

July 4, 1961

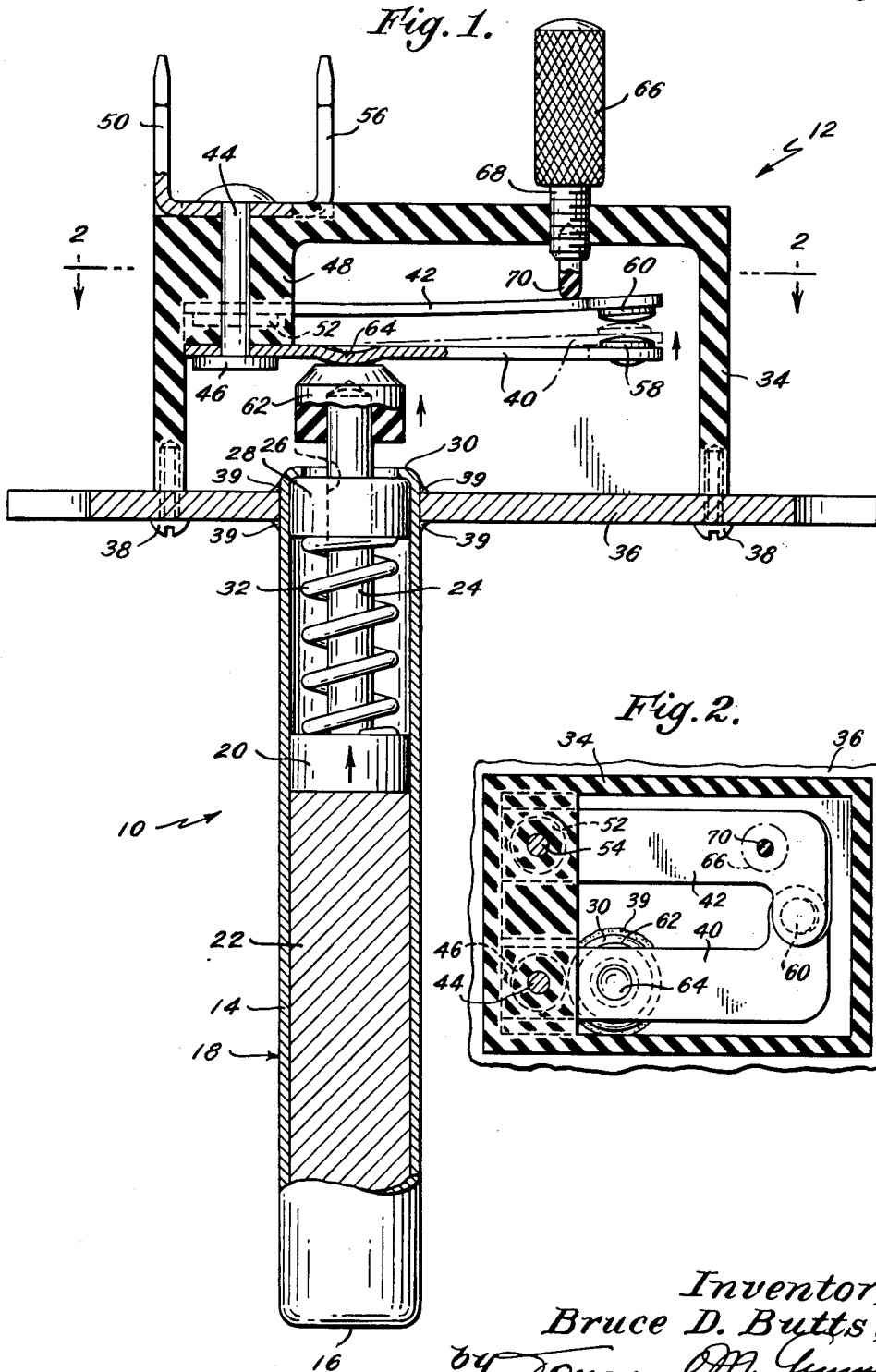
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2,990,716

