Aug. 9, 1955 A. SKROBISCH 2,714,799

ELECTRO THERMAL ACTUATOR

Filed Jan. 16, 1952

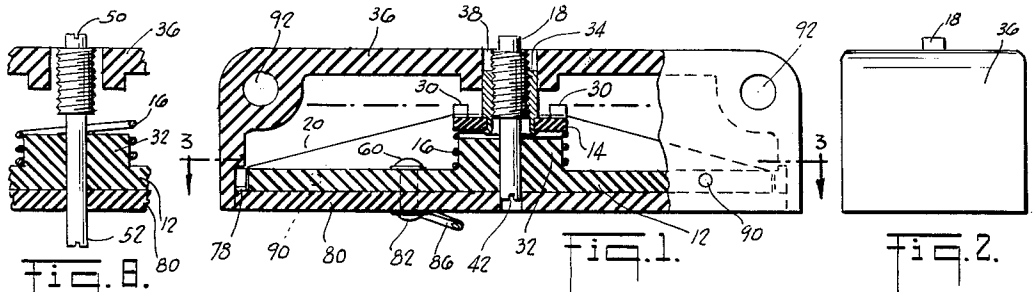


Fig. 8. Fig. 1. Fig. 2.

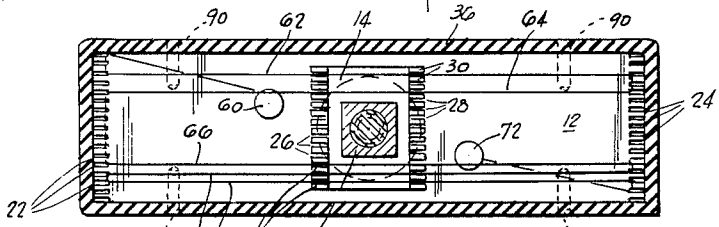


Fig. 3.

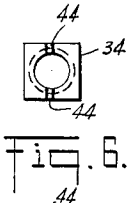


Fig. 6.

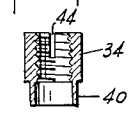


Fig. 7.

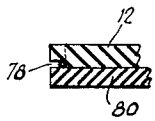


Fig. 11.

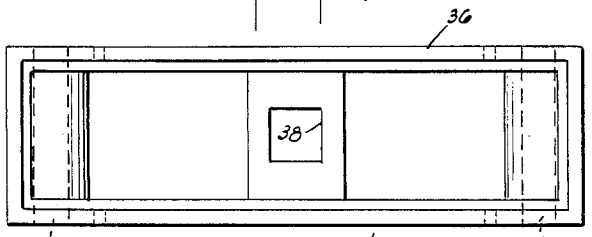


Fig. 4.

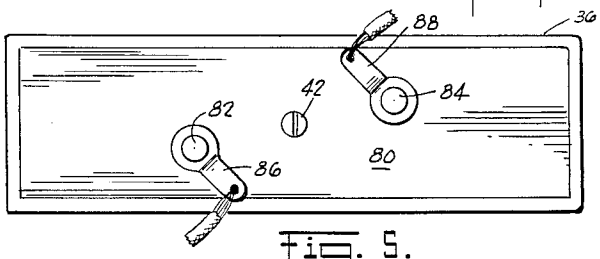


Fig. 5.

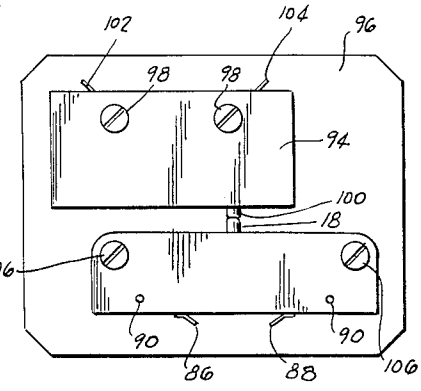


Fig. 9. Fig. 12.

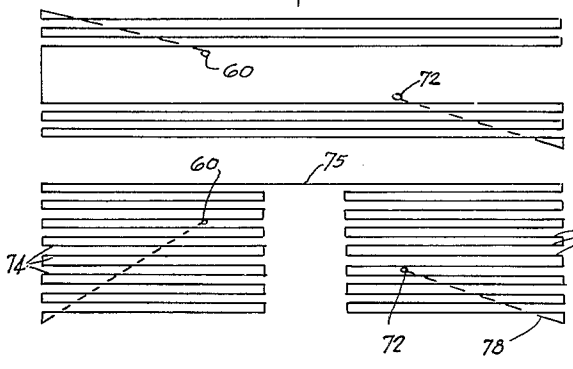


Fig. 10.

