

- [54] **TEMPERATURE-OPERATED SWITCH**
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[51] Int. Cl. **H01h 37/58**
[58] Field of Search..... **335/146, 208, 205**

[56] References Cited			
UNITED STATES PATENTS			
3,008,019	11/1961	Scheidig.....	335/208
3,465,271	9/1969	Koepke.....	335/205
3,161,742	12/1964	Bagno.....	335/208

3,295,081 12/1966 Bowyer et al..... 335/208

FOREIGN PATENTS OR APPLICATIONS

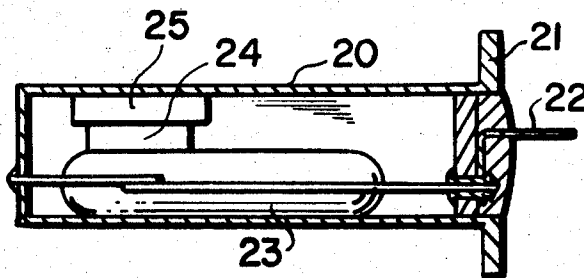
1,549,349 11/1968 France..... 335/146

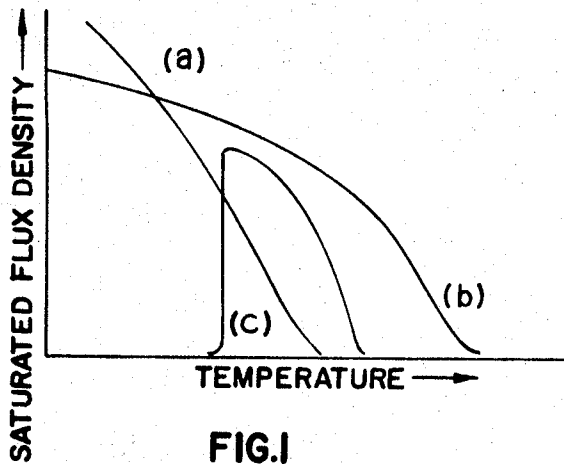
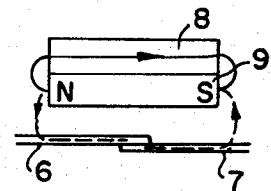
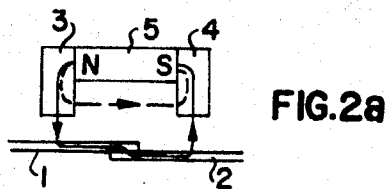
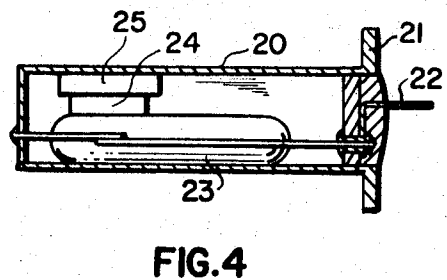
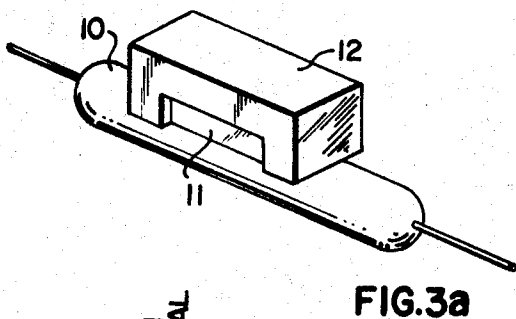
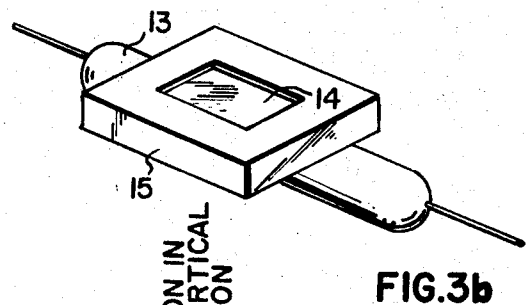
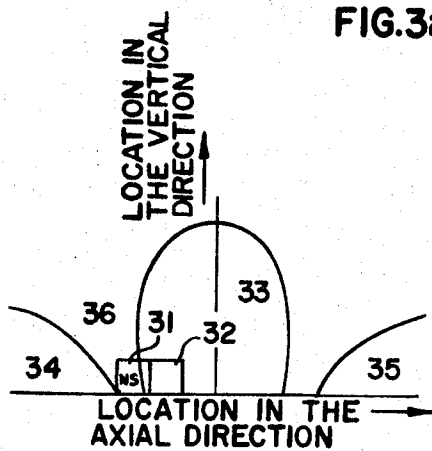
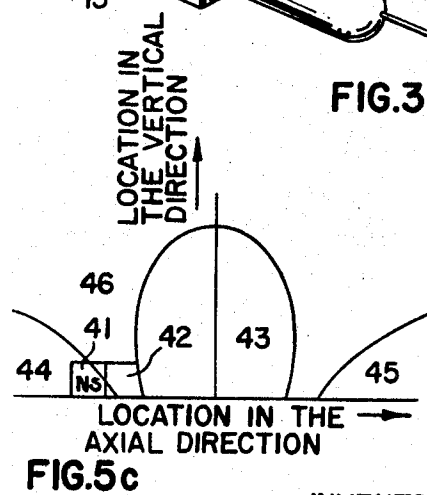
Primary Examiner—Roy N. Envall, Jr.
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[57] **ABSTRACT**

A thermostat comprises a reed switch having a pair of normally open contacts, a barium-ferrite permanent magnet disposed parallel to the reed switch, and a manganese-zinc group ferrite member positioned proximate the permanent magnet to form a series circuit for the magnetic flux of the permanent magnet. The ferrite member exhibits a saturation magnetic flux density characteristic varying in response to temperature changes whereby the reed switch contacts are closed.

6 Claims, 15 Drawing Figures





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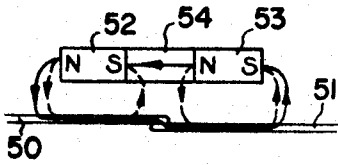


FIG. 6a

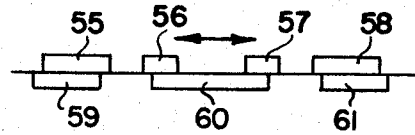


FIG. 6b

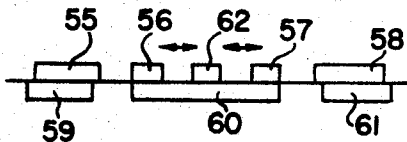


FIG. 6c

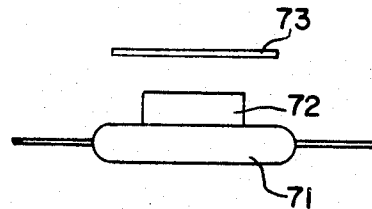


FIG. 7a

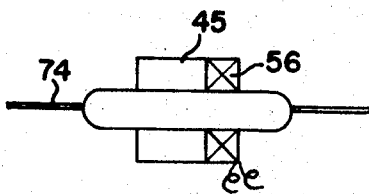


FIG. 7b

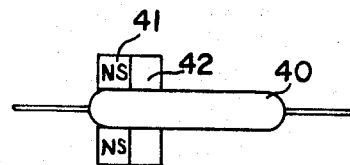


FIG. 5d

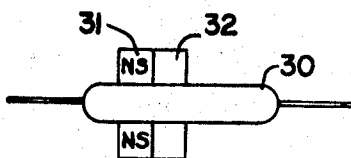


FIG. 5b

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TEMPERATURE-OPERATED SWITCH

Broadly speaking, this invention relates to a temperature-operated switch. More particularly, in a preferred embodiment, this invention relates to a temperature-operated switch which utilizes the saturation flux density (saturation induction) versus the temperature characteristic of a magnetic substance to control the switching temperature; and which is constructed by positioning a permanent magnet and a magnetic substance proximate a reed switch whereby the contacts of the reed switch are opened and closed in response to changes in the temperature.

Temperature-operated switches using magnetic materials are known. Such switches are of the type in which the saturation flux density versus temperature characteristics of a magnetic substance are utilized to control the flux of a permanent magnet to cause opening and closing of the switch contacts in response to the strength or distribution of the magnetic flux. Other types of temperature operated switches which utilize phenomena, such as expansion, contraction, variations in electric resistance, or thermoelectric potentials developed by substances located at the detecting portion of the switch, are also known.

Hitherto, it had been thought necessary to use ferrites for such temperature-operated switches. However, temperature-operated switches using ferrites have not been successful because a ferrite is a kind of ceramic, and thus differs largely in thermal expansion coefficient from the other structural components of the switch; it is poor in its resistance to heat-shock; it has a large thermal capacity; and it is poor in thermal conductivity. Further, such switches suffer from the disadvantage that it is impossible to make the temperature, at which they switch, variable.

The present invention has overcome the foregoing disadvantages of the prior art by the provision of a temperature-operated switch which is constructed so that its contacts are opened and closed by the use of a small amount of ferrite material which has a preferential heat-response characteristic and a high resistance to heat-shock, and which permits adjustment of the switching temperature.

In the drawing,

FIG. 1 is a graph showing the saturation flux density versus temperature of various magnetic substances;

FIGS. 2a and 2b are cross-sectional views of two prior art magnetic switches useful in understanding the operation of the instant invention;

FIGS. 3a and 3b are isometric views of two embodiments of the invention having improved performance over the prior art structure disclosed in FIGS. 2a and 2b;

FIG. 4 is a cross-sectional view of another embodiment of the invention wherein the magnetic elements and the reed switch is offset from the center of the device;

FIGS. 5a and 5b are a magnetic flux graph and a cross-sectional view, respectively, of yet another embodiment of the invention using annular magnetic members;

FIGS. 5c and 5d are a magnetic flux graph and cross-sectional view respectively of another embodiment of the invention, differing slightly from that shown in FIGS. 5a and 5b;

FIGS. 6a and 6b, 6c are a cross-sectional view and dimensional relationship graphs, respectively, of another embodiment of the invention; and

FIGS. 7a and 7b are cross-sectional views of still further embodiments of the invention.

The present invention will be explained in detail with reference to the drawing. FIG. 1 shows several saturation magnetic flux density (saturation induction) versus temperature characteristics in which curve *a* illustrates the characteristic of nickel-group alloys, such as an alloy consisting of Ni (32 percent) and Fe (balance), which are generally referred to as magnetic shunt alloys and have long been used to compensate for the thermal characteristic of permanent magnets. Curve *b* illustrates the characteristic of ferrites, where the saturation magnetic flux density falls as the temperature rises, and disappears when the temperature reaches the Curie point temperature T_c . The Curie point temperature of a ferrite can be regulated freely by varying its composition. For instance, a substance whose Curie point temperature ranges from -100°C to $+300^\circ\text{C}$ can easily be produced from a Mn-Zn-group ferrite. The characteristic illustrated by curve *c* shows the property of a material, such as a Fe-Rh-group powdered alloy or an Mn-Cr-Sb-In-group powdered alloy, where the saturation magnetic flux density rises sharply at a certain temperature, due to phase transformation. To compare the aforementioned materials, it should be observed that a magnetic shunt alloy is a metal and is, therefore, superior in heat-conductivity and workability to ferrites, but it is virtually impossible to determine the Curie point temperature by controlling the combination ratio of the elements in such a material, thus resulting in high cost. On the other hand, a ferrite is a metal oxide and a kind of ceramic and, thus, poses problems relating to resistance to heat-shock and the like. But control over the composition of the ferrites can be achieved relatively easily, to provide a material having a large variation in the Curie point temperature. Ferrite also has the further advantage of being massproducible, resulting in low costs. Of course, use of materials having the property of phase transformation would be most preferable of all, in view of their sharp temperature characteristic but, because this type of material is a powdered metal substance, fragile and expensive, applications of this material are limited. Accordingly, from an industrial point of view, the use of ferrites is the most practicable solution.

FIGS. 2a and 2b are diagrammatic views which explain the operation of a temperature-operated switch of the type in which a permanent magnet and a magnetic substance (hereinafter referred to as a temperature-responsive magnetic substance) are operatively combined, the saturation magnetic flux density of the magnetic substance varying in response to temperature variations.

This temperature-operated switch is similar in construction to the well known magnetically operated switches (hereinafter referred to as reed switches) comprising a pair of elastic reeds made of magnetic material and contacts thereon, which are normally open, and which are closed when a magnetic flux passes through both reeds. However, unlike the prior art switches, the instant switch can be controlled in its opening and closing operation by the ambient temperature. The solid line depicted in the drawing illustrates the flow of magnetic flux when the temperature-

responsive magnetic substance is a ferromagnetic material, and the dotted line illustrates the same when the temperature-responsive magnetic substance is a paramagnetic material.

In FIG. 2a, reeds 1 and 2 of the reed switch and temperature-responsive magnetic substances 3 and 4 are positioned so as to be in series with the magnetic flux of a permanent magnet 5 and, if magnetic substance 3 and 4 are ferromagnetic, the magnetic flux is conducted into the magnetic substance 3 and 4 and flows into the reeds, to move the reeds to the closed position. On the other hand, if the temperature-responsive magnetic substances 3 and 4 are paramagnetic, the magnetic flux flows as shown by the dotted line so that the reeds 1 and 2 will be in a spaced apart position. If the magnetic substances are made of ferrite, the magnetic flux flowing through the reeds will decrease at elevated temperatures, so that this switch will act as a temperature-operated switch of the type in which contacts open at elevated temperatures.

In the embodiment shown in FIG. 2b, the reeds 6 and 7 of a reed switch, and a temperature-responsive magnetic substance 8, are positioned in parallel with a permanent magnet 9, so that, if magnetic substance 8 is ferromagnetic, the flux of the permanent magnet 9 exists within the substance 8, as shown by the solid line in the drawing, so that the contacts are in the spaced-apart position. If the magnetic substance 8 is paramagnetic, the magnetic flux flows into the reeds 6 and 7 so that the contacts will be moved into the closed position. That is to say, if the magnetic substance 8 is made of ferrite, the contacts will close when the temperature rises and the saturation magnetic flux density of the ferrite decreases. Further, if the magnetic substance is made of a material which has a characteristic as shown in curve c (FIG. 1), the contacts will open when the temperature of the magnetic substance exceeds the phase transformation temperature. Since the characteristic of the flux density versus temperature of the magnetic substance is reversible, the operation of the contacts is reversed when the temperature falls again.

Because the switch has a structure such that a pair of reeds are sealed in a glass container with inert gas, the switch is explosion-proof and can be used in applications where a conventional temperature-operated switch is not safe, for example, in an environment where there are explosive gases or dusts. Further, because the contacts have a snap action, a large number of switching operations can be expected if used with consideration of environmental conditions. Such a switch may prove unsatisfactory, however, because it includes glass which may break, or the operating characteristics, such as the switching temperature, may deviate from the expected figure due to differences in the thermal expansion coefficient of the glass and the magnetic substance, particularly when the device is subjected to elevated or low temperatures or to heat-shock.

In order to overcome the foregoing problem, the present invention uses a barium-ferrite magnet as the permanent magnet and a ferrite as the temperature-responsive magnetic substance, assembles the former with the glass of the reed switch, and constructs all the important parts of the switch from ceramic. Thus, when the three elements noted above are bonded together by a heat-resistant synthetic resin, there will be no cracks formed in the glass, permanent magnet or temperature-

responsive magnetic substance due to a difference in the coefficient of thermal expansion therebetween. It is particularly advantageous if the reed switch is assembled with a ring shaped permanent magnet and temperature-responsive magnetic substance. In addition, we propose techniques for increasing the temperature-response, of preventing the occurrence of partial differences in thermal expansion, and of protecting the operation of the switch.

FIGS. 3a and 3b illustrate two embodiments for implementing the afore-mentioned techniques. In FIG. 3a, the numeral 10 designates a reed switch. A permanent magnet 11 is inserted in the hollow portion of a U-shaped temperature-responsive magnetic substance 12, both wing portions functioning as yokes to concentrate the magnetic flux of permanent magnet 11 when magnetic substance 12 is ferromagnetic. Therefore, the upper portion of the magnetic substance shunts the magnetic flux, the variation in magnetic flux acting to control the contacts of the reed switch 10 being quite large, and reliable operation can be expected. Further, the flux-shunting upper portion of the magnetic substance is the part of the device which directly senses temperature and thus can be miniaturized to increase the response of the device. It is possible to make the flux-shunting upper portion wider than the width of the permanent magnet 11 and correspondingly, to make the same portion thinner, whereby the temperature-response is still further increased.

In FIG. 3b, the numeral 13 designates a reed switch, 14 designates a permanent magnet, and 15 designates a temperature-responsive magnetic substance. In this arrangement, the magnetic substance 15 surrounds the entire periphery of the side face of the magnet, so that the temperature-responsive magnetic substance has an increased area, resulting in an increased response to temperature changes. The embodiments shown in FIG. 3a and FIG. 3b operate so that the switch contacts will be closed when the temperature-responsive magnetic substance behaves as if it were paramagnetic. It will be noted that, if the magnetic substance is made of a ferrite, the U-shaped or O-shaped magnetic substances can be molded integrally so that this device is readily mass-producible.

The temperature-operated switch shown in FIG. 4 is of the type wherein the reed switch contacts are not positioned in the center portion of the switch assembly. The structure of this type of switch can generally be miniaturized, and the temperature-response may become rapid, depending upon its applications. As shown, a metal case 20 is immersed in fluid, the temperature of which is to be detected, and is mounted to the wall of a vessel, for example, by means of a flange 21. The numeral 22 designates one of the terminals of the switch, the other end being connected to the switch body. In this embodiment, the temperature operated switch, comprising a pair of reeds 23, a permanent magnet 24 and a temperature-responsive magnetic substance 25 is sealed in a metal case. Because the temperature detecting portion is proximate the far end of the device, there is little influence from the wall temperature, and in the case of fluid, the flow of the fluid increases as one moves away from the wall. Thus, this device has a good temperature response and operates as an accurate, temperature-operated switch. That is to say, in contrast to the usual type of switch in which the reeds are located at the center of a glass tube, in this

embodiment the reeds are offset to one side and the magnetic substance is correspondingly shifted towards the far end of the switch.

FIGS. 5a and 5b show an embodiment of the invention wherein a ring-shaped magnetic substance is fitted around a reed switch and thus the magnetic substance has an increased surface area. This type of switch is characterized by an improved temperature response and is preferable for detection of temperatures about the whole peripheral area of the switch. In FIG. 5b, the numeral 30 designates a reed switch having contacts located at its center, 31 designates a cylindrical permanent magnet, and 32 designates a cylindrical temperature-responsive magnetic substance, the positional relationship between the above elements being shown in FIG. 5a.

FIG. 5a illustrates the reed switch contact closing and opening zones which appear when the axial direction of the reed switch is in alignment with the pole direction of the permanent magnet, and the contacts are moved relatively in the axial direction and in a vertical direction normal to the axial direction. If FIG. 5a, the zones designated 33, 34 and 35 are the contact closing zones and 36 designates the contact opening zone. If arranged so that the permanent magnet 31 is fitted around the reed switch and positioned in the switch closing zone 36, the reed switch will be in the open position if the temperature-responsive magnetic substance 32 exhibits the property of a paramagnetic material, and will be in the closed position if the temperature-responsive magnetic substance 32 exhibits the property of a ferromagnetic material. That is, if the magnetic substance 32 is made of a ferrite, this temperature-operated switch operates in such a manner that the contacts will be open if the device is subjected to elevated temperatures.

FIG. 5d shows a switch which operates in a manner inverse to the operation of the device shown in FIG. 5b, that is, the combination of a permanent magnet 41 and a temperature-responsive magnetic substance 42 which is located around an end portion of reed switch 40 closer to its end than the relationship shown in FIG. 5b. With reference to FIG. 5c, if the temperature-responsive magnetic substance 42 exhibits the property of paramagnetic material, only the permanent magnet 41, located in the contact closing zone 44, has any magnetic influence on the reed switch 40, so the contacts of the reed switch will be in the closed position. If the temperature-responsive magnetic substance 42 assumes the property of a ferromagnetic material, the permanent magnet 41 and the temperature-responsive magnetic substance 42 serve substantially as a single permanent magnet, and the magnetic center of the equivalent single magnet shifts to the contact opening zone 46 and, thus, the contacts will open.

While the temperature-operated switch shown in FIG. 5b operates in the normal contact operation with conventional direction, the temperature-operated switch shown in FIG. 5d operates in the inverse manner and its operation is the same as that of the device shown in FIG. 2b. The device shown in FIG. 2b becomes large in size if it is designed in a cylindrical shape, but the temperature-operated switch shown in FIG. 5d is of smaller size and cylindrical and, thus, is easy to seal in a metal case, and the like.

The temperature-operated switch shown in FIG. 6a has permanent magnets 52 and 53, together with a

temperature-responsive magnetic substance 54 sandwiched therebetween, arranged in parallel with the reeds 50 and 51 of a reed switch. The magnetic substance 54 is located so as to correspond in location to the intermediate overlapping portion of the reeds. In this embodiment, the magnetic flux appears as shown in the solid lines if the magnetic substance 54 exhibits the property of a ferromagnetic material. Thus, the contacts will be in the closed position. On the other hand, if the magnetic substance 54 exhibits the property of a paramagnetic material, the magnetic flux produced by permanent magnets 52 and 53 is shunted by the respective reeds 50 and 51 of the reed switch, as shown by the dotted lines, so that the magnetic flux in the contact portion of the reeds disappears and the contacts will open. This switch can be constructed by mounting the combination of permanent magnets 52 and 53 and magnetic substance 54 about the central portion of the switch, so that this embodiment is easier to manufacture than the switch shown in FIG. 5b and gives a larger contact pressure due to the use of two permanent magnets. Thus, the contacts have a very long life.

FIGS. 6b and 6c explain the dimensional relationship between permanent magnets 52, 53 and the magnetic substance 54 for the foregoing switch.

FIG. 6b shows the case where the temperature-responsive magnetic substance 54 is smaller in size than one of the permanent magnets 52 and 53, and FIG. 6c shows the case where the magnetic substance is larger than either. FIG. 6b, above the horizontal center line, illustrates the case where the magnetic substance exhibits the property of a paramagnetic material and therebelow is illustrated the case where the magnetic substance exhibits the property of a ferromagnetic material. In this figure, the length, measured along the horizontal center line, represents the shift distance of either the permanent magnet or the temperature-responsive magnetic substance in the axial direction. Zones designated 55, 56, 57, and 58 represent the contact closing zones which appear as the permanent magnet, and not the magnetic substance, which is moved in the axial direction. Contact closing zones 59, 60 and 61 are drawn, similarly to the above, by shifting the permanent magnet, in combination with the temperature-responsive ferromagnetic substance. Accordingly, when the temperature-responsive magnetic substance changes in property from a ferromagnetic material to a paramagnetic material, the state of the contacts change from the condition shown below to that shown above. That is, if the permanent magnets and the magnetic substance are located in the center portion of the switch, the contacts move from the closed position to the open position, within the limit shown by the arrows.

In the case of FIG. 6c, where the temperature-responsive magnetic substance is larger in size than the permanent magnets, a closing zone 62 appears in the center portion on the upper side and, if the permanent magnets and the temperature-responsive magnetic substance are located in the center portion of the switch, the contacts are kept closed so that, in order to get the intended type of operation, the contacts must be shifted slightly to the left or right. That is, in order to make good use of the advantages of this type of temperature-operated switch, it is necessary to make the axial dimension of the temperature-responsive magnetic

substance shorter than the length of the permanent magnet.

As described above, the switching temperature of these types of temperature-operated switches is defined by the operating properties of the reed switch, i.e. the strength of the retracting magnetic field, the characteristic of the saturation magnetic flux density versus temperature of the magnetic substance, the magnetic strength of the permanent magnet, the positional relationship between elements of the switch, and the like. Therefore, once the structural elements are bonded together, it was heretofore virtually impossible to vary any of the foregoing parameters. To obviate the above problem, a ferromagnetic body other than the switching elements may be moved towards or spaced from the temperature-operated switch, or a magnetic field may be applied to the device by use of a coil.

In FIG. 7a, the numeral 71 designates a reed switch, 72 designates the combination of a permanent magnet and a temperature-responsive magnetic substance, and 73 designates a ferromagnetic substance to permit adjustment of the switching temperature. The ferromagnetic substance employed will permit adjustment of the switching temperature regardless of whether it is comprised of soft or hard ferromagnetic material. For example, if an iron piece approaches the switches shown in FIG. 2, the switching temperature of the switch shown in FIG. 2a is lowered and that shown in FIG. 2b rises. In FIG. 7b, the numeral 74 designates a reed switch, 45 designates the combination of a ring-shaped permanent magnet and a temperature-responsive magnetic substance, and 56 designates a coil for adjusting the switching temperature, the coil being wound coaxially with respect to element 45. The adjustment of the working temperature can be effected by increasing or decreasing the supply of current to the coil.

One skilled in the art can make various modifications and changes to the illustrative embodiment shown, without departing from the spirit and scope of the invention.

We claim:

1. A temperature-operated switch, which comprises:

1. a reed switch having, in the absence of any external magnetic field, at least one pair of normally open contacts;
2. a barium-ferrite permanent magnet disposed substantially parallel to said reed switch; and
3. at least one manganese-zinc group ferrite member positioned proximate said permanent magnet such that a series circuit is formed for the magnetic flux of said magnet, said series circuit including said ferrite member and the reeds of said reed switch, said ferrite member exhibiting a saturation magnetic flux density characteristic which varies in response to changes in temperature, whereby the contacts of said reed switch are opened and closed by variations in the intensity and distribution of the magnet flux from said magnet caused by temperature induced variations in the magnetic characteristic of

said ferrite member.

2. A temperature-operated switch, which comprises:

1. a reed switch having, in the absence of any external magnetic field, at least one pair of normally open contacts;
2. a rectangular permanent magnet having four side faces, the permanent magnet being arranged substantially parallel to the reed switch; and
3. a magnetic member adjacent and surrounding the four side faces of the permanent magnet,
 - a. the magnetic member being disposed substantially parallel to the reed switch and forming therewith a series circuit for the magnetic flux of the permanent magnet, and
 - b. the magnetic member being comprised of a material exhibiting a saturation magnetic flux density characteristic varying in response to changes in temperature.

3. The temperature-operated switch of claim 2, wherein the magnetic member material is a manganese-zinc group ferrite.

4. A temperature-operated switch, which comprises:

1. a reed switch having, in the absence of any external magnetic field, at least one pair of normally open contacts;
2. a permanent magnet arranged substantially parallel to the reed switch;
3. a magnetic member positioned proximate the permanent magnet and forming therewith a series circuit for the magnetic flux of the permanent magnet, the series circuit including the magnetic member and the reeds of the switch,
 - a. the magnetic member being comprised of a material exhibiting a saturation magnetic flux density characteristic varying in response to changes in temperature whereby the contacts of the reed switch are opened and closed by variations in the intensity and distribution of the magnetic flux from the permanent magnet caused by temperature induced variations in the characteristic of the magnetic member;

4. an electromagnetic coil mounted adjacent the magnetic member and arranged, upon energization, to alter the saturation magnetic flux density characteristic of the magnetic member whereby the temperature at which the switch operates may be adjusted; and

5. means for energizing the coil to establish an electromagnetic field therein.

5. The temperature-operated switch of claim 4, wherein the permanent magnet and magnetic member are ring-shaped and coaxially surround the reed switch and the electromagnetic coil is coaxial with the permanent magnet and magnetic member.

6. The temperature-operated switch of claim 4, wherein the magnetic member material is a manganese-zinc group ferrite.

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