biased into firm engagement with the contacts 75 by virtue of a counterclockwise torque translated across the knife-edge fulcrum opening 62 in the end wall 61 from the reed convolution located without the chamber.

As previously stated, a toggle or "over-the-center" switching action is provided in the present embodiment by virtue of the nonuniform construction of the reed convolution located externally of the chamber 56. A complete explanation of the operation of such nonuniform reed elements to provide an "over-the-center" action, as well as various forms of such elements suitable for use in the present invention are taught in Richards U.S. Pat. No. 3,259,142, issued Jul. 5, 1966.

Briefly, however, rightward movement of the actuator arm 70 is initially resisted by the reed 65 because of the increasing width of the reed with its proportionally greater resistance to bending. However, as the widest reed segment passes the midpoint of the open reed convolution which is the point of maximum bending, the resisting force abruptly reverses and becomes an aiding force which draws the actuator arm forward. This abrupt "over-the-center" action effects a correspondingly abrupt shifting of the end portion 63 of the reed between the contact pairs 74 and 75. Upon return movement of the actuator arm 70 to its original position a similar unstable condition is experienced intermediate its length of travel. The resistance of the reeds to movement in each longitudinal position assures an ample biasing force for the reed end portion 63 in its respective contact positions. Again, the switching of the reed end is exclusively dependent upon the longitudinal position of the actuator arm and not its rate of travel or the like. Thus, in the present embodiment that portion of the reed member outside of the chamber constitutes a part of both an overcenter means and an actuating means.

Although only a reed having a widened segment is illustrated, reeds with perforations or thickened intermediate portions, etc. as taught in the above cited Richards U.S. Pat. No. 3,259,142 are also satisfactory. The reed may also be provided with laminations as taught in Richards U.S. Pat. No. 3,131,709, issued May 5, 1964. By a further alternative taught in Richards et al. U.S. Pat. No. 3,154,091, issued Oct. 27, 1964, the reeds may be of uniform construction and the actuator arm 70 or the housing walls contoured in such a fashion as to provide an "over-the-center" action. For example, as taught in this latter patent, if the opposed faces of the actuator arm 70 initially slope outwardly toward their associated walls, the reeds are further compressed by longitudinal movement of the actuator arm and, accordingly, resist such movement. Tapering the latter portion of these faces inwardly towards one another permits release of a portion of the stored potential energy in the reeds with an aiding force for the actuator arm. The contour of the transition region determines the quickness or abruptness of the "over-the-center" action.

A third embodiment of the present invention is illustrated in FIG. 9. Herein, the actuator mechanism is mounted within a hollow cylindrical pipe section 80 or other suitable casing which is adapted to accept liquid flow therethrough. A chamber 81 is formed on the interior wall of the pipe section 80 by a longitudinal wall section 83 and a pair of end closure walls 84 and 85. A pair of spaced electrical contacts 86, only one of which is visible in FIG. 9, project into the chamber, at approximately the midpoint of the longitudinal extent thereof, from the underside of the casing 80.

The end wall 85 of the chamber is provided with a knife-edge opening 85*a* for receiving one end portion 88 of a flexible metal reed 87 therein; the opening 85*a* may be sealed or not as previously taught herein. The reed 87 is return bent on itself to lie in a generally U-shaped configuration and its remaining end is affixed to a guide member 89 by a yieldable tapered button 91 which is inserted through an appropriate aperture near this end of the reed.

Similarly, a second flexible reed member 93 is formed in a generally U-shaped configuration and is fixed at its opposite ends to respectively the upper interior surface of pipe 80 and the guide member 89 by tapering retaining buttons 96 and 97. Longitudinal movement of that end of the reed 87 fixed to the guide member 89 is effected by the pressure of a fluid flowing through the pipe, as schematically indicated by the arrows 98. The pressure of the fluid intercepting the transverse faces of the reeds 87 and 93 urges the reeds to the right to thereby actuate the switch mechanism. Alternatively, or in addition, a transverse plate may be affixed to the guide rod 89 to provide a pressure surface for the fluid. The previously described embodiments of the invention may, of course, also be adapted to operate in response to an applied fluid pressure or the like.

