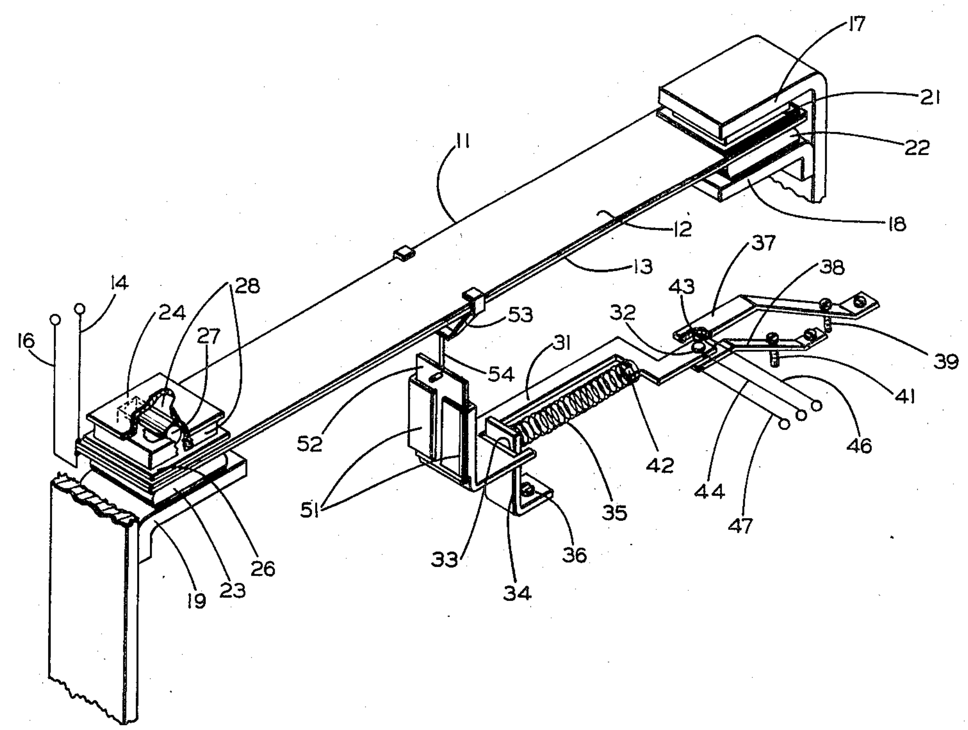
Jan. 6, 1959 E. G. THURSTON 2,867,701

DEVICE FOR PROVIDING REPRODUCIBLE MECHANICAL MOTIONS

Filed Feb. 15, 1955



INVENTOR.
EDWARD G. THURSTON
BY
Harris A. Mumma Jr.
ATTORNEY

United States Patent Office

2,867,701
Patented Jan. 6, 1959

1

2,867,701

DEVICE FOR PROVIDING REPRODUCIBLE MECHANICAL MOTIONS

Edward G. Thurston, Cleveland, Ohio, assignor to Clevite Corporation, Cleveland, Ohio, a corporation of Ohio

Application February 15, 1955, Serial No. 488,374

11 Claims. (Cl. 200—87)

This invention relates to devices for providing reproducible mechanical motions, and certain more specific embodiments of the invention relate to relay devices in which the reproducible motions are effective to close or open electrical contacts.

It often is desired to provide mechanical motions using a driving or motor element, which conveniently may be a motor giving limited translational displacements as distinguished from a rotating machine, in which the effectiveness of the device requires that the motion or displacement be reproducible within more or less closely defined limits. In an electrical relay, for example, a pair of electrical contact points should be brought into positive mechanical contact when the relay is thrown into the closed position and should be separated with substantial spacing when the relay is opened. With some types of motor elements, however, it may be difficult to provide the desired motions within the required tolerances for extended periods of time and under changing conditions, and this tends to be true particularly when the motor element is sensitive enough to provide the necessary mechanical response in a small space or with the application of only small amounts of energy.

As an example, if the motion is to be provided by applying electrical energy to an electromechanical transducer which draws only small currents, it may be convenient to use an arrangement of electromechanically responsive dielectric elements developing response to an applied electric field by converting longitudinal motions into flexural or bending motions. Such devices may be quite sensitive and efficient, due to the favorable electromechanical response characteristics of certain dielectric materials and to the mechanical advantage obtained in the conversion of the longitudinal motions into flexural motions. However, the resting position of such a motor element may be affected by other factors, such as thermal stresses, so that the position occupied by the motor element under a given electrical excitation is subject to slow variations. Over a period of hours or days these variations may change the resting position, and hence the positions occupied by the motor element under various conditions of excitation, by amounts of the same order as the motion produced by the application of the usual excitation to the element. In the case of a relay, where the mechanical motion must be sufficiently reproducible to move the relay contacts into closed and open positions, these perturbations even may be sufficient to throw the relay unintentionally without electrical excitation or to prevent it from being thrown when excited.