THERMALLY RESPONSIVE ACTUATOR

Filed Nov. 4, 1958

2 Sheets-Sheet 1



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*Fig. 3.*

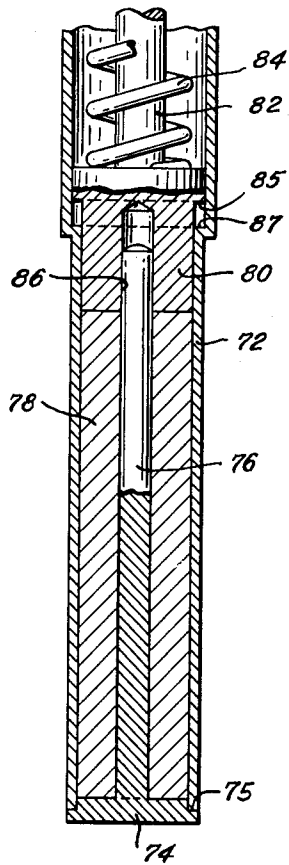
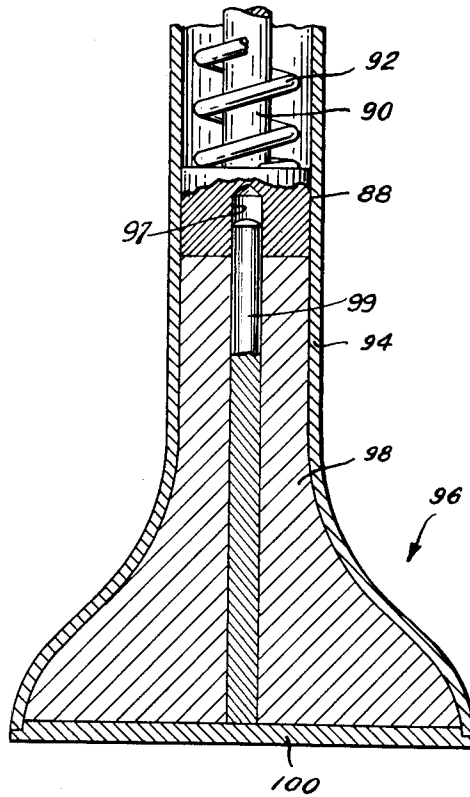


*Fig. 4.*



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2,990,716

## THERMALLY RESPONSIVE ACTUATOR

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4 Claims. (Cl. 73-363)

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 which takes advantage of volumetric expansion and contraction of a thermally responsive medium.

Other objects will be in part obvious 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 one of the various possible embodiments of the invention is 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 elevational view in section taken along line 2-2 in FIG. 1; and

FIGS. 3 and 4 are fragmentary elevational views in section of portions of actuators according to two other respective embodiments of the invention.

Referring to FIG. 1, a thermally responsive actuator according to a first embodiment of the invention is shown 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 having a closed end 16 to provide a cylinder 18 for the reception of a plunger or piston 20. Piston 20 is disposed in interfitting, slidable engagement with the internal wall presented by cylinder 18. Within the variable-volume chamber provided by cylinder 18 with piston 20 disposed therein is a thermally responsive, solid material 22. By "solid" material as used herein there is intended material contra-distinguished from liquid or gaseous material.

Piston 20 has a piston rod 24 which extends through an interfitting aperture 26 provided by an annular member 28 for guiding the piston rod in its vertical movement as viewed in FIG. 1. The end 30 of tubular member 14 opposite end 16 is turned in, as shown, to retain annular member 28 in fixed position relative to the tube. A compression spring 32 is disposed about a portion of piston rod 24, has one end bearing against piston 20 and its opposite end bearing against annular member 28 thereby to bias piston 20 toward and against thermally responsive, solid material 22 and to bias member 28 against the turned-in end of tubular member 14.

