United States Patent

Harris

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[54] **CATASTROPHICALLY BUCKLING COMPRESSION COLUMN SWITCH AND ACTUATOR**

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[73] Assignee: **International Business Machines Corporation,** Armonk, N.Y.

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[52] **U.S. Cl.**......**200/67 DB,** 200/159 R, 200/166 BA, 200/181

[51] **Int. Cl.**..**H01h 13/28**

[58] **Field of Search**......200/166 BA, 67 DB, 67 DA, 159 R, 200/181, 67 A

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Assistant Examiner—Robert A. Vanderhye
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[57] **ABSTRACT**

A snap-action switch and actuator are disclosed in which a resilient columnar compression member is axially loaded to the point of catastrophic buckling. In one embodiment, the column serves as both an electrical conductor and a contact. In this embodiment, it buckles into contact with another conductive member to complete a circuit. Alternatively, the buckled column may actuate a piezoelectric, optical, or other signal producing means to produce signals used for switching or to close other contacts.

15 Claims, 9 Drawing Figures

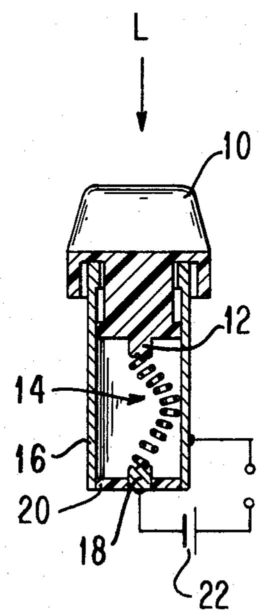

FIG. 1a

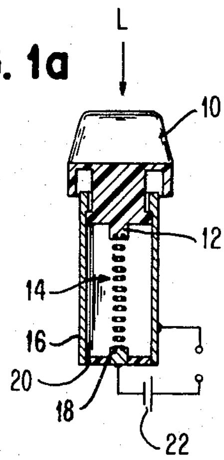

FIG. 1b

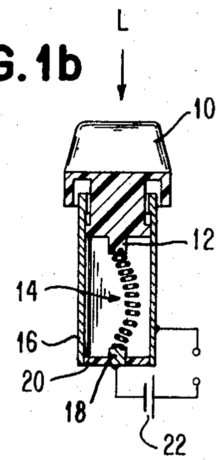

FIG. 1c

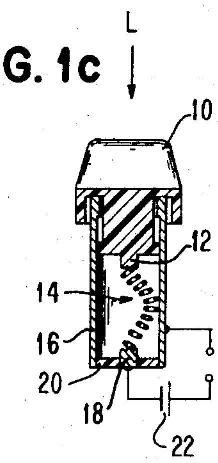

FIG. 2a

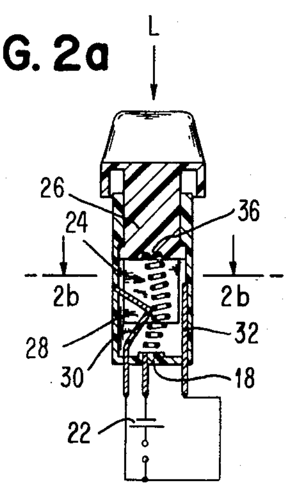

FIG. 2b

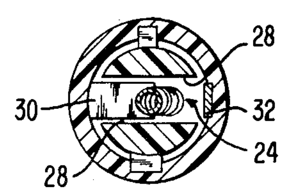

FIG. 3

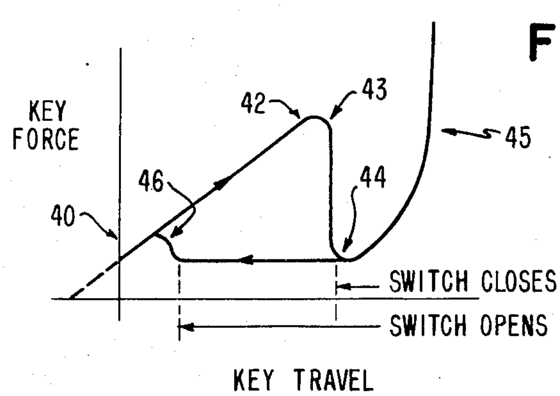

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FIG. 4

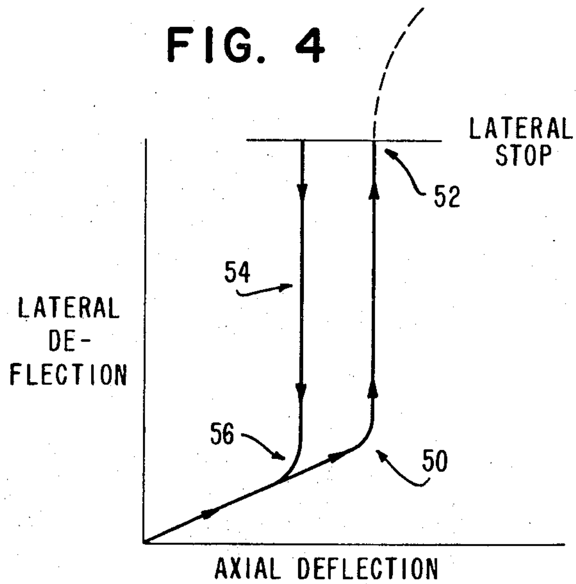


FIG. 5

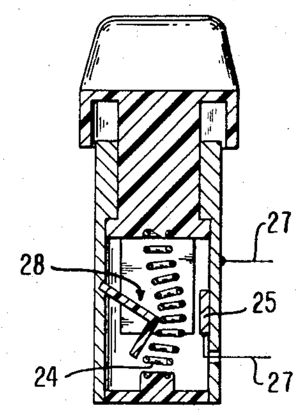


FIG. 6a

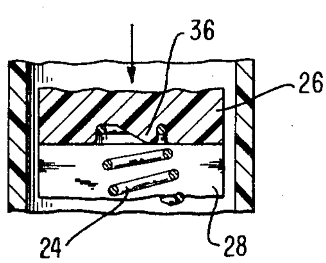
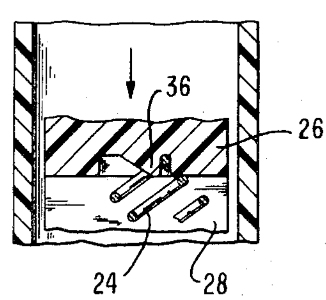


FIG. 6b



CATASTROPHICALLY BUCKLING COMPRESSION COLUMN SWITCH AND ACTUATOR

BACKGROUND

1. Field of the Invention

This invention relates to electrical switching apparatus in general and in particular to the mechanism for actuating or driving electrical switch contacts or electrical signal generating means for producing electrical switching signals.

2. Prior Art