Various arrangements, such as clutches, dashpots, and related devices using frictionally engaging surfaces, hydraulic fluids, or viscous materials, have been utilized to modify or convert mechanical motions having undesirable characteristics into desired motions. However, such prior arrangements have not provided the reproducible mechanical motions into a plurality of predetermined positions of the type provided by the present invention.

2

It is an object of the present invention, therefore, to furnish an improved device for providing reproducible mechanical motions into a plurality of predetermined positions which avoids one or more of the above-mentioned disadvantages of the prior art devices.

It is another object of the invention to furnish a new and improved device for providing reproducible mechanical motions which includes as a driving element a motor which may be subject to slow but substantial variations or perturbations of its position under predetermined excitation.

It is a further object of the invention to provide a new and improved relay device including such a motor element in which electrical excitation of the motor element within reasonable limits of magnitude causes dependable operation of the relay in spite of relatively slow but substantial variations of the resting position of the motor element.

It is still another object of the invention to provide a new and improved relay device, having an arrangement of the detent or toggle type for establishing a plurality of definite positions or throws of the relay switch, which is capable of providing dependable relay operation in spite of slow but relatively large perturbations of the positions of the driving element for given applied excitations.

In accordance with the present invention, a device for providing reproducible mechanical motions into a plurality of predetermined positions comprises a motor element, a driven element, and position-stabilizing means establishing a plurality of stable positions for the driven element so as to act upon the driven element to urge it from other positions into an adjacent one of the stable positions. The device further includes coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, each of these two coupling members being connected individually to one of the motor and driven elements to provide relatively tight slip-free mechanical coupling between the two elements during relatively rapid motions of the motor element, resulting from changes in the energization thereof for driving the driven element between positions corresponding to two of its stable positions, but providing relatively loose coupling, with viscous slippage between the members of the coupling means, to conform to any relatively slow variations of the individual positions of the motor element which correspond to the stable positions of the driven element.

In accordance with a feature of this invention, a relay device comprising a motor element, a relay switch arm, a first electrical contact point carried by the switch arm, position-stabilizing means establishing a plurality of stable positions for the switch arm so as to act upon the arm to urge it from other positions into an adjacent one of its stable positions, and at least one additional electrical contact point disposed to make positive contact with the first contact point when the switch arm is in a corresponding one of its stable positions. This relay device further comprises coupling means between the motor element and the switch arm providing relatively tight slip-free mechanical coupling between the element and the arm during the relatively rapid motions of the motor element resulting from changes in its driving energization, but providing relatively loose coupling, with slippage within the coupling means, to conform to any relatively slow variations of the positions of the motor element.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, the single figure is a perspective view, partly cut away in places better to reveal the structure, of a device for providing reproducible mechanical motions, in the form of a relay device including a dielectric, electromechanically responsive driving element.

Referring now more particularly to the drawing, there is illustrated a device for providing reproducible mechanical motions into a plurality of predetermined positions, comprising a motor element **11**. As illustrated, this device is a single pole, double throw relay switching device having two predetermined stable positions. It will be understood that a similar device can be provided with, for example, three stable positions by the inclusion of a detent mechanism of a type generally known to the art. In the case of such a three position device the central position can be neutral, while one pair of relay contacts can be closed when the relay is thrown in one direction and another pair closed when the relay is thrown in another direction. For convenience of illustration, however, a two position relay is shown and described.

In the device illustrated the motor element **11** includes an upper elongated, electromechanically responsive member **12** affixed to another, lower elongated member **13** with major faces of the two elongated members adjacent to each other. A motor element of this type is illustrated and described in Reissue Patent No. 20,213 to C. B. Sawyer. The elongated member **12** and, if desired, also the member **13** may be piezoelectric single-crystalline material. The upper and lower exposed surfaces of the two crystal slabs are provided with thin, adherent electrodes, not shown separately in the drawing, while conductive electrode material also is provided between the slabs so that a central electrode is available if needed. The crystal material is chosen and oriented so that application of a potential difference between the two outer electrodes through leads **14** and **16** causes one of the slabs to expand longitudinally while the other contracts longitudinally. Upon such electrical energization of these electromechanically responsive members in a longitudinal mode, motions are obtained associated with bending distortions of the two members. The bending of this sandwich type of motor element is a result of mechanical reaction between its two elongated members, as described in the aforementioned Sawyer patent.

