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[54] **TEMPERATURE-RESPONSIVE SWITCH**
ASSEMBLIES
 28 Claims, 8 Drawing Figs.

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 337/140, 337/382, 337/393

[51] Int. Cl..... **H01h 37/46,**
 H01h 61/00

[50] Field of Search..... **337/123,**
 126, 139, 140, 141, 382, 393

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ABSTRACT: Temperature-responsive switch assemblies including a control member controlling the position of a movable contact with respect to a stationary contact, the control member being constructed of a material having a temperature-actuated shape memory and having an initial shape and a distorted shape, means biasing the movable contact into one position when the control member has the distorted shape, and temperature control means for reverting the control member to the initial shape to move the movable contact to another position.

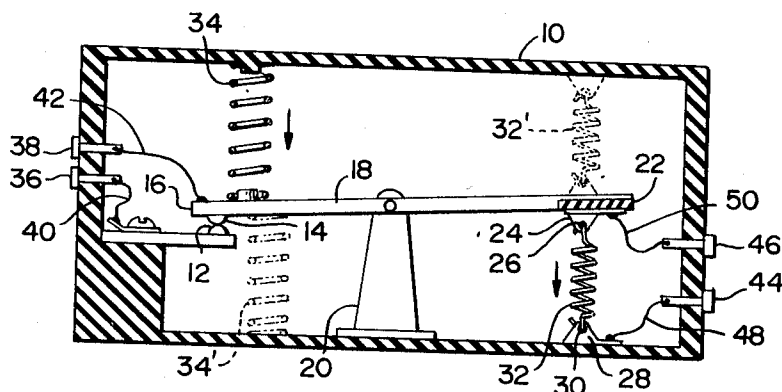


FIG. 1

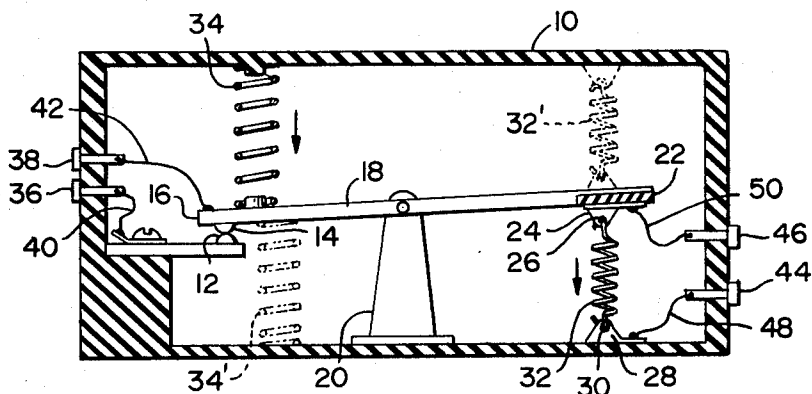


FIG. 2

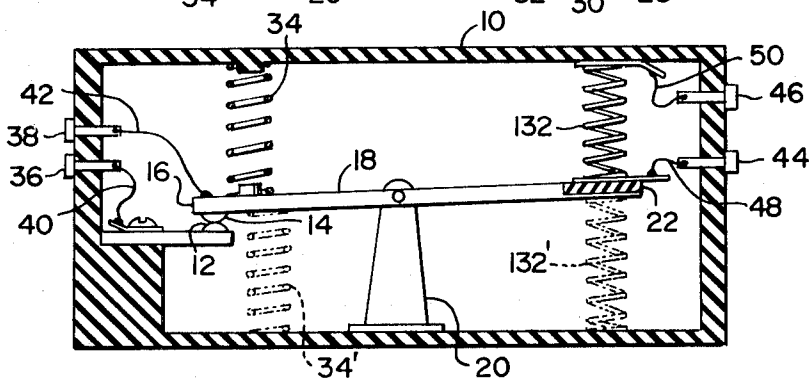


FIG. 3

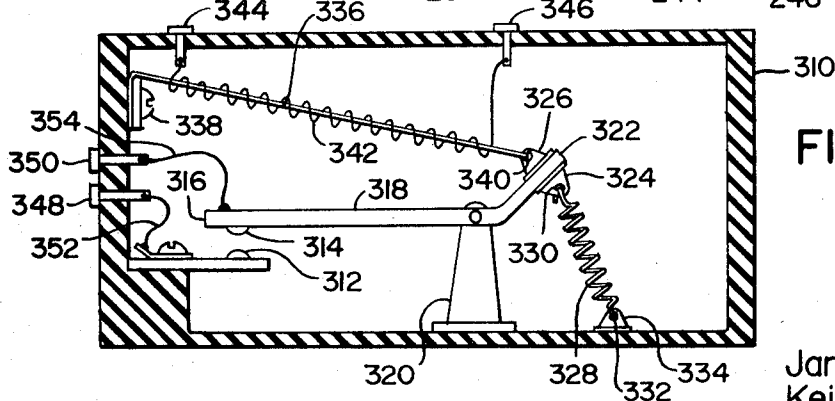
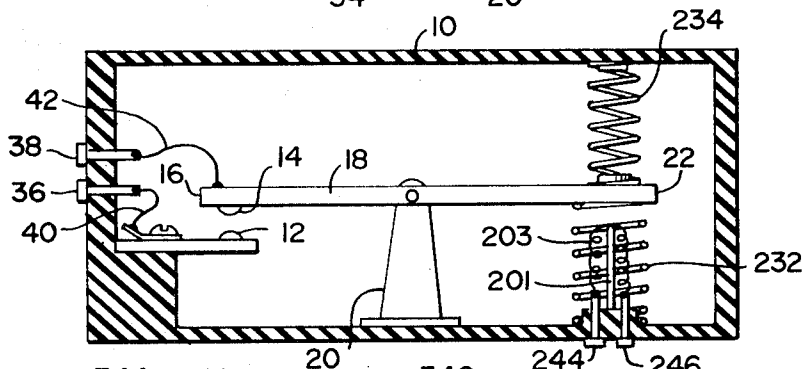


