Oct. 19, 1965 H. J. McCARRICK 3,212,337

THERMALLY RESPONSIVE ACTUATORS

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Fig. 1.

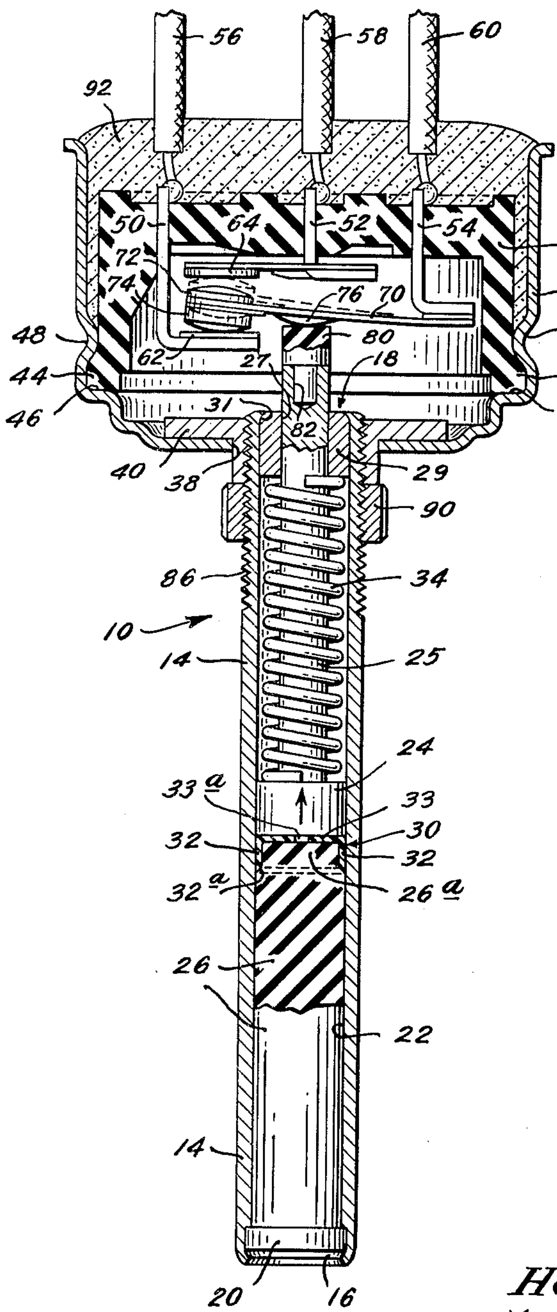


Fig. 3.

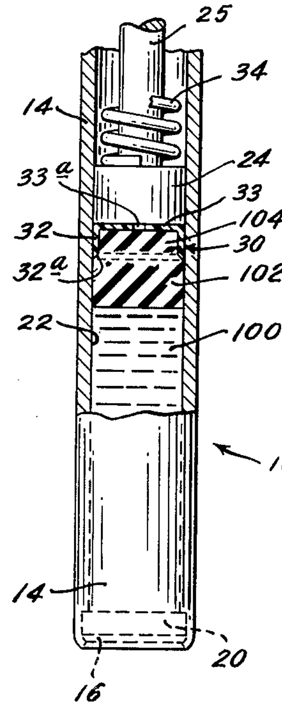
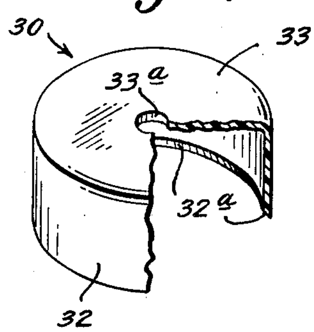


Fig. 2.



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THERMALLY RESPONSIVE ACTUATORS

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This invention relates to thermally responsive actuators and to control means incorporating such actuators.

An object of this invention is to provide a new and improved thermally responsive actuator having improved operating characteristics.

A further object of the invention is the provision of such an actuator which is simple in construction, dependable in operation and capable of being easily and expeditiously manufactured.