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ELECTROTHERMAL ACTUATOR

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Application January 16, 1952, Serial No. 266,747

20 Claims. (Cl. 60—23)

This invention relates to actuators operated in response to the thermal effect producted by an electric current, or so-called electrothermal actuators.

The primary object of the present invention is to generally improve electrothermal actuators. A more particular object is to provide a compact device capable of exerting substantial force, although operating in response to the thermal expansion of a fine resistance wire. Still another object is to so arrange the resistance wire as to obtain a substantial or multiplied motion in response to expansion thereof. A still further object is to arrange the resistance wire in multiple passes which are in bifilar relation, thereby making the device useable with either D. C. or A. C. current, and independent of frequency when used with A. C. current.

Still another object of the invention is to so arrange the device that its actuating pin is concentric with its actuating spring, and symmetrically disposed in relation to the resistance wire. A further object is to provide for ready adjustment of the actuating pin, and to make the adjustment self-locking.

Still another object is to so arrange the structure that the pin is freely accessible at either end so that it may be used at either end, and when used at one end may be adjusted from the other end, thus making possible an exact adjustment of the pin for desired result, after the actuator has been fixedly mounted in final position.

Still another object of the invention is to provide an actuator which will "fail safe."

To accomplish the foregoing objects, and such other objects as will hereinafter appear, my invention resides in the actuator elements and their relation one to another as are hereinafter described in the following specification. The specification is accompanied by a drawing, in which:

Fig. 1 is a partially sectioned elevation taken through an electrothermal actuator embodying features of my invention;

Fig. 2 is an end view thereof;

Fig. 3 is a horizontal section taken approximately in the plane of the line 3—3 of Fig. 1;

Fig. 4 is a bottom plan view of the cover alone;

Fig. 5 is a bottom plan view of the assembled actuator;

Fig. 6 is a plan view of an internally threaded metallic bushing forming a part of the invention;

Fig. 7 is a section through said bushing;

Fig. 8 is a fragmentary section corresponding to the center part of Fig. 1 but showing a modification using a longer pin which projects from the bottom of the actuator;

Fig. 9 is a schematic diagram explanatory of one method of stringing the resistance wire;

Fig. 10 is a similar view showing a modified method of stringing the resistance wire;

Fig. 11 is a detail; and

Fig. 12 shows how the actuator may be assembled with an over-the-center switch to provide a relay assembly.

Referring to the drawing, and more particularly to Figs. 1, 2 and 3, the actuator comprises a base 12, a deck 14

which is small compared to the base, and a compression spring 16 disposed between the base 12 and the deck 14. The actuator has an operating pin 18, and this is carried by the deck 14. Resistance wire 20 is strung between the base 12 and the deck 14 in order to resist the force of the spring 16. Ordinarily a single long wire is employed, and multiple passes of the wire are disposed electrically in series. They are preferably in bifilar relation in order to neutralize inductance so as to make the operation independent of frequency.

Considering the arrangement in greater detail, the base 12 is preferably made of a ceramic or other insulation material which is heat resistant. The deck 14 is similarly preferably made of a heat resistant insulation material. The ends of the base 12 are inwardly slotted with multiple slots best shown at 22 and 24 in Fig. 3. Similarly the ends of the deck 14 are preferably slotted with multiple slots 26 and 28, and these may correspond substantially to the slots 22 and 24 in the ends of the base. The bridge 14 is preferably formed with raised ridges 30 (Fig. 1) at its ends, and these may be slotted downward to provide the slots 26 and 28.

The compression spring 16 is accurately located in concentric relation to the pin 18, and for this purpose the base 12 may have a cylindrical boss 32 molded thereon, as is best shown in Figs. 1 and 8.