FIG. 4

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FIG. 5

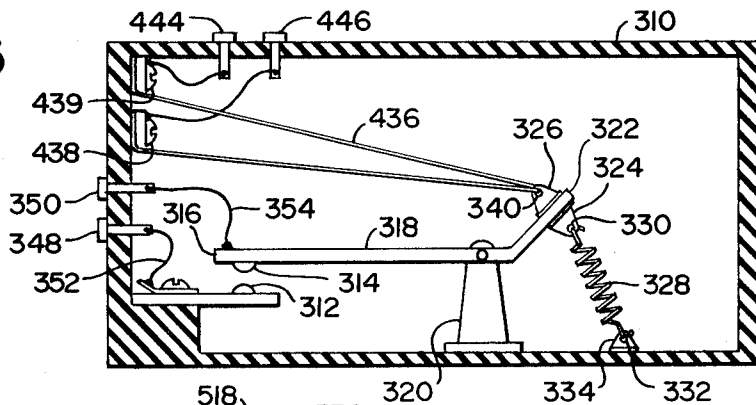


FIG. 6

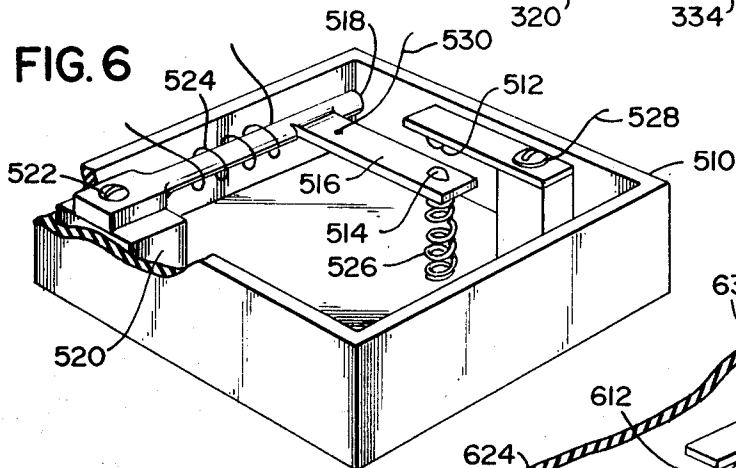


FIG. 7

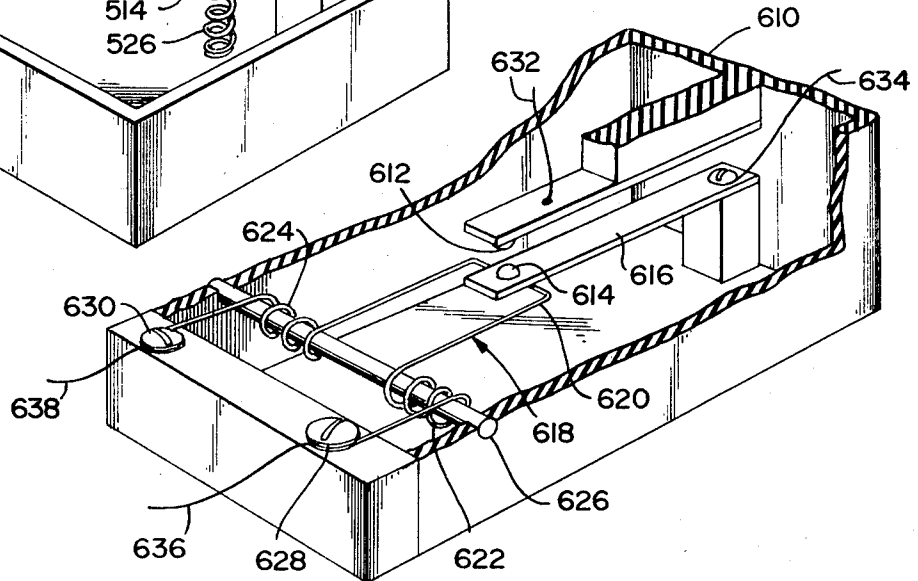
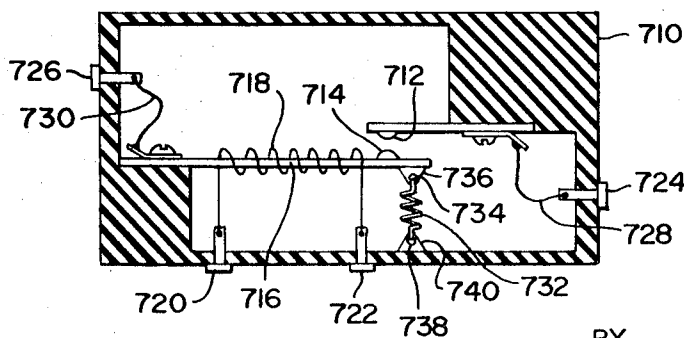


FIG. 8



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TEMPERATURE-RESPONSIVE SWITCH ASSEMBLIES

BACKGROUND OF THE INVENTION

The present invention pertains to temperature-responsive switch assemblies and more particularly to switch assemblies including a control member constructed of a material having a modulus of elasticity varying with temperature to provide a temperature-actuated shape memory.

Many types of temperature-responsive switch assemblies have been used in the past for various electrical control purposes. Such switch assemblies normally utilize temperature-responsive operators such as bimetals, hydraulic bulbs and bellows, and expansible rods and tubes; however, all of these conventional operators have suffered from common disadvantages. The major disadvantage in using conventional temperature-responsive operators is that the amount of work obtained from the amount of energy supplied by way of heat is low thereby providing inefficient operation. Furthermore, conventional temperature-responsive operators have standardized invariable shapes and cross sections and are not adaptable to new and varying switch assembly applications.

