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THERMO-MAGNETIC CONTROL COMPRISING A THERMO-INFLUENCED
MAGNETIC ELEMENT AND A PERMANENT MAGNET

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2 Sheets-Sheet 1

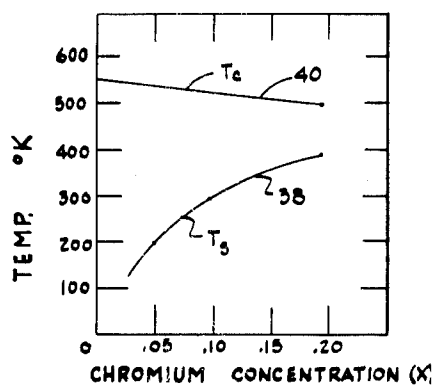
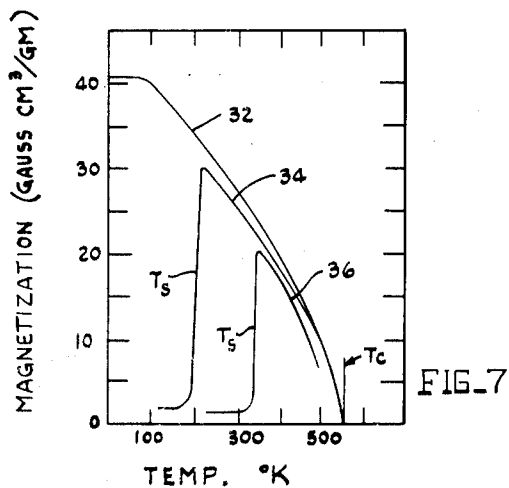
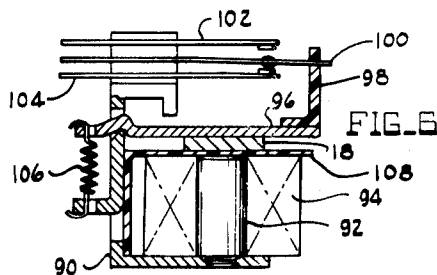
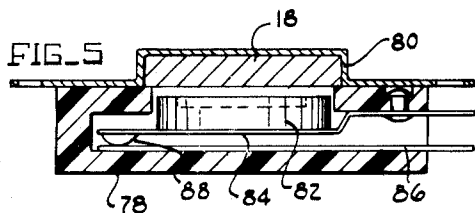
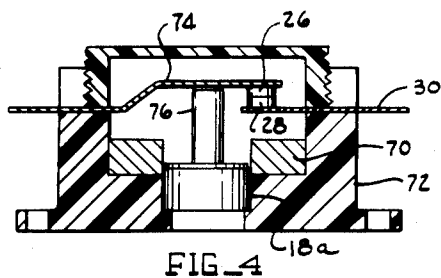
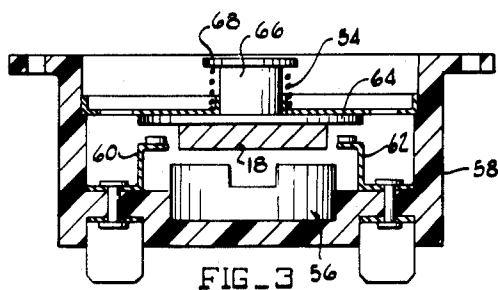
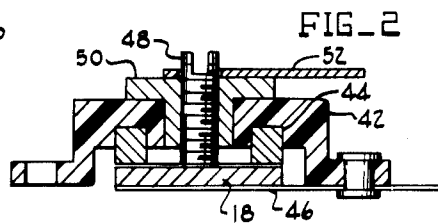
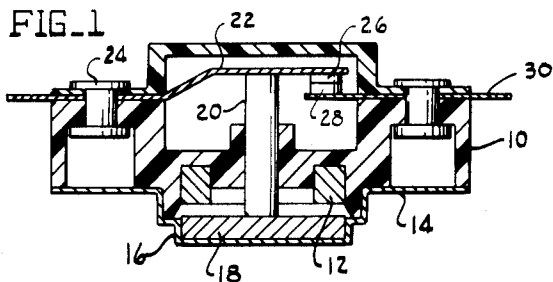