A further object of the invention is the provision of such an actuator having a construction which permits wide and economical manufacturing tolerances between parts, and facilitates and admits of simple and low-cost production and assembly.

It is yet another object of the invention to provide an actuator which takes advantage of volumetric expansion and contraction of a thermally responsive medium, which is versatile and can provide desired thermostatic response over a wide range of temperatures.

Among the further objects of the invention are the provision of actuators, of the type described which include a new and improved sealing means and the provision of such a sealing means which is reliable, simple and economical to manufacture and assemble.

Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which some of the various possible embodiments of the invention are illustrated:

FIG. 1 is an elevational view in section of a thermally responsive actuator according to one embodiment of the invention, the actuator being shown in operative relationship with an electrical switch;

FIG. 2 is a fragmentary perspective view of a sealing element according to the instant invention; and

FIG. 3 is a fragmentary elevational view of a portion of an actuator according to a second embodiment of the instant invention.

A thermally responsive actuator according to a first embodiment of the invention is shown in FIG. 1, as being generally designated by the reference numeral **10**, and in operative relationship with an electrical switch generally indicated by the reference numeral **12**. Thermally responsive actuator **10** includes a tubular member **14** which may be formed of a heat-conductive material such as, for example, 304 stainless steel. Tubular member **14** is preferably open ended, as at **16** and **18**. Disc or washer **20** is mounted in the open end **16** of tubular member **14** to close and seal that end. Disc or washer **20** is held in place, as by crimping the open end of the tube as shown, to provide a sealed closed-end portion and a cylindrical cavity **22** within the tubular member **14**. It should be understood that the closed end of tube **14** may be formed integrally with the tube, if desired. The cylinder **22** is adapted to receive a plunger or piston **24**, which is disposed in interfitting sliding relationship therewithin. The tolerance of fit between piston **24** and the internal walls

presented by cylinder **22** are not critical, and the piston need not be in close interfitting slidable engagement with the cylinder walls. This advantage is afforded by the unique sealing means of the instant invention to be described in greater detail below.

It will be understood that in the construction of thermal actuators which generate motion through displacement of a piston by a thermally expansive material, it is important that the thermally expansive material does not extrude between the piston and cylinder walls. In this consideration, it should also be appreciated that any loss in the volume of the thermally expansive material will deleteriously affect the temperature calibration and consistency and predictability of operation of any device which incorporates an actuator of the class described.

The thermally responsive actuator **10** may employ a thermally responsive material which is solid and elastically deformable at those temperatures at which thermostatic response is desired. An example of such a thermally responsive material is disclosed in the U.S. patent to Brown No. 2,548,941. I have found that such solid and elastically deformable thermal materials provide thermostatic response over a wide range of temperatures. It has also been found that even with very close tolerances of fit between the piston and the surrounding tube, undesirable extrusion of this solid and elastically deformable material occurs between the piston and cylinder walls. This extrusion results after a given time of operation of the device and prolonged application of force on the thermal material. When relatively soft rubber-like materials are employed, the problem of extrusion is magnified. Harder rubber-like thermal materials tend to minimize extrusion problems (with very close tolerances of fit) but require greater piston spring forces to make the material conform to the shape of the container. The harder rubber-like materials also require stronger tube and piston structures to accommodate greater spring pressures, which generally result. Such stronger structures generally increase costs and heat transfer problems for the device.

The instant invention eliminates the necessity for close tolerances, such as those encountered in the aforesaid patent, and provides an inexpensive sealing means to prevent extrusion of the thermally responsive material (both soft and hard rubber-like materials). The instant invention also affords the advantages of: (1) quicker and less expensive production and assembly, and (2) permits the utilization of other types of thermally responsive materials which, like the solid and elastically deformable rubber-like materials, are operable for thermostatic response over a wide range of temperatures and do not depend on a change of state for thermostatic response, but which also are not limited to solid materials, and may also include thermal wax materials as will be more apparent with the ensuing description.

