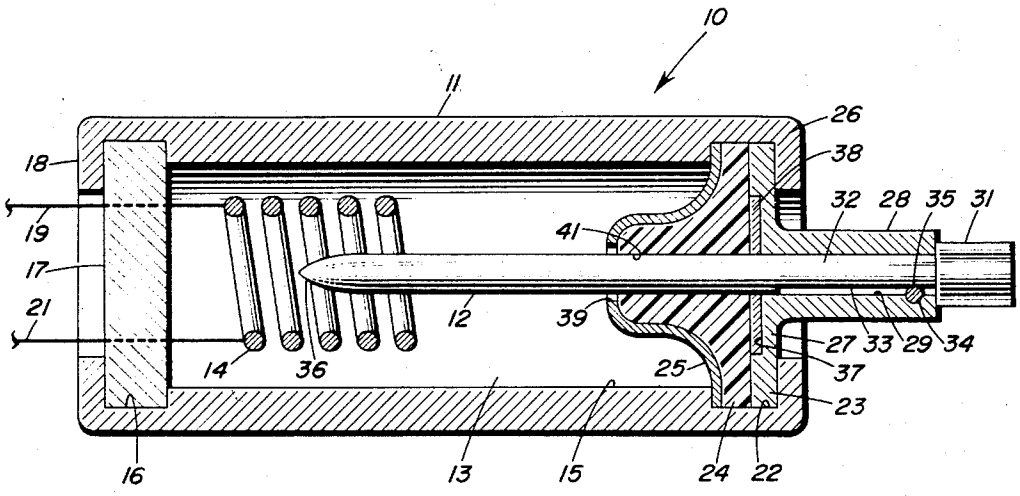
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ELECTRO-THERMAL ACTUATOR

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ELECTRO-THERMAL ACTUATOR

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ABSTRACT OF THE DISCLOSURE

This invention relates to an electro-thermal actuator and, more particularly, to an actuator consisting of a housing containing a thermally-expansible material, a piston slidable in and out of the housing, and an electrically-energized heater for raising the temperature of the material to force the piston out of the housing.

This is a continuation of my patent applications Ser. No. 286,297, filed June 7, 1963, now abandoned, Ser. No. 415,851, filed Nov. 24, 1964, now abandoned, and Ser. No. 477,520, filed Aug. 5, 1965, now abandoned.

There are many applications in which it would be useful to have a compact electrical-mechanical transducer, i.e., a motor producing linear action in response to an electrical signal. In the past, motors of this type have been constructed which make use of an electrical resistance which causes mechanical movement by action of heat on a thermally expansible material. However, such prior art motors have suffered from a number of defects. They have been complicated and expensive and, in general, have been unreliable. They have not acted promptly in response to the electrical signal and have presented considerable problem insofar as leakage of operating liquid and the like are concerned. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide an electro-thermal actuator giving linear action in response to an electrical signal.

Another object of this invention is the provision of an actuator consisting of an electrical-mechanical transducer which is simple in construction, inexpensive to manufacture, and which is capable of a long and useful life of maintenance-free service.

A further object of the present invention is the provision of an actuator making use of a thermally-expansible liquid contained in a housing in which provision is made to assure that there is no leakage of the expansible liquid.

It is another object of the instant invention to provide an actuator using a thermally-expansible liquid which is quick to react in response to an electrical signal received from an exterior source, the motor functioning to give a maximum linear motion in a controlled time lapse.

It is a further object of the invention to provide an actuator in which the main operating element may be readily removed for the introduction of operating fluid.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawing in which:

The single figure is a longitudinal sectional view of an actuator embodying the principles of the present invention.

Referring to the drawing, the actuator, indicated generally by the reference numeral **10**, is shown as consisting of a housing **11** carrying a piston **12** and of a body **13** of thermally-expansible material, such as a liquid in which is carried an electrical heating element **14**. The housing is of generally tubular form and is provided with a main bore **15**. One end of the bore is provided with a groove **16** in which resides a disk-like head **17** and a flange **18** which extends inwardly to lock the head **17** in place. The assembly of the head and the housing **11** takes place in the following manner: as originally constructed, the groove **16** is a counterbore and the flange **18** extends axially of the housing. In assembly, after the head **17** has been slipped in the counterbore the flange **18** is bent radially inwardly by a swaging operation. Extending from the opposite ends of the heating element **14** are leads **19** and **21** adapted to be connected to a source of electrical power (not shown).