It is now well known that certain dielectric ceramic materials also may be made highly electromechanically responsive by suitable conditioning or polarization. Notable among such materials are the titanate-type electromechanical transducer materials exemplified by barium titanate, which may or may not be modified by additions of lead titanate or other oxides or salts. Another ceramic material providing useful electromechanical responses when polarized is a solid solution of lead zirconate and lead titanate in proportions which are roughly, but not ordinarily exactly, equimolar. The motor element **11** advantageously includes elongated members **12** and **13** of such a ceramic material affixed together in face to face relationship to obtain motions, associated with bending distortions of the two members, resulting from changes in length of one or both of the elongated ceramic element or elements upon application of electric field signal energization thereacross. For this purpose it is desirable that both of the elongated elements **12** and **13** be of the same material, and they may be permanently polarized, or prepolarized, in opposite thickness directions by the initial application of unidirectional polarizing potentials, which may be high enough to approach the electrical breakdown strength of the ceramic material. These initial polarizing potentials are applied for a limited period of time in opposite thickness directions in the two elements, utilizing a temporary polarizing connection to the aforementioned central electrode. If the signal potentials available to actuate the relay are of high voltages and of one polarity only, it may be desired to excite only one of the ceramic slabs **12** and **13**, so that the electric field energization always is in the same polarity as the polarity of the prepolarizing field initially applied to the element. In such a case one of the leads **14** and **16** would be connected to the central electrode rather than to an external electrode.

It also is possible, and in some cases highly desirable, to make the motor element **11** of a noncomposite ceramic material. Bending-responsive elements utilizing the composite sandwich structure illustrated in the drawing are described and claimed in Patent No. 2,484,950 to H. Jaffe, while a noncomposite ceramic body having a similar principle of operation is described and claimed in Patent No. 2,659,829 to H. G. Baerwald, both of these patents being assigned to the same assignee as is the present invention. Other noncomposite, bending responsive ceramic motor elements may be utilized, such as those described and claimed in the copending application for Letters Patent of C. K. Gravley Serial No. 343,054, filed March 18, 1953, and assigned to the same assignee as the present invention. Accordingly, it will be understood that the two elongated members **12** and **13** may be affixed to each other in such intimate relationship as to constitute essentially a single, noncomposite motor element having effectively two layers **12** and **13** but without a continuous interface therebetween.

The motor element **11** may be mounted securely to a fixed bracket or other support at one end only of the element. The arcuate motions of the other end, due to bending distortions of the elongated element, then are utilized to drive the relay switch arm or other mechanism to be driven. Relay devices incorporating such cantilever mounting of the motor element have been built and operated successfully.

However, greater stability under conditions of mechanical shock or acceleration may be obtained with the beam mounting illustrated in the drawing. With this type of mounting, during the bending distortions of the motor element **11** strictly linear motions are obtained at the center of the element in directions perpendicular to the major faces of the members **12** and **13**. Provision should be made in mounting the motor to accommodate the slight shortening of the distance measured in a straight line between the two ends of the element **11** when it bends from a straight configuration, as well as to accommodate the changes in the angular positions of the ends of the element when its center is displaced vertically as a result of the bending distortions.

A mounting arrangement providing the necessary resilience without permitting gross motions of the entire motor element is shown in the drawing. Upper and lower mounting brackets **17** and **18** are provided for the right end of the element and a corresponding lower bracket **19** is provided for the left end. A corresponding upper left bracket has been cut away in the illustrated view to show the detailed structure of the mounting arrangements, which may be identical for the two ends of the element. A supporting unit **21** is affixed between the upper bracket **17** and the upper surface of the right end of the element. A body **22** of resilient, rubbery material formed from an elastomer is forced between the lower surface of the right end of the element and the lower bracket **18**. It will be understood that the mounting brackets are firmly affixed to an outer supporting or enclosing structure, so that the bracket **17** may be a part of the top of an enclosure, not shown, containing the entire relay device. Another resilient body **23** is shown between the lower left face of the element **12** and the lower left bracket **19**.