It has been known in the prior art to use a resilient spring means as an electrical contact member which performs the dual functions of forming electrical connection and of exerting a biasing force to return the actuating member to its unactuated position upon the release of the actuating force. However, these prior art devices did not provide the quick snap-action necessary to unambiguously define the switch make condition; i.e., they do not provide a fixed point in the actuator travel position at which the operator is certain that he has completed contact. The snap-action feature is a desirable addition to electrical switches in general, as has been known in the prior art, because it provides the operator with a definitely identifiable switch make point. As stated, while prior art devices have provided the dual functions of forming electrical connection and of providing a restoring force by using a spring member, these devices have not provided both the desirable snap-action and the restoring force by using a spring member, and they have not utilized such simple, reliable construction to achieve long life and low cost.

Similarly, while many prior art devices have provided "contact hysteresis," in that once contact is made, it is maintained until after the actuator is restored some distance above the make point, these prior devices have been relatively complex and expensive to build. The contact hysteresis effect is desirable to ensure that the contacts will remain made and not be accidently opened by the operator. (The lack of hysteresis allows contact bounce to occur that is dependent upon actuator velocity and small changes in actuator direction resulting in unpredictable ambient vibrations.) Also, it is desirable to provide a resilient "key feel," of a sudden snap followed by increasing resistance to actuator travel beyond the point of make. It is also desirable to prevent erroneous switching caused by insufficient contact duration. While prior art devices have provided contact hysteresis and the desirable force buildup and overtravel for "key feel," they have not provided these features in a simple, reliable snap-action switch, nor have they utilized a spring member as both a snap actuator and as biasing and restoring means.

OBJECTS

In light of the foregoing desired features, it is an object of this invention to provide an improved switch and an improved switch actuator having an unambiguous "-make-point" provided by an improved snap-action member.

It is also an object of this invention to isolate the making of electrical contact from the operator's control once he has depressed an actuator beyond a fixed amount, in an improved and simpler way.