Generally, conventional temperature-responsive operators operate by expansion and contraction; that is, in the case of a bimetal, the varying coefficient of expansion of the two strips of metal secured to each other causes deflection of the bimetal; and in the case of a rod and tube, the rod is constructed of a metal having a low coefficient of expansion and is secured at one end to the tube which has a much higher coefficient of expansion such that the rod is moved by the tube in response to temperature.

Since conventional temperature-responsive switch assemblies utilize operators that are dependent upon the expansion and contraction of materials they require ambient temperature compensation in order to prevent inaccurate and faulty operation. Complete ambient temperature compensation is difficult to provide; and, accordingly, the need for ambient temperature compensation is a distinct disadvantage.

SUMMARY OF THE INVENTION

It is an object of the present invention to construct a temperature-responsive switch assembly utilizing a material having a temperature-actuated shape memory.

Another object of the present invention is to utilize a control member constructed of a material having a temperature-actuated shape memory to control a switch assembly such that when the temperature sensed by the control member changes the control member reverts to an initial shape to change the state of the switch assembly.

A further object of the present invention is to utilize a spring constructed of a material having a temperature-actuated shape memory to control a switch assembly.

The present invention has another object in that a torsion bar constructed of a material having a temperature-actuated shape memory is utilized to control a switch assembly.

Another object of the present invention is to utilize a wire constructed of a material having a temperature-actuated shape memory to control a switch assembly.

Switch assemblies constructed in accordance with the present invention are advantageous over conventional switch assemblies in that a high work output is obtained for the amount of energy supplied to the switch operators by way of temperature change. The switch operators may be constructed for fail-safe operation such that a set in the switch operators or breakage of switch operators returns the switch assembly to its normal state, the switch operators may have many different configurations and cross sections, operation of the switch assemblies is silent, and no ambient temperature compensation is required for the switch assemblies.

The present invention is generally characterized in a temperature-responsive switch assembly including a switch housing, a stationary contact secured to the switch housing, a movable contact having a position in contact with the stationary contact and a position spaced from the stationary con-

tact, means biasing the movable contact toward one of the positions and operator means controlling the position of the movable contact, the operator means including a control member having an initial shape and a distorted shape and being constructed of a material having a temperature-actuated shape memory, the movable contact being in the one position when the control member has the distorted shape and in the other position when the control member has the initial shape, and means controlling the temperature of the control member to control the shape of the control member.

Further objects and advantages of the present invention will become apparent from the description of the preferred embodiments as shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view partially in section of an embodiment of the present invention.

FIG. 2 is an elevational view partially in section of a modification of the embodiment of FIG. 1.

FIG. 3 is an elevational view partially in section of a further modification of the embodiment of FIG. 1.

FIG. 4 is an elevational view partially in section of another embodiment of the present invention.

FIG. 5 is an elevational view partially in section of a modification of the embodiment of FIG. 4.

FIG. 6 is a broken perspective view of a further embodiment of the present invention.

FIG. 7 is a broken perspective view of another embodiment of the present invention.

FIG. 8 is an elevational view partially in section of a further embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

All of the embodiments of the present invention utilize control members constructed from a material having a temperature actuated shape memory. By this is meant that a straight wire of such a material can be bent or contorted below its "martensitic" transition temperature and it will retain its deformed or distorted shape, but when the deformed wire is heated above its transition temperature with nothing constraining its movement such wire will spring back to its initial straight shape.

Similarly, the wire may have a loop in it in its initial annealed shape above the transition temperature. After annealing the temperature may be decreased below the transition temperature, and a load such as a weight secured to the lower end of the wire. The modulus of elasticity, being dependent on temperature, is low at this time; and, accordingly, the weight distorts the wire from its initial shape to a straight or distorted shape. The wire will remain in this condition until the temperature sensed by the member is raised above the transition temperature at which time the modulus of elasticity will increase; and, once the modulus of elasticity is such that the amount of force or stress applied by the weight is out of relation with the distortion or strain, the wire will revert to its initial looped shape thereby providing work in lifting the weight.

The transition temperature is represented by a rapid change in modulus on a modulus of elasticity vs. temperature curve. That is, as temperature decreases through the transition zone, the modulus of elasticity decreases. As temperature increases through the transition zone the modulus of elasticity increases. For the purposes of the invention of this disclosure, material with a relatively high transition temperature should be used. This will allow the shape memory material to cool to a temperature below its transition zone when used at normal operating ambient temperature. These operating ambients will generally be greater than room temperature.

One of the great advantages of the present invention is that the material may be utilized to form control members having greatly varying shapes and cross sections, such as rods, flat bars, torsion bars, helical springs, flat springs, wave washers, spring washers, Belleville springs, hair springs, or wires, to

name a few. Accordingly, the use of wires has been described only to provide an understanding of the operation of control members constructed of a material having a temperature-actuated shape memory, and it is clear that control members for use with the present invention may have any desired shape and cross section as will be appreciated from the following description of the preferred embodiments.

The above description of materials useful with the present invention is provided for general background in order to aid in understanding the present invention. For specific information with respect to one such material, reference is made to U.S. Pat. No. 3,174,851 to Buehler et al. and U.S. Pat. No. 3,403,238 to Buehler et al. The above-cited patents are concerned with alloys formed of nickel and titanium; however, while an alloy having a composition of 55 percent nickel by weight with the remainder being essentially titanium may be used with the present invention, the present invention is not limited to these alloys but may utilize any materials having similar properties. That is, any material having a temperature-actuated shape memory or a modulus of elasticity that varies with temperature may be used with the present invention.

A first embodiment of the present invention is illustrated in FIG. 1 and includes a switch assembly housing 10 constructed of an electrically nonconductive material. The switch assembly includes a stationary contact 12 secured to a step support on a sidewall of housing 10 and a movable contact 14 secured to the underside of a first end 16 of a lever 18 which is supported at its center by a fulcrum 20 secured to a bottom wall of housing 10. A second end 22 of lever 18 has an ear 24 secured to the underside thereof and insulated therefrom, and an aperture 26 is provided in ear 24. An ear 28, having an aperture 30 therein, is secured to the bottom wall of housing 10 directly below the second end 22 of lever 18, and a spring control member 32 is mounted in tension between ears 24 and 28 by having one end hooked through aperture 24 and the other end hooked through aperture 30. A helical bias spring 34 is mounted in compression between a top wall of housing 10 and the first end 16 of lever 18.