The actuator may also be provided with guide means to prevent rotation of the deck 14 about the axis of the pin 18. For this purpose the deck 14 has secured thereto a bushing 34 which is non-circular in cross-section. The actuator is enclosed by a cover 36 which is secured to the base, and which has a non-circular hole 38 mating with the bushing 34. In the particular case here shown the bushing and the hole are square in outline, the square hole being best shown at 38 in Fig. 4, and the square bushing being shown at 34 in Figs. 6 and 7. The lower end of the bushing, shown at 40 in Fig. 7, may be cylindrical, and after being passed through a mating hole in the deck, it is expanded and riveted fixedly in position, as shown in Fig. 1. The parts are held against relative rotation by the riveting action alone, but, if desired, may be additionally keyed together. The fit of the square bushing 34 in the square guide hole 38 then prevents rotation of the deck 14. This is not essential because the wires alone would hold the deck against rotation, and the sides of the deck 14 would prevent more than a slight rotation by reaching the sides of the housing, but nevertheless is of advantage in oder not to spoil delicate and accurate rotational adjustment of the pin next described.

For ready adjustment of the exact amount of protrusion of the pin 18, the pin is preferably threadedly received in the bushing 34. For this purpose the bushing is internally threaded, and the pin is matingly externally threaded. An end of the pin is slotted, as indicated at 42, for screwdriver adjustment. It will be noted that both ends of the pin are accessible, and this is of great convenience in adjusting the actuator, for it may be adjusted while already mounted in final position, and with current flowing therethrough.

To hold the adjustment of the pin against accidental change, the upper part of the bushing 34 is preferably slotted as indicated at 44 in Figs. 6 and 7. The sides of the bushing are compressed toward one another enough to provide a frictional grip on the threaded pin.

The accessibility of both ends of the operating pin is useful for another reason, because either end of the pin may be made the working end. In the construction shown in Figs. 1 and 2 it is assumed that the upper end is to be the working end, and that is usually the case. Increased current causes a pushing movement, and decreased current retracts the pin. However, if opposite operation is desired it is merely necessary to substitute for the pin 18

shown in Fig. 1, a longer pin as shown at 50 in Fig. 8. This is lengthened so that the lower end 52 projects beneath the base, and may be used as the operating end, in which case decreased current causes a pushing motion, and increased current causes retraction.

The wire 20 is preferably a resistance wire having a high temperature coefficient of expansion. Ordinarily a single long wire is employed, and its length and diameter, for a given resistivity, depend on the relation of the operating current available to the force required.

Some of the possible methods of stringing or winding the wire may be illustrated with reference to Figs. 3, 9 and 10. Referring first to Fig. 3, the wire starts at a terminal post 60 and runs along the inside surface of the base to one of the slots 22 where it is turned downward, and then runs transversely to a starting slot at the same end of the base. The wire is then passed upwardly and then over the deck 14, as indicated at 62, it being located by an appropriate one of the slots 26 and 28, and then runs on to a corresponding slot 24 in the other end of the base. The wire then runs transversely beneath the base to another slot 24, and is then passed upwardly and then back over the deck 14, as indicated at 64, through appropriate slots 28 and 26, to a corresponding one of the slots 22 at the other end of the base. The wire then runs transversely beneath the base to another slot 22 symmetrically related to the deck and pin, and is then passed upwardly and then over the deck 14, as shown at 66. It is located by a slot 26 and a slot 28, and then passes to a corresponding one of the slots 24 at the other end of the base, where it is turned downwardly and then transversely beneath the base, and is then passed upward through another one of the slots 24, and then passes over the deck 14, as shown at 67, to a corresponding slot 22 at the other end of the base. The wire then turns transversely beneath the base to another slot 22, and then passes over the deck 14, as shown at 68, to a corresponding slot 24 at the other end of the base. Thus, in this illustrated example, five passes or strands of resistance wire resist the force of the spring 16, and control the operation of the pin 18.

To complete the circuit the resistance wire may be turned transversely and upward and then run along the inside surface of the base to the second terminal 72 where it is secured in position. In respect to one of the five strands, the wires are not in bifilar relation, but nevertheless the unit is substantially non-inductive because the inductance of the strand of wire is infinitesimal compared to the resistance of the wire, and is negligible throughout the audio frequency range contemplated. The arrangement is to be contrasted with a solenoid type actuator having a highly inductive solenoid.