Thermally responsive, solid material 22 is sufficiently deformable entirely to fill the chamber in which it is disposed under the pressure exerted thereagainst by pis-

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ton 20 due to the relatively strong force exerted against piston 20 by spring 32. Material 22 has a higher coefficient of thermal expansion than the material of cylinder 18 and, upon heating of this material, the latter expands volumetrically against piston 20. Thermally responsive material 22 is sufficiently resistant to deformation to prevent the entry thereof between piston 20 and the adjacent portion of the internal wall of cylinder 18. In this regard, so long as the thermally responsive material is sufficiently resistant to deformation, the inner diameter of cylinder 18 and the outside diameter of piston 20 can often be formed with common (i.e. comparatively wide) manufacturing tolerances without the possibility of such entry of the thermally responsive material.

One of the important features of the actuator according to the invention is that advantage is taken of the volumetric rather than merely the lineal expansion and contraction of the thermally responsive material 22. Volumetric expansion of the thermally responsive material is prevented in all directions except against the piston 20 with the result that this volumetric expansion is confined to the lineal direction against piston 20. Conversely, of course, volumetric contraction of the thermally responsive material is confined to the lineal direction away from piston 20. It will be clear that for a given temperature change the amount of movement of piston 20 due to the volumetric expansion and contraction in opposite lineal directions of the thermally responsive material 22 is significantly greater than that afforded by the lineal expansion and contraction in opposite lineal directions of the same or corresponding materials. Accordingly, it will be apparent that not only must thermally responsive material 22 be sufficiently deformable entirely to fill the chamber in cylinder 18 under the pressure exerted by spring 32 through piston 20 against the thermally responsive material, but the latter must also be sufficiently deformable to expand and contract volumetrically in the opposite lineal directions against and away from the piston 20 upon corresponding temperature changes thereof. To the extent it is true that the less the plastic deformation that takes place, the longer will be the useful life of the thermally responsive material; it is preferable that this material be as elastically deformable (as opposed to plastically deformable) as is compatible with the other parameters thereof. It will be clear that piston 20, being resiliently biased by spring 32 against thermally responsive material 22, follows and remains in engagement with the latter during contraction thereof when its temperature is lowered.

An example of a thermally responsive material having the requisite deformation characteristics as described above is a silicone rubber sold under the trademark "Silastic 152," which is a trademark of Dow Corning Corporation for a silicon 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. (Tubular member 14 may be formed, for example, of stainless steel.) 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 20 per unit change in temperature of the thermally responsive material.

Among other advantages of the actuator according to the invention, it is to be noted that no sealing problem between the outer periphery of the cylinder and the inner

periphery of the adjacent portion of the inner cylinder wall is necessary, because the thermally responsive material is sufficiently resistant to deformation to prevent the entry thereof between the piston and cylinder wall.

The thermally responsive material 22 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 22 which is practically incompressible, as opposed to spongy, so that a positive movement of the piston 20 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 FIGS. 1 and 2, an electrical switch 12 is shown in operative relation with the actuator 10, this to 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 34 formed of one of the conventional, moldable, electrically insulating materials and secured to and closed by a supporting plate 36 with means such as screws 38, 38. Tubular member 14 is secured at its upper end to supporting plate 36 such as by brazing at 39. Disposed within casing member 34 are a pair of electrically conducting, L-shaped, contact-carrying arms 40 and 42, respectively. Contact-carrying arm 40 is supported at one level by means of a rivet 44 having a flange 46 bearing against the adjacent surface of contact-carrying arm 40. The shank of rivet 44 extends through successive aligned apertures in contact-carrying arm 40, a boss 48 integral with casing member 34, and an electrical terminal 50. In a similar manner, contact-carrying arm 42 is supported at a second level by means of a rivet 54 having a flange 52 at one end. The shank of rivet 54 extends in succession through aligned apertures in contact-carrying arm 42, boss 48, and an electrical terminal 56. Each of rivets 44 and 54 is headed over at the end adjacent the terminals 50 and 56 thereby to secure the parts through which it extends in the relationship shown in FIGS. 1 and 2.

