Nov. 29, 1960 I. W. COX 2,961,827

ELECTRO-THERMAL DEVICE OF THE THRUST ACTUATOR TYPE

Filed May 20, 1958

2 Sheets-Sheet 1

Fig. 1

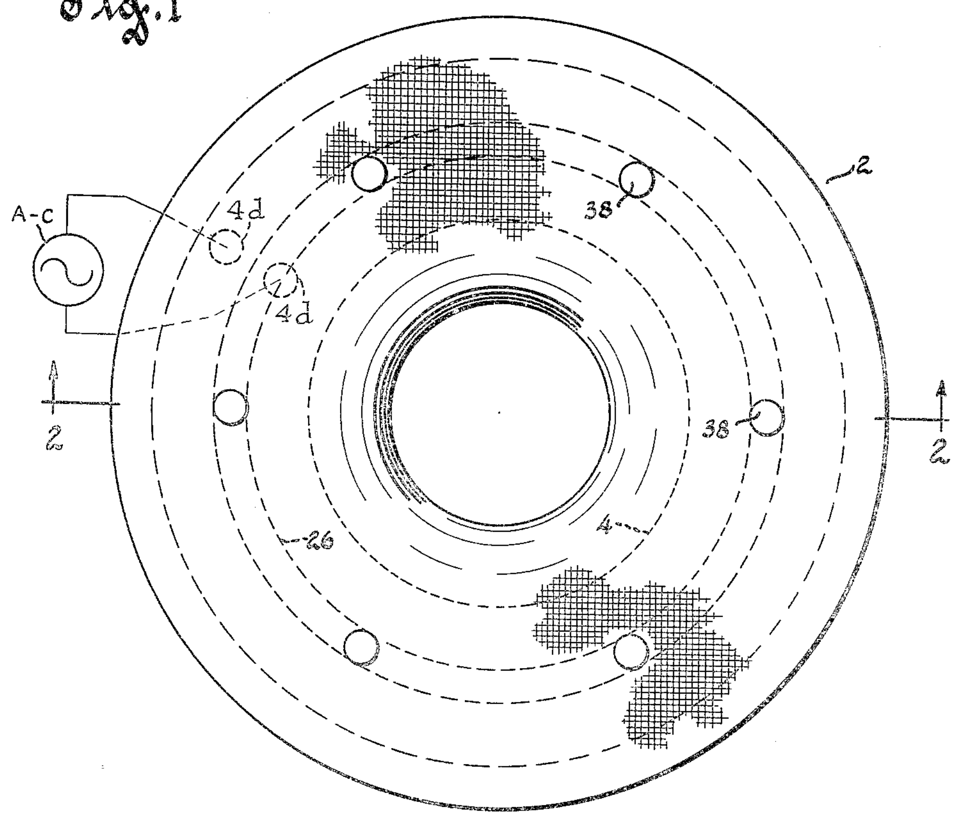

Fig. 2

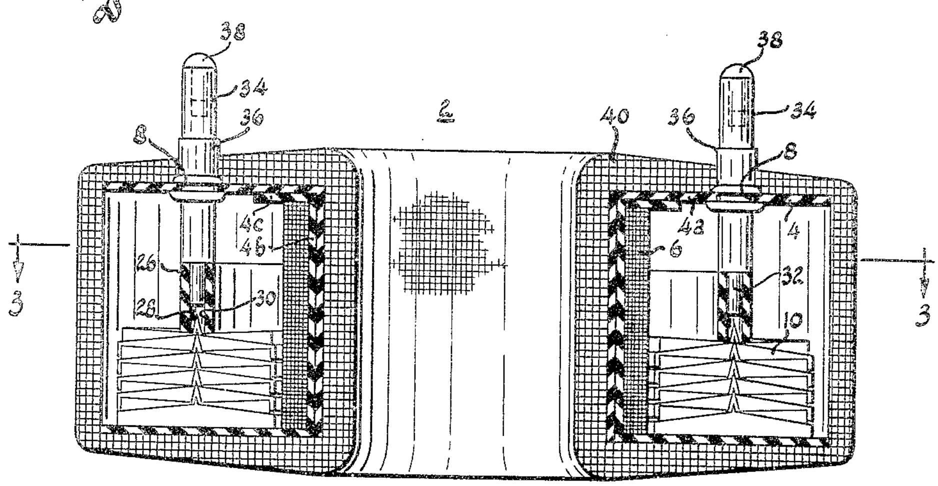

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Fig. 3

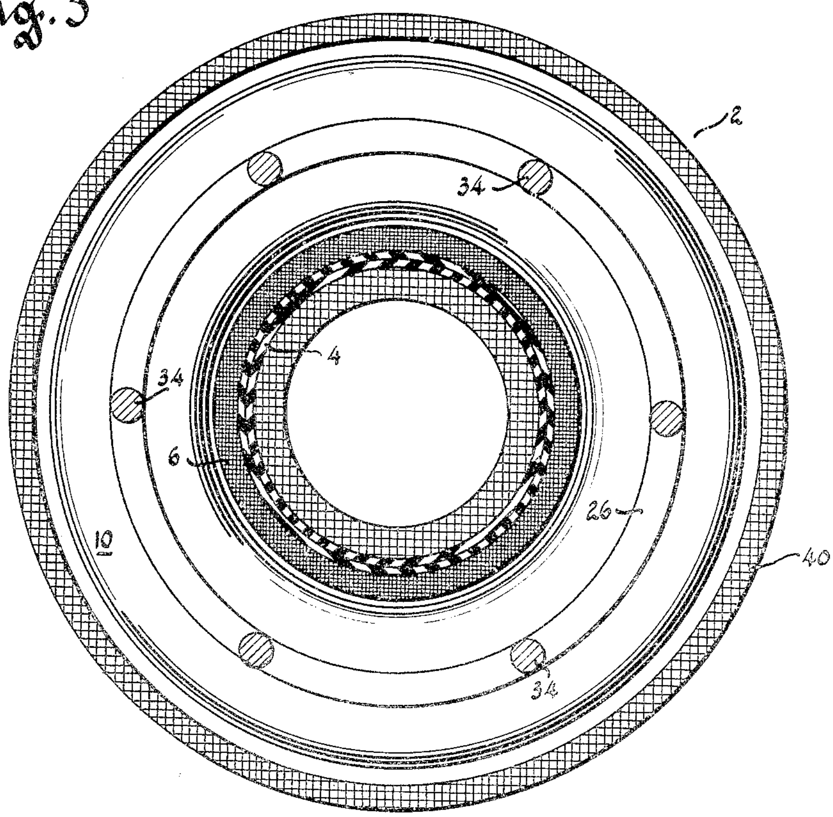
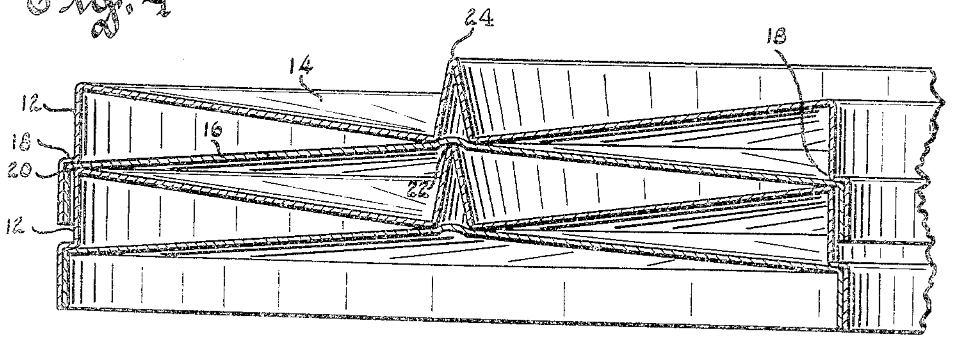


Fig. 4



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ELECTRO-THERMAL DEVICE OF THE THRUST ACTUATOR TYPE

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12 Claims. (Cl. 60—25)

This invention relates to control devices and more particularly to electro-thermal devices of the thrust actuator type.

While not limited thereto, the invention is especially applicable to control devices for the operation of electrical contacts and the like.

A general object of the invention is to provide an improved thrust actuator.

A more specific object of the invention is to provide an improved actuator of the electromagnetic-thermal type.

Another specific object of the invention is to provide such actuator having an improved work-to-weight ratio.

Another specific object of the invention is to provide such actuator having improved cantilever action affording a long operational life.

Other objects and advantages of the invention will hereinafter appear.

While the apparatus hereinafter described is effectively adapted to fulfill the objects stated, it is to be understood that I do not intend to confine my invention to the particular preferred embodiment of electro-thermal device disclosed, inasmuch as it is susceptible of various modifications without departing from the scope of the appended claims.

The invention will now be described with reference to the accompanying drawings, wherein:

Figure 1 is a top view of the device constructed in accordance with the invention;

Fig. 2 is a vertical cross sectional view taken along lines 2—2 of Fig. 1;

Fig. 3 is a horizontal cross sectional view taken along lines 3—3 of Fig. 2; and

Fig. 4 is a vertical cross sectional view of a detail of the device of Fig. 2.