It will be understood that a greater or lesser number of strands of resistance wire may be strung between the base and the deck, and preferably in bifilar relation, in the manner already described for the five strands shown in Fig. 3. Thus Fig. 9 shows schematically how the actuator may be wound with nine strands of wire. If, however, a still larger number of strands are wanted, so many that it is desired to employ the slots in the center region, they too may be wound in substantially bifilar relation by running the resistance wire between one end of the base and one end of the deck, without passing the wire over the deck. Thus, referring to Fig. 10, the wire starts at terminal 60 and is wound back and forth between the slots 22 (Fig. 3) and the slots 26, as is indicated by the short strands 74 (Fig. 10). (The slots are not shown in Fig. 10, which is only schematic.) At the edge of the base a single long strand 75 passes over the deck to the other end of the base, whereupon the wire is wound in short strands between the slots 24 (Fig. 3) and the slots 28, as is indicated at 76 (Fig. 10). Near the opposite edge of the base the strands terminate in a connection 78 running along the inside surface of the base to the other end terminal 72.

In lieu of no long strands at the bottom of Fig. 10, as shown, the layout may be provided with two long strands, then terminating at 78 and 72 as shown. It should be understood that the action of the short strands is substantially the same as that of the long strands.

It is largely to facilitate the use of short strands of wire that the ridges 30 are formed on the deck 14, with the slots 26 and 28 formed in the ridges 30. Because the only resistance wire located beneath the base 12 extends transversely at the ends from one slot to another, the base is preferably recessed upward at the slots 22 and 24, as is shown at 78 in Figs. 1 and 11. This provides clearance for the resistance wire when run transversely from one end slot to another. The section of Fig. 1 is through a slot, while that of Fig. 11 is between slots.

The base 12 and deck 14 are preferably made of a heat resistant insulation, preferably a ceramic material, because they are in direct contact with the heated resistance wire. The cover 36, however, may be made of a molded plastic, preferably a thermosetting plastic of the phenolic type such as Bakelite. The base 12 is preferably supplemented by an outer lamination 80, and this too may be made of Bakelite or the like. After the base has been wound with resistance wire the lamination 80 may be added to the base and secured in position by eyeletting or riveting the terminals, as inlicated at 82 in Fig. 1, and at 82 and 84 in Fig. 5. Conventional soldering lugs 86 and 88 are preferably interposed before expanding the rivets or eyelets. The cover 36 is added and may be secured in position by the use of four small pins driven sidewardly into mating holes, as indicated at 90 in Figs. 1 and 3 and 11. The molded cover 36 preferably includes a pair of transverse through-holes indicated at 92 in Figs. 1 and 4, to facilitate mounting the unit in desired position. Those familiar with conventional snap switches of the "Micro-switch" type will recognize the construction as a convenient one.

The electro thermal actuator may be employed for a variety of purposes. It may be used to operate a needle valve. It may be used with an over-center or snap switch as a relay. The latter possibility is illustrated in Fig. 12, in which an over-center switch is shown at 94, mounted on a plate 96 by means of screws 98. This switch may be any of the standard products known commercially as a "Micro-switch," "Acro Snap," or "Unimax." The switch is operated by a slight movement of a plunger 100. Conductors for the main circuit may be connected to soldering lugs 102 and 104. The electro thermal actuator of the present invention is similarly mounted on base 96 by means of screws 106. The pin 18 is disposed in alignment with the pin 100. The control circuit of the relay is connected to the soldering lugs 86 and 88. It will be understood that a control current passing through the actuator is used to control a main current passing through the over-center switch 94.

The illustrated combination provides an electrical relay which is particularly valuable for certain purposes. For example, on aircraft the engines may be operated over a large range of speed, resulting in a variation of frequency commonly stated in specifications to be from 320 to 1,000 cycles. This makes it difficult to provide a satisfactory relay, for in changing from 320 to 1,000 cycles there is a tremendous variation in inductive reactance, and if enough voltage were supplied to operate at the high frequency end of the range, the relay coil would be burned out at the low frequency end of the range. The present relay is non-inductive, and therefore is independent of frequency. The relay may be actuated by an input of as little as three watts, yet may control an over-center switch handling, say, 15 amperes at 125 volts.

The relay is not truly instantaneous, and may take from, say, one-quarter to one second to operate, depending on the adjustment of the plunger or the motion required. For most purposes the delay is not excessive, and indeed for some purposes a slight delay may be wanted. When

for certain purposes a delay of only one second is needed, it is found that ordinary time delay relays provide too much delay, and in such cases a relay such as that here shown may be used for short time delay purposes.

It will be understood that the force delivered by the actuator depends on the compression spring employed, and a suitable spring is used to provide whatever force is needed. This force is then opposed by the resistance wire, and it is for that reason that multiple strands are employed. Another design factor to be met is to provide enough series resistance to keep the relay current and wattage down, to prevent overheating. With low wattages the base and deck may be made of a molded plastic insulation such as Bakelite, instead of a ceramic such as Steatite, but a ceramic is preferred when the actuator is to operate at higher temperature.