Within the variable volume chamber provided by cylinder **22** with piston **24** disposed therein, is a thermally responsive solid and elastically deformable material **26**. Disposed between thermally responsive material **26** and piston **24** is a sealing cap or sealing means generally referred to by numeral **30**, which sealing cap or sealing means is shown in a fragmentary perspective in FIG. 2. Sealing cap **30** is cup-shaped and has a substantially cylindrical cross section, as shown. The cap is fabricated from a relatively stiff but flexible material, for example such as Teflon (which is a trademark of the E. I. du Pont de Nemours & Co., for its fluorocarbon resins including a plastic consisting of a tetrafluoroethylene polymer); or soft thin materials, for example, such as tin or brass. It is preferred that the cylindrical sidewall or skirt portion **32** be relatively thin and flexible. The outside diameter of the cylindrical sidewall **32** of sealing cap **30** preferably approximates the inside diameter of cylinder **22**, but substantial manufacturing tolerances may be permitted. The inside lower peripheral edge of wall **32** is beveled as at **32***a* to minimize the possibility of extrusion of the thermal material between the cap sidewall **32** and adjacent wall of cylinder **22**, by directing a component of the force exerted by the material **26**, perpendicular to sidewall or skirt portion **32** of cap **30** against the adjacent inner wall of cylinder **22**. This is particularly advantageous with a fluid type of thermal material.

Piston **24** has a piston rod **25** which extends through an interfitting aperture **27** provided by an annular member **29** for guiding the piston rod in its vertical movement, as viewed in FIG. 1. The end **31** of open end **18** of tubular member **14** is turned in, as shown, to retain annular member **29** in fixed position relative to the tube. A compression spring **34** is disposed about a portion of piston rod **25** and has one end bearing against piston **24** and its opposite end bearing against and to bias annular member **29** against the turned in end **31** of tubular member **14**, and also to bias piston **24** in a direction toward thermally responsive material **26**, and against sealing cap **30**.

Thermally responsive, solid material **26** is sufficiently deformable entirely to fill the chamber in which it is disposed under the pressure exerted thereagainst by piston **24** due to the relatively strong force exerted against piston **24** by spring **34**. Material **26** has a higher coefficient of thermal expansion than the material of cylinder **22** and, upon heating of this material, the latter expands volumetrically against piston **24**, through sealing cap **30**. Thermally responsive material **26**, when subjected to an increase in temperature, expands volumetrically and since confined by the cylinder wall, expands to displace piston **24** against compression spring **34** and against bushing or annular member **29** which is held in place by crimping **31** of the open end portion **18** of tube **14**. Sealing cap **30** assures that the displacement of the thermally expansive material **26** is confined below the bottom surface of piston **24**, and eliminates the possibility of any of the material extruding or entering between the piston **24** and the adjacent portion of the internal wall of cylinder **22**. An increase in the pressure exerted by thermally expansive material **26** due to increase in temperature thereof results in greater lateral pressures exerted on the interior surfaces of flexible cylindrical wall or side portions **32** of sealing cap **30** to urge the latter against the adjacent internal walls of cylinder **22**. The beveled portions **32***a* of cap **30** assist in creating a concentration of lateral forces against the lower edge of wall or skirt portion **32** to urge the latter into sealing pressure engagement with the adjacent cylinder wall to preclude extrusion of thermal material therebetween. Thus it can be seen that the sealing effectiveness of sealing cap **30** to prevent extrusion of the thermally responsive material about piston **24** is increased upon an increase in pressure exerted against thin flexible wall **32** of sealing cap **30** by the thermally responsive material **26**. The increase in axial and radial pressure exerted against the various portions of sealing cap **30** by the thermally responsive material tends to force the sealing cap sidewall **32** into greater sealing pressure engagement with the internal wall of cylinder **22** to thereby create an increase in the effectiveness of the seal. Upper portion **26***a* of solid and elastically deformable thermally responsive material **26**, which is confined within the cylindrical cavity defined by sealing cap **30**, serves to transmit increase in pressures against the sealing cap, both in an axial direction against the upper portion **33** of the cap which abuts the piston **24** and also transmits pressures radially to the cylindrical sidewall **32** of the cap to urge the latter into more firm pressure sealing engagement with the internal walls of cylinder **22**. Upper portion 33 is provided with a small aperture 33a which is effective to bleed off air which may be entrapped in the thermally responsive material. Hole **33***a* is small enough so that any thermal material which may extrude thereinto will be of an insignificant amount and will be sealed through pressure exerted by piston **24** against part **33** and thermal material **26**. Sealing cap **30**, having relatively flexible sidewalls **32**, is free to move with the thermally expansible material **26** upon volumetric change in response to temperature change thereof, and also permits wide or common maunfacturing tolerances. The sealing member **30** not only moves upwardly and against piston **24** upon expansion of the thermally responsive material **26**, but also moves outwardly into increased intimate pressure sealing engagement with the internal sidewall of cylinder **22**. The Teflon, tin or brass materials are preferred because of their relatively flexible nature, and also because of their desirable bearing properties in that they offer minimum frictional sliding resistance with respect to the interior wall of cylinder **22**.