The supporting unit for the left end of the element **11** is shown broken away in part to illustrate the structure of the supporting units. This supporting unit includes an upper plate **24** of a hardened metal and a similar lower plate 26. The upper surface of the plate 24 may be cemented or otherwise affixed firmly to the upper left bracket or other mounting surface, while the lower surface of the plate 26 may be firmly affixed to the upper surface at the left end of the motor element 11. These plates are separated by a small cylindrical or roller bearing 27, which has its axis oriented parallel to the upper surface of the motor element 11 but transversely of the length of the element, and which is maintained pressed against the inner surfaces of the plates 24 and 26 by the action of the compressed resilient body 23. The roller 27 is made only long enough to prevent lateral tipping of the element 11 and conveniently is retained in its desired orientation between the plates 24 and 27 by a pad 28, which is cemented to the two plates and has a rectangular central opening within which the roller is positioned.

It will be understood that shortening of the linear distance between the ends of the element 11, supported by the two similar supporting units, causes the roller 27 to roll slightly to the right and the corresponding roller in the right supporting unit 21 to roll slightly to the left, causing slight shear distortions in the pad 28 and in the corresponding pad in the supporting unit 21. Changes in the angular positions of the ends of the element 11 are accommodated by rotation about the roller surface of the plate 26 along with slight compression of the pad 28 on one side of the roller and expansion of the pad on the other side of the roller. Thus these supporting units permit the desired relative movements of the element 11 and the supporting structure while positively maintaining the mean position of the element. It is noted that the bending of the motor element 11, which results in linear motion at the center of the element, also is accompanied for most dielectric electro-mechanically responsive materials by a lateral bending or cupping along the width of the element, as viewed from its ends. This lateral bending, however, ordinarily is very small with a long, narrow element, and the relatively short roller 27 with its associated structure can tolerate such a slight lateral distortion while giving adequate lateral support without significant damage to the device or constraint of its motion.

The relay device includes a driven element in the form of a relay switch arm 31. The arm 31 as illustrated in the drawing is generally horizontally disposed and carries a first electrical contact point 32 at its upper surface near its right end. The arm 31 is arranged to be driven at its left end and pivoted about a horizontal knife edge 33 which is nearer its left end than its right end. The central portion of the switch arm is bent or cut out, forming a lateral opening to accommodate a support 34 and a compression spring 35. The support 34 is fastened by means of a screw 36 to a base member, not shown, and is provided with a horizontal notch near the top of its left face within which the knife edge 33 can bear. Accordingly the relay switch arm 31 is pivotally supported about a transverse horizontal axis at the line along which the knife edge 33 bears against the notch in the support 34, while the contact point 32 is carried by the arm 31 remote from this transverse axis defined by the knife edge. Reference numeral 33 will be used to refer to both the knife edge and to its horizontal axis.

Stop members 37 and 38, likewise screwed to the base member, not shown, are arranged so that their left ends limit, to the ends of a small arc, the extreme positions of pivotal motion of the switch arm 31 about the axis defined by knife edge 33. The stop members are of stiff spring metal and are shaped so that their left ends tend to take positions somewhat lower than those desired. Screws 39 and 41 then are passed through tapped holes near the mounted right ends of the members 37 and 38 respectively and tightened so that they bear against the base surface (not shown) to lift the left ends of the stop members into the desired, individually adjustable positions. These positions in turn determine the aforementioned extreme positions of pivotal motion of the arm 31. If the relay is intended to switch only rather small potential differences, the total separation of the confronting surfaces at the left ends of the two stop members may be only slightly greater than the thickness of the switch arm 31 and its associated contact points, so that no attempt has been made in the drawing to indicate the small deviation of the switch arm from a horizontal position when the contact point or points carried by the arm are in contact with one or the other of the stop members 37 or 38.

The spring 35 is a compression spring bearing at its right end against a point of attachment on the switch arm remote from the axis 33, this point of attachment conveniently being a small projection 42 from the right edge of the lateral opening in the arm 31. The left end of the spring 35 bears against a fixed point which lies between the point of attachment 42 and the axis 33 and which is adjacent to, i. e., in the plane of, the switch arm when the arm is in a position intermediate of the extreme positions permitted by the stop members 37 and 38. This fixed point, hidden in the drawing, is on the right hand surface of the support 34 or may extend somewhat to the right from that surface.