FIG. 8

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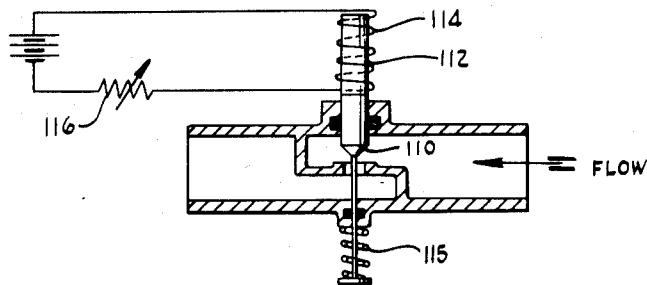
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FIG. 9



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THERMO-MAGNETIC CONTROL COMPRISING A THERMO-INFLUENCED MAGNETIC ELEMENT AND A PERMANENT MAGNET

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This invention relates to magnetically and thermally-operated control devices wherein temperature change is utilized to vary the magnetic permeability of a part of the control device operator. The invention is applicable to various types of control devices, including switches (such as motor overload switches, furnace limit control switches, fire alarms, engine temperature indicator light switches, and room thermostats) and fluid valves (such as relief valves, fuel gas valves, water valves, and air valves).

The invention takes advantage of a recently developed crystalline material comprised of manganese, chromium and antimony, said material having the usual property of being very weakly magnetically permeable in a low temperature range and becoming very highly magnetically permeable as the temperature increases by a few degrees above the low temperature range. The sharp change in magnetic properties makes the material particularly advantageous in an operator for various thermally-actuated control devices such as thermal switches and thermal fluid valves, particularly control devices which are required to have snap action in response to small temperature change.

One object of the present invention is to provide an improved control device utilizing the advantageous thermal magnetic characteristics of the aforementioned manganese-chromium-antimony compound.

A further object of the invention is to provide a thermally actuated control device wherein either a snap action control means or a slower acting force balance control means is operated by a relatively small temperature change.

A further object of the invention is to provide a snap action or slower action force balance control means wherein the actuating member consists of a relatively small mass of motive material, thereby enabling the control device to be manufactured as a relatively small size structure.

A general object of the invention is to provide a temperature-operated control device which can be readily manufactured to operate at precise temperatures and which will retain its manufactured operating characteristics after prolonged service.

Other objects of this invention will appear from the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

In the drawings:

FIGURE 1 is a sectional view taken through one embodiment of the invention;

FIG. 2 is a sectional view taken through a second embodiment of the invention;

FIG. 3 is a sectional view taken through a third embodiment of the invention;

FIG. 4 is a sectional view taken through still another embodiment of the invention;

FIG. 5 is a sectional view taken through a further embodiment of the invention;

FIG. 6 is a sectional view through another embodiment of the invention;

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FIG. 7 is a chart depicting the temperature-magnetization characteristics of a motive material which may be utilized in the FIG. 1 through FIG. 6 embodiments;

FIG. 8 is a chart depicting the effect of varying the chromium concentration in the material whose magnetic characteristics are shown in FIG. 7; and

FIG. 9 is a schematic view showing the invention as used in a fluid valve control device.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Referring to FIG. 1, there is shown a thermally-operated electrical switch comprising a dielectric base 10 in which is fixedly embedded an annular permanent magnet 12. Base 10 carries a non-magnetic cover member 14 which is suitably configured to form a cylinder-like guide portion 16 for the floatable disc-like element 18, said element being constructed of a material having the characteristic of being substantially non-magnetically permeable in a low temperature range and undergoing a rapid transition to a high magnetic permeability state as its temperature is increased very slightly above said low temperature range.

