United States Patent [19]

Otte

[11] **3,783,429**

[45] **Jan. 1, 1974**

[54] **TEMPERATURE ACTUATED CONNECTOR**

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[73] Assignee: **Raychem Corporation,** Menlo Park, Calif.

[22] Filed: **June 21, 1972**

[21] Appl. No.: **264,782**

[52] **U.S. Cl.** **337/393**

[51] **Int. Cl.** **H01h 37/46**

[58] **Field of Search** 337/393, 394, 395, 337/397, 123

[56] **References Cited**

UNITED STATES PATENTS

3,613,732 10/1971 Willson et al. 337/393

FOREIGN PATENTS OR APPLICATIONS

181,311 8/1954 Austria 337/393

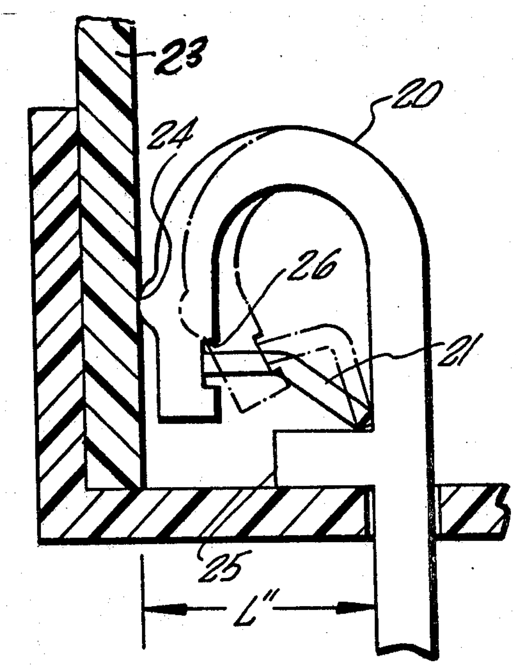
Primary Examiner—Harold Broome

Attorney—Charles G. Lyon et al.

[57] **ABSTRACT**

A temperature actuated device is disclosed which is capable of movement with a change in temperature of at least a portion of the device. The device has a first member which is fabricated from a material which undergoes a relatively large change in strength over the operating temperature range of the device. This first member may be operably connected to a second spring member so that movement of the second spring member causes movement of the first member. The second spring member preferably has a different strength-temperature characteristic so that the device will attempt to assume a first stable configuration at a first temperature and a different stable configuration at a second temperature.