Contact-carrying arm 40 supports an electrical contact 58 in co-operating relationship with an electrical contact 60 carried by member 42. Each of contact-carrying members 40 and 42 is formed of a resilient, electrically conductive spring material such as beryllium-copper or Phosphor-bronze. Each of contact-carrying members 40 and 42 is inherently and resiliently biased in the direction away from the other. The outer end of piston rod 24 is capped with a member 62 formed of suitable electrical insulating material (such as ceramic), the latter being disposed in engagement with a dimpled portion 64 of contact-carrying member 40 and electrically insulating piston rod 24 from contact-carrying member 40.

It will be apparent that with the parts in the full-line positions shown in FIG. 1 at which contacts 58 and 60 are separated from each other, heating of thermally

responsive material 22, resulting in upward movement of piston 20, moves cap 62 against contact-carrying arm 40 thereby to move contact 58 toward and ultimately into engagement with electrical contact 60. Sufficient subsequent cooling of thermally responsive material 22 results, of course, in opening of contacts 58 and 60. An adjustment screw 66 is provided for calibration purposes. Screw 66 includes a shank 68 threadedly engaged with casing member 34 and carries a projection 70 formed of a ceramic or other electrical insulating material. It will be apparent that rotation of adjustment screw 66 in opposite directions is effective to adjust the position of contact-carrying member 42 within the casing 34 and thereby correspondingly to adjust the respective temperatures of thermally responsive material 22 at which contacts 58 and 60 close and open.

Actuator 10 is readily and easily assembled simply by successively inserting thermally responsive material 22 (in this case as a unitary piece), piston 20, compression spring 32 and annular member 28 into tubular member 14 from the upper end thereof as viewed in FIG. 1 and then turning in the upper end of the latter to retain the parts as shown.

Although thermally responsive material 22 is described above as being in the form of a single unitary piece, it, as well as that of each of the remaining embodiments to be described, can be in the form of a plurality of pieces and can even be particulate so long as the pieces or particles are sufficiently large as to be incapable of entry between any relatively movable surfaces adjacent the thermally responsive material. Also, the thermally responsive material may include particles of a material (such, for example, as aluminum in many cases) which has a higher thermal conductivity than the remainder of the thermally responsive material, this to increase the thermal conductivity of the latter as a whole.

Referring to FIG. 3, a second embodiment of the actuator according to the invention is shown. According to this embodiment, a cylinder-providing, tubular member 72 has its end opposite the piston closed by a plug 74, the latter being provided with a step 75 about its periphery to interfit with the respective end of tubular member 72. Plug 74 is fixedly secured to the end of tubular member 72 by any suitable means such as brazing. Integral with or otherwise fixedly carried by plug 74 is a member in the form of a shank 76 composed, as is plug 74, of material having a higher thermal conductivity than that of thermally responsive material 78 through and against which the shank extends in good heat-transfer relation. Piston 80, piston rod 82 and compression spring 84, as well as the remaining parts of the actuator embodiment of FIG. 3, are or may be identical with their respective counterparts in the embodiment as shown in FIG. 1 except as particularly pointed out hereinafter. According to the embodiment shown in FIG. 3, piston 80 is provided with a bore 86 for the reception of the distal end of shank 76. It will be apparent that the tolerances of the outside diameter of shank 76 and the diameter of the internal wall of bore 86 provided by piston 80 need be no smaller than substantially that described above with respect to the outside diameter of the piston and the adjacent portion of the cylinder wall.

With heating of thermally responsive material 78 the latter expands volumetrically in the lineal direction against piston 80, thus moving the piston upwardly as viewed in FIG. 3 and along the respectively adjacent portions of the internal wall of the cylinder provided by tubular member 72 and of the distal end of shank 76; the converse being true upon cooling of thermally responsive material 78.