Referring to Figs. 1 and 2, there is shown a thrust actuator **2** having the form of a toroid. The actuator is provided with a frame or bobbin **4** of non-magnetic material. Bobbin **4** may be formed of a pair of circular members **4***a* and **4***b* each having a generally L-shaped cross-section and telescoped within one another. The end of the hub portion of outer member **4***b* may be provided with an outwardly extending annular flange portion **4***c* to afford rigidity to the bobbin and to retain a primary winding **6** of a transformer which may be wound therearound before members **4***a* and **4***b* are assembled. Member **4***a* is provided with a plurality of angularly spaced apertures **8** for reasons hereinafter described. As shown schematically in Fig. 1, the primary winding **6** may be connected in any well known manner to an A.-C. electrical source by leads which pass through spaced circular openings **4***d* in circular member **4***b* of frame **4**.

The secondary winding of the transformer is comprised of an actuator member **10** surrounding primary winding **6**. Actuator member **10** comprises a plurality of generally annular shaped completely enclosed cells or capsules **12**, more clearly shown in Fig. 4, stacked upon one another. Each capsule **12** is formed of a pair of generally inverted U-shaped members **14** and **16** connected to one

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another to form an enclosed space therebetween. To this end, the upper member **14** of each capsule **12** is provided with a shoulder **18** intermediate its leg portions for abutting engagement with the peripheral portion **20** of the lower member **16**. Member **16** is telescoped within member **14** into the aforementioned abutting engagement and the free ends of the leg portions beyond the shoulder may be welded together to form a hermetically sealed cavity between the members.

Each lower member **16** is provided with a circular groove **22** centrally of its annular face for receiving a circular projection **24** formed centrally of the annular face of member **14** of each adjacent capsule when the capsules are stacked upon one another. When so stacked, the welded leg portions of each capsule surround the enclosed cavity portion of each adjacent capsule to maintain the same in registration with one another. The annular faces of members **14** and **16** are normally mechanically biased toward one another and are formed of thin metallic material so that when a predetermined amount of pressure is produced within the cavity, members **14** and **16** quickly "pop" to an extended position.

The device is also provided with a thrust ring **26** of insulating material or the like having a circular groove **28** at its lower portion for accommodating projection **24** of the uppermost capsule in the stack. Thrust ring **26** is also provided at its upper surface with a plurality of angularly spaced holes **30** for securing therein the reduced end portions **32** of a plurality of thrust rods **34** shown in Figs. 2 and 3. The aforementioned apertures **8** in bobbin **4***a* have secured thereto sleeves or tubular grommets **36** for slidably accommodating thrust rods **34**. Thrust rods **34** may be provided with suitable semi-circular portions **38** at the driving ends thereof extending outside the device for engagement with the driven device (not shown).

Bobbin **4** has wound therearound a toroidal winding **40** of silicon iron wire or the like to form a core for the transformer.

The operation of the device will now be described. When an electrical power supply source is connected to primary winding **6**, the transformer action produced by the presence of core winding **40** in the magnetic field induces a secondary current in capsules **12**. Members **14** and **16** of capsules **12** being constructed of relatively thin conductive material having suitable electrical resistance, the heat produced by the flow of secondary current effects operation of the capsules to their extended positions. As a result, thrust rods **34** are moved outwardly to effect operation of contacts or the like. Conversely, disconnection of the primary winding from the power supply source effects cooling of capsules **12** to effect return thereof to their normal positions under the force of the mechanical bias therein. The return of thrust rods **34** to their normal positions may be aided by contact return springs or the like (not shown).

The enclosed space within each capsule may be provided with a suitable gas such as atmospheric air or a condensable gas for maximum thrust. Thus, the application of heat expands the gas within each endless hollow flat tube to snap the same to its extended position. The relatively large surface area of the capsule affords rapid radiation of heat to return the actuator to its normal position when the primary winding is deenergized.

The wound core **40** adapts the device for alternating current operation especially for the higher frequencies such as 400 cycles and the like and affords an improved work-to-weight ratio for single cycle operation over traction type electromagnets, particularly at the higher frequencies.