The primary distinction of the present embodiment from those discussed hereinbefore is again the manner in which a toggle or abrupt switching action of the end portion of the reed within the chamber is effected and the yieldable biasing force obtained. In the present embodiment, the entire reed end portion 88 is maintained in a bowed condition by means of confining the end in a space materially shorter than its longitudinal extent. Specifically, the reed end portion 88 which is itself longer than the chamber 81 is fixedly confined therein by providing a pair of retaining posts 100 and 101 on opposite lateral sides of the knife-edge aperture opening 85*a*, as is visible in FIG. 10. The retaining posts project into complementary pocket recesses formed in the end portion 88 of the reed and in so doing, preclude longitudinal movement of the reed with respect thereto. An end view of the reed 88 as retained by posts 100 and 101 is provided in FIG. 11. The terminus of the reed end 88 is seated in a horizontal V-shaped guide recess 103 in the opposite end of the chamber 81. In this arrangement, the structure for confining the reed end portion within the shorter chamber comprises an overcenter means.

Assembly of the reed end within the chamber is again facilitated by making the chamber 81 of a bipartite, molded plastic construction. Specifically, the chamber divides into two sections along a horizontal plane through the knife-edge opening 85*a* in the end wall 85 of the chamber. A portion of the horizontal mold-parting line 104 is visible along the chamber end wall 84.

The operation of this embodiment insofar as the longitudinal movement of the convolutions of the reeds 87 and 93 are concerned is substantially identical to that of the embodiments previously discussed. However, in the present case the reed end 88 is abruptly shifted away from and into engagement with the single contact pair 86 by a significantly different type of toggle action. Specifically, rightward movement of the reed convolutions 87 and 93 under the influence of the pressure of the fluid 98 results in the convolution 87 being displaced to the right and downward towards the lower surface of the pipe 80, as seen from the dotted line representations of the reed in the drawing. This causes a clockwise torque to be translated across the fulcrum defined at the knife-edge opening 85*a* of the chamber 81 which torque tends to reverse the normal bowed contour of the reed end portion 88. At a critical point of travel, indicated by the rightward most dotted line representation of the reed, the clockwise torque is sufficient to displace the reed end portion 88 to an oppositely bowed or curved condition as denoted by the dotted lines in the drawing; the reed end is totally unstable intermediate its oppositely bowed positions and, hence, movement between these positions always occurs with an abrupt snapping action.

At this point the electrical circuit is opened and, if the reed convolutions are of uniform construction, the circuit will remain open until an actuating force is applied from a direction opposite to that of the fluid 98. On the other hand, the present switch mechanism, as well as that of the first embodiment may be made monostable by applying the teachings of any of the previously mentioned U.S. Pat. Nos. 3,131,709, 3,154,091 or 3,259,142. For instance, the reed convolutions may each uniformly taper in width from one end to the other and thus provide a continuing resistance to longitudinal movement. Thus, if the fluid 98 ceases to flow or is reduced below a predetermined pressure the convolutions of the reeds 93 and 87 will exert a positive restoring force to return the reeds to their original longitudinal position. The reed end portion 88 is, of course, restored to its original position in engagement with contact 86 by such action. Any desired combination of aiding and resisting characteristics may also be obtained by using the teachings of the aforesaid patents.

The above-described embodiment is also especially well suited for use as a simple miniature electrical switch in a manner generally similar to that previously discussed in connection with the embodiment of FIGS. 1—4. Specifically, the chamber 81 may be replaced by a suitable frame for retaining the reed end portion 88 in the illustrated contour while that portion of the reed to the right of the fulcrum is replaced by a straight stub segment or the like suitably adapted to effect dis-

placement of the reed end portion between its spaced positions.