A pair of terminals 36 and 38 extend through a sidewall of housing 10 and are adapted to be connected to a source of electricity and any circuitry or components for which it is desired to control the application of electricity through the switch assembly. Terminal 36 is connected with stationary contact 12 through a wire 40, and terminal 38 is connected with movable contact 14 through a wire 42. A pair of terminals 44 and 46 extend through an opposite sidewall of housing 10 and are adapted to be connected with a source of electricity through a selective control such as a thermostat. Terminals 44 and 46 are connected with ears 24 and 28 through wires 48 and 50, respectively.

Spring control member 32 is constructed of a material having a temperature-actuated shape memory and has a tightly coiled initial shape and a loosely coiled distorted shape.

The switch assembly is illustrated in FIG. 1 in its normally closed state with movable contact 14 normally in contact with stationary contact 12 due to the force from bias spring 34, and control member 32 is in its distorted shape at this time since normal room temperature exists and the modulus of elasticity is low.

When it is desired to open the switch assembly, electricity is applied to terminals 44 and 46, for instance, by the closing of the selective control between terminals 44 and 46 and the source of electricity to raise the temperature sensed by spring control member 32. The application of electricity to terminals 44 and 46 causes a current to flow through wire 48, ear 24, spring control member 32, ear 28 and wire 50. The current passing through spring control member 32 generates heat to increase the modulus of elasticity of spring control member 32, and spring control member 32 will revert to its initial shape once the modulus of elasticity has been increased to a point where the load constituted by the force from bias spring 34 is insufficient to distort spring control member 32 to the extent required to maintain contacts 12 and 14 closed. Thus,

movable contact 14 will be moved to a position spaced from stationary contact 12 due to the action of lever 18 about fulcrum 20 when spring control member 32 reverts to its initial shape.

When it is desired to return the switch assembly to its normally closed state, the supply of electricity to terminals 44 and 46 is interrupted thereby stopping the flow of current through spring control member 32 and reducing the temperature sensed by spring control member 32 to decrease the modulus of elasticity. Once the modulus of elasticity decreases to a point where the force from bias spring 34 is sufficient to distort spring control member 32, spring control member 32 assumes its distorted shape to close contacts 12 and 14 and return the switch assembly to its normally closed state.

The embodiment of FIG. 1 is illustrated as a normally closed switch, however, it should be clear that the operation of the embodiment of FIG. 1 as a normally open switch requires merely the reversing of forces on lever 18, for instance, as shown in phantom in FIG. 1. That is, by mounting bias spring 34' in compression between the bottom wall of housing 10 and the underside of the first end 16 of lever 18 and mounting spring control member 32' in tension between the upper side of the second end 22 of lever 18 and the top wall of housing 10, the operation of the embodiment of FIG. 1 will be such that contacts 12 and 14 will be normally spaced; and, once spring control member 32' reverts to its initial tightly coiled shape, contacts 12 and 14 will be closed. Of course, the embodiment of FIG. 1 may be modified in many other ways to operate as a normally open switch, such as by merely transposing spring control member 32 and bias spring 34.

A modification of the embodiment of FIG. 1 is illustrated in FIG. 2. Parts in FIG. 2 identical to parts in FIG. 1 are given identical reference numbers and are not described again, and similar parts are given reference numbers with 100 added.

The primary difference between the embodiments of FIGS. 1 and 2 is that the downward force on the second end 22 of lever 18, which is supplied by spring control member 32 mounted in tension in FIG. 1, is supplied by a spring control member 132 mounted in compression between the upper side of the second end 22 of lever 18 and the top wall of housing 10. Spring control member 132 is constructed of a material having a temperature-actuated shape memory and has a loosely coiled initial shape and a tightly coiled distorted shape.

The switch assembly is illustrated in FIG. 2 in its normally closed state with movable contact 14 normally in contact with stationary contact 12 due to the force from bias spring 34. The operation is identical to that described with respect to the embodiment of FIG. 1 except for the variance in the position and shapes of spring control member 132. That is, spring control member 132, as illustrated, is loosely coiled in its initial shape such that once electricity is supplied to terminals 44 and 46 to pass a current through spring control member 132, it forces the second end 22 of lever 18 down to compress bias spring 34 and open contacts 12 and 14. In order to return the switch assembly to its normally closed state, the electricity applied to terminals 44 and 46 is interrupted such that spring control member 132 cools and returns to its distorted shape to close contacts 12 and 14 and return the switch assembly to its normally closed state.

In the same manner as mentioned with respect to the embodiment of FIG. 1, the embodiment of FIG. 2 may be modified to operate as a normally open switch by merely reversing the forces on lever 18 as shown in phantom in FIG. 2 with spring control member 132' and bias spring 34' or by transposing spring control member 132 and bias spring 34.

Another modification of the embodiment of FIG. 1 is illustrated in FIG. 3. Parts in FIG. 3 identical to parts in FIG. 1 are given identical reference numbers and are not described again, and similar parts are given reference numbers with 200 added.

The forces acting on lever 18 are all located at the second end 22 of the lever with a helical bias spring 234 mounted in compression between the upper side of the second end 22 and

a top wall of housing 10 and a spring control member 232 mounted in compression between the underside of the second end 22 and a bottom wall of housing 10. Spring control member 232 is constructed of a material having a temperature-actuated shape memory and has a loosely coiled initial shape and a tightly coiled distorted shape.

An upright 201 extends from the bottom wall of housing 10 and supports a heating element 203 within spring control member 232. Heating element 203 is connected with a pair of terminals 244 and 246 which extend through the bottom wall of housing 10 and are adapted to be connected with a source of electricity through a selective control.