The upper face of disc element 18 engages a plunger 20 which slidably extends through base 10 into thrust-transmitting engagement with a spring leaf 22, said spring leaf being mounted on base 10 by means of a rivet 24. As can be seen from FIG. 1, the right end portion of spring leaf 22 carries an electrical contact 26 which registers with a contact 28 carried on the electrically conductive leaf 30. In the FIG. 1 low temperature position element 18 is restrained from movement by spring leaf 22, and an electrical circuit is completed across contacts 26 and 28. When the temperature is raised a predetermined amount element 18 becomes highly magnetically permeable, whereupon said element snaps upwardly toward permanent magnet 12 so that plunger 20 separates contact 26 from contact 28. Lowering of the temperature renders element 18 again weakly magnetically permeable and enables spring leaf 22 to move plunger 20 and element 18 back to their illustrated positions.

Element 18 is preferably formed as a disc of crystalline material having the formula $Mn_{2-x}Cr_xSb_{1-y}In_y$, where $0.025 \leq x \leq 0.20$ and $0 \leq y \leq 0.05$. The properties of this material are pointed out in an article entitled "Evidence for an Antiferromagnetic-Ferrimagnetic Transition in Cr-Modified Mn_2Sb " appearing at pages 509 through 511 in Physical Review Letters, volume 4, Number 10, issued May 15, 1960.

The above-mentioned article contains two charts which are reproduced in the accompanying drawings as FIGS. 7 and 8. Referring to FIG. 7, the temperature-magnetic permeability characteristics of three materials are depicted. The curve designated generally by numeral 32 is for the crystalline material Mn_2Sb . It will be seen that as the temperature increases the material slowly loses its magnetic permeability characteristics until the Curie temperature of about 550° is reached. The material is not particularly desirable for use in the FIG. 1 switch, but its operating curve is representative of the performance of the Curie point materials which have been used in the past for switch actuators.

The curve designated generally by numeral 34 in FIG. 7 is for a crystalline compound having the formula $Mn_{2-x}Cr_xSb_{1-y}In_y$ where $x=.05$ and $y=.05$. It will

be seen that at temperatures below about 200° K. this material is very weakly magnetic, i.e., substantially non-magnetic, but at about 200° K. the material undergoes a rapid transition from the weakly magnetic state to a relatively high magnetic state. A change in temperature of about 10° causes the material to undergo its transition from the weakly magnetic state to the highly magnetic state. In using the material in a control device such as a switch the material may be disposed in an ambient which varies less than the above-mentioned 10° transition temperature range. Thus the magnetic material does not necessarily undergo the entire transition between its highly magnetic and weakly magnetic states; instead a partial change in magnetic characteristics is in some cases sufficient to operate a control device such as the switch blade 22 shown in FIG. 1. In many situations a temperature change of one or two degrees provides sufficient magnetic change to operate the switch blade with snap action.

In FIG. 7, the curve generally designated by numeral 36 is for a compound $Mn_{2-x}Cr_xSb_{1-y}In_y$ where $x=.13$ and $y=.05$. It will be seen that this material has a transition temperature of approximately 330° K., so that it can be used on a control device operating in an ambient of about 330° K. By comparing curves 34 and 36 it will be seen that the transition temperature T_s is varied or controlled by changing the amount of chromium in the compound. FIG. 8 plots in curve 38 the effect of varying the chromium concentration in the compound $Mn_{2-x}Cr_xSb_{1-y}In_y$ where y is held at .05. The Curie temperature T_c for the materials of the figure is plotted by curve 40. It will be seen that by varying the chromium concentration the transition temperature can be effectively varied from about 100 degrees K. to almost 400 degrees K., whereas the Curie temperature for this general compound can be varied only from about 550 degrees K. to 500 degrees K. Thus, by using the transition temperature as the sensed condition for material 18, and by varying the chromium concentration it is possible to provide a large variety of actuation temperatures. If the Curie temperature were utilized as the sensed condition, variation in chromium concentration could not be relied on to provide such a large variety of actuation temperatures. Hence, the use of transition temperatures as the sensed condition is preferable to Curie temperatures, both because of the sharper magnetic changes and because of the versatility provided by the larger variety of actuation temperatures.

The materials of curves 34 and 36 both contain indium, but according to the aforementioned article in Physical Review Letters the indium is not an essential component in the compound. It appears that indium tends to retard the precipitation of Mn_2Sb , and that such a precipitate is responsible for the small residual magnetization possessed by the material in the low temperature range. This small residual magnetization characteristic is not an insurmountable handicap in the control device environment of the present invention, and it is contemplated that the chromium-manganese-antimony compound can be employed without the indium.

