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THERMALLY RESPONSIVE PERMANENT MAGNET OPERATED SWITCH

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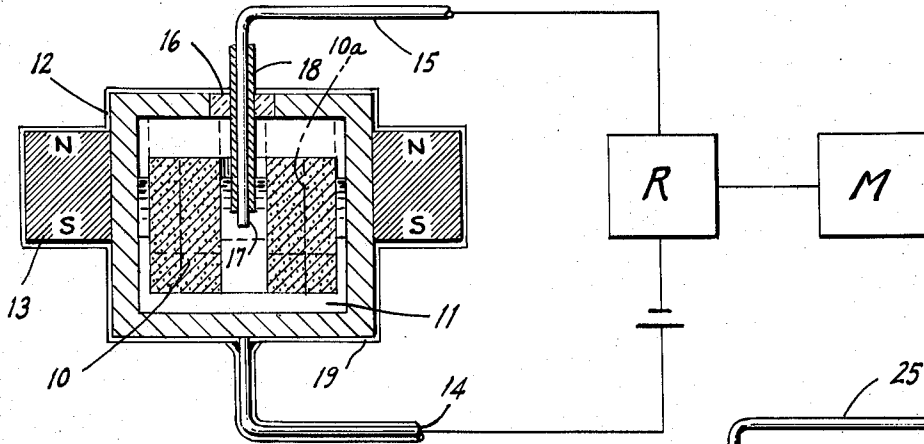


FIG. 1.

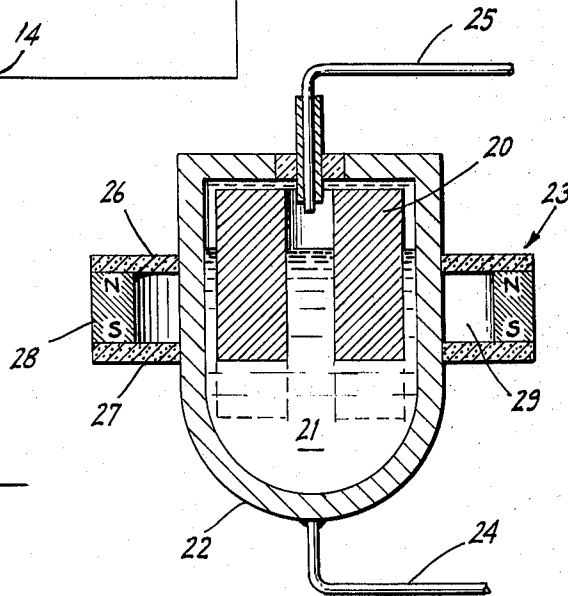


FIG. 2.

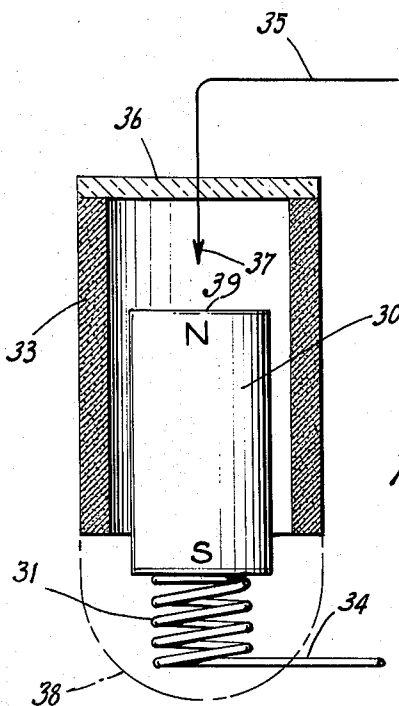


FIG. 3.

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THERMALLY RESPONSIVE PERMANENT MAGNET
OPERATED SWITCHElmer W. Zearfoss, Jr., Philadelphia, Pa., assignor to
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8 Claims. (Cl. 200-88)

This invention relates to thermally actuated electric switches. The invention has broad applicability in temperature responsive systems including for instance the temperature controlling systems or thermostats of freezers, refrigerators, room heaters, ranges and other systems, both domestic and industrial, where changing temperatures are encountered or provided.