It will be understood that, starting with the arm 31 in an intermediate or horizontal position, any rotation, however small, of the arm 31 about the axis 33 tends to make the portions of the arm extending rightward from the axis 33 move out of the plane which includes the bearing groove in the left surface of the support 34 and which includes the fixed point, on or near the right surface of the support 34, holding the left end of the spring. The small separation between the knife edge 33 and this fixed point, against which the active portions of the spring 35 bear, determines the force with which the right end of the arm 31, or a contact point carried thereby, presses against the confronting surface of one of the stop members 37 and 38. When the entire switch arm 31, including the point of attachment 42, lies in the plane containing the axis 33 and the fixed point of attachment of the left end of the spring 35, the spring 35 is at maximum compression. As the arm 31 rotates about the axis 33 to either of its extreme positions, the distance from the fixed point, at which the left end of the spring bears against the support 34, to the point of attachment 42 of the right end of the spring increases. With a toggle mechanism of this type the most stable positions are those in which the elastically stored energy in the spring is at a minimum, and this condition is fulfilled when the right end of the arm 31, or a contact point carried thereby, presses against one of the stop members 37 and 38. The spring force causes a slight motion of the end of the respective stop member, which itself is a stiff spring, and the arm 31 then comes to rest at one of the two aforementioned extreme positions. The arm 31 also may be quite resilient and so may deform somewhat before coming to rest.

Accordingly, the arrangement of the axis 33, the spring 35 which holds the knife edge 33 in its notch and exerts the force holding the arm 31 in one of its extreme positions, and the stop members 37 and 38 constitutes position-stabilizing means establishing a plurality of stable positions for the driven element or switch arm 31, specifically the aforesaid two extreme positions, so as to act upon the switch arm to urge it from other positions into an adjacent one of these two stable positions. The spring 35 included in this position-stabilizing means may be identified more generally as a spring member associated with the switch arm so as to have minima of elastically stored energy when the arm is in the aforesaid stable positions.

At least one additional electrical contact point is disposed to make positive contact with the first contact point 32 when the switch arm 31 is in a corresponding one of its stable positions. More specifically, a second contact point 43 is disposed on the lower surface of the left end of the stop member 37 to make contact with the point 32 when the arm 31 is held in the upper one of its extreme positions. Thus upward motion of the right end of the arm 31 makes a positive contact under pressure between the points 32 and 43, while downward motion past the unstable neutral position of maximum compression of the spring 35 causes the switch to throw into its other extreme position, at which this contact with the point 43 is broken. In the double throw switch illustrated the upper surface of the left end of the lower stop member 38 also is provided with a third electrical contact point, not visible in the drawing, which makes contact when the right end of the arm 31 is in its lower extreme position with a contact point, also not visible, on the lower surface of the switch arm 31, this latter contact point being connected electrically through the arm 31 to the contact point 32.

Thus the spring arrangement, whereby the position of the switch arm is stabilized at one of the two extreme positions, serves to maintain positive contact between the contact points carried by the switch arm and one or the other of the contact points carried by the stop members. In practice, of course, these contact points may be formed integrally with the individual switch arm and stop members. Alternatively, the contact points described as carried by the stop members could be carried by separate structures with corresponding changes in the positions of the contact points on the switch arm, so that the contact between the arm 31 and the stops 37 and 38 would be mechanical only, rather than both mechanical and electrical.

A lead wire 44 is connected to the switch arm and hence to its contact point 32 and to the corresponding point on the lower side of the arm, while lead wires 46 and 47 are connected respectively to the contact point 43 on the stop member 37 and to the similar contact point on the stop member 38.

Coupling means is provided between the motor element 11 and the driven element or switch arm 31, providing relatively tight, slip-free mechanical coupling between the element and the arm during relatively rapid motions of the motor element, resulting from changes in the energization thereof for driving the driven element or switch arm between positions corresponding to two of its stable positions, but providing relatively loose coupling, with slippage within the coupling means, to conform to any relatively slow variations of the individual positions of the motor element which correspond to the two stable positions of the driven element, in this case the two extreme positions of the switch arm 31. The energization referred to, of course, is a signal voltage applied across the leads 14 and 16. It is convenient to adjust the coupling means so that, when no energizing signal is applied and the element 11 is essentially undeformed, the right end of the switch arm is in its lower extreme position.