12 Claims, 6 Drawing Figures



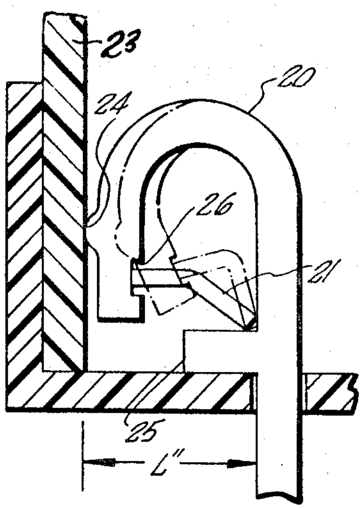


FIG. 1

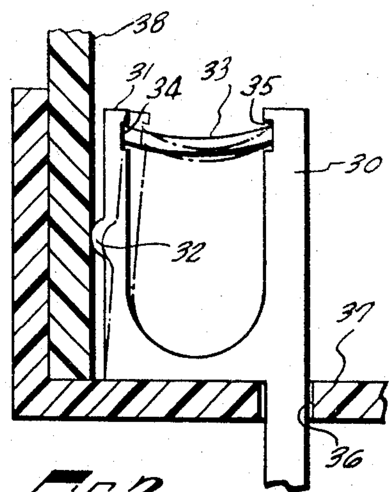


FIG. 2

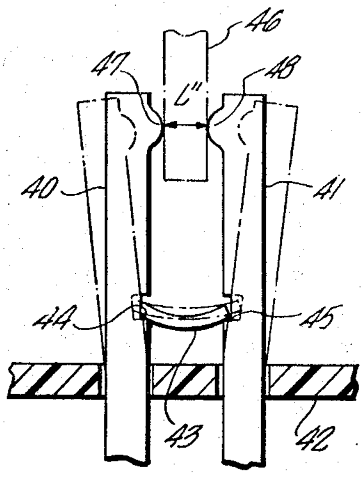


FIG. 3

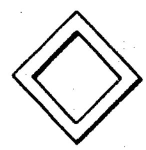


FIG. 4

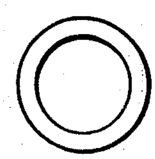


FIG. 5

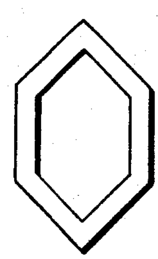


FIG. 6

TEMPERATURE ACTUATED CONNECTOR

BACKGROUND OF THE INVENTION

The field of the invention is connectors of the type useful for forming a mechanical or electrical connection between two or more members. The connector is temperature actuated so that at a first temperature, the device will attempt to assume a first stable configuration and at a second temperature it will attempt to reach a different stable configuration.

The device is particularly useful for forming an electrical and mechanical connection between a conductor and a printed circuit board. In the past, such connections have been commonly made by a plug-in type connection where the conductive board fits into a slot and a conductive resilient member contacts a conductive portion of the board. Such connections have several disadvantages. First, the board is not tightly held in its plugged-in position. Secondly, the electrical connection tends to degrade if the contact is not exercised. A soldered connection can be used to connect a conductor to a printed circuit board. Such a connection does not have the "plug in" capability and requires resoldering at any time the printed circuit board needs to be removed or replaced. When multiple connections are involved, this disadvantage is particularly acute

An improved connector is disclosed in an application filed by Otte and Fischer, U.S. Pat. Ser. No. 157,890 filed June 29, 1971 and assigned to the assignees of the present invention. This connector utilizes a heat recoverable metallic member disposed about a resilient member, such as the tines of a forked member. A conductor is inserted between the tines and the heat recoverable metallic member is caused to shrink, thereby forcing the tines inwardly and against the conductor. Such a device is somewhat limited in amount of movement, and is also relatively expensive to fabricate and thus the need for an improved connector exists.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a temperature actuated device which will form a first stable configuration at a first temperature, and a second stable configuration at a second temperature.

It is another object of the present invention to provide a reusable connecting device capable of maintaining a secure contact at relatively high temperatures.

The present invention is for a temperature actuated device comprising a first member fabricated to be capable of undergoing a relatively large change in force/deflection characteristics with temperature which member is operably attached to a second spring member so that flexure of the second spring member causes a flexure of the first member. The first member and the second spring member are attached in an opposing manner so that they tend to work against one another. When the temperature of the device is changed, the force/deflection characteristics of one member changes with respect to the other member, and the device exhibits movement. When the first member is fabricated from a heat recoverable metal such as an alloy of titanium and nickel, a connector capable of operation at high temperatures results since such alloys maintain their strength at high temperatures. Furthermore, when one of the members is configured so that it has a nonproportional load/deflection relationship, a connector which has the ability to "snap" from one position to a second position may result. A longitudinally loaded leaf spring is particularly effective for this purpose.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation of a device of the present invention.

FIG. **2** is a side elevation of an alternate embodiment of a device of the present invention.

FIG. **3** is a side elevation of an alternate embodiment of a device of the present invention.

FIG. **4** is a side elevation of a spring member useful with the device of the present invention.

FIG. **5** is a side elevation of a spring member useful with the device of the present invention.

FIG. **6** is a side elevation of a spring member useful with the device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The temperature actuated device of the present invention is caused to move by the action of two members, which are operably attached to one another in an opposing manner. The materials from which these members are fabricated have a different strength/temperature relationship so that the stable configuration of the device will vary with temperature.

