

July 19, 1966

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3,261,945

TEMPERATURE RESPONSIVE MAGNETIC SWITCH

Filed June 29, 1964

2 Sheets-Sheet 1

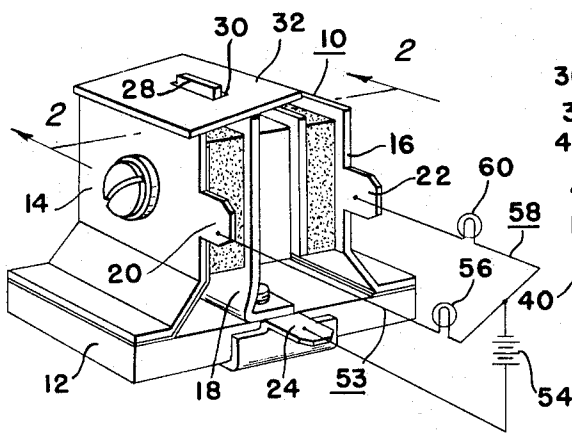


Fig. 1

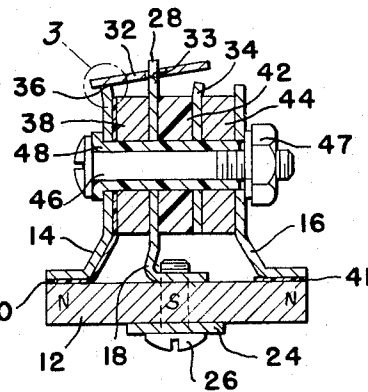


Fig. 2

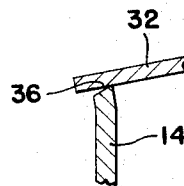


Fig. 3

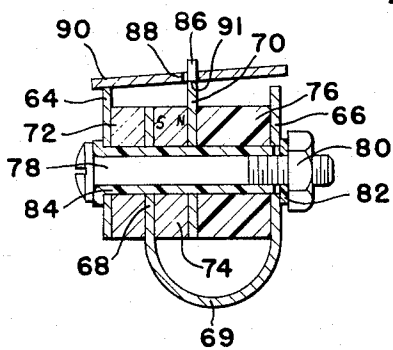


Fig. 4

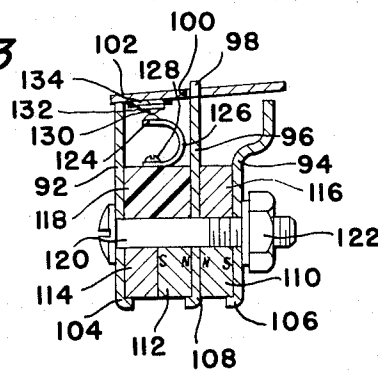


Fig. 5

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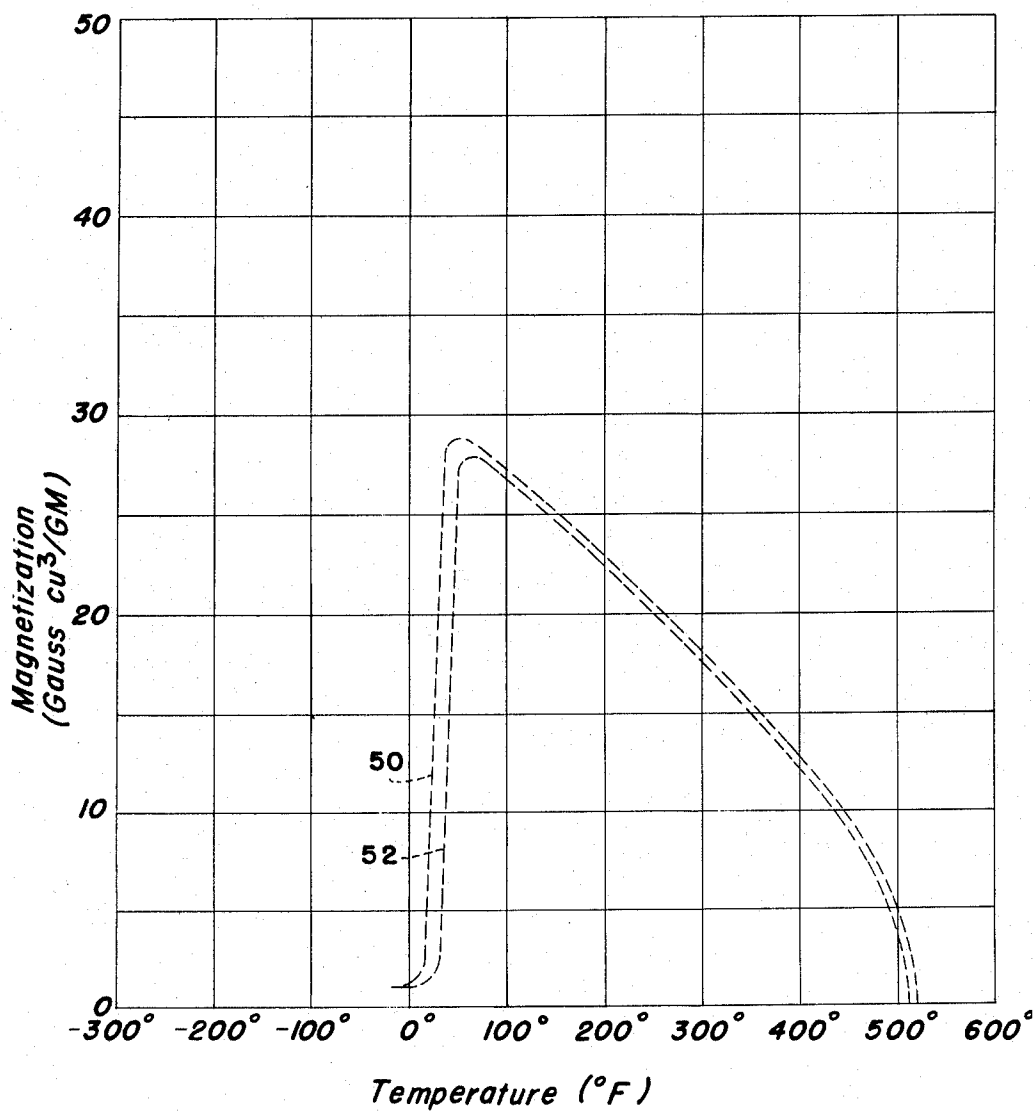


Fig. 6

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1

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TEMPERATURE RESPONSIVE MAGNETIC SWITCH
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Filed June 29, 1964, Ser. No. 378,832
12 Claims. (Cl. 200-88)

This invention relates to thermostatic switches and more particularly to magnetically operated thermally responsive switching devices.

In many control systems it is desirable to utilize thermostatic switches that are responsive to a predetermined sensed temperature to effect a desired controlling action in electrical control circuits.

Typically, to assure switching at an exact temperature control point complex, expensive calibrating means must be included in such devices. The provision of such means, however, reduces the reliability of the switching device.

An object of the present invention, therefore, is to improve temperature responsive magnetically operated switching devices having plural switch pole pieces by the provision therein of a selectively magnetizable switching element characterized by having little or no magnetic characteristics below a predetermined temperature and a strong magnetic characteristic above the predetermined temperature, arranged with respect to permanent magnet means to produce a reversal of relative magnetic flux concentrations between the pole pieces for effecting a continuously reliable switching action.

A further object of the present invention is to reduce the exterior dimensions of temperature responsive magnetically operated switching devices having plural switch pole pieces by the provision therein of permanent magnet and selectively magnetizable switching elements arranged in a compact, modular fashion and operable to produce a desired reversal of relative flux concentration between switch pole pieces upon sensing a predetermined control temperature.

A still further object of the present invention is to further reduce the complexity of such temperature responsive magnetically operated switches by the provision of electrical terminals on the switch pole pieces adapted to be connected in control circuit means and electrically connectable one to the other by conductor means including an armature movable relative to the pole pieces upon flux reversal therebetween.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

FIGURE 1 is a view in perspective of one embodiment of the temperature responsive magnetically operated switch incorporating the present invention;

FIGURE 2 is a view in vertical section taken along the line 2-2 of FIGURE 1;

FIGURE 3 is an enlarged fragmentary sectional view of the area 3 in FIGURE 2;

FIGURE 4 is a view in vertical section of another embodiment of the invention;

FIGURE 5 is a view in vertical section of still another embodiment of the invention; and

FIGURE 6 is a chart showing the saturation magnetization curves of a material having magnetic characteristics suited for use in the present invention.