An advantage of the actuator embodiment shown in FIG. 3 is that thermally responsive material 78 as a whole will be more quickly responsive to a change in temperature of the ambient of the actuator due to the more rapid conduction of heat along shank 76 to and

from the interior of thermally responsive material 78. Examples of the material of which shank 76 and plug 74 may be formed are copper or aluminum.

The embodiment as shown in FIG. 3 incorporates a modification which, as will become apparent as this description proceeds, can be incorporated as well into the respective embodiments as shown in FIGS. 1 and 4. According to this modification piston 80 provides a shoulder 85 co-operable with a shoulder 87 provided in tubular member 72. Depending upon such factors as the minimum temperature to which the thermally responsive material will be subjected, shoulder 87 will act as a stop limiting the extent of retraction of piston 80 upon engagement of shoulder 85 with shoulder 87 during contraction of the thermally responsive material as its temperature drops. That is, if the temperature of thermally responsive material 78 continues to drop past the point at which shoulder 85 comes into engagement with shoulder 87, further retraction of piston 80 is prevented as contraction of the thermally responsive material continues. Conversely, and with thermally responsive material 78 at such a temperature lower than that at which shoulders 85 and 87 come into engagement during a temperature drop, piston 80 will not begin to move until the temperature of the thermally responsive material rises to a particular value. An advantage of this modification is that of less total movement of the piston for a given change in temperature of the thermally responsive material in an environment where, for example, space is limited. It will be noted that whether or not the actuator is provided with such stop means limiting the extent of retraction of the piston, the thermally responsive material must be sufficiently deformable entirely to fill the chamber in which it is disposed at least at a particular minimum temperature thereof.

The actuator according to the embodiment of FIG. 3 can be assembled in the manner described with respect to the embodiment of FIG. 1 except that plug 74 would first be secured in the position shown before insertion of the remaining parts into tubular member 72; or, alternatively, said remaining parts could be inserted from the lower end of tubular member 72 after which plug 74 with shank 76 would be positioned and the plug secured to the end of tube 72.

As with the embodiment shown in FIG. 3, the respective parts of the embodiment of FIG. 4 are or may be identical with their counterparts in the embodiment of FIG. 1 except as particularly pointed out herein. Piston 88, piston rod 90 and compression spring 92 are shown in FIG. 4 as being substantially identical with their counterpart in the embodiment of FIG. 1. The cylinder-providing, tubular member 94 of this embodiment, however, includes an increased-diameter portion generally indicated by the reference numeral 96. Portion 96, in section as shown in FIG. 4, is provided in the form of a smooth curve to accommodate deformation of thermally responsive material as the latter expands and contracts volumetrically. The end of cylinder 94 adjacent enlarged portion 96 is closed by a plug 100 in the same manner as that described with respect to plug 74 in the embodiment of FIG. 3. The embodiment of FIG. 4, if desired, may also include a heat-conducting shank integral with or otherwise fixedly carried by plug 100 similar to shank 76 of the embodiment of FIG. 3. Referring now to FIG. 4, plug 100 may be provided with a shank 99 formed integrally therewith or otherwise fixedly secured thereto. Shank 99, like plug 100, is formed of a material having a higher thermal conductivity than that of the thermally responsive material 98, through and against which the shank 99 extends in good heat transfer relation. As with the embodiment shown in FIG. 3, piston 88 is provided with a bore 97 for the reception of the distal end of shank 99. The co-operation of shank 99 with plug 100 and bored cylinder 88 provides substan-

tially all of the advantages provided by their respective counterparts in the FIG. 3 embodiment.

An advantage of the embodiment of FIG. 4 is the increased volume of thermally responsive material per unit length of the cylinder of the actuator with the resulting increased amount of movement of the piston per unit change in temperature of the thermally responsive material.