For convenience in the production and servicing of such systems it has long been desired that a fundamental heat responsive switch design be made available which can satisfy different requirements arising from different operating conditions. It is often, but not invariably, necessary that the switch contacts be enclosed hermetically to protect their surfaces from oxidation and dirt; the fundamental switch design should therefore be such as to allow hermetic enclosure. The contacting motion must sometimes be gradual and sensitive and at other times rapid and snap acting and the fundamental switch design should contemplate producing switches responsive to either type of motion. Compactness of the entire thermostat or switch or thermoelectric transducer is needed in many applications and the construction should be compatible with this requirement as well as those mentioned above, aside from still others which are known to the art.

It is an important object and feature of the invention to provide a transducer with such basic actuating elements as to combine these several characteristics and capabilities.

Heretofore there has been no such apparatus. The well known bimetallic devices were far from being compact as they required built-up spring elements of appreciable size. They could be enclosed hermetically and could be constructed for either slow or snap acting operation, but only with the use of actuators which made the hermetic encapsulation cumbersome and expensive. Another type of thermostat is known wherein the heat responsive contact actuating element is a liquid body, for instance a body of water in contact with a body of mercury; at the freezing point of water the first mentioned body freezes and expands, displacing mercury and thereby making or breaking electrical contact. Thermostats of this latter type are illustrated for instance in applicant's Patent 3,028,464; they differ from the bimetal devices in that they can be made much more compact, but they are not always as prompt in action as may be necessary or desired, since a considerable and frequently unpredictable period of time is required to convert even a small body of water into ice and vice versa. Still other switch constructions are subject to still other related difficulties, as is well understood by persons skilled in this art.

The invention provides a new and improved arrangement of elements for controlling an electric circuit in response to temperature changes. Fundamentally, the new arrangement uses a permanent magnet body and a body of thermally controlled magnetic character (hereinafter called a thermally magnetizable-demagnetizable body), as closely coupled magnet elements of a magnetic circuit and actuator elements of an electric circuit. Primarily, the latter body as considered herein is thermally controlled as to its magnetic permeability.

A coaxial arrangement of these elements allows especially effective use of the magnetic force which becomes available when the magnetic circuit is closed by thermal influence, as hereinafter described. Miniaturization of a

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circuit unit is thus facilitated. There is no need for the usual elongate bimetal leaf springs or the like; coaxial magnet bodies of required strength for contact actuation need hardly be larger than the electric contact members themselves. Nor is it necessary to rely on the use of a contact-actuating body of water or the like and to allow a more or less extended time interval for thermal response, or to limit the orientation of the device to suit the requirements of such a liquid body. Yet it is possible to combine the new switch design with the use of electrodes consisting for instance of mercury or other conductive liquids, in order to gain the various advantages thereof.

Typical embodiments of the new construction will be described in detail. Two of these are shown in FIGURES 1 and 2 of the drawing appended hereto; FIGURE 3 shows another type of switch, embodying a broad aspect of the invention; in each figure the switch is shown, somewhat schematically, in enlarged vertical sectional view.

In the embodiment of FIGURE 1, a ring 10 of thermally controlled magnetic character floats on mercury 11 in a stationary housing 12, this housing being made of non-magnetizable, thermally and electrically conductive metal directly contacting the mercury. It is closely surrounded by and rigid with a permanently magnetized ring 13. Mercury 11 in the lower portion of the housing provides an electric contact element, connected by the housing to a wire 14. Another wire 15 extends through an insulator 16 into the top of the housing and further into an upper interior region of the float ring, desirably filled with hydrogen or the like. The free end 17 of this second wire is of bare metal to provide a second contact element, while the remainder of said wire preferably has an electrically insulating coating or sleeve 18. The two wires can be used if desired to support the entire thermostat structure, which can be made very small and light, it being feasible to limit the diameter of housing 12 to a fraction of an inch. Both housing and magnet can be protected by a thin coating 19 of electrically insulative but thermally conductive material, e.g., lacquer. The outer ring 13 is a permanent magnet (a magnetized ferro-magnetic body) with a pair of annular pole areas N, S, one positioned above the other. The inner ring or float 10 is surrounded by magnet 13 with only slight annular spacing therebetween, as required by housing 12, and this inner ring has thermally controlled magnetic character; for instance it can be made of a material which becomes magnetic (ferrimagnetic) above a predetermined temperature. The combined magnetic field of the inner and outer rings then axially displaces the inner, movable ring from its previous floating position, thereby providing energy for positive and powerful switch actuation.