Referring now to the drawings in FIGURE 1 a switching device 10 is illustrated including a base 12 of a permanent magnetic material having poles therein as illustrated in FIGURE 2 which are merely representative of one suitable magnet arrangement suitable for use in

2

the present invention. The base 12 supports a plurality of soft iron pole pieces 14, 16 and 18 that extend outwardly so that the pole pieces 14, 16 serve as the side walls of the switching device 10 and the pole piece 18 is located therebetween in spaced parallelism therewith. Terminal extensions 20, 22 present on pole pieces 14, 16, respectively, as best illustrated in FIGURE 1, are adapted to be electrically connected to first and second external circuits each of which is completed by a terminal 24 secured to the magnetic base 12 by means of a screw element 26 directed therethrough into electrical engagement with pole piece 18 at the base supported end thereof. The pole piece 18 has an extension 28 on its free end directed through an opening 30 in an armature 32 whereby shoulders 33 on either side of the extension 28 serve to pivotally support armature 32 with respect to the free end of the pole piece 14 and the free end of a pole piece 34 formed as a flat plate that is located between and in spaced parallelism with the pole piece 16 and pole piece 18. Each of the pole pieces 14, 34 has a surface 36 on the free end thereof that is inclined from a horizontal plane, as best seen in FIGURE 3, so that the surface of the armature 32 that mates with the ends of the pole pieces 14, 34 will only contact the pole piece through a limited area to prevent magnetic locking between the armature 32 and its respective mating pole piece.

In accordance with certain principles of the present invention a first magnetizable switching element 38 is located between the pole piece 14 and pole piece 18 so that one face thereof is in juxtaposition with the mating surface of the pole piece 18 and the other face thereof is in closely adjacent juxtaposition with but insulated from the inner surface of the pole piece 14 by an electrical insulating layer of material 40, for example Mylar, of approximately 2 mils thickness. The layer 40 also extends between pole piece 14 and permanent magnet 12 and a like insulating layer 41 separates pole piece 16 from magnet 12.

Interposed between the pole pieces 34, 18 is a spacer element 42 formed as a flat plate having opposite flat faces thereon in juxtaposition with the respective mating surfaces of pole pieces 34, 18. The element 42 is made of a suitable electrical insulating material, for example nylon. Between the pole pieces 16, 34 is located a selectively magnetizable switching element 44 like element 38 which has the inner and outer side faces thereof located in juxtaposition with coextensive mating surfaces on the pole pieces 34, 16, respectively.

In the illustrated arrangement the pole pieces, the magnetizable switching elements and the insulating layers are interconnected by an elongated screw element 46 that is directed therethrough into threaded engagement with nut 47 to maintain such interconnected elements in a colinear relationship whereby the switching unit has unusually compact outer dimensional characteristics. The screw element 46, in the embodiment illustrated in FIGURES 1-3, is surrounded by a sleeve 48 formed of a suitable electrical insulating material such as nylon whereby electrical circuits through the various pole pieces are completely isolated one from another.

In accordance with certain principles of the present invention, the magnetizable elements 38, 44 are constructed of a chromium modified manganese antimonide which have a magnetic characteristic as best shown in FIGURE 6 wherein curves 50, 52 represent the magnetization at various temperatures of modified manganese antimonide materials having different percentages of chromium therein. The general formula for such material is $Mn_{2-x}Cr_xSb$ with x being the percent of chromium present in the material. In such material by varying the chrome content therein a family of curves like curves

50, 52 are available so that the selectively magnetizable switching elements like 38, 44 can make a transition from a substantial non-magnetic state to a highly magnetized state when a predetermined temperature is attained. For example, with a material having characteristics as shown in curve 50 when the temperature reaches 15° F. the magnetic switching element will change from a very low magnetization order to a relatively high magnetization as illustrated. Accordingly, if the switching arrangement shown in FIGURES 1 and 2 includes material characterized by the magnetization curve shown at 50 in FIGURE 6 the switch can be located within the cold compartment of a refrigerating device or the like to respond to the temperature therein to perform a warning function by selectively opening and closing the external circuits from the switch as follows.