An example of a thermally responsive solid and elastically deformable material having the requisite deformation characteristics is a silicone rubber sold under the trademark "Silastic 152," which is a trademark of Dow Corning Corporation for a silicone rubber material having characteristics which provide high tensile strength, elongation and tear resistance without long oven cure, and which has very good dielectrical properties and low water absorption. Materials such as "Silastic 152" which have a comparatively high coefficient of thermal expansion are particularly advantageous in that this high expansion characteristic, taken in combination with the feature of volumetric expansion and contraction in opposite lineal directions, results in a relatively large movement of piston **24** per unit change in temperature of the thermally responsive material.

The thermally responsive material **26** according to the embodiment shown in FIG. 1 is in the form of a single, integral piece. This being the case, it is apparent that handling of the component parts of the actuator and assembly thereof is a very simple matter. Also, advantage can be taken of thermally responsive material **26** which is practically incompressible, as opposed to spongy, so that a positive movement of the piston **24** occurs upon a temperature rise of the actuator as distinguished from an amount of movement of the piston dependent upon the magnitude of the yieldable load against which it moves. It will be clear that such factors as variations in atmospheric or otherwise circumambient pressure will have practically no effect on the calibration of the actuator so long as the thermally responsive material is practically incompressible. Of course, the thermally responsive material as well as the remaining parts of the actuator must be stable under the conditions of temperature, etc. to which the actuator is to be subjected.

The thermally responsive actuator of this invention is useful for a number of purposes including signaling and controlling or operating a second mechanism, all of these in response to temperature change. By way of example, the thermally responsive actuator could be utilized to operate a second mechanism in the form of a valve for a hydraulic or pneumatic system in a manner well known to those skilled in the art. In the arrangement shown in FIG. 1, by way of example, an electrical switch **12** is shown in operative relation with the actuator **10**, which can provide a signaling function or a controlling function, depending upon appropriate electrical connection of the switch **12**.

Electrical switch **12** includes a hollow casing member **36** which may, for example, be formed, as by stamping from a 302 or 304 stainless steel. Casing member **36** is provided with an aperture **38** in which is disposed a flanged internally threaded bushing **40**, which is fixedly secured to casing **36** in a suitable manner, as by welding, for example. Disposed within casing **36** is a cup-shaped housing member **42** formed of one of the conventional, moldable, electrically insulating materials. Housing **42** provides an enlarged, flange-like, annularly extending portion **44** which interfits with the interior sidewall surface of casing **36**. Housing **42** rests on an annularly extending shoulder portion **46** provided by casing **36**. Housing **42** and casing **36** are secured against relative movement therebetween by crimping or deforming the casing **36**, as at **48**. Housing **42** mounts electrically conductive terminals **50**, **52** and **54** for external connection to electrical leads, as at **56**, **58** and **60**. Terminals **50** and **52** respectively mount stationary contacts **62** and **64**, as shown. Terminal **54** cantilever mounts a contact-carrying arm **70**, as shown. Contact arm **70** carries a movable contact **72** for engagement with stationary contact **64**, and a second movable contact **74** for engagement with stationary contact **62**. Contact arm **70** is a spring member formed of an electrically conductive material, such as, for example, beryllium copper.