Some materials such as heat shrinkable metals exhibit a relatively large change in strength with temperature. An example of a suitable heat shrinkable metal is the alloys having about equal atomic proportions of titanium and nickel. They typically have an austenitic secant modulus of about 12,000,000 PSI at a strain of ½ percent and a martensitic secant modulus of about 850,000 PSI at a strain of 5 percent. This large difference in secant modulus coupled with the large variation in strain makes these alloys particularly suitable for use in thermally activated devices of the sort described. Relatively large amounts of force and movement per unit volume of material are attainable with them. Note also that the stress and strain applied must be such that the material does not deform permanently to any substantial degree during repeated cycling. An initial permanent or plastic deformation is allowable but it must not continue on cycling because if it does, the points between which the members move will vary with eacy cycle and that is undesirable.

Other alloys are known which exhibit a similar phenomena, and examples of such alloys are disclosed in A. Nagasawa, 31 J. Phys. Soc. Japan No. 1, July, 1971 pp. 136–147. Examples include cadmium-gold, copper-aluminum-nickel, indium-thallium, uranium-molybdinum and uranium-niobium. Some polymers and elastomers are also known to exhibit a relatively large modulus change with temperature and may also be used in the practice of the present invention.

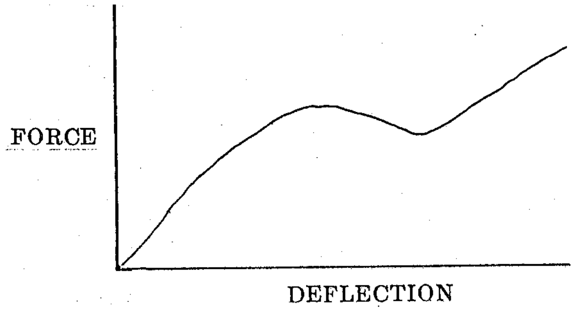
The members of the device of the present invention can be of practically any configuration. For instance, the device of FIG. **1** utilizes a curved end cantilever spring **20** which is operably attached to a longitudinally loaded leaf member **21**. Spring **20** is inserted through an opening in base **22**. If member **21** is fabricated from a material which has a relatively low modulus at low temperatures, and spring **20** is fabricated from a material which has a relatively high modulus at low temperatures, the device will attempt to assume a position such as that indicated by the phantom lines. As the temperature is increased, the longitudinal force exerted by member **21** also increases, and it will extend in the position shown by the solid lines in FIG. **2.** If a circuit board **23** is placed between the device and base **22,** a strong contact will be made between the printed circuit board and contact point **24** of spring **20** when member **21** is at a temperature at which it has a relatively high strength. Member **21** is held in spring **20** by stop **25** and indentation **26.** Stop **25** also positions spring **20** in base **22.**

The device shown in FIG. **1** represents a particularly effective temperature activated device for a reason which is not readily apparent. This reason relates to the load/deflection characteristics of member **21.** Although member **21** is generally in the shape of a leaf spring, it is not loaded near its midpoint, but instead is only longitudinally loaded. By so loading member **21,** it will exert a relatively large force in a longitudinal direction when it is nearly straight. That is, it takes a relatively large force to deform member **21** from its relaxed position, but once it has been partially deformed it will actually take less force to cause further deformation. Thus, unlike most springs, the load to deflection ratio is not constant but instead varies depending upon the amount of deflection. Stated differently, if a plot is made of load versus deflection for most springs, a straight line will result whereas with a longitudinally loaded leaf spring a curved line will result.

By choosing the proper combination of load/deflection characteristics of springs **20** and member **21,** it is possible to create a device which will tend to "snap" open and closed with a relatively small temperature change.

Although a longitudinally loaded leaf spring comprises a particularly simple method for achieving this "snap" action, other nonlinear springs may also be used. For instance, a Belleville spring may be configured to have a highly nonlinear load/deflection curve. Furthermore, if the ratio of the height to the thickness of the Belleville spring is properly chosen, the load/deflection curve may have a peak which may be utilized to produce a "snap" effect. See, for instance, Machine Design by J. E. Shigley -McGraw-Hill, 1956 at FIG. 7–15 on page 237 which shows load/deflection curves for a series of different Belleville springs which curves are incorporated by reference herein.