The other end of the housing is also provided with a radial groove **22** in which reside the outer peripheries of a head **23**, an elastomer body or rubber block **24**, and a retainer **25**, these elements being locked in the groove by an inwardly-directed flange **26**. These elements are locked in place in the same manner that the head **17** is held in its end of the housing; that is to say, the groove **22** is originally a counterbore in which the elements **23**, **24**, and **25** are placed. Then, the flange **26** (which originally extended axially) is swaged radially inwardly to lock the elements together.

The head **23** consists of a disk-like body **27** which is locked in the groove **22** and from the center of which emerges an axially-extending neck **28**. The neck extends axially outwardly of the body **11** and is provided with a central bore **29**. In this bore resides the piston **12**, which, for the purposes of illustration, is shown as a rod-like member having an outer head **31** which is substantially larger than the bore **29**. The outer end of the rod **32** can be formed with various geometric shapes so that it can be used to function in various applications. This head is adapted to be connected to mechanisms which are to be moved; in other words, the linear motion resulting from the motor action takes place on this head and is transferred to other elements of the mechanism in which the motor is incorporated. The piston **12** is provided with a piston rod **32** which is formed with a recess such as the flat **33** which extends along the length of the piston rod **32** a substantial distance. The recess, however, may take the form of a slot or a relief. Extending transversely across the neck **28** of the head **23** is a bore **34** through which extends a pin **35**. The bore **34** has its axis generally tangential to the bore **29** so that a substantial portion of the pin **35** extends upwardly into the flat **33** and, therefore, is capable of limiting the lengthwise movement of the piston **12**. The inner end of the piston is shown as an extension of the piston rod **32** and it is provided with no enlarged head.

The inwardly-facing surface of the body **27** of the head **23** is provided with a counterbore **37** which resides a washer-shaped seal member **38**. The retainer **25** is made out of sheet metal and is in the shape of a hat having a flange which is held in the groove **22** and a crown which extends axially into the chamber of the housing. The retainer is provided with a circular aperture **39** through which the piston **12** passes and which is larger than the piston. The elastomer body **24** is interposed and prestressed between the transverse surface of the body **27** of the head **23** and the outwardly-directed surface of the retainer **25**. It is, therefore, of a generally hat-shaped conformation and is provided with a central axis bore **41** which is of approximately .020" less in diameter than the diameter of the piston so that it embraces the piston **12** tightly. In addition, the locking of the retainer **25**, the block **24**, and the head **23** in place by the crimping of

the end of the housing produces an additional prestress in the rubber block **24**, thus producing even further pressure of the rubber on the piston. The thermally-expansive material may be any one of a number of suitable chemicals, such as the fluoro-chemicals. In general, they should be selected to have a high coefficient of thermal expansion, a high thermal conductivity, they should be nonelectrically conductive (good insulators), they should be of such a nature as to be noncorrosive so far as the housing and the elastomer body are concerned, and, of course, they should be fairly inexpensive. The elastomer body **24** may be formed of rubber, or a rubber-like artificial material, such as Teflon or butadiene.