Contact-carrying spring arm **70** is inherently and resiliently biased for movement in a direction to close contacts **74** and **62**. The outer end of piston rod **25** is capped with a member **80** formed of an electrically insulating material (such as a phenolic resinous material or a ceramic), the latter being suitably mounted within an aperture **82** provided on the outer end of piston rod **25**. Insulating member **80** is disposed in engagement with a dimpled or abutting portion **76** provided on contact-carrying spring arm **70**, and serves to electrically insulate piston rod **25** from contact-carrying arm **70**.

The upper end of tube **14** is threaded, as at **86**, and is adapted to be received in threaded engagement within threaded bushing **40** so as to mount the thermal actuator **10** on switch **12** in calibrated operative relation therewith. It will be understood that calibration of the unit is made by adjusting the relationship between switch arm **70** and piston rod **25**. This adjustment may be effected by rotation of the threaded portion **86** of tube **14** within threaded bushing **40**. After desired calibration has been effected by suitable rotation of the tubular member **14**, as above described, a knurled lock nut **90** is applied to the threaded portion **86** of tube **14** so as to fix and retain the thermal actuator in final adjusted calibrated relation to switch **12**. Switch **12** may then be provided with a sealing compound **92** which seals, electrically insulates and maintains the switch element in final assembled and oriented position.

It will be apparent that with the parts in the full-line positions, as shown in FIG. 1, at which contacts **74** and **62** are in engagement with each other, and contacts **72** and **64** are separated from each other, heating of the thermally responsive material **26**, resulting in upward movement of piston **24**, moves member **80** against the dimpled portion **76** of contact-carrying arm **70** thereby to separate contacts **74** and **62**, and upon continued further heating of the thermally responsive member, to cause further movement in an upward direction as seen in FIG. 1, to effect closing of contacts **72** and **64**. Sufficient subsequent cooling and contraction of thermally responsive material **26** results, of course, in opening of contacts **72** and **64** (as seen in dashed lines in FIG. 1) and subsequent reclosing of contacts **74** and **62**. It will be understood that by suitably adjusting the relationship between the piston rod **25** and the contact arm **70** (as by rotation of tube **14** within threaded bushing **40**), that switch arm **70** can be calibrated so as to operate at any one of a number of desired temperatures within a wide temperature range.

Actuator **10** is readily and easily assembled simply by successively inserting disc **20**, deforming end **16** of tube **14**, inserting thermally responsive material **26**, sealing cap **30**, piston **24** and piston rod **25**, compression spring **34**, and annular member **29** into the tubular member **14** from the upper end thereof, as viewed in FIG. 1, and turning down the upper end **31** of the latter to retain the parts in operative condition, as shown.

Although the thermally responsive material **26** is described above as being in the form of a single unitary piece, it can be in the form of a plurality of pieces. Also, the thermally responsive material may include particles of a material (such as, for example aluminum in many cases) which has a higher thermal conductivity than the remainder of the thermally responsive material, which is advantageous to increase the thermal conductivity of the latter as a whole.

The construction disclosed in the aforementioned Brown patent is not applicable to use with fluid type thermal materials, which, although fluid, do not depend on a change of state to provide desired thermostatic response and like the solid and elastically deformable material, are also operable over a wide range of temperatures to provide desired thermostatic response. The unique sealing means of the instant invention permits large economical tolerances between parts to provide a lower cost device, and also permits employment of both such solid and elastically deformable and fluid type thermally responsive materials. The sealing means alse permits use of fluid type thermal materials which depend upon a change of state for operation to provide desired thermostatic response, such as a thermal wax.