The switch assembly is illustrated in FIG. 3 in its normally open state with movable contact 14 spaced from stationary contact 12 due to the force from bias spring 234. At this time control member 232 is in its distorted shape since normal room temperature exists and the modulus of elasticity is low.

When it is desired to close the switch assembly, electricity is applied to terminals 244 and 246 to energize heating element 203. The heat generated by heating element 203 raises the temperature sensed by spring control member 232 and the modulus of elasticity increases with the rising temperature. Once the modulus of elasticity has been increased to a point where the load constituted by the force from bias spring 234 is insufficient to distort spring control member 232, spring control member 232 will revert to its initial shape thereby pushing the second end 22 of lever 18 up to accordingly move the first end 16 of the lever down to place movable contact 14 in contact with stationary contact 12.

When it is desired to return the switch assembly to its normally open state, the supply of electricity to terminals 244 and 246 is interrupted thereby deenergizing heating element 203 and reducing the temperature sensed by spring control member 232. The modulus of elasticity, thus, decreases until a point is reached where the force from bias spring 234 is sufficient to distort spring control member 232. Spring control member 232 will then assume its distorted shape, and the second end 22 of lever 18 will be pushed down to open contacts 12 and 14.

If it is desired to operate the embodiment of FIG. 3 as a normally closed switch the forces on the second end 22 of lever 18, need merely be reversed. For instance, by transposing spring control member 232 and bias spring 234 the switch assembly may have a normally closed mode of operation.

Another embodiment of the present invention is illustrated in FIG. 4 and includes a switch assembly housing 310 constructed of an electrically nonconductive material. The switch assembly includes a stationary contact 312 secured to a step support on a sidewall of housing 310 and a movable contact 314 secured to the underside of a first end 316 of an elongated leg of a lever 318. Lever 318 is supported by a fulcrum 320 and has a short offset leg 322 having a pair of ears 324 and 326 disposed on either side thereof. A bias spring 328 is mounted in tension between an aperture 330 in ear 324 and an aperture 332 in an ear 334 secured to a bottom wall of housing 310. A single-strand wire control member 336 has a first end secured to a sidewall of housing 310 by a screw 338 and a second end secured to an aperture 340 in ear 326. A heating coil 340 is disposed around wire control member 336 and is connected with a pair of terminals 344 and 346 which extend through a top wall of housing 310 and are adapted to be connected to a source of electricity through a selective control.

A pair of terminals 348 and 350 extend through the sidewall of housing 310 and are adapted to be connected to a source of electricity and any circuitry or components for which it is desired to control the application of electricity through the switch assembly. Terminal 348 is connected with stationary contact 312 through a wire 352, and terminal 350 is connected with movable contact 314 through a wire 354.

Single-strand wire control member 336 is constructed of a material having a temperature-actuated shape memory and has a short effective length between ends in its initial shape and a longer effective length between ends in its distorted

shape. The initial shape of wire control member 336 may be linearly shorter than the wire control member in its distorted shape or may have a loop or other curvature to reduce the effective length between the ends of the wire control member.

The switch assembly of FIG. 4 is illustrated in its normally open state with movable contact 314 spaced from stationary contact 312 due to the force from bias spring 328. At this time wire control member 336 is in its distorted shape since normal room temperature exists and the modulus of elasticity is low.

When it is desired to close the switch assembly electricity is applied to terminals 344 and 346 to energize heating element 342. The heat generated from heating element 342 raises the temperature sensed by wire control member 336 to increase the modulus of elasticity; and, once the modulus of elasticity has been increased to a point where the load constituted by the force from bias spring 328 is insufficient to distort wire control member 336, the wire control member will revert to its initial shape. Thus, movable contact 314 will be moved to a position in contact with stationary contact 312 due to the action of lever 318 about fulcrum 320 when wire control member 336 reverts to its initial shape.

When it is desired to return the switch assembly to its normally open state the supply of electricity to terminals 344 and 346 is interrupted to deenergize heating element 342 and reduce the temperature sensed by wire control member 336. The modulus of elasticity of wire control member 336 decreases with the decrease in temperature; and, once the modulus of elasticity decreases to a point where the force from bias spring 328 is sufficient to distort wire control member 336, the wire control member assumes its distorted shape to open contacts 312 and 314 and return the switch assembly to its normally open state.

If it is desired to operate the embodiment of FIG. 4 as a normally closed switch, the forces on lever 318 need only be reversed. For instance, by transposing bias spring 328 and wire control member 336, the embodiment of FIG. 4 may be provided with a normally closed mode of operation.

A modification of the embodiment of FIG. 4 is illustrated in FIG. 5. Parts in FIG. 5 identical to parts in FIG. 4 are given identical reference numbers and are not described again, and similar parts are given reference numbers with 100 added.

The primary difference between the embodiments of FIG. 4 and 5 are that a double-strand wire control member 436 is utilized, and the temperature sensed by wire control member 436 is controlled by passing an electrical current therethrough. Wire control member 436 has both ends secured to a sidewall of housing 310 by screws 438 and 439 to define two lengths and a center portion freely movable through aperture 340 in ear 326 such that the forces on wire control member 436 are evenly distributed. Wire control member 436 is constructed of a material having a temperature-actuated shape memory and has an initial shape in which the effective length between the center portion and the ends is short and a distorted shape in which the effective length between the center portion and the ends is long. As mentioned with respect to the embodiment of FIG. 4, this may be accomplished linearly or with loops. A pair of terminals 444 and 446 are connected with the two ends of wire control member 436, respectively, and extend through a top wall of housing 310.

The switch assembly is illustrated in its normally open state in FIG. 5; and, in order to close the switch assembly, electricity is applied to terminals 444 and 446 to pass a current through both lengths of wire control member 436. The current passing through wire control member 436 raises the temperature sensed thereby to accordingly increase the modulus of elasticity; and, once the modulus of elasticity has increased sufficiently to overcome the force from bias spring 328, wire control member 436 reverts to its initial shape to move lever 318 about fulcrum 320 to close contacts 312 and 314.