It is further an object of this invention to provide an improved switch actuating mechanism having contact hysteresis and good key feel which is simpler, more reliable, and less costly than those known in the prior art.

SUMMARY

This invention achieves the foregoing objects by utilizing the catastrophic buckling phenomenon exhibited by a resilient columnar member under axial load to provide the snap action desired. The catastrophic buckling of the columnar member provides contact hysteresis and a desirable key feel as will be further described herein. To allow for catastrophic buckling of the columnar member, at least one end of the column is mounted to allow a degree of freedom in the end constraint which permits the column to change rapidly from a higher energy load condition to a lower energy load condition. In one embodiment, the columnar member is utilized as an electrical conductor which buckles into contact with a cooperating electrical conductor to complete a circuit. Alternatively, the buckling columnar member is used to actuate electrical signal producing devices to control switching functions electronically.

In the drawings:

FIGS. 1*a* through 1*c* illustrate an embodiment of the invention which utilizes a helical compression spring as the columnar buckling contact member and as a key biasing or restoring means.

FIGS. 2*a* and 2*b* illustrate another embodiment of the invention in which the columnar contact member makes contact with cooperating contact members to complete circuits in both its unbuckled (normally closed contact) and in its buckled condition (normally open contact).

FIG. 3 illustrates a force-displacement diagram of a typical embodiment of this invention and shows how key force builds up to a peak followed by a catastrophic buckling or snap action and a later increase of force to produce greater key travel, and it shows the delayed release or contact break point upon the release of the actuator.

FIG. 4 illustrates how lateral deflection of a columnar member having large eccentricity is a function of axial deflection.

FIG. 5 illustrates another embodiment of the invention in which the buckled knee of the columnar member actuates a signal generator.

FIGS. 6*a* and 6*b* show a more detailed view of the embodiment shown in FIG. 1 which illustrates one type of end mounting which permits catastrophic buckling of the columnar member.

An important aspect of this invention lies in the use of a bucklable columnar member to provide the desired snap action and hysteresis. Therefore, some columnar member must be provided which can be loaded to the point of catastrophic buckling. The column need be of no particular material to satisfy this criteria; but, in general, thicker cross-sections and stronger materials produce columns of a given length which buckle catastrophically at higher loads than a column of the same length but of smaller cross-section or one of more easily strained material. Similarly, it is well-known that column length is a vital factor in determining the buckling point or load. Any good mechanical engineering handbook will contain longer discussions of column buckling and can easily be resorted to by those unfamiliar with these considerations of length, cross-section, etc. to design a column which will buckle at any desired load.

Since the buckling column provides the actuating element in this invention, it is obvious that if only one-time operation is desired, the column can be made of relatively less elastic and, therefore, fracturable or easily ruptured material, or the dimensions of the column may be adjusted to ensure that catastrophic buckling will also fracture the column. However, for most purposes, a reusable, and, therefore, a necessarily more resilient and elastic column is desired. Therefore, I have described embodiments in which the column is designed not to fracture when it catastrophically buckles.

As shown in FIGS. 1*a* through 1*c*, a preferred embodiment of my invention as used in an electrical switch can be constructed as follows. Resilient columnar buckling member **14** is disposed between mounting means **12** and **18**. In FIG. 1*a*, buckling member **14** is shown in its extended, (It is actually partly compressed to give an initial 25 grams preload to the actuator) or unactuated, unloaded state. To provide a means for axially loading the column, axial loading end cap **10** is shown as being slidably disposed within conductive sleeve **16**, but many other types of support for this cap could be utilized, or the cap could be replaced with a pivoted lever or plunger or any other suitable load applying mechanism. As shown, buckling member **14** is supplied with electric current through end mounting **18** which is insulated from conductive sleeve **16** by insulator **20**. Also, as shown, current source **22** is connected between sleeve **16** and mounting means **18**, but in its unbuckled condition, buckling member **14** does not contact sleeve **16** and, hence, a circuit is not complete. Some means must be provided for insulating the opposite end of buckling member **14** from electrical contact with sleeve **16**. In the present embodiment, this is accomplished by making end cap **10** of electrically non-conductive material, but suitable sleeve insulators could also be used.