By way of a specific example, it may be stated that an over-center switch such as a "Micro-switch" will operate with a force of one-half pound. For safety the spring in my actuator when used in the combination shown in Fig. 11, may provide a force of one pound. This may be restained by using four strands of "Nichrome" wire 5 mils in diameter, and the device may be made with Bakelite insulation for operation at 26 volts. The actuator may be provided with sixteen strands of Nichrome wire having a diameter of 1.75 mils for operation at 70 volts with Bakelite insulation, and various other combinations of wire diameter and wire length may be employed. With ceramic insulation the permissible operating voltage for any particular winding will be appropriately higher. The restraining forces provided by the above combinations of wire are well in excess of the one pound force exerted by the spring, being, respectively, about seven pounds and four pounds.

In designing the actuator it may be assumed that the wire may be heated to a temperature level of 600° C., with a thermal expansion of from 0.004 to 0.008" per inch. In the actuator here illustrated the sloping strands are one inch long. Because of the angular relation of the strands of wire to the direction of movement of the pin, as best shown in Fig. 1 of the drawing, the expansion of the wire is multiplied approximately four-fold in the direction of movement of the pin, giving a pin travel of from 0.016 to 0.032", which is more than that needed to operate an over-center or snap action switch of the "Micro-switch" type.

However, it will be understood that the size and the number of wire strands, and the angle of the strands, and the pressure of the spring, may all be varied while still using the convenient structural arrangement of the present invention, and that the numerical or quantitative values given above are only approximate, and have been presented solely by way of exemplification, and not in limitation of the invention.

It is believed that the method of design and construction of my improved actuator, as well as the operation and advantages thereof, will be apparent from the foregoing description. It will be understood that while I have shown a single resistance wire, with all strands arranged electrically in series (though mechanically in parallel), it is also possible to employ two pieces of resistance wire arranged electrically in parallel, each wire providing half of the strands. With three pieces each would provide a third, etc. It will be understood that the layout of the wire may consist of through strands, as shown in Figs. 3 and 9, or short strands, as shown in Fig. 10, or a combination of both. While I have described the use of slots formed in the ends of the base and at the top of the deck, it will be understood that the base and deck may equally well be molded with projections or posts, in which case the spaces between the posts may be considered to be the slots here referred to. It will be understood that while I have shown the bushing 34 and its guide hole 38 as square in cross-section, these need not be square, and may be any other

non-circular outline, thus preventing rotation of the deck, and even that is not essential to the operation of the actuator, although it is highly desirable. The actuating pin passes entirely through the housing, which is particularly desirable because it makes it possible to use either end of the pin for drive purposes, and makes it possible to adjust the pin at the end remote from the working end, so that it can be accurately adjusted while in operation. The actuator will "fail safe," because should the wire snap at any strand it does not unravel from the slots and does not allow the spring to push up the pin. The sharp bends in the wire caused by threading it through the slots, and from slot to slot, prevent this from happening.

It will therefore be apparent that while I have shown and described my invention in a preferred form, changes may be made in the structure disclosed, without departing from the scope of the invention, as sought to be defined in the following claims.

I claim:

1. An electrothermal actuator comprising a base, a deck which is disposed above the base, a compression spring disposed between the base and deck for urging the deck away from the base, an operating pin disposed generally perpendicular to the base and deck and carried by the deck for movement in the direction of the axis of the pin, and resistance wire strung in bifilar relation between the base and the deck in order to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between and being insulated from said base and said deck and serving to hold the deck against the force of the spring, and both lying approximately in a common plane disposed transversely of the pin.

2. An electrothermal actuator comprising an insulation base, a deck also made of insulation material and which is disposed above the base, a compression spring urging the deck away from the base, an operating pin carried by the deck and disposed in substantially perpendicular relation to the base and deck, guide means operative in the direction of the axis of the pin, said guide means being non-circular in cross-section in order to prevent rotation of the deck about the axis of the pin, and resistance wire strung in bifilar relation between the base and the deck in order to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck in order to hold the deck against the force of the spring, and both lying approximately in a common plane disposed transversely of the pin.