When it is desired to open the switch assembly, the electricity applied to terminals 444 and 446 is interrupted to decrease the temperature of wire control member 436 and accordingly decrease the modulus of elasticity. Once the modulus of

elasticity has decreased sufficiently, bias spring 328 will return wire control member 436 to its distorted shape and move lever 318 to open contacts 312 and 314 and return the switch assembly to its normally open state.

If it is desired to provide the embodiment of FIG. 5 with a normally closed mode of operation, the forces on lever 318 need only be reversed such as by transposing wire control member 436 and bias spring 328 as previously described with respect to the embodiment of FIG. 4.

A further embodiment of the present invention is illustrated in FIG. 6 and includes a switch assembly housing 510 constructed of electrically nonconductive material. The switch assembly includes a stationary contact 512 secured to a post at a sidewall of housing 510 and a movable contact 514 disposed on an arm 516 which is secured to a torsion control member 518. Torsion control member 518 is rigidly attached to a block 520 at another sidewall of housing 510 by means of a screw 522. A heating element 524 is disposed around torsion control member 518 and is adapted to be connected to a source of electricity through a selective control. A bias spring 526 is mounted in compression between a bottom wall of housing 510 and the underside of arm 516. A pair of wires 528 and 530 are electrically connected with contacts 512 and 514, respectively, and are adapted to be connected to a source of electricity and any circuitry or components for which it is desired to control the application of electricity through the switch assembly.

Torsion control member 518 is a bar or rod constructed of a material having a temperature-actuated shape memory and has a high torsion initial shape such that it is twisted clockwise as shown in FIG. 6 and a low torsion distorted shape such that it is twisted slightly counterclockwise from its initial shape.

The switch assembly of the embodiment of FIG. 6 has a normally closed state; however, it is illustrated in FIG. 6 in its open state. In its normally closed state contacts 512 and 514 are in contact due to the force from bias spring 526. At this time torsion control member 518 is in its low torsion distorted shape since normal room temperature exists and the modulus of elasticity is low.

In order to open the switch assembly, heating element 524 is energized to raise the temperature sensed by torsion control member 518 and increase the modulus of elasticity. Once the modulus of elasticity has increased to a point where the load constituted by the force from bias spring 526 is insufficient to distort the torsion control member to the extent required to maintain contacts 512 and 514 closed, torsion control member will revert to its initial high torsion shape by twisting clockwise to thereby open contacts 512 and 514.

In order to return the switch assembly to its normally closed state, heating element 524 is deenergized to decrease the temperature sensed by torsion control member 518 and accordingly decrease the modulus of elasticity. Once the modulus of elasticity decreases to a point where the force from bias spring 526 is sufficient to distort torsion control member 518, the torsion control member assumes its distorted shape to close contacts 512 and 514 and return the switch assembly to its normally closed state.

In order to provide the embodiment of FIG. 6 with a normally open mode of operation, it is merely necessary to alter the forces on arm 516 such that torsion control member 518 twists counterclockwise to its initial shape and bias spring 526 biases the end of arm 516 down away from stationary contact 512.

Another embodiment of the present invention is illustrated in FIG. 7 and includes a switch assembly housing 610 constructed of an electrically nonconductive material. The switch assembly includes a stationary contact 612 secured to a support on a sidewall of housing 610 and a movable contact 614 secured to a step on the sidewall of housing 610 by a linear flexible bar 616. A spring control member 618 has a squared center portion 620 connected with the underside of the end of flexible bar 616 and two side portions 622 and 624 coiled in opposite directions on a rod 626 supported by the sides of

housing 610. The ends of coiled side portions 622 and 624 are secured to housing 610 by means of screws 628 and 630, respectively.

A pair of wires 632 and 634 are electrically connected with contacts 612 and 614, respectively, and are adapted to be connected to a source of electricity and any circuitry or components for which it is desired to control the application of electricity through the switch assembly. A pair of wires 636 and 638 are connected with the ends of spring control member 618 and are adapted to be connected with a source of electricity through a selective control.

Spring control member 618 is constructed of material having a temperature-actuated shape memory and has a loosely coiled initial shape and a tightly coiled distorted shape such that the center portion 620 rotates counterclockwise as the spring control member reverts from its distorted shape to its initial shape as viewed from the right of FIG. 7.

The switch assembly is illustrated in its normally open state with movable contact 614 spaced from stationary contact 612 due to the tendency of flexible bar 616 to remain linear. At this time control member 618 is in its distorted shape since normal room temperature exists and the modulus of elasticity is low.

In order to close the switch assembly electricity is supplied to wires 636 and 638 to pass a current through control member 618 and accordingly raise the temperature thereof. The modulus of elasticity increases with the rising temperature until it reaches a point where the load constituted by the force from flexible bar 616 is insufficient to distort control member 618 to the extent required to maintain contacts 612 and 614 open. At this time spring control member 618 reverts to its initial shape with a counterclockwise movement to move contact 614 up to contact stationary contact 612.

In order to return the switch assembly to its normally open state the supply of electricity to wires 636 and 638 is interrupted to stop the flow of current through spring control member 618 and decrease the temperature. The modulus of elasticity decreases with the temperature until the force of flexible bar 616 overcomes spring control member 618 to return it to its distorted shape thereby opening contacts 612 and 614 and returning the switch assembly to its normally open state.

In order to utilize the embodiment of FIG. 7 in a normally closed mode of operation, it is necessary only to reverse the forces on movable contact 614 such that flexible bar 616 tends to close the contacts and spring control member 618 tends to open the contacts in its initial shape.