The operation of the invention will now be readily understood in view of the above description. The actuator will normally appear in the condition shown in the drawing. In this condition, the elastomer body **24** is in a prestressed condition and the retainer **25** is in its expanded position. The piston **12** is in its left-hand position in the drawing with the retaining pin **35** residing at the right-hand end of the flat **33** on the side of the piston. Presumably, also, the head **31** can be pressed against the outboard end of the neck **28** of the head **23** or head **31** can be located by pin **35** in the flat **33**. The body **13** of thermally-expansible liquid is cold and is in a shrunken condition. When it is desired to energize the motor to operate a mechanism, an electrical current is connected across the leads **19** and **21** so that an electrical current flows through the heating element **14**, the heating element being embedded in the body **13** of thermally-expansible liquid. The material immediately begins to heat and to react to the heat and it begins to increase in volume. When it does so increase, it presses in all directions against all parts of the inside of the housing **11** and all articles contained therein, one of the set of surfaces being the surface of the piston **12**. Particularly, the shaped surface **36** thereof receives the full stress of the added pressure. The piston, therefore, moves outwardly of the housing **11**, through the bore **41** in the elastomer body **24**, through the aperture **39** in the retainer **25** and through the bore **29** in the head **23**. As the body **13** expands the piston is forced outwardly more and more until, eventually, it reaches the position in which the pin **35** resides at the left-hand side of the flat **33** in the piston, thus limiting the motion. Whatever mechanism is attached to the head **31** has been actuated through a full stroke of the motor. The expanding of the liquid body **13**, of course, operates on the surface of the body **24** through the aperture **39** which serves it to compress the elastomer body **24** and to cause it to press tightly around the surface of the piston **12** as it slides through the bore **41**. The removal of the electrical current from the leads **19** and **21**, thus causing a drop or substantial decrease or termination of passage of current through the heating element **14**, causes the body **13** to cool down so that the piston **12** is free to reenter the housing **11** and to reside with its head **31** residing against the outer end of the neck **28**. The elastomer body **24** acts as an alignment guide and seal for the piston **32** during linear motion.

It can be seen that, since the heating element is embedded deeply in the body **13**, any heating of the heating element due to electrical current passing through it is quick to react on the thermally-expansive material so that the actuator operates very readily. Also, it is a simple matter to dismantle the piston and replace it by removing the pin **35**, so that the piston is free to leave the housing. The operation of the pressure of the thermally-expansive material **13** on the body **24**, thus compressing it, causes a very tight seal so that there is no danger of leakage of the material around the exit of the piston. The greater the pressure of the liquid, the greater the sealing effect.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such forms as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. An actuator, comprising:

(a) a housing including an end wall,

(b) a nonelectrically conductive, thermally-expansible material in the housing,

(c) a piston rod movable in the housing and movable through an aperture in the said end wall in response to expansion of the material,

(d) an electrical heating element in the material and having leads extending exteriorly of the housing,

(e) a block of elastomer material encasing the piston rod on its perimeter and extending between the piston rod and the housing, the block engaging the said end wall and the piston rod extending entirely through the block and the wall the configuration of the block being such that the surface area facing away from the said end wall is substantially greater than the surface area facing toward the end wall, and

(f) a rigid restraining member encasing the block to press it against the piston rod at all times, an aperture extending through the restraining member to permit at least a portion of the block to be acted upon by the said material whereby, as the pressure in the material increases, the pressure of the block on the piston rod also increases.

2. An actuator, as recited in claim **1**, wherein the housing is provided with an axially-elongated cylinder in which the piston rod resides.

3. An actuator, as recited in claim **1**, wherein the thermally-expansible liquid occupies the entire volume of the housing exclusive of the piston rod, the heating element, and the block.

4. An actuator, comprising:

(a) a housing,

(b) a nonelectrically conductive, thermally-expansible liquid in the housing,

(c) a piston rod movable in the housing and movable in response to expansion of the liquid,

(d) a separate electrical heating element in the liquid and having leads extending exteriorly of the housing,

(e) a block of prestressed elastomer material surrounding the piston rod and extending between the piston rod and the housing, the block engaging an end wall of the said housing and the piston rod extending entirely through the block and the wall, and

(f) a rigid restraining member encasing the block to press it against the piston rod at all times, the member and the block being acted upon by the said liqiud whereby, as the pressure in the liquid increases, the pressure of the block on the piston rod and on the said end wall increases to provide greater sealing against escape of the liquid from the housing.

5. An actuator as recited in claim **4**, wherein the outer portion of the block is locked to the housing to obviate a gap therebetween.

6. An actuator as recited in claim **5**, wherein the elastomer material in the block and the locking of the block to the housing is brought about by crimping the housing around the end wall.

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