The coupling means comprises two coupling members, a sleeve member 51 and a rectangular slide member 52 slidably disposed therewithin, with clearances of capillary dimensions between these members, and a viscous material disposed therebetween but unconstrained by external structure from escaping. The sleeve member 51 conveniently is formed integrally with the upturned left end of the arm 31 by bending two side portions of the upturned extension forward and together, leaving a small separation between the ends thus turned in. For simplicity of illustration the viscous material is not shown in the drawing. It will be understood, however, that this material fills the spaces surrounding the slide member 52 on all sides where the surfaces of the slide member confront the inner surfaces of the sleeve member 51, and it will be evident that the viscous material is unconstrained from escaping at the open ends of the sleeve member. The viscous material advantageously may be any of a number of liquids available in a variety of viscosities at room temperature and having fairly small variations of viscosity with temperature changes.

As an example, a relay including a ceramic, bending responsive motor element about 3.5 inches long and 0.5 inch wide with an over-all thickness of about 0.03 inch was provided with a coupling means having a sleeve member about 0.4 inch in length and about the same in width with clearances of about 0.01 inch between the slide member and the sleeve member. The spaces between the slide and sleeve members were filled with a silicone liquid of high molecular weight having a viscosity of about 1,000,000 centistokes at room temperature. The viscous fluid may have a tendency to ooze out above or below the sleeve member and through the opening between the turned-in portions forming the sleeve, but the spaces between the slide and sleeve members are kept substantially full of the viscous material through capillary attraction in view of the affinity of the liquid for the metallic surfaces and of the small clearances in relation to the surface tension forces and high viscosity of the liquid.

Each of the two coupling members, that is, the sleeve member 51 and the slide member 52, is connected individually to one of the motor and driven elements, specifically to the left end of the switch arm 31 and to the motor element 11 respectively, to provide the aforementioned mechanical coupling between these two elements. As mentioned above, the sleeve member 51 is formed integrally with the arm 31. To connect the motor element 11, a clamp 53 is fastened around the middle of the element 11 and carries a rod 54 extending downwardly below the center of the element. The lower end of the rod 54 is bent into the horizontal plane and passes through a hole with a very small clearance in the upper portion of the slide member 52; this clearance is sufficient to permit small sliding and turning motions of the end of the rod 54 relative to the hole when the arm 31 carrying the coupling means pivots about its axis 33.

Assuming that the coupling means were to provide positive mechanical coupling between the element 11 and the arm 31, the mode of operation of the device illustrated in the drawing would be evident to those skilled in the art from the description hereinabove. Considering now the actual functioning of the coupling means, the faster the motion of one of the two members 51 and 52 of the coupling means, the less time will be available for any slippage between the two members within the coupling means due to viscous flow of the viscous material adhering to both members. In other words, the force coupled from one member to the other is generally proportional to the rate of driving. Ordinarily the signal potential, which may be of the order of 100 volts, applied across the leads 14 and 16 to actuate the switch is applied with a steep wave front, so that downward motion of the center of the element 11 occurs in a small fraction of a second. With the element having the dimensions given hereinabove and with the liquid of high viscosity between the coupling members, the application across the motor element of a potential of about 150 volts and of the proper polarity causes the center of the element to move downwardly about 0.004 inch. The switch arm 31 is proportioned so that the resulting travel between the two extreme positions of the switch arm is about 0.020 inch. The motor element, mounted as shown, can deliver ample force to utilize a lever arm ratio of 5 or more in the pivotally mounted switch arm. It is preferred to apply an actuating potential equal to or somewhat greater than that necessary to move the left end of the switch arm to the position corresponding to the stable position of the switch arm, as determined by the toggle spring and stop arrangement. A moderate over-voltage assists in the establishment of the desired positive contact when the switch is thrown.