In each of the embodiments of the invention illustrated, a second convoluted reed has been used as a locating and guiding means for the reed of the actuator mechanism. However, it should be understood that any type of guiding and locating means suitable for guiding the actuating reed is contemplated within the scope of the present invention. Furthermore, it will be understood that although only one switch chamber has been illustrated for each pair of reeds that the end of each reed disposed adjacent the housing wall may be situated in a chamber and suitably adapted to function as a switch mechanism. Again, as exemplified by the several embodiments specifically described herein, the reed of the actuator mechanism may be responsive to any of a variety of applied mechanical forces. Additionally, the various constructions herein disclosed are also of utility in contexts other than electrical switching. For instance, as disclosed in the aforementioned concurrently filed application of the present applicant, the embodiment of FIG. 9 is useful to open and close valve ports in conjunction with control of fluid amplifiers or the like.

While particular embodiments of the present invention have been shown and described, it is apparent that various changes and modifications may be made, and it is therefore intended in the following claims to cover all such modifications and changes as may fall within the true spirit and scope of this invention.

I claim:

1. An actuator mechanism comprising:
wall means defining an enclosed chamber;
an elongated resilient reed member having first and second end portions and an intermediate portion;
means defining an aperture in said chamber for receiving said first end portion of said reed member therein; and
locating means, operative in conjunction with said aperture-defining means and said second end portion of said reed member, for retaining the intermediate portion of said reed member between said remaining end portion and said aperture-defining means in a flexibly bowed, generally U-shaped configuration with said second end portion extending towards said first end portion, said locating means being further adapted for permitting the terminus of said second end portion to be moved longitudinally with respect to said first end portion of said reed member from a first to a second position for displacing said first end portion from a first to a second position within said chamber.

2. The combination according to claim 1 and further including electrical contact means extending into said chamber and adapted to be selectively contacted by said one end portion of said reed member in at least one of said first and second positions.

3. The combination according to claim 2 in which said aperture-defining means provides a fulcrum across which energy is translated to deflect said one end portion of said reed member from said first to said second position.

4. The combination according to claim 3 and further including means for establishing an unstable condition intermediate said first and second positions to provide a toggle action in shifting said one end portion between said positions.

5. The combination according to claim 4 in which said locating means includes a second resilient reed member bent in a generally U-shaped configuration and having opposite end portions affixed respectively to said wall means and said remaining end portion of said first reed member for exerting a substantially equal and opposite transverse reaction force on said first reed member in movement between said first and second longitudinal positions.

6. The combination according to claim 5 in which said first reed member includes a segment along said U-shaped portion having a different resistance to bending stress than other segments of said U-shpaed portion for providing said toggle action.

7. The combination according to claim 5 in which said unstable condition establishing means is effective for retaining at least a segment of said one end portion of said reed member in a bowed condition.

8. The combination according to claim 7 in which said unstable condition establishing means defines a V-shaped recess in said wall means of said chamber, opposite said aperture-defining means, for seating and pivotally guiding the extremum of said one end portion of said reed member and further comprises retaining apparatus positioned adjacent said aperture-defining means for constraining said one end portion against longitudinal movement whereby said one end portion is maintained in said bowed condition.

9. The combination according to claim 8 in which said contact means are positioned in said chamber so as to be contacted by the apex of said bowed end portion in at least one of said first and second positions.

10. The combination according to claim 7 in which:
said one end portion of said reed is provided with a tongue segment having a free end and a secured end; and
further including a member for pivotally seating said free end of said tongue so as to continually maintain said tongue in a bowed condition during shifting of said one end portion between said first and second positions for effecting said toggle action.

11. The combination according to claim 4 in which:
said chamber is a sealed, airtight enclosure; and
said aperture-defining means provide an opening into said chamber of a knife-edge contour.