FIG. 1b shows buckling member **14** partially deflected under the influence of load L applied to end cap **10**. Increasing load L will increase the deflection of buckling member **14**, until, as shown in FIG. 1c, buckling member **14** reaches its critical or catastrophic buckling position. At this point, either one or both ends of member **14** pivot about a point on the periphery of the end surface of the member where it touches the end mounting means **12** or **18** and lateral deflection of member **14** increases rapidly, bringing member **14** into contact with sleeve **16** and completing an electric circuit. However, once member **14** is in its buckled condition, the release of load L on end cap **10** will not immediately cause member **14** to break contact with sleeve **16**, since a lesser load L is necessary to maintain member **14** in its buckled condition than was necessary to cause it to buckle initially. Thus, some upward travel of end cap **10** must take place in order for buckled member **14** to return to an unbuckled, and non-contacting position. This phenomenon provides a hysteresis effect and is particularly useful in electric switches as pointed out earlier.

An important aspect of the invention as embodied in FIG. **1** is that the end mount **12** and/or **18** must allow some pivotal deflection of member **14** about a point on its periphery at one or both ends thereof in order to permit the catastrophic buckling to take place. Exactly how this pivoting is accomplished will be discussed further below. Of course, one end mounting means, such as mounting **18**, must resist axial forces applied at the opposite end of member **14** in order for the build up of stress to take place which leads to catastrophic buckling. While member **14** is shown to be a helical compression spring in FIG. **1**, other resilient columnar members, such as thin wires or tin flat plates, might be similarly utilized.

Another embodiment of the invention is shown in FIGS. 2*a* and 2*b* in which the conductive sleeve **16** of FIG. **1** is replaced with two conductive strips **30** and **32**. As shown in FIG. 2*a*, strip **30** is in contact with columnar member **24** when the columnar member is in its unbuckled condition (although it is partially deflected). If external wires were added, a circuit would thus be completed between conductive member **30** and buckling member **24** until such time as member **24** is deflected or buckled far enough to break contact with conductive member **30**. As shown, member **30** biases the deflection of member **24** in a predetermined or preferred direction. And, as shown in FIG. 2*b*, the buckling of member **24** is further constrained by guide members **28** so that it can buckle only into contact with member **32**. However, it is obvious that guide members **28** could be eliminated if contact **32** were enlarged to surround the columnar member as shown in FIGS. 1*a*–1*c*. In this configuration, the invention exhibits both normally closed and normally opened contact points.

As shown in FIG. 2*a*, and in FIGS. 6*a* & 6*b*, end mount **36** in cap **26** restrains a portion of the periphery of buckling member **24** during catastrophic buckling, so that buckling member **24** can pivot about the restraint point. However, end mount **36** could easily be made with a pivoting ball base to permit holding the entire periphery of the end of member **24**, but still providing a means thereby to allow member **24** to pivot

FIG. **3** shows a schematic plot of how the force on the end of the buckling member varies with the amount of displacement of the end. This figure is useful in defining the phenomenon, which, for this specification and claims, is called catastrophic buckling. As can be seen, the force required to deflect the columnar member begins at some pre-load point as shown at point **40** and increases linearly to a point **42** just prior to catastrophic buckling then drops sharply at the point **43**, where catastrophic buckling occurs, to point **44**. It then rises more rapidly as the buckled column is further deflected by additional movement of the end cap after the columnar member contacts the side wall or other contact. In this condition, electrical contacts would be closed. Continued depression is followed by an extremely steep rise in force **45** when the column is completely buckled or the end cap is bottomed out. On the release of force on the end of the columnar member, the columnar member remains buckled until the force falls substantially below that necessary to originally cause buckling, as shown by the arrows on the force-travel diagram. "Switch Break" would occur at point **46** when the catastrophic buckling condition is relieved.

FIG. 4 graphically illustrates the amount of laterial deflection of the columnar member as a function of axial deflection of one end thereof. As can be seen, lateral deflection of the columnar member increases gradually with increasing axial deflection of one end of the columnar member until a critical point **50** is reached at which catastrophic buckling occurs and lateral deflection increases very rapidly with only a slight increase in axial deflection. If the buckling "knee" of the columnar member then reaches a stop member, such as a contact member, as shown at point **52**, additional lateral deflection is stopped as indicated on the diagram. Axial deflection may be increased at this point, but on release, the deflection path is the same as shown at **54**, until catastrophic buckling is relieved at **56**.

FIG. 5 illustrates another embodiment of the invention in which the buckled columnar member actuates a piezoelectric or other signal generator to provide an electric signal pulse useful for actuating electronic switching devices. By way of example, the impact produced when the rapidly buckling columnar member **24** hits the device **25**, which for the moment will be considered to be a piezoelectric device, causes a voltage signal to be produced on leads **27**. This signal will die as contact pressure between buckled member **24** and the piezoelectric device **25** stabilizes, but a new pulse is produced upon the release of pressure.