The switch can operate satisfactorily with very substantial over-voltage or under-voltage. In such a case the spring 35 ordinarily will cause te right end of the resilient arm 31 to reach a position approximating one of its stable positions very quickly, thus establishing or breaking the circuits by relay action as desired, for example to effect the connection of the common lead 44 to one of the other contact point leads 46 or 47. With over-voltage or under-voltage, some or all of the tendency of the motor element to drive the left end of the arm 31 to a position past, or short of, its equilibrium position—that is, the stable position determined by the toggle and stop mechanism—will be overcome by the force exerted by the toggle action, causing deformations due to the resiliency of the stop members 37 and 38, the arm 31, and the motor element 11 itself. If the switch remains with such an over-voltage or under-voltage applied for more than a few minutes, slow, viscous slippage occurs in the material between the two coupling members 51 and 52, which results over a period of time in the removal of the stresses set up as a result of the application of a voltage not exactly sufficient to move the switch arm into an equilibrium position. If the over-voltage was extreme, upon removal of the signal after a lapse of many hours the element 11 will tend to move so far past its original no-voltage position that the arm 31 will be urged against the stop 38 with considerable pressure, but this pressure will decrease due to the slow, viscous slippage until it is relieved if the relay remains in the unexcited condition for an extended period of time. Assume, on the other hand, that the exciting voltage is so low that the arm 31 moves upwardly just enough to permit the toggle action to establish contact between the points 32 and 43, and then this voltage is maintained long enough to permit equalization of the stress difference between the forces applied by the spring 35 and by the excitation of the motor 11. Upon subsequent removal of the low exciting voltage, the effort of the motor 11 to return to its unexcited condition may drive the arm 31 only somewhat beyond a position midway between the two stable positions, but even then the contact between the points 32 and 43 will be broken, and thereafter the arm 31 will return slowly to its original position against the stop member 38 as slippage occurs in the coupling means.

The function of the coupling means, however, is primarily to permit the device to conform to any relatively slow variations of the individual positions of the motor element which correspond to the stable positions of the driven element or switch arm. Relative variations of the positions of the motor and the driven element may arise over extended periods of time due to thermal distortions of various parts, particularly of the motor itself, or simply to the application of unforeseen mechanical stresses to portions of the structure or to the housing within which it is supported. Since motion of only several thousandths of an inch may be sufficient to throw the switch, it is clear that these undesirable distortions may be sufficient to throw the switch without a change in excitation or to prevent its being thrown when the excitation is changed. However, when these undesirable distortions occur slowly, as usually is the case, the viscous coupling arrangement provides practically no resistance to slippage in the coupling means, and the slide member 52 simply moves within the sleeve 51 to maintain the assembly in the equilibrium positions determined by the position-stabilizing means. As a consequence, changes in the excitation voltage within reasonable tolerances continue to result in operation of the switch, in spite of such slow variations of relative positions of the parts, up to the limits imposed by the total travel available to the slide member 52 within the sleeve member 51.

It may be noted that any such slow variations of the equilibrium positions of the motor element can be corrected even though the relay is being excited by a frequently repeated application and removal of the exciting potential. During the periods when the switch arm is momentarily in positions approximating the stable positions there will be a component of force exerted on the coupling means, in the same direction whether the relay is open or closed, to cause viscous slippage and thus to conform the mean positions of the elements over a period of time to such relatively slow variations, even though this component of force may have to act through many successive reversals of the relay position.

While there has been described what at present is considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention, and it is aimed, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A device for providing reproducible mechanical motions into a plurality of predetermined positions, comprising: a motor element; a driven element; position-stabilizing means establishing a plurality of stable positions for said driven element so as to act upon said driven element to urge it from other positions into an adjacent one of said stable positions; and coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, each of said two coupling members being connected individually to one of said motor and driven elements to provide relatively tight slip-free mechanical coupling between said two elements during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said driven element between positions corresponding to two of said stable positions, but providing relatively loose coupling, with viscous slippage between said members of said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said driven element.

2. A device for providing reproducible mechanical motions into a plurality of predetermined positions, comprising: a motor element; a driven element; position-stabilizing means establishing a plurality of stable positions for said driven element so as to act upon said driven element to urge it from other positions into an adjacent one of said stable positions; and coupling means, comprising a sleeve member, a slide member slidably disposed therewithin with clearances of capillary dimensions between said members, and a viscous material disposed therebetween but unconstrained from escaping at an open end of said sleeve member, each of said sleeve and slide members being connected individually to one of said motor and driven elements to provide relatively tight slip-free mechanical coupling between said two elements during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said driven element between positions corresponding to two of said stable positions, but providing relatively loose coupling, with viscous slippage between said members of said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said driven element.

3. A device for providing reproducible mechanical motions into a plurality of predetermined positions, comprising: a motor element; a driven element; position-stabilizing means establishing two stable positions for said driven element so as to act upon said driven element to urge it from other positions into an adjacent one of said stable positions; and coupling means, comprising two coupling members, constrained in relatively

slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, each of said two coupling members being connected individually to one of said motor and driven elements to provide relatively tight slip-free mechanical coupling between said two elements during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said driven element between positions corresponding to said two stable positions, but providing relatively loose coupling, with viscous slippage between said members of said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said driven element.