A further embodiment of the present invention is illustrated in FIG. 8 and includes a switch assembly housing 710 constructed of an electrically nonconductive material. The switch assembly includes a stationary contact 712 secured to a block at a corner of housing 710 and a movable contact 714 secured to the end of a control member 716 which has its other end fastened to a step at a sidewall of housing 710. A heating element 718 is disposed around control member 716 and is electrically connected to a pair of terminals 720 and 722 which extend through a bottom wall of housing 710 and are adapted to be connected to a source of electricity through a selective control. A pair of terminals 724 and 726 extend through opposite sidewalls of housing 710 and are electrically connected to contacts 712 and 714 through a wire 728 and a wire 730 and control member 716, respectively.

A bias spring 732 is mounted in tension between the bottom wall of housing 710 and the underside of control member 716 with one end connected to an aperture 734 in an ear 736 secured to control member 716 below contact 714 and another end connected to an aperture 738 in an ear 740 secured to the bottom wall of housing 710.

Control member 716 is a bar or rod constructed of a material having a temperature-actuated shape memory and has an upwardly curved initial shape and a linear distorted shape.

The switch assembly is illustrated in its normally open condition in FIG. 8 with movable contact 714 spaced from sta-

tionary contact 712 due to the force from bias spring 732. At this time control member 716 is in its linear distorted shape since normal room temperature exists and the modulus of elasticity is low.

In order to close the switch assembly, electricity is applied to terminals 720 and 722 to energize heating element 718 and raise the temperature sensed by control member 716. The modulus of elasticity increases with the rising temperature; and, once the modulus of elasticity is increased to a point where the load constituted by bias spring 732 is insufficient to distort control member 716 to the extent required to maintain contacts 712 and 714 open, control member 716 will revert to its initial upwardly curved shape to close contacts 712 and 714.

In order to return the switch assembly to its normally open state, the supply of electricity to terminals 720 and 722 is interrupted to decrease the temperature sensed by control member 716. Accordingly, the modulus of elasticity is decreased until a point is reached where the force from bias spring 732 is sufficient to cause control member 716 to return to its linear distorted shape to open contacts 712 and 714.

If it is desired to provide the embodiment of FIG. 8 with a normally closed mode of operation, the bias spring may be mounted in compression between a top wall of housing 710, and control member 716 may be formed with a linear initial shape and an upwardly curved distorted shape.

The embodiments of FIG. 3, 4, 6 and 8 have the advantage that the heating elements may be varied with respect to electrical characteristics to permit the use of the switch assembly with various systems and selective controls. Furthermore, when auxiliary heating elements are utilized no specific electrical characteristics are required for the control members thereby permitting the control members to be sized for optimum operation. While the embodiments of FIGS. 1, 2, 5 and 7 must be precisely matched to various systems and selective controls with respect to the electrical characteristics of the control members, these embodiments have the advantages of reduction of components, rapid heating, and sensitivity to small operating currents due to the passing of the current through the control members to internally generate heat.

Any of the above-described embodiments may be modified with respect to the temperature-controlling means by merely adding a heating element or passing a current through the control member in accordance with desired operation and the system in which the switch assembly is to be utilized.

The spring control members illustrated in FIGS. 1, 2, 3, and 7 are particularly adaptable for use with low power because the coiled configuration reduces heat loss and permits adjacent coils to heat each other. The advantages of spring control members can be increased by utilizing a barrel configuration to minimize stress at the spring ends where the load carrying capacity is less due to the fact that the ends of the spring control member will heat less than the center.

The control members illustrated in the above-identified embodiments are not meant to be the only shapes, configurations and cross sections of control members that can be utilized with the present invention. Almost any form of control member can be utilized as long as it will deflect with a load, such as a spring, and can be heated by current or an auxiliary heating element.

The control members for the embodiments above described may be formed by annealing the material in its initial shape in a position that will effect the normally closed or normally open mode of operation desired for the switch assembly. The annealing step may be performed in the switch assembly or external of the switch assembly. After annealing, which may be accomplished by passing a current through the control member and adjusting the annealed control member, a force is applied to the control member below the transition temperature to stretch and stabilize the control member. The control member is thus cycled through its initial and distorted shapes, and the switch assembly is ready for operation.

In as much as the present invention is subject to many variations, modifications and changes in detail, it is intended that all matter described in the foregoing specification or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electrically operated switch assembly comprising a switch housing; a stationary contact secured to said housing; a movable contact disposed adjacent said stationary contact and having a first position in contact with said stationary contact and a second position spaced from said stationary contact; said stationary contact and said movable contact being electrically connected in a first electrical circuit having a first operative state when said movable contact is in said first position and a second operative state when said movable contact is in said second position;
- operator means mounted within said housing and connected with said movable contact, said operator means including a control member constructed of a material having a temperature-actuated shape memory, said control member having an initial shape and being deformable to a distorted shape when its temperature is below a preselected transition temperature and reverting to said initial shape as a result of said temperature-actuated shape memory when its temperature is above said transition temperature, said movable contact being in said first position when said control member has said distorted shape and in said second position when said control member has said initial shape,
- bias means mounted within said switch housing and engaging said control member, said bias means mechanically biasing said control member to deform the same to its distorted shape when the temperature of said control member is below said transition temperature, and
- electrical controlling means disposed within said switch housing and connected in a second electrical circuit, said electrical controlling means being selectively energizable to control the temperature of said control member for controlling the shape of said control member whereby the operative state of said first electrical circuit is controlled in response to energization of said second electrical circuit.
2. The invention as recited in claim 1 wherein said control member is a wire.
3. The invention as recited in claim 1 wherein said control member is a double-strand wire.
4. The invention as recited in claim 1 wherein said control member is a spring.
5. The invention as recited in claim 1 wherein said control member is a bar having a high torsion initial shape and a low torsion distorted shape.
6. The invention as recited in claim 1 wherein said control member is a bar having a curved initial shape and a linear distorted shape.
7. The invention as recited in claim 1 wherein said control member is a bar having a linear initial shape and a curved distorted shape.
8. The invention as recited in claim 1 wherein said operator means includes lever means connected with said movable contact and said control member whereby said lever means controls the position of said movable contact in accordance with the shape of said control member.
9. The invention as recited in claim 1 wherein said control member is a wire having a first end connected with said switch housing and a second end connected with said operating means, the distance between said first end of said wire and said second end of said wire being greater when said wire has said distorted shape than when said wire has said initial shape.
10. The invention as recited in claim 1 wherein said control member is a torsion spring having a loosely coiled initial shape and tightly coiled distorted shape, said torsion spring being directly connected with said movable contact.