One method of achieving this "snap" action is by choosing a member which has a force/deflection curve which has a peak therein. That is, the force deflection curve should reach a maximum followed by at least some portion of decreasing slope. For instance, the force/deflection curve of the first member might look like:



A device with a snap action would result if the second member was connected to the first member in such a way that the deflection of the first member was on the left-hand side of the peak when the device was in a first stable position and on the right hand side of the peak when the device was in its second stable position.

Several shapes of devices exhibit a force deflection/-curve with some negative slope and two examples include some Belleville springs (e.g. Belleville springs having an OD of 5 inches, an ID of 2 ½ inches, a thickness of 0.040 inches and a height to thickness ratio greater than about 2.0) and longitudinally loaded leaf springs.

A slightly different configuration of temperature actuated device is shown in FIG. **2.** A fork spring **30** has a tine **31** having a contact point **32.** A longitudinally loaded member **33** is held in grooves **34** and **35** of spring **30.** Spring **30** is held in an opening **36** in base **37.**

In order to bring about movement of the device, the temperature of the device of FIG. **2** is first set so that member **33** requires a relatively low force to cause a deflection. For instance, if spring **33** is fabricated from an alloy having major proportions of titanium and nickel, the temperature should be decreased in order to convert the titanium-nickel alloy to its martensitic phase configuration. As stated above, this decreases the force it exerts and thus weakens it with respect to spring **30** which then can deform member **33** to a position shown by the phantom lines in FIG. **2.** This cooling may be carried out by means such as by spraying with a low boiling liquid which has been pressurized. Suitable liquid coolants include tetrafluoromethane, chlorotrifluoromethane and trifluoromethane. Alternatively, cooling may be carried out by contact with ice, by liquid nitrogen, or the like. Printed circuit board **38** is then inserted against a portion of base **37** and the temperature of the device is then changed in order to increase the force exerted by member **33** which then forces spring **30** and contact point **32** to the position shown by the solid lines in FIG. **3.** In this position, it is capable of exerting a relatively large force against board **38,** since spring **33** is in a nearly columnar position.

The device of FIG. **3** closes against an object when the leaf spring-shaped member is in its low strength configuration. Cantilever springs **40** and **41** are mounted through base **42,** and a member **43** is held in notches **44** and **45** of springs **40** and **41.** Springs **40** and **41** are fabricated from a material which exhibits a relatively large change in force/deflection characteristics with temperature whereas member **43** is fabricated from a conventional material such as spring steel. When the temperature of the device of FIG. **4** is such that springs **40** and **41** are in their low strength configuration, the member **43** will force springs **40** and **41** apart into a position indicated by the phantom lines of FIG. **3.** When the temperature is changed so that the force/deflection characteristics of springs **40** and **41** is relatively high with respect to the modulus of member **43,** the device will close to the position shown by the solid lines of FIG. **3.** Thus, if an object **46** is placed between the contact points **47** and **48** of springs **40** and **41,** it will be held as shown in FIG. **4.**

Various spring configurations are shown in FIGS. **4** through **6.** These springs can be used in devices of the type shown in FIGS. **1** through **3.** Although it is advantageous that the member which is analogous to member **21** of FIG. **1** have a nonlinear load/deflection curve, this is not essential, since the device will nonetheless be operative if the member has a constant load/deflection ratio. Although the devices described in FIGS. **1** and **2** were described as if the longitudinal leaf spring-like member was fabricated from a material whose modulus changed substantially with temperature, the device could also be made where the member which corresponds to member 21 of FIG. 1 is fabricated from a material having a relatively constant load/deflection characteristics with temperature. The other spring should then be fabricated from a material whose modulus changed substantially with temperature. For instance, if the device of FIG. 1 were fabricated so that spring 20 was made from a titanium/nickel alloy, the device would tend to seek the position shown by the solid lines in FIG. 1 when spring 20 is in a low modulus configuration. Similarly, the device of FIG. 1 would tend to seek the shape shown by the phantom lines shown in FIG. 1 when spring 20 was in a relatively high modulus configuration.