When the material is below the predetermined temperature of 15° F. the switching elements 38, 44 are unmagnetized so that a first magnetic circuit is produced from the base 12 through the pole pieces 14, 18 characterized by a relatively strong concentration of magnetic flux in the vicinity of the end of the pole piece 14 that attracts the armature 32 into the position shown in FIGURES 1 and 2. In this position an external electrical circuit 53 including terminals 20, 24 is closed whereby current passes from a suitable power source 54 through an indicating light 56 or the like in the circuit and thence through the terminal 24, the base 12 that serves as a conductor, screw 26 to pole piece 18, the armature 32 and thence through the pole piece 14 and the terminal 20 to the external circuit. The indicator light 54, for example, can establish that the temperature in the cold compartment is within a safe operating range.

When the temperature in the cold compartment associated with the improved switch 10 reaches a predetermined temperature as for example 15° F., the switching elements 38, 44 immediately make a transition to a highly magnetized state, as shown in FIGURE 6, whereby the previously mentioned magnetic circuit through the pole pieces 14, 18 is shunted by the switching element 38 away from the armature 32 so there is a relatively low magnetic flux concentration at the terminal end of the pole piece 14. Simultaneously, the switching element 44 acts to complete a serial magnetic circuit from the magnetic base 12 through pole piece 16 to the pole piece 34 whereby a relatively large flux concentration is produced at the terminal end thereof being of a greater magnitude than that flux concentration at the terminal end of pole piece 14 whereby the armature is pivoted about the pole piece 18 to open the external circuit 53 and close an external circuit 58 to energize an indicator bulb 60 therein that will show that the temperature of the associated cold compartment is in excess of the desired operating range.

While the switching arrangement is shown associated with a plurality of external circuits having energizable indicia means therein, it will be appreciated by those skilled in the art that the switch is equally suited for association with circuits for energization of air motor compressor units, or other electrically energizable operating devices that are desirably controlled in response to the predetermined sensed temperatures.

With reference to FIGURE 4 another embodiment of the invention is illustrated that includes end members 64, 66 serving as pole pieces that include electrical terminals therein like terminals 20, 22 in the embodiment of FIGURES 1-3. The end pole piece 66 has a U-shaped extension 69 therein that joins to a pole piece 68 located intermediate of and in spaced parallelism to the end pole piece 64 and a pole piece 70 interposed in spaced parallelism between pole pieces 66, 68. In this embodiment of the invention a variably magnetizable switching element 72 is located between pole pieces 64 and 68 and arranged in juxtaposition therewith. A permanent magnet switching element 74 is located between pole pieces 68 and 70 and arranged in juxtaposition relationship

therewith and a spacer element 76 of a suitable insulating material, for example nylon, is located between pole pieces 66, 70 in juxtaposition relationship therewith. As in the embodiment of FIGURES 1 and 2 the switching elements and spacing element are formed as relatively compact units that are joined as an integral unit by an elongated screw element 78 that is directed therethrough to threadably receive a nut 80 and both the nut 80 and screw 78 are insulated in the remainder of the switching unit by a washer 82 and sleeve element 84, respectively, of a suitable insulating material, for example nylon.

In this arrangement the pole piece 70 has an extension 86 that is directed through an opening 88 in movable armature 90 whereby the armature is pivotally supported on shoulders 91 formed on either side of the extension 86. In this arrangement the pole piece 70 is also electrically connected to a terminal (not shown) whereby external circuits like the external circuits in the embodiment of FIGURES 1 and 2 can be opened and closed by movement of the armature 90 into electrical contact with the pole 66 or the pole 64.

Assuming that the selectively energizable switching element 72 is like the switch elements 38, 44, in the embodiment of FIGURES 1-3, when the switching unit senses a temperature above the predetermined switching temperature, as for example 15° F., the switching element 72 has a high magnetization whereby a serial magnetic circuit is completed from the permanent magnet 74 through switching element 72 and the pole 64 whereby a strong magnet flux concentration is produced at the terminal end of pole piece 64 to attract the armature thereagainst. Since the magnetic path through the U-shaped pole piece extension 69 and pole piece 66 is substantially greater than the path through the previously described serial circuit, the magnetic flux concentration at the terminal end of the pole piece 66 is relatively smaller than that at the terminal end 64 during this phase of operation.