4. A relay device, comprising: a motor element; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing a plurality of stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; at least one additional electrical contact point disposed to make positive contact with said first contact point when said switch arm is in a corresponding one of said stable positions; and coupling means between said motor element and said switch arm providing relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to two of said stable positions, but providing relatively loose coupling, with slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

5. A relay device, comprising: a motor element; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing two stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said stable positions; and coupling means between said motor element and said switch arm providing relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two stable positions, but providing relatively loose coupling, with slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

6. A relay device, comprising: a motor element; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing two stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said stable positions; and coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, one of said two coupling members being connected to said motor element and the other being connected to said switch arm to provide relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two stable positions, but providing relatively loose coupling, with viscous slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

7. A relay device, comprising: a motor element; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing two stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said stable positions; and coupling means, comprising a sleeve member, a slide member slidably disposed therewithin with clearances of capillary dimensions between said members, and a viscous material disposed therebetween but unconstrained from escaping at an open end of said sleeve member, one of said sleeve and slide members being connected to said motor element and the other being connected to said switch arm to provide relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two stable positions, but providing relatively loose coupling, with viscous slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

8. A relay device, comprising: a motor element; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing a plurality of stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions, said means including a spring member associated with said switch arm so as to have minima of elastically stored energy when said arm is in said stable positions; at least one additional electrical contact point disposed to make positive contact with said first contact point when said switch arm is in a corresponding one of said stable positions; and coupling means between said motor element and said switch arm providing relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to two of said stable positions, but providing relatively loose coupling, with slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

9. A relay device, comprising: a motor element; a relay switch arm pivotally supported about a transverse axis; a first electrical contact point carried by said switch arm remote from said transverse axis; stop members arranged to limit to the ends of a small arc the extreme positions of pivotal motion of said switch arm about said axis; a compression spring bearing against a point of attachment on said switch arm remote from said axis and against a fixed point which lies between said point of attachment and said axis and which is adjacent to said switch arm when said arm is in a position intermediate of said extreme positions, whereby the position of said switch arm is stabilized at one of said two extreme positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said extreme positions; and coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, one of said two coupling members being connected to said motor element and the other being con-

nected to said switch arm to provide relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two extreme positions, but providing relatively loose coupling, with viscous slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said extreme positions of said switch arm.

10. A relay device, comprising: a motor element including an elongated, electromechanically responsive member affixed to another elongated member with major faces of said two elongated members adjacent to each other to obtain motions associated with bending distortions of said two members upon electrical energization of said electromechanically responsive member in a longitudinal mode; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing two stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said stable positions; and coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, one of said two coupling members being connected to said motor element and the other of said switch arm to provide relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two stable positions, but providing relatively loose coupling, with viscous slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

11. A relay device, comprising: a motor element including an elongated member of electromechanically responsive dielectric ceramic material affixed to another elongated member in face-to-face relationship to obtain motions, associated with bending distortions of said two members, resulting from changes in length of said elongated ceramic element upon application of electric field energization thereacross; a relay switch arm; a first electrical contact point carried by said switch arm; position-stabilizing means establishing two stable positions for said switch arm so as to act upon said arm to urge it from other positions into an adjacent one of said stable positions; a second electrical contact point disposed to make positive contact with said first contact point when said switch arm is in one of said stable positions; and coupling means, comprising two coupling members, constrained in relatively slidable relationship with clearances of capillary dimensions therebetween, and a viscous material disposed therebetween but unconstrained by external structure from escaping, one of said two coupling members being connected to said motor element and the other being connected to said switch arm to provide relatively tight, slip-free mechanical coupling between said element and said arm during relatively rapid motions of said motor element, resulting from changes in the energization thereof for driving said switch arm between positions corresponding to said two stable positions, but providing relatively loose coupling, with viscous slippage within said coupling means, to conform to any relatively slow variations of the individual positions of said motor element which correspond to said stable positions of said switch arm.

References Cited in the file of this patent

UNITED STATES PATENTS

786,696	Vreeland	Apr. 4, 1905
2,135,864	Weber	Nov. 8, 1938
2,144,120	Parks	Jan. 17, 1939
2,151,744	Clark	Mar. 28, 1939
2,195,417	Mason	Apr. 2, 1940
2,228,523	Johnson	Jan. 14, 1941
2,365,738	Williams	Dec. 26, 1944
2,587,482	Keller	Feb. 26, 1952
2,640,899	Dickey	June 2, 1953