With the embodiment of FIG. 4 and so long as thermally responsive material 98 is in the form of a unitary piece, insertion of the respective parts into tubular member 94 would be accomplished from the lower end of the latter as viewed in FIG. 4, after which plug 100 would be secured in place. When thermally responsive material 98 of the FIG. 4 embodiment, as well as thermally responsive material 78 of the FIG. 3 embodiment, are in particulate form, it would be possible and often preferable to secure the respective plug in place before inserting the thermally responsive material and remaining parts from the upper or opposite end of the respective tubular or cylinder-providing member.

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 drawing have been modified for the purposes of clarity of illustration.

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.

#### I claim:

1. A thermally responsive actuator comprising a cylinder; a piston disposed in said cylinder to provide a hollow chamber therewithin; a sealing member secured to and sealing one end of said cylinder, said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder and member; means urging said piston in a direction for pressure engagement with said material; said member including a rod-like member projecting into said chamber toward said piston; said piston being provided with a bore opening into said chamber for reception of the distal end of said rod-like member for reciprocal sliding movement therewithin; said rod-like member being disposed in intimate heat-transfer relationship with said cylinder, sealing member and said thermally responsive material; and said cylinder, sealing member, and rod-like member each being formed of material having a higher thermal conductivity than that of said thermally responsive material.

2. A thermally responsive actuator comprising a cylinder; a piston disposed in said cylinder to provide a hollow chamber therewithin; a sealing member secured to and sealing one end of said cylinder, said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion than the material of said cylinder and member, said thermally responsive material being solid and elastically deformable during operating temperatures at which thermostatic response is desired; means urging said piston in a direction for pressure engagement with said material; said member including a rod-like member projecting into said chamber toward said piston; said piston being provided with a bore opening into said chamber for reception of the distal end of said rod-like member for reciprocal sliding movement therewithin; said rod-like member being disposed in intimate heat-transfer relationship with said cylinder, sealing member and said thermally responsive material; said cylinder, sealing member, and rod-like member each being formed of material having a higher thermal conductivity than that of said thermally responsive material.

3. A thermally responsive actuator comprising a tubu-

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lar member, said tubular member including a cylindrical portion and a flared enlarged diameter end portion adjacent said cylindrical portion; a piston disposed in said cylindrical portion to provide a hollow chamber there-within; a flat plate-like member secured to and sealing said enlarged diameter end portion of said cylinder; said chamber having disposed therewithin, thermally responsive material having a higher coefficient of thermal expansion than the material of said tubular member and plate-like member; means urging said piston in a direction for pressure engagement with said material; said member including a rod-like member projecting into said chamber toward said piston; said piston being provided with a bore opening into said chamber for reception of the distal end of said rod-like member for reciprocal sliding movement therewithin; said rod-like member being disposed in intimate heat-transfer relationship with said tubular member, plate-like member, and said thermally responsive material; said tubular member, plate-like member, and rod-like member each being formed of material having a higher thermal conductivity than that of said thermally responsive material.

4. A thermally responsive actuator comprising a tubular member, said tubular member including a cylindrical portion and a flared enlarged diameter end portion adjacent said cylindrical portion; a piston disposed in said cylindrical portion to provide a hollow chamber there-within; a flat plate-like member secured to and sealing said enlarged diameter end portion of said cylinder; said chamber having disposed therewithin thermally responsive material having a higher coefficient of thermal expansion

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than the material of said tubular member and plate-like member; said thermally responsive material being solid and elastically deformable during operating temperatures at which thermostatic response is desired; means urging said piston in a direction for pressure engagement with said material; said member including a rod-like member projecting into said chamber toward said piston; said piston being provided with a bore opening into said chamber for reception of the distal end of said rod-like member for reciprocal sliding movement therewithin; said rod-like member being disposed in intimate heat-transfer relationship with said tubular member, sealing member, and said thermally responsive material; said tubular member, plate-like member, and rod-like member each being formed of material having a higher thermal conductivity than that of said thermally responsive material.

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