A primary requisite for capsules **12** is low thermal capacity at a resistivity which will permit utilization of adequate wattage in the secondary winding of the small transformer. If it be assumed that many structural metals have adequate strength for the required pressure at the limited thinness which can be formed and welded, the figure of merit for the capsules becomes the product of density, specific heat and resistivity. Under these assumptions, titanium is superior, aluminum is next with copper, nickel, iron and steel following very close together thereafter. Silver plated stainless steel is also practicable but age hardened aluminum alloy such as that which is employed in the diaphragms of sound powered telephones is preferable. Members 14 and 16 of the capsule may be formed and age hardened at moderate temperatures before welding.

Due to the annular shape affording improved cantilever action of capsules 12, the area distortion is negligible throughout a long life span of the actuator. Any desired number of capsules 12 may be stacked on one another to provide the amount of thrust desired.

I claim:

1. A thermo-responsive device for operating a driven element comprising a generally annular-shaped endless hollow completely sealed flat tube having its opposing faces mechanically biased toward one another, said opposing faces being formed to converge from the inner and outer circular edges thereof toward one another at a point intermediate such edges to provide such mechanical bias, at least one actuator member extending from a face of said tube, heat responsive expansible gas in said tube, and means for selectively heating said tube to a predetermined temperature whereby expansion of said gas effects snap-action operation of said tube to an extended position separating said opposing faces at said intermediate point and corresponding movement of said actuator member.

2. The invention defined in claim 1, wherein said means for selectively heating said tube comprises an electrical power supply source, and a transformer having a primary winding connectable to said source, said annular-shaped tube forming the secondary winding for said transformer.

3. The invention defined in claim 2, wherein said transformer further comprises a core formed of magnetic wire wound around said primary winding and said tube.

4. In an actuator device operable to afford mechanical moving forces responsive to predetermined conditions, in combination, at least one actuator member, expansible chamber means having a cellular structure comprising a plurality of substantially annular-shaped cells stacked upon one another on a common axis to form a cylindrical structure having a bore along its axis, each cell having a pair of opposed walls formed of thin flexible metal hermetically sealing the space therein and both of the opposing walls of said cells being normally biased toward one another, and means for conductive heating of the walls of said expansible chamber means to actuate said member in a first direction as a function thereof, said member being actuated in another direction responsive to cooling of said expansible chamber means.

5. The invention defined in claim 4, wherein said heating means comprises a transformer, said expansible chamber means comprising the secondary winding of said transformer.

6. The invention defined in claim 5, wherein said transformer comprises a primary winding connectable to an alternating current power supply source, and a wire wound core of magnetic material coupling said primary winding to said expansible chamber means.

7. In an electro-thermal responsive device for operating a driven element, in combination, a plurality of generally annular-shaped endless hollow completely sealed flat tubes stacked upon one another to form a cellular structure, each of said tubes having its opposing faces normally biased toward one another at a point intermediate the inner and outer circular edges of such annular-shaped tube, a plurality of angularly spaced actuator members extending from the face of the uppermost tube, and electromagnetic means for selectively heating said cellular structure to effect operation of said actuator members.

8. The invention defined in claim 7, wherein said electromagnetic means comprises a transformer having a primary winding and a magnetic coil coupling said primary winding to said cellular structure, each of said tubes being formed of electrical conducting material having electrical resistance to effect heating thereof responsive to induced current flow.

9. In an actuator device operable to afford mechanical movement of a driven device responsive to electrical energy, in combination, expansible chamber means having a cellular structure comprising a plurality of substantially annular shaped cells stacked upon one another on a common axis to form a cylindrical structure having a bore along its axis, each said cell having a pair of opposed walls formed of thin flexible electrically conductive metal hermetically sealing the space therein and both of the opposing walls of said cells being normally biased toward one another, said cells having complementary engaging portions on abutting walls for registration with one another, an annular thrust ring secured to and overlying the uppermost cell, a plurality of symmetrically disposed actuator members extending from said thrust ring, and electrical induction means for selectively heating said cellular structure to operate said actuator members.

10. The invention defined in claim 9, together with a frame for supporting said actuator device, said frame having a plurality of apertures for slidably accommodating said actuator members.

11. The invention defined in claim 9, together with a frame comprising a non-magnetic spool, a primary winding wound on said spool, said cellular structure and said thrust ring surrounding said primary winding with said cellular structure constituting a secondary winding, a plurality of apertures in one side of said spool each having a tubular bearing sleeve secured therein for slidably accommodating one of said actuator members, and a toroidal magnetic winding wound on said spool affording a path for the magnetic flux to induce a current in said cellular structure when said primary winding is energized.

12. The invention defined in claim 11, together with expansible gas in each of said cells for operating the latter to their extended positions responsive to induction heating thereof.

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