11. The invention as recited in claim 1 wherein said electrical controlling means includes a heating element disposed adjacent said control member.

12. The invention as recited in claim 1 wherein said electrical controlling means includes circuit means connected with said control member to pass an electrical current therethrough to internally heat said control member.

13. The invention as recited in claim 1 wherein said material is an alloy having a composition of 55 percent nickel by weight with the remainder being essentially titanium.

14. A temperature-responsive switch assembly comprising
a switch housing;
a stationary contact secured to said switch housing;
a movable contact disposed adjacent said stationary contact and having a position in contact with said stationary contact and a position spaced from said stationary contact;
means biasing said movable contact toward one of said positions; and

operator means connected with said movable contact to control the position of said movable contact, said operating means including a coiled compression spring control member having a loosely coiled initial shape and a tightly coiled distorted shape and being constructed of a material having a temperature-actuated shape memory, said movable contact being in said one position when said control member has said distorted shape and in the other position when said control member has said initial shape and said operator means further including means controlling the temperature of said control member to control the shape of said control member.

15. The invention as recited in claim 14 wherein said temperature controlling means includes electrical means connected with said coiled spring to pass an electrical current therethrough to internally heat said coiled spring.

16. The invention as recited in claim 15 wherein said bias means includes a coiled compression spring.

17. The invention as recited in claim 14 wherein said operator means includes lever means connected with said movable contact and said coiled spring, and wherein said coiled spring is mounted in compression between said lever means and said switch housing.

18. The invention as recited in claim 17 wherein said bias means includes a helical spring mounted in compression between said lever means and said switch housing.

19. The invention as recited in claim 18 wherein said temperature controlling means includes electrical means connected with said coiled spring to pass an electrical current therethrough to internally heat said coiled spring.

20. The invention as recited in claim 18 wherein said temperature controlling means includes a heating element disposed adjacent said coiled spring.

21. The invention as recited in claim 17 wherein said lever means has a first end, a second end connected with said movable contact and a center portion secured to a fulcrum, said coiled spring being mounted in compression between said first end of said lever means and said switch housing, and said bias means being mounted in compression between said second end of said lever means and said switch housing.

22. The invention as recited in claim 17 wherein said lever means has a first end, a second end connected with said movable contact and a center portion secured to a fulcrum, said coiled spring being mounted in tension between said first end of said lever means and said switch housing, and said bias means is mounted in compression between said second end of said lever means and said switch housing.

23. A temperature-responsive switch assembly comprising
a switch housing;
a stationary contact secured to said switch housing;
a movable contact disposed adjacent said stationary contact and having a position in contact with said stationary contact and a position spaced from said stationary contact;
means biasing said movable contact toward one of said positions and including a helical spring; and

operator means connected with said movable contact to control the position of said movable contact, said operating means including a coiled spring control member having a tightly coiled initial shape and a loosely coiled distorted shape and being constructed of a material having a temperature-actuated shape memory, lever means connected with said movable contact and said coiled spring, said coiled spring being mounted in tension between said lever means and said switch housing, and said helical spring being mounted in compression between said switch housing and said lever means, said movable contact being in said one position when said control member has said distorted shape and in the other position when said control member has said initial shape, and said operator means further including means controlling the temperature of said control member to control the shape of said control member.

24. The invention as recited in claim 23 wherein said lever means has a first end connected with said movable contact, a center portion secured to a fulcrum and a second end, said coiled spring being mounted in compression between one side of said second end of said lever means and said switch housing and said bias means being mounted in compression between the other side of said second end of said lever means and said switch housing.

25. A temperature-responsive switch assembly comprising
a switch housing;
a stationary contact secured to said switch housing;
a movable contact disposed adjacent said stationary contact and having a position in contact with said stationary contact and a position spaced from said stationary contact;
means biasing said movable contact toward one of said positions; and

operator means connected with said movable contact to control the position of said movable contact, said operating means including a torsion spring control member connected directly with said movable contact and having a loosely coiled initial shape and a tightly coiled distorted shape and being constructed of a material having a temperature-actuated shape memory, said torsion spring having a first section coiled in a first direction, a second section coiled in a direction opposite said first direction, and a central section directly connected with said movable contact, said movable contact being in said one position when said control member has said distorted shape and in the other position when said control member has said initial shape, and said operator means further including means controlling the temperature of said control member to control the shape of said control member.

26. The invention as recited in claim 25 wherein said temperature-controlling means includes electrical means connected with said first and second sections of said torsion spring to pass an electrical current therethrough and internally heat said torsion spring.

27. A temperature-responsive switch assembly comprising
a switch housing;
a stationary contact secured to said switch housing;
a movable contact disposed adjacent said stationary contact and having a position in contact with said stationary contact and a position spaced from said stationary contact;
spring means biasing said movable contact toward one of said positions; and

operator means connected with said movable contact to control the position of said movable contact, said operating means including a torsion bar control member having a high torsion initial shape and a low torsion distorted shape and being constructed of a material having a temperature-actuated shape memory, said movable contact being in said one position when said control member has said distorted shape and in the other position when said control member has said initial shape, means connecting said movable contact with said torsion bar, said spring means being mounted in compression between said con-

necting means and said switch housing, and said operator means further including means controlling the temperature of said control member to control the shape of said control member.

28. The invention as recited in claim 27 wherein said temperature-controlling means includes an electrical heating element disposed around said torsion bar.

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