3. An electrothermal actuator comprising a rectangular heat resistant insulation base, a deck also made of heat resistant insulation material and disposed above the base, a compression spring for urging the deck away from the base, an operating pin carried by the deck and disposed substantially coaxially of the spring in substantially perpendicular relation to the base and deck for movement in the direction of its axis, and resistance wire having a high temperature coefficient of expansion strung between the base and the deck in order to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck in order to hold the deck against the force of the spring, and both lying approximately in a common plane disposed transversely of the pin.

4. An electrothermal actuator comprising a base, opposite ends of said base being inwardly slotted with multiple slots, a deck which is relatively small compared to the base, opposite ends of said deck being slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire extending from a slot at one

end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on.

5. An electrothermal actuator comprising a rectangular insulation base, the ends of said base being inwardly slotted with multiple slots, a deck also made of insulation material and relatively short compared to the base, the ends of said deck being slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed in substantially perpendicular relation to the base and deck, guide means to prevent rotation of the deck about the axis of the pin, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire extending from a slot at one end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on.

6. An electrothermal actuator comprising a rectangular heat resistant insulation base, the ends of said base being inwardly slotted with multiple slots, and the bottom of said base being recessed at the slots, a deck also made of heat resistant insulation material and relatively short compared to the base, the ends of said deck being slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed substantially coaxially of the spring in substantially perpendicular relation to the base and deck, and resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, said wire extending from a slot at one end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on.

7. An electrothermal actuator comprising a base, opposite ends of said base being inwardly slotted with multiple slots, a deck, opposite ends of said deck having multiple projections with slots therebetween corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire being strung in bifilar relation from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

8. An electrothermal actuator comprising a rectangular insulation base, the ends of said base being inwardly slotted with multiple slots, a deck also made of insulation material, the ends of said deck having multiple projections with slots therebetween corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed in substantially perpendicular relation to the base and deck, guide means to prevent rotation of the deck about the axis of the pin, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire being strung in bifilar relation from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

9. An electrothermal actuator comprising a rectangular heat resistant insulation base, the ends of said base being inwardly slotted with multiple slots and the bottom of said base being recessed at the slots, a deck also made of heat resistant insulation material and relatively short compared to the base, the ends of said deck being raised and slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed substantially coaxially of the spring in substantially perpendicular relation to the base and deck, and resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, said wire being strung in bifilar relation from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands at one end, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

10. An electrothermal actuator comprising a base, opposite ends of said base being inwardly slotted with multiple slots, a deck which is relatively small compared to the base, opposite ends of said deck having multiple projections with slots therebetween corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire near the side edges of the base and deck being strung from a slot at one end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on, and said wire near the center region of said base being strung from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands at one end, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

11. An electrothermal actuator comprising a rectangular insulation base, the ends of said base being inwardly slotted with multiple slots, a deck also made of insulation material and relatively short compared to the base, the ends of said deck being raised and slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed in substantially perpendicular relation to the base and deck, guide means to prevent rotation of the deck about the axis of the pin, and resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, said wire near the side edges of the base and deck being strung from a slot at one end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on, and said wire near the center

region of said base being strung from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands at one end, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

12. An electrothermal actuator comprising a rectangular heat resistant insulation base, the ends of said base being inwardly slotted with multiple slots and the bottom of said base being recessed at the slots, a deck also made of heat resistant insulation material and relatively short compared to the base, the ends of said deck being raised and slotted with multiple slots corresponding substantially to the slots at the ends of the base, a compression spring disposed between the base and deck, an operating pin carried by the deck and disposed substantially coaxially of the spring in substantially perpendicular relation to the base and deck, and resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, said wire near the side edges of the base and deck being strung from a slot at one end of the base over the deck in slots thereof to a slot at the other end of the base, and thence transversely beneath the base to another slot at the second end of the base, and thence upwardly from the second end of the base over the deck in slots thereof to a slot at the first end of the base, and so on, and said wire near the center region of said base being strung from a slot at one end of the base to a slot at one end of the deck, and thence transversely to another slot at the same end of the deck, and thence back to a slot at the original end of the base, and so on, to provide a desired number of strands at one end, and additional wire being strung in similar bifilar relation between slots at the other end of the base and the other end of the deck.

13. An electrothermal actuator comprising a base, a deck, a compression spring disposed between the base and deck for urging the deck away from the base, an internally threaded bushing secured to said deck with its axis perpendicular to the deck and base, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, and a resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck to hold the deck.