In the manufacture of thermally actuated magnet control devices improved calibration may be realized by regulating the air gap between the magnet and the thermally influenced magnetic element. One arrangement for providing a calibrated air gap is shown in FIG. 2. As there shown the construction includes a base 42 in which is embedded an annular permanent magnet 44. The thermally influenced magnetic element 18 is secured to an electrically conductive spring leaf 46 which has a normal position biased downwardly from that shown in FIG. 2. The upper face of element 18 abuts against the lower end of a set screw 48 which threads into an internally threaded metallic sleeve 50. A terminal strip 52 is suitably secured to the upper face of sleeve 50.

The FIG. 2 arrangement is such that in the illustrated

high temperature position electric current flows through leaf 36, element 18, screw 48, sleeve 50 and terminal 52; in the illustrated position element 18 is magnetically attracted toward magnet 44. Lowering of the ambient temperature causes element 18 to substantially lose its magnetic characteristics, which enables leaf 46 to move element 18 away from magnet 44, thus disconnecting the electrical circuit between the two electrical terminals provided by leaves 46 and 52.

By adjusting screw 48 it is possible to change the minimum air gap between elements 18 and 44 so as to provide an adjustable control of the temperature which is effective to snap element 18 between its two positions. Thus, downward adjustment of screw 48 increases the minimum air gap so that spring 46 is enable to snap element 18 away from magnet 44 at a slightly higher temperature than would otherwise be possible; the adjustment does not affect the temperature at which element 18 snaps toward magnet 44. Such an arrangement can be used to compensate for slight variations in manufacture of the components, particularly spring leaf 46, in which case a predetermined snap-away temperature may be achieved even in spite of substantial manufacturing tolerance variations.

Both the FIG. 1 and FIG. 2 embodiments utilize leaf springs as the mechanisms for returning magnetic element 18 away from the permanent magnet. It is contemplated however that other types of springs can be employed. For example, there is shown in FIG. 3 an arrangement wherein a coil-type compression spring 54 is utilized to draw magnetic disc element 18 away from permanent magnet 56. In this form of the invention magnet 56 is embedded in the base 58, said base being suitably configured to mount the conventional fixed contact members 60 and 62 which are arranged beneath the metallic disc 64 carried on the upper face of element 18. Disc 64 carries a plunger 66 having a head 68. In operation of the FIG. 3 embodiment, at low ambient temperatures spring 54 is effective to hold disc 18 away from magnet 56 so that the control circuit across terminals 60 and 62 is disconnected. In the aforementioned transition temperature range at T_s , element 18 snaps toward magnet 56 so that electrically conductive disc 64 completes the circuit across terminals 60 and 62.

FIG. 4 illustrates an arrangement wherein the thermally influenced magnetic element takes the form of a cylindrical plunger 18a. In this form of the invention the permanent magnet 70 is fixedly disposed within the dielectric base 72 so that element 18a is free to slide upwardly into the central space encompassed by the permanent magnet. At low ambient temperatures a spring leaf 74 acts against a stem 76 to force element 18a to its illustrated position. At the transition temperature of element 18a the element snaps axially upwardly so that the electrical contact 26 is disengaged from the electrical contact 28 which is carried on conductive leaf 30.

FIG. 5 illustrates an arrangement wherein the magnetic element 18 is fixedly disposed on a base 78, as by means of the pocket-forming strap or cover 80. Element 18 is arranged above the permanent magnet 82 which is carried within a large chamber on the contact-carrying spring leaf 84. A second fixed contact element is shown at 86. In operation of the FIG. 5 embodiment, at low ambient temperatures spring leaf 84 holds magnet 82 in its illustrated position. At the transition temperature for element 18 magnetic 82 is snapped upwardly toward element 18 to thus separate contact 88 from strip 86.