12. The combination according to claim 11 in which resilient means are provided at said aperture-defining means for maintaining said chamber in a sealed condition upon shifting of said one reed end portion between said first and second positions.

13. A miniature electrical switch comprising:
an elongated resilient reed member having first and second end portions and an intermediate portion and further having a tongue member integrally formed with said first end portion, said tongue member having a free end and a secured end;
means defining a spatially fixed fulcrum member pivotally supporting said first end portion of said reed member for angular movement between a first and second position in which said first end portion lies respectively above and below a horizontal plane through said fulcrum;
means comprising a spatially fixed support member for pivotally locating said free end of said tongue member in approximately said horizontal plane, said tongue member being continually maintained in a bowed condition for exerting a force to bias said first reed end portion away from said horizontal plane toward a preselected one of said first and second positions;
electrical contact means positioned to engage said first end portion in at least one of said first and second positions; and
actuating means operatively connected to said second reed end portion for maintaining said intermediate portion of said reed member in a resiliently bowed, generally U-shpaed configuration with said second end portion extending towards said first end portion, said actuating means being moveable along a path generally parallel to said first reed end portion between first and second positions for displacing said first reed end portion between said first and second positions.

14. The combination according to claim 13 in which said fulcrum means comprises opposed knife-edge portions defining an opening for locating said reed member therebetween.

15. The combination according to claim 14 in which:
said tongue segment is defined by a partially cutout portion of said reed member; and
in which said pivoting means is positioned to project through said cutout portion of said reed member.

16. The combination according to claim 15 in which said pivoting means is formed to define an elongated V-shaped recess with the line formed by the intersection of the legs of said V lying in said horizontal plane.

17. The combination according to claim 16 in which a transverse edge of said reed member bordering said cutout portion abuts a stop at said fulcrum means for precluding longitudinal shifting of said reed member under the influence of the potential energy stored in said bowed tongue portion.

18. The combination according to claim 17 and further including:

a sealed housing for enclosing said one end portion of said reed member on one side of said fulcrum means and in which said electrical contact means projects into said housing in a position for selectively contacting said one reed end portion; and

further in which said opposed knife-edge portions of said fulcrum means and said reed member cooperate to effect sealed entry of said reed member into said housing.

19. The combination according to claim 18 in which said contact means comprises a pair of electrical contacts located at one of said first and second positions with said contacts lying in a common plane and adapted to be bridged by said one end portion of said reed member.

20. An actuator mechanism comprising:

wall means having a fixedly positioned fulcrum bearing surface portion;

an elongated resilient reed member having first and second end portions and an intermediate portion;

positioning means for maintaining said first end portion of said reed member in pivotal, but nonshiftable engagement with said fulcrum bearing surface;

overcenter means operatively associated with said reed member for yieldably maintaining said first reed end portion in either of the two spaced positions; and

actuating means operatively connected to said second reed end portion for maintaining said intermediate portion of said reed member in a resiliently bowed, generally U-shaped configuration with said second end portion extending toward said first end portion, said actuating means being moveable along a path generally parallel to said first reed end portion between first and second positions for coacting with said overcenter means to selectively shift said first reed end portion between said spaced portions.

21. The combination according to claim 20 in which said overcenter means comprises:

a tongue segment having one end secured to said first reed end portion and further having a free end; and

a member for pivotally seating said free end of said tongue segment so as to continually maintain said tongue segment in a bowed condition for providing a biasing force to yieldably maintain said first reed end portion in either of said two spaced positions.

22. The combination according to claim 20 in which said overcenter means comprises retaining apparatus, spaced from said fulcrum-bearing surface by a predetermined distance which is shorter than the length of said first reed end portion, for seating and pivotally guiding the extremum of said first reed end portion and for cooperating with said positioning means for retaining said first end portion in a bowed condition.

23. The combination according to claim 20 in which said overcenter means is positioned on said second reed end portion side of said fulcrum-bearing surface portion.