It may for instance be assumed that initially, a certain low temperature of ambient atmosphere prevails in a refrigerator (not shown), so that the float is non-magnetic and not attracted by the permanent magnet but free to sink relatively deeply into mercury 11, some of which is thereby displaced into the hollow portion of float body 10 to immerse wire end 17 and thus to close an electric circuit from 14 to 15. This circuit as shown energizes a relay unit R which in turn de-energizes refrigerator motor unit M. This may be the normal and desired condition of the illustrated system.

If and when a certain higher temperature, characteristic of the material of float 10, is reached in atmosphere surrounding the switch unit, and when such temperature has been transmitted to the float—which happens very rapidly by virtue of heat conductive structure 11, 12, 19—this new temperature promptly establishes the magnetic condition of the float. Thereupon the concentrated magnetic force now provided and applied by the two coaxial magnets, lifts the central magnet by a

small but significant distance from its former floating position on mercury 11, as is shown in broken lines in the upper part of housing 12. Thus the mercury level is lowered and the electric circuit is broken. This de-energizes relay unit R, energizes refrigerator motor unit M and thereby initiates gradual reestablishment of the desired low temperature.

It is generally preferred for purposes of this invention to use a permanent magnet 13 of reasonably powerful ferromagnetic material, such as one of the aluminum-nickel-cobalt-iron alloys or barium carbonate-ferric oxide material known to this art. Due consideration can and should however be given to other requirements, such as: mechanical strength of the magnet, particularly if it is desired to hold it on the switch casing by a press fit; ability of the magnet to resist the various temperatures to be expected in operation; suitable cost of the magnet, etc.

It is further preferred in most instances to make the heat-responsive magnetic float 10 from a material exhibiting a reasonably large thermo-magnetic effect and doing so in response to a fairly well defined thermal change. For example this float can be made from a chromium-manganese antimonide or similar compound, having a flux density of several thousand gauss at and above its so-called transition temperature and less than one hundred gauss therebelow. This transition temperature of float 10 is established, by suitable compounding of the material as to the admixture of chromium, at any predetermined "point" between -200°C. and $+150^{\circ}\text{C.}$, to suit the thermoelectric transducer action which is desired. The transition, provided by a suitable antimonide or the like, can be made very sharp; typically it can be caused to occur at a temperature predetermined with a tolerance or error of not more than about 1 to 3°C.

Antimonide body 10, as well as a great variety of suitable materials for permanent magnet 13, are resistant to temperatures within the indicated range of -200°C. to $+150^{\circ}\text{C.}$ Down to about -38°C. , such temperatures are also permitted with reference to the liquid mercury pool 11 and, up to about $+100^{\circ}\text{C.}$, with reference to typical phenolic lacquers 19. It will thus be seen that the new device is particularly suitable for exposure to and control of such temperatures as are typically encountered in the air circulating in domestic refrigerators and freezers. Such temperatures are near $+10^{\circ}\text{F.}$ or -15°C. as generally maintained in freezers; near $+40^{\circ}\text{F.}$ for refrigeration of food; and somewhat higher, such as $+45^{\circ}\text{F.}$, during the defrosting of a refrigerator cold plate. It is immaterial for the performance of magnet 13 and enclosure 12 of float 10 whether the atmosphere surrounding it is dry or moist.

It may be noted that mercury pool 11, whereon body 10 floats, has a certain thermal response of its own, as the bulk of a mercury body is temperature-dependent. This latter response is subtracted from that of magnetic circuit 10, 13, in the arrangement as illustrated in FIGURE 1. For this and other reasons it may be preferred to make the total volume of mercury relatively small and to make the interior of hollow float 10 relatively large, as shown.

The positions of permanently magnetized and thermally magnetized elements 10, 13, relative to the inside and outside of housing 12, can be reversed, without great effect upon the switch action, as will be described in connection with FIGURE 2 hereof.