In some instances it may be desirable to employ an electromagnet instead of a permanent magnet. Thus in FIG. 6, there is shown an arrangement comprising a base 90 which suitably mounts the core 92 for the solenoid 94. Fulcrummed on a portion of base 90 is an arm 96 having the thermally influenced magnetic element 18 secured thereto. In the illustrated embodiment arm 96 is provided with an upwardly projecting extension 98 which

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suitably engages the end portion of a flexible contact carrying reed or leaf 100. Two contact-carrying leaves are shown at 102 and 104.

The FIG. 6 device takes its illustrated position when element 18 is above its transition temperature, providing solenoid 94 is energized. Under these circumstances core 92 acts as a magnet to hold element 18 thereagainst in opposition to the bias of tension spring 106. In the event that solenoid 94 is de-energized and/or element 18 has its temperature lowered below its transition temperature, spring 106 will snap arm 96 upwardly to thereby effect movement of control element 100. A heat shield 108, preferably formed of material having low thermal conductivity may in certain circumstances be provided between coil 94 and element 18, this to prevent the electric heat develop in the coil windings from adversely affecting the performance of element 18.

It will be seen that by using the FIG. 6 construction it is possible to control the position of control element 100 remotely by the suitable energization of solenoid 94. Thus the thermal sensing provided by element 18 may be conveniently turned on and off from a remote point by the use of an electromagnet as shown in FIG. 6. It is contemplated that the term "magnet" as used in the claims will comprehend both permanent magnets and electromagnets, except of course where the term is pre-faced by the word "permanent" or "electro."

The device shown in FIGS. 1 through 6 are all electric switches, but it is contemplated that principles of the invention can also be incorporated in other control devices such as fluid valves. Thus, for example, the FIG. 1 plunger could if desired be connected to a fluid valve element instead of the illustrated switch element 22. Similarly plunger 66 in FIG. 3, stem 76 in FIG. 4, spring leaf 84 in FIG. 5, and arm 96 in FIG. 6 could each be operatively associated with fluid valve elements.

FIG. 9 illustrates a fluid valve having a valve element 110 connected with an armature 112 for a solenoid operator 114. Armature 112 may be formed of the same material as element 18, in which case the flow of current through solenoid 114 will actuate valve element 110 against the action of spring 115 only if the ambient is within the transition temperature range of the armature material.

In some cases it may be desirable to provide an adjustment of the exact actuation temperature within the transition temperature range. For this purpose there may be provided a variable resistor 116 arranged to vary the current supplied to coil 114. By reducing the current supplied to coil 114 we may raise the actuation temperature for element 110. By increasing the current supplied to coil 114 we can reduce the actuation temperature for element 110.

We have shown and described particular embodiments of the invention, but it will be understood that the in-

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vention may be practiced in other forms, all coming within the scope of the appended claims.

We claim:

1. In a temperature responsive switch, the improvement comprising a dielectric base; a contact fixedly disposed on said base; an elongated contact leaf swingably mounted on said base for movement toward and away from the fixed contact to control the flow of current thereacross; a rigid heat-conduction cover structure mounted on said dielectric base; said cover structure being configured to define a cup-shaped pocket facing the base; an immovable thermally influenced magnetic disc engaged with the cover structure and snugly fitting within the pocket to respond to external temperature change; and a permanent magnet carried by the contact leaf in operative registry with the magnetic disc so that temperature change in said disc effects swinging movement of the contact leaf.

2. In a temperature-responsive switch, the improvement comprising a dielectric base; a contact fixedly disposed on said base; an elongated contact leaf swingably mounted on said base for movement toward and away from the fixed contact to control the flow of current thereacross; a rigid heat-conducting cover structure mounted on said dielectric base; said cover structure being configured to define a cup-shaped pocket facing the base; an immovable thermally influenced magnetic disc engaged with the cover structure and snugly fitting within the pocket to respond to external temperature change; and a permanent magnet carried by the contact leaf in operative registry with the magnetic disc so that temperature change in said disc effects swinging movement of the contact leaf; said magnetic disc comprising the material $Mn_{2-x}Cr_xSb_{1-y}$ where $0.025=x=0.20$ and $0=y=0.025$.

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BERNARD A. GILHEANY, *Primary Examiner*