Similarly, device **25** could be replaced with a capacitive switch element such as shown in IBM Technical Disclosure Bulletin, Vol. 5, No. 12, May 1963, p. 22 or Vol. 12, No. 8, January 1970, p. 1166.

Also, it is obvious that the columnar member need not physically contact a signal generating device if, instead of the above devices, a photosensitive circuit device is arranged to detect the buckling of the column. In such a case, device **25** could be replaced by a suitable light sensitive element. Such devices wherein a moving object interrupts a light beam to trigger associated electrical switching means are well known and need no description to those of ordinary skill in the art, but a variety of photoelectric trigger circuits are to be found in Markus' *Handbook of Electronic Control Circuits*, pp. 191–203, First Edition, 1959, the McGraw-Hill Book Co., Inc.

FIGS. *6a* and *6b* show a more detailed view of the end mount **36** of the type used in FIG. *2a* which permits catastrophic buckling of the columnar member. As can be seen, this mount engages a portion of the periphery of the end of the columnar member so that the end surface of the columnar member may pivot in its mount. Many other types of pivot mechanism could be substituted such as a pivoted mount instead of a fixed mount in which the column pivots. This pivoting of the end surface of the columnar member about a point on its periphery or, as otherwise expressed, a pivoting of the end of the column with respect to the axis of the column, changes its deflection energy characteristic to a lower energy mode and permits the columnar member to remain buckled, even though the buckling force is later reduced to a point below which buckling would have originally occurred.

STATEMENT OF OPERATION

The embodiment illustrated in FIGS. *1a–1c* can be used to visualize the operation of the invention. As shown, the end cap **10** may be a keybutton which is depressed by an operator. As the operator depresses the keybutton, the columnar member **14** undergoes axial compression and begins to assume a laterally deformed or curved shape as shown in FIG. *1b*. This curve has two inflection points and is thus a high-energy deformed shape. As the operator continues to push on the keybutton, the force necessary for each additional increment of travel increases as shown in FIG. 3 until a point is reached at which the column becomes unstable and buckles catastrophically to a lower energy condition in which the column has only one inflection point. Its end pivots in mount **12** about a point on its periphery. This catastrophic buckling of the columnar member causes the "knee" of the buckled column to come into contact with conductive sleeve **16**, in the embodiment shown, thus completing a circuit with current source **22**. To the operator, this phenomenon is accompanied by a sudden decrease in the amount of force required to deflect the keybutton. This is shown in FIG. 3. Continued depression of the keybutton does not affect the contact made between buckled columnar member **14** and sleeve **16**, but the amount of force required to deflect the column further does increase as the remaining portion of the column becomes more highly stressed.

If the operator now releases the force on the keybutton, it will spring back under the urging influence of the deflected columnar member; but because of the changed end condition at mount **12** with relation to the columnar member **14**, less force is required to keep the columnar member in its buckled, contact-forming condition. This means that contact will be maintained between columnar member **14** and sleeve **16** until the force drops to some point below that at which original buckling occurred. Such buckling conditions are described further by Wahl in *Mechanical Springs* (p. 69), Second Edition, McGraw-Hill. This is the contact hysteresis effect which is desired in this type of electrical switch and it also provides a desirable key feel.

The mode of operation of the embodiments shown in FIGS. 2 and 5 are similar, except that in FIG. 2, the internal guide members **28** and the urging of the normally closed contact member **30**, guide the buckling columnar member into a preferred direction of buckling to insure that contact will be made with normally open contact **34** as shown in FIG. 2 or to actuate a piezoelectric or other type of transducer as shown in FIG. 5 to produce an electric signal indicative of a closed contact condition.

ADVANTAGES

The foregoing description has alluded to some of the advantages of this invention, but notable among them are the following:

The invention is simpler, more rugged, and more reliable than switches and their actuator mechanisms known in the prior art and it is cheaper to construct.

Further, the invention provides an electric switch mechanism with a desirable contact hysteresis characteristic and a desirable snap-action without the use of numerous and complicated parts.

Additionally, the invention provides an actuator mechanism which gives the operator a desirable "key feel" or tactile signal in the form of reduced operating force to inform the operator when contact has been made.