Other modifications are also possible. For instance the structure illustrated in FIGURE 1 can be installed in vertically reversed orientation, that is, so that wire 14 and pole area S are above wire 15 and pole area N. In this case mercury 11 of course collects around the inwardly projecting wire and insulation 18; float 10 then generally rides on this mercury so as to leave terminal 17 uncovered, in other words the switch is then normally open; but when float 10 becomes magnetic the permanent magnet 13 then forces this float into the mer-

cury, thereby causing the mercury to contact wire terminal 17 and thus closing the switch. In this modified arrangement, as well as in FIGURE 2, the thermal expansion of the mercury assists the thermo-magnetic action of the switch actuating unit.

The unit of FIGURE 1 can, if desired, be caused to operate faster than the bimetallic, or ice and water actuated devices, initially mentioned. The speed of operation can be varied for instance by making float 10 more or less massive, thus requiring greater or lesser heat exchange before the float reaches and loses its transition temperature. A thin-walled float 10-A, shown in broken lines, is more sensitive and more rapid in action than the more massive float 10 shown in full lines. In any event, the entire unit can be made much smaller than the usual bimetallic device. It provides a real micro-thermostat.

Referring next to the embodiment of FIGURE 2: in this case mercury 21 in housing 22 again supports a float 20 of annular form. The arrangement of wires 24-25 is similar to that shown above at 14-15, but a different magnetic circuit 23 is shown, wherein float 20 is made of the material sometimes called magnetically soft iron, which has high magnetic permeability and low remanence, and a pair of flat, thermally magnetizable-demagnetizable rings 26, 27 surround and contact the float housing 22, while a permanent magnet ring 28 is clamped between these flat rings, an open area 29 being provided between the magnet ring and housing 22 to minimize permanent flux linkage between elements 20, 28. In many cases an advantage resides in so installing the magnetically active unit 26, 27, 28 and mainly the thermo-magnetic rings 26, 27 on the outside of closed housing 22; the arrangement facilitates replacement of these rings with differently calibrated material, as is often desired in actual practice.

In this embodiment the normal floating position of core 20 is shown as being disposed above the center of the force field of annular magnet 28, and the metallic end of wire 25 is shown as being normally disposed above the surface level of mercury pool 21. The wire is immersed when the temperature of rings 26, 27 rises sufficiently to make these rings magnetic, thus closing the magnetic circuit 28, 26/27, 20 and effectively applying the force of the permanent magnet to the soft iron core: the core is thus forced more deeply into the liquid mercury, upwardly displacing portions thereof and thereby closing the electric circuit 24, 21, 25.

This further arrangement can be modified additionally, for instance by inwardly-outwardly reversing the positions of elements 20 and 28.

The device of FIGURE 2 adds an extra element, 20, to the magnetic circuit; however, it has several advantages over the unit of FIGURE 1. It can be made still faster, not only because the heat sensitive elements 26, 27 can be directly exposed to the ambient conditions, and can be given flat and extended form, as shown, for maximum heat transfer, while encapsulated housing 22 can be kept small, but also for the further reason that the speed is no longer dependent on the mass of the float. In addition, this arrangement uses only simple components, such as pure mercury and an iron float, in the encapsulated mercury chamber, making it possible thereby to achieve maximum safety against any deleterious chemical or physical action of the float on the mercury, and vice versa.

Still another arrangement is shown in FIGURE 3. In this case a permanently magnetized, electrically conductive, solid or hollow cylinder 30, with magnet poles N, S near its ends, is resiliently mounted on a coil spring 31 and is concentrically surrounded by a thermally magnetizable-demagnetizable ring 33. Spring 31 can be integral with electric terminal 34, mainly when the electrical system uses frequencies and other characteristics such as not to be deleteriously affected by the inductance of such a coil spring. The opposite terminal 35 has an end portion 37 extending coaxially into ring 33 through an elec-

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trically insulative top plate 36 of said ring, opposite a contact portion 39 of magnet 30.

The device of FIGURE 3 can have all elements thereof directly exposed to the ambient temperatures, although it can also be encapsulated, as schematically indicated at 38, if such be preferred. No liquid electrode is needed in this embodiment and the device can thus be disposed in any desired orientation, if spring 31 is made strong enough to support magnet 30 in reasonably predictable positions, subject to displacement by magnetic force when ring 33 becomes magnetic.