Referring now to FIG. 3, a second embodiment of the actuator according to the invention is shown generally referred to by numeral **110**. The FIG. 3 embodiment is substantially identical to the FIG. 1 embodiment in all respects, except for the thermal actuating material and sealing means, as will be described in greater detail below.

The thermally responsive material in the FIG. 3 embodiment consists of a fluid material **100**. Thermally responsive fluid material **100** may, for example, be a liquid silicone oil, or a thermal wax material. The sealing means comprises sealing cap **30** and a solid and elastically deformable member **102**. Member **102** may, for example, comprise rubber, or may comprise materials such as the solid elastically deformable thermally responsive material **26**, described above. Portion **104** of member **102** interfits with sealing cap **30** in substantially the same way as portion **26***a* of thermally responsive material **26**, and serves the same function described above. That is, portion **104** serves to transmit forces, axially and radially, to the walls **32** of sealing cap **30** to urge the latter into intimate pressure sealing engagement with the adjacent inner sidewalls of cylinder **22**. As with the embodiment of FIG. 1, the effectiveness of the seal provided by sealing cap **30** in the FIG. 3 embodiment, increases with an increase in pressure exerted against sealing cap **30** generated by the thermally responsive fluid **100** upon a volumetric change due to increase in temperature thereof. Member **102** is cylindrical in configuration and is solid and elastically deformable, and is also urged into intimate sealing engagement with the interior internal sidewalls of cylinder **22** by pressure and forces exerted by the thermally responsive fluid **100** upon volumetric expansion thereof.

A silicone oil type thermally responsive fluid **100** provides advantages similar to those of solid and elastically deformable thermally responsive material **26**. Such a thermally responsive fluid expands volumetrically upon an increase in temperature thereof, and does not depend for its operation upon a change of state to provide desired thermostatic response, and can provide desired thermostatic response at any one of a wide range of temperatures. Thus the FIG. 3 embodiment actually provides a dual sealing means, one provided by member **102** and the other by sealing cap **30**. It should be understood that if member **102** is of material such as thermally responsive solid and elastically deformable material **26**, that additional thermostatic motion will be provided. The actuator according to the FIG. 3 embodiment can be assembled in the manner described with respect to the embodiment in FIG. 1.

In view of the above, it can be seen that the actuator of the instant invention, with its unique sealing means, permits utilization of both solid and fluid type thermally responsive materials. The unique sealing means according to the instant invention also permits manufacturing of parts with wider and more common tolerances, thus permitting less costly production and assembly of parts, while maintaining a simple construction with a minimum number of parts.

Although a cylindrical tubular member 14 is illustrated as exemplary of the tubular element that may be used, it is to be understood that the cross sectional shape of this element may also be square, rectangular, polygonal or the like. The term "tubes" is used herein as characterizing each of these configurations.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

Dimensions of certain of the parts as shown in the drawings hae been modified for the purposes of clarity of illustration.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense, and it is also intended that the appended claims shall cover all such equivalent variations as come within the true spirit and scope of the invention.

I claim:

1. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therein thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material; and sealing means disposed intermediate said material and said piston, said sealing means including a cap member having a cross-sectional shape complementary to that of said cylinder, said cap member having an upper wall and a continuous flexible skirt portion interconnected with said upper wall and movable into intimate pressure sealing engagement with an interior surface portion of said cylinder in response to volumetric expansion of said material; said sealing means further including a solid and elastically deformable member disposed intermediate and in engagement with said cap member and said thermally expansive material; said solid and elastically deformable member having a portion disposed in intimate engagement within said sealing cap member and being sufficiently deformable to move said skirt portion into intimate pressure sealing engagement with the adjacent interior surfaces of said cylinder in response to pressure exerted against said member by said thermally responsive material upon volumetric expansion thereof.

2. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therein thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material, said material being volumetrically expandable without undergoing a change of state during operating temperatures at which thermostatic response is desired; and sealing means disposed intermediate said material and said piston, said sealing means including a cap member having a cross-sectional shape complementary to that of said cylinder, said cap member having at least one flexible portion movable into intimate pressure sealing engagement with an interior surface portion of said cylinder in response to volumetric expansion of said material upon an increase in temperature thereof, said material comprising a fluid material and said sealing means further including a solid and elastically deformable member disposed intermediate said cap member and said thermally expansive fluid material; said solid and elastically deformable member being disposed in intimate engagement with said sealing cap member and being sufficiently deformable to move at least a portion of the latter into intimate sealing pressure engagement with the adjacent interior surfaces of said cylinder in response to pressure exerted against said member by said thermally responsive material upon volumetric expansion thereof.

3. The thermally responsive actuator as set forth in claim 2 and wherein said solid and elastically deformable member comprises a silicone rubber material.

4. The thermally responsive actuator as set forth in claim 3 and wherein said thermally responsive fluid material comprises a silicone oil, and said solid and elastically deformable member is formed of a rubber-like material.

5. The thermally responsive actuator as set forth in claim 4 and wherein said solid and elastically deformable member of a thermally expansive material, such as a silicone rubber or the like.

6. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material; and sealing means disposed intermediate and in engagement with said material and said piston; said sealing means including a cup-shaped member formed of brass having an upper wall and a flexible continuous skirt portion interconnected with said upper wall, said skirt portion being adapted for intimate pressure sealing engagement with the adjacent interior surfaces of said cylinder upon volumetric expansion of said material, and said skirt portion having an outer surface which is relatively freely slidable with respect to the interior surfaces of said cylinder.

7. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material; sealing means disposed intermediate said material and said piston, said sealing means including a cap member having a cross-sectional shape complementary to that of said cylinder; said cap member being formed of a relatively stiff but flexible material, said cap member being cup-shaped, said cap shape being defined at least in part by a relatively thin, circumferentially extending continuous sidewall formed integrally with said cap member, the free end of said sidewall being beveled, said cap member being positioned within said cylinder for intimate engagement of at least a portion thereof with said thermally responsive material and said piston, and for a portion of said thermally responsive material to be confined within the area defined by said sidewall, said flexible sidewall being movable into intimate pressure sealing engagement with an adjacent interior surface portion of said cylinder in response to expansion of said thermally responsive material.

8. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material; sealing means disposed intermediate said material and said piston, said sealing means including a cap member having a cross-sectional shape complementary to that of said cylinder; said cap member being formed of a relatively stiff but flexible material, said cap member being cup-shaped, said cup shape being defined at least in part by a relatively thin, circumferentially extending continuous sidewall formed integrally with said cap member, said cap member being positioned within said cylinder for intimate engagement of at least a portion thereof with said thermally responsive material and said piston, said cap member portion being provided with an aperture, and for a portion of said thermally responsive material to be confined within the area defined by said sidewall, said flexible sidewall being movable into intimate pressure sealing engagement with an adjacent interior surface portion of said cylinder in response to expansion of said thermally responsive material.

9. A thermally responsive actuator comprising a cylinder; means closing one end of the cylinder; a piston disposed in said cylinder to provide with said cylinder end a hollow chamber therewithin, said chamber having disposed therein thermally responsive material comprising a fluid type thermal wax material having a higher coefficient of thermal expansion than the material of said cylinder; means resiliently urging said piston in a direction for pressure engagement with said material; and sealing means disposed intermediate said material and said piston, said sealing means including a cap member having a cross-sectional shape complementary to that of said cylinder, said cap member having an upper wall and a

continuous flexible skirt portion interconnected with said upper wall and movable into intimate pressure sealing engagement with an interior surface portion of said cylinder in response to volumetric expansion of said material; said sealing means further including a solid and elastically deformable member formed of a rubber-like material disposed intermediate and in engagement with said cap member and said thermally expansive material; said solid and elastically deformable member having a portion disposed in intimate engagement within said sealing cap member and being sufficiently deformable to move said skirt portion into intimate pressure sealing engagement with the adjacent interior surfaces of said cylinder in response to pressure exerted against said member by said thermally responsive material upon volumetric expansion thereof.

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ISAAC LISANN, *Primary Examiner.*