It is significant to note that the movement brought about in the devices of the present invention do not require that there be a dimensional or length change in one of the spring members. It is a change in load/deflection characteristics which brings about a movement rather than a dimensional change. In this way, the devices of the present invention differ in kind from bimetallic members which depend upon differential expansion or contraction with temperature. Changes in properties such as the secant modulus bring about a change in the load/deflection characteristics of a spring. For example, the alloys having about equal atomic proportions of titanium and nickel typically have a secant modulus of about 850,000 PSI at a strain of 5 percent when in the martensitic phase and a secant modulus of about 12,000,000 PSI at a strain of ½ percent when in the austenitic phase.

The devices of the present invention have the potential advantage of being fabricated wholly from metals, and thus can be made to withstand great temperature extremes. The alloy TiNi remains strong at high temperatures; for instance, the Young's modulus of TiNi at 600°C is about 14,000,000 and the strength of many spring steels remains high at 600° C.

The present embodiments of this invention are thus to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims therefore are intended to be embraced therein.

I claim:

1. A snap-action temperature actuated spring device comprising a combination of first and second spring members bearing against one another such that flexure of one such member toward its relaxed position causes flexure of the other such member away from its respective relaxed position, one of said members undergoing a substantial change in modulus in passing from a first to a second temperature within the temperature operating range of said device while the modulus of the other such member remains relatively constant such that, absent external restraint, said combination assumes a first stable configuration at one temperature within said range and another stable configuration at another; said first member having a non-linear load-deflection curve having a peak lying within the useful deflection range of said device such that in passing from one to another of those temperatures at which said stable configurations respectively obtain the flexure of said members causes deflection of said first member from one to the other side of said peak in the absence of external restraint.

2. The device of claim 1 wherein said first member undergoes a substantial change in modulus in passing from a first to a second temperature within the temperature operating range of said device.

3. The device of claim 2 wherein said first member is a longitudinally loaded leaf spring which is operably connected to said second spring member.

4. The device of claim 2 wherein said second spring member is a curved end cantilever spring and wherein said first member is positioned across the curved end thereof.

5. The device of claim 2 wherein said second spring member is a fork spring having at least two tines and wherein said first member is positioned therebetween.

6. The device of claim 5 wherein said first member is fabricated from a metallic alloy composed of major porportions of titanium and nickel.

7. The device of claim 1 wherein said second member undergoes a substantial change in modulus in passing from a first to a second temperature within the temperature operating range of said device.

8. An assembly comprising a first electrode and a spring device according to claim 2, said second member serving as a second electrode and being urged (1) into electrical contact with said first electrode by said first member at a temperature at which said first stable configuration would obtain absent the restraint of said first electrode, and (2) out of contact with said first electrode at a lower temperature at which said second stable configuration obtains.

9. An assembly comprising a temperature actuated spring device comprising a combination of first and second spring members bearing against one another such that flexure of one such member toward its relaxed position causes flexure of the other such member away from its respective relaxed position, said first member undergoing a substantial change in modulus in passing from a first to a second temperature within the temperature operating range of said device while the modulus of said second member remains relatively constant such that, absent external restraint, said combination assumes a first stable configuration at one temperature within said range and another stable configuration at another; said assembly further comprising a first electrode and said second member serving as a second electrode which is urged (1) into electrical contact with said first electrode by said first member at a temperature at which said first stable configuration would obtain absent the restraint of said first electrode, and (2) out of contact with said first electrode at a lower temperature at which said second stable configuration obtains.

10. An assembly according to claim 9 wherein said first member is a longitudinally loaded leaf spring which is operably connected to said second spring member such that said first member assumes a near columnar shape when said second member electrically contacts said first electrode.

11. The device of claim 10 wherein said second member is a curved end cantilever spring and wherein said first member is positioned across the curved end thereof.

12. The assembly of claim 10 wherein said second member is a fork spring having at least two tines and wherein said first member is positioned therebetween.

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