The transducer of FIGURE 3 can therefore be mounted in upright position as shown, or can be reversed without reversal of its switching pattern. It can also be mounted in other desired positions, for instance horizontally or obliquely. Within the limits of stiffness of spring 31, which can generally be selected very freely, the unit can also be exposed to vibrations which would not be tolerated by a mercury switch or the like.

On the other hand mercury switch arrangements, such for instance as those of FIGURES 1 or 2, have important advantages including, for instance, the feature that snap-acting operation can be provided with a minimum of linkage and complication, by the use of suitable metal for "contact wetting" of the "make-break electrode" (element 17 in FIGURE 1). While enclosure means are needed for using mercury as a switch actuator the extra cost thereof can often be justified, particularly since hermetic enclosure protects the switch contacts from oxidation and dirt. This latter consideration applies particularly when the device is used as a thermostat for the control of a household refrigerator or freezer. For this reason the switches of FIGURES 1 and 2 are particularly useful for the control of such a device. Various refrigerator or freezer control circuits, other than R, can be connected with switch terminals 14, 15 or 24, 25 as is well known to the art. It is believed to be unnecessary for present purposes to illustrate other details of such circuits.

While only three embodiments of the invention have been described the details thereof are not to be construed as limitative of the invention. The invention contemplates such variations and modifications as come within the scope of the appended claims.

I claim:

1. In a thermostat for controlling a refrigerator or freezer unit by an electric circuit:

a thermo-magnetic circuit breaker for the control of said electric circuit, comprising at least two hollow elements, one surrounding the other, one of said elements being permanently magnetic and having axially spaced magnetic poles, and another of said elements being thermally magnetizable-demagnetizable;

a housing surrounded by and rigid with an outer one of said elements, said housing being partly filled with mercury and an inner one of said elements floating on said mercury in said housing; a pair of electric contact members forming part of said electric circuit, being enclosed in said housing and surrounded by the inner one of said magnetic circuit elements, and one of said contact members being movable to and from the other in response to thermal magnetization and demagnetization of said one magnetic circuit element to control said electric circuit.

2. In a thermostat as described in claim 1, the feature

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that said housing is filled with a neutral gas, such as hydrogen, above said mercury.

3. In a thermostat as described in claim 1 the feature that said element floating on said mercury in said housing and forming part of said magnetic circuit breaker is an iron core of high magnetic permeability and low remanence and that said thermally magnetizable-demagnetizable element is a ring structure surrounding said housing.

4. A thermostatic switch for the control of a region such as a refrigerator chamber, said switch comprising: a first ring structure, permanently magnetized with axially spaced magnetic poles; a second ring structure, magnetizable and demagnetizable in response to changing temperatures in said region, the second ring structure being coaxial with the first; a third structure providing a central iron core, movable axially of said first and second ring structures; and an electric circuit control member movable on movement of said core to open and close the switch.

5. A thermostatic switch comprising: a first and permanently magnetized ring, having axially spaced magnetic poles; a second and thermally magnetizable and demagnetizable ring, coaxial therewith; a container closely surrounded by said rings and partly filled with liquid; an iron core floating on the liquid and disposed for axial movements relative thereto in response to thermal magnetization and de-magnetization of the second ring; and electric contact means disposed in said container and controlled by the movements of said iron core to open and close the switch.

6. A thermostatic switch comprising

an annular permanent magnet with axially spaced poles; a housing surrounded by a non-magnetic, heat-transmissive annular wall rigid with the inside of said magnet;

a solid electrode and a liquid electrode both disposed in said housing, both electrically connected to the exterior thereof, and being adapted to be axially spaced from or contacted with one another in said housing; and

a thermally magnetizable-demagnetizable float on said liquid electrode in said housing, for magnetic displacement of said float by said magnet, pursuant to heating or cooling of the float, and for consequent displacement of the liquid electrode by the float to make or break contact with the solid electrode.

7. A switch as described in claim 6, wherein the total volume of said liquid is relatively small and said magnetic displacement is relatively large to minimize effects of thermal expansion of said liquid.

8. A switch as described in claim 6 wherein said electrodes are so related to said housing, magnet and float that the making and breaking of contact between said electrode can be reversed by reversing the housing.

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