In this arrangement when the temperature is below the predetermined switching temperature the switching element 72 is no longer magnetized and the magnetic circuit through the pole piece 68 and pole piece 66 is thereby more direct than that across switching element 72 which is now effectively an air gap. The magnetic flux concentration in the vicinity of the terminal end of pole 66 is thereby stronger than that in the vicinity of the terminal end of pole piece 64 and the armature pivots about the end of pole piece 70 to close against pole piece 66 to energize the other external circuit.

In the embodiment illustrated in FIGURE 5 a switch is shown including end plates 92, 94 that serve as pole pieces. In this arrangement between pole pieces 92, 94 is located a plate 96 that has an extension 98 on the end thereof directed through an opening 100 in an armature 102 that is thereby pivotally supported by the terminal end of plate 96 for movement with respect to the terminal ends of pole pieces 92, 94 that are aligned like those in FIGURES 1 and 2 to prevent magnetic locking between the pole pieces and armature. In this embodiment the pole pieces 92, 94 are turned inwardly at ends 104, 106, respectively, and the end of the plate 96 is bent at 108 toward pole piece 92. The bent end 106 of the pole piece 94 serves to supportingly receive a permanent magnet switching member 110 that is thereby located between pole piece 94 and plate 96 in juxtaposition relationship therewith. Similarly, a second permanent magnet switching member 112 is supported by the bent end 108 of plate 96 and a variably magnetizable switching element 114 is supported by the bent over portion 104 of pole piece 92. The permanent magnetic member 112 and the switching element 114 are located in juxtaposition between the plate 96 and pole piece 92.

Above the permanent magnet 110 is located another variably magnetizable switching element 116 that is between the pole piece 94 and plate 96 in juxtaposition re-

5

relationship therewith and above the supported members 112, 114 is located a block 118 of electrical insulating material, for example nylon, that is in juxtaposition relationship with pole piece 92 and plate 96. In this embodiment the various switching members and insulating blocks are held as an integral modular unit by an elongated screw element 120 threadably engaged by nut element 122 for holding the parts together. In this arrangement a first contact 124 is carried on the end of U-shaped spring member 126 serving as an electrical terminal, that is fixedly secured to the insulating block 118 by a screw member 128. The contact 124 is located and arranged to electrically connect or mate with a movable contact 130 carried by a conductor strip 132 secured to a layer of insulating material 134 for electrically insulating the contact 130 from the armature and pole pieces of this embodiment of the invention.

In the position shown in FIGURE 5 the variably magnetizable switching elements 114, 116 are highly magnetized to thereby complete a first serial magnetic circuit from the permanent magnet 112 through the pole piece 92 so as to produce a relatively strong magnetic flux concentration on the terminal end of pole 92 and to complete a magnetic circuit from permanent magnet 110 and shunted between pole piece 94 and plate 96 whereby the flux concentration at the end of pole piece 94 is relatively weak compared to that at the end of pole piece 92. In this position the contact 130 is moved into electrical contact with the fixed contact 124 to complete an external indicating, operating or the like electrical circuit.

When the switching elements 114, 116 sense a temperature below the switching temperature, they immediately make a sharp transition to little or no magnetization whereby the pole piece 92 is effectively magnetically isolated from the permanent magnets and the pole piece 94 and an unshunted magnetic circuit is completed from magnet 110 through pole piece 94 to produce a relatively strong flux concentration at the terminal end thereof which moves the armature into contact therewith to thereby separate contact 132 from contact 124 to open the external circuit.

In view of the above description of the various embodiments of the present invention, it will be appreciated by those skilled in the art that the present invention provides a switching device that is unusually compact and unusually economical in that the operative parts thereof serve as the switch housing and in some cases as portions of both a magnetic circuit system and an electrical circuit system. These multiple purpose aspects and the compact nature of the switch is attributed to a great degree to the use of the variably magnetizable switching element that is characterized by a very low magnetization on one side of the control temperature and a very high magnetization on the other side of the control temperature. Moreover, by using such a material, a highly responsive switching device is provided that is suitable for operating an electrical device that requires a very reliable switching device in association therewith to carry out its intended operation over a substantial period of time.