While this invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An actuating mechanism for initiating operation of electrical contacting apparatus, which actuating mechanism comprises:

a columnar member;

end mounting means for mounting the ends of said columnar member;

at least one end of said columnar member being pivotally mounted by one of said end mounting means; and

means for axially loading said columnar member in compression to catastrophically buckle said columnar member with at least one end thereof pivoting on its said mounting means and with the buckled portion of said columnar member moving laterally with respect to the ends thereof to initiate the operation of associated electrical contacting apparatus.

2. An electrical switch mechanism, as in claim 1, further comprising:

first electrical contact initiating means for contacting said columnar member prior to the application of said catastrophically buckling axial load; and

second electrical contact initiating means disposed laterally adjacent said columnar member for contacting the buckled portion of said columnar member when said member is catastrophically buckled.

3. An electrical switch mechanism, as described in claim 2, wherein:

said resilient columnar member is electrically conductive;

said first electrical contact initiating means for contacting said columnar member prior to the application of said catastrophically buckling axial load is an electrically conductive contact; and

said second electrical contact initiating means disposed laterally adjacent said columnar member for contacting the buckled portion of said columnar member when said member is catastrophically buckled is an electrically conductive contact.

4. An electrical switch mechanism as described in claim 3, wherein:

said mechanism includes guide means for guiding the buckling columnar member into contact with said second contact initiating means.

5. A self-restoring electrical switch mechanism as described in claim 2, wherein:

said movable end mounting means is resiliently biased against movement in compression of said columnar member by said columnar member.

6. A self-restoring electrical switch mechanism as described in claim 5, wherein:

said resilient columnar member is electrically conductive; and

said first and second electrical contact initiating means are electrically conductive.

7. An electrical switch mechanism as described in claim 5, wherein said mechanism includes guide means for guiding the buckling columnar member into contact with said second contact initiating means.

8. An electrical switch mechanism as described in claim 7, wherein:

said resilient columnar member is electrically conductive; and

said first and second electrical contact initiating means are electrically conductive.

9. An actuating mechanism for initiating operation of electrical contacting apparatus, which actuating mechanism comprises:

a resilient columnar member;

end mounting means for mounting the ends of said columnar member;

one of said end mounting means being freely disposed to move axially with respect to the longitudinal axis of said columnar member;

at least one end of said columnar member being pivotally mounted by one of said end mounting means; and

means for axially loading said columnar member in compression, said means for axially loading said columnar member acting upon said movable end mount, with said axial load being of sufficient magnitude to buckle said columnar member catastrophically with at least one end thereof pivoting on its said mounting means and with the buckled portion of said columnar member moving laterally with respect to the ends thereof to initiate the operation of associated electrical contacting apparatus.

10. An electrical switch mechanism, as described in claim 9, wherein:

said resilient columnar member is electrically conductive;

said associated electrical contacting apparatus is an electrically conductive contact means disposed laterally adjacent said columnar member; and

when the columnar member buckles catastrophically, the buckled portion of said columnar member moves laterally with respect to the ends thereof to electrically contact said electrical contact means, thereby completing an electrical circuit.

11. A self-restoring actuating mechanism for initiating operation of electrical contacting apparatus as described in claim 9, wherein:

said axially movable end mounting means is resiliently biased against movement in compression of said columnar member by said columnar member.

12. A self-restoring contact actuating mechanism as described in claim 11, wherein:

said associated electrical contacting apparatus contacted by said columnar member when said member is catastrophically buckled is a piezoelectric means for producing electrical signals; and

said piezoelectric means is further connected to an electric circuit completing device responsive to electrical signals produced by said piezoelectric means for closing electrical contacts.

13. A self-restoring contact actuating mechanism as described in claim 11, wherein:

said associated electrical contacting apparatus contacted by said columnar member when said member is catastrophically buckled is a capacitive electric means for producing electrical signals; and

said capacitive electric means is further connected to an electric circuit completing device responsive to electrical signals produced by said capacitive electric means for closing contacts.

14. A self-restoring contact actuating mechanism as described in claim **15**, wherein:

said columnar member is an electrically conductive compression spring;

and the lateral movement of the buckled portion of said columnar member during catastrophic buckling thereof moves the buckled portion into both physical and electrical contact with associated electrical contacting apparatus.

15. A self-restoring contact actuating mechanism as described in claim **11**, further including:

guide means for guiding buckling columnar member into contact with said associated electrical contacting apparatus.

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