14. An electrothermal actuator comprising a base, a deck, a compression spring disposed between the base and deck for urging the deck away from the base, an internally threaded bushing secured to said deck with its axis perpendicular to the deck and base, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, at least a part of said bushing being slit and compressed to frictionally grip and hold the adjustment of the threaded pin, and a resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck to hold the deck.

15. An electrothermal actuator comprising a base, a deck, a compression spring disposed between the base and deck for urging the deck away from the base, an internally threaded bushing secured to said deck with its axis perpendicular to the deck and base, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, and a resistance wire strung in bifilar relation between the base and the deck to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck to hold the deck, both ends of said pin being kept open and accessible for utilization either for adjustment or for actuation of another element.

16. An electrothermal actuator comprising a rectangular heat resistant insulation base, a deck also made of heat resistant insulation material, a compression spring disposed between the base and deck for urging the deck away from the base, an internally threaded bushing secured to said deck with its axis substantially concentric with the spring and perpendicular to the deck and base, a section through said bushing being non-circular in outline, a cover secured to said base and having a non-circular hole mating with said bushing to prevent rotation of the deck, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, and a resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck to hold the deck.

17. An electrothermal actuator comprising a rectangular heat resistant insulation base, a deck also made of heat resistant insulation material, a compression spring disposed between the base and deck, an internally threaded bushing secured to said deck with its axis substantially concentric with the spring and perpendicular to the deck and base, a section through said bushing being non-circular in outline, a cover secured to said base and having a non-circular hole mating with said bushing to prevent rotation of the deck, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, at least a part of said bushing being slit and compressed to frictionally grip and hold the adjustment of the threaded pin, and a resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring.

18. An electrothermal actuator comprising a rectangular heat resistant insulation base, a deck also made of heat resistant insulation material, a compression spring disposed between the base and deck, an internally threaded bushing secured to said deck with its axis substantially concentric with the spring and perpendicular to the deck and base, a section through said bushing being non-circular in outline, a cover secured to said base and having a non-circular hole mating with said bushing to prevent rotation of the deck, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, and a resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, both ends of said pin being kept open and accessible for utilization either for adjustment or for actuation of another element.

19. An electrothermal actuator comprising a rectangular heat resistant insulation base, a deck also made of heat resistant insulation material, a compression spring disposed between the base and deck, an internally threaded bushing secured to said deck with its axis substantially concentric with the spring, and perpendicular to the deck

and base, a section through said bushing being non-circular in outline, a cover secured to said base and having a non-circular hole mating with said bushing to prevent rotation of the deck, an operating pin carried by said bushing, said pin being externally threaded to mate with the bushing, an end of said pin being slotted to facilitate rotational adjustment of the same to axially adjust the position of the actuator pin after installation of the actuator, at least a part of said bushing being slit and compressed to frictionally grip and hold the adjustment of the threaded pin, and a resistance wire having a high temperature coefficient of expansion strung in bifilar relation between the base and the deck to resist the force of the spring, both ends of said pin being kept open and accessible for utilization either for adjustment or for actuation of another element.

20. An electrothermal actuator comprising a rectangular heat resistant insulation base, the ends of said base being inwardly slotted with multiple slots, a deck also made of heat resistant insulation material, the ends of said deck being raised and slotted with multiple slots, a compression spring urging the deck away from the base, an operating pin carried by the deck and disposed substantially coaxially of the spring in substantially perpendicular relation to the base and deck for movement in

the direction of its axis, and resistance wire having a high temperature coefficient of expansion strung between the base and the deck in order to resist the force of the spring, said wire being held in proper spaced relation by the aforesaid slots of the base and the deck, the back-and-forth strands of the bifilar resistance wire both extending between said base and said deck to hold the deck, and both lying approximately in a common plane disposed transversely of the pin.

References Cited in the file of this patent

UNITED STATES PATENTS

346,430	Cutten	July 27, 1886
1,110,254	Conklin	Sept. 8, 1914
1,703,803	Widström	Feb. 26, 1929
1,738,072	Källe	Dec. 3, 1929
1,783,474	Hotchkiss	Dec. 2, 1930
2,030,932	Persons	Feb. 18, 1936
2,076,275	Jorgenson	Apr. 6, 1937
2,265,586	Vernet	Dec. 9, 1941
2,271,307	Ray	Jan. 27, 1942

FOREIGN PATENTS

345,050	France	Sept. 28, 1904