While the embodiments of the present invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. In a temperature responsive switch the combination of, a first pair of pole pieces and a second pair of pole pieces, a selectively magnetizable switching element arranged between at least one pair of said pole pieces, permanent magnet means associated with said magnetizable switching element and coacting therewith to produce a first predetermined differential flux pattern in said first and second pair of pole pieces, movable armature means responsive to said predetermined differential flux pattern to be drawn toward one of said pair of pole pieces, said switching element having a low magnetiza-

6

tion below a predetermined temperature and a high magnetization immediately above the critical temperature, said switching element upon sensing the critical temperature producing a reversal in said first predetermined flux pattern to cause said movable armature means to be attracted to the other of said pair of pole pieces.

2. A temperature responsive magnetically operated switch comprising a permanent magnet, a first and a second pole piece, a variably magnetizable switching element interposed between said permanent magnet and at least one of said pole pieces, said permanent magnet and said variably magnetizable switching element producing a first predetermined differential magnetization between said pole pieces, said switching element upon sensing a predetermined temperature immediately shunting a portion of the flux pattern from said permanent magnet to produce a reversal of the relative strength of the flux concentration in said first and second pole pieces, an armature, means for pivotally supporting said armature with respect to said pole pieces whereby the position thereof upon reversal of the relative flux concentration strength therein is reversed.

3. In a temperature responsive magnetically operated switch, the combination of, a pair of pole pieces, a permanent magnet means for producing a predetermined flux pattern in said pole pieces, a variably magnetizable switching element, means for interconnecting said pole pieces, magnet and switching element into a unitary structure wherein said pole pieces, magnet and switching element are aligned colinearly as a modular unit, said variably magnetizable switching element having a relatively low magnetization below a predetermined temperature and a relatively high magnetization above the predetermined temperature, said switching element being operative to effect a reversal of the relative flux concentration produced in said pole pieces by said permanent magnet means upon sensing of the predetermined temperature.

4. In a temperature responsive magnetically operated electrical switch the combination of a permanent magnet, a variably magnetizable switching element having substantially no magnetization below a predetermined temperature and a substantial magnetization above the predetermined temperature, a first and a second pole piece of electrically conductive material, a conductor element located between said first and second pole pieces, means including a movable armature for electrically connecting said first and second pole pieces in external circuits through said conductor element, said permanent magnet producing a predetermined flux pattern in said first and second pole pieces, said flux pattern being varied by said switching element upon its sensing a predetermined control temperature, said variation in flux pattern acting upon said armature means to produce movement thereof against one or the other of said first and second pole pieces to complete the electrical circuits associated therewith.

5. In a temperature responsive magnetically operated switching device, the combination of a first and second conductor element, a third conductor, a permanent magnet, a variable magnetizable switching element, said permanent magnet and switching element producing a first predetermined flux pattern in said conductors below a predetermined temperature and a second flux pattern therein immediately at the predetermined temperature, armature means movable by the variation in flux patterns to electrically connect one of said first and second conductors to said third conductor during one of the changes in flux pattern whereby said first and second electrical conductors are included as a part of an external electrical circuit controlled by said switching device.

6. In a temperature responsive magnetically operated switch, the combination of a switch housing including end walls serving as combination electrical terminals and magnetic pole pieces, a permanent magnet, a variably

magnetizable switching means, means for fastening said magnet and said switching means between said end walls in supported relationship thereon, said permanent magnet producing a predetermined flux pattern in said end walls, said switching means operative to effect a reversal of relative flux concentration strength in said end walls at a predetermined critical temperature, an armature, said armature being movable upon the reversal of flux concentration between first and second switching controlling positions.

7. In the combination of claim 6, said permanent magnet serving as a base for supportingly receiving said combination electrical terminal, pole piece end wall portions.

8. In the combination of claim 6, means for pivotally supporting said armature with respect to said first and second end walls for supportingly directing said armature into first and second positions upon flux reversal.

9. In the combination of claim 6, a third pole piece located between said end walls, said switching means including a variably magnetizable element located between one of said end walls and said third pole piece for selectively varying the flux concentration in said third pole piece upon sensing the critical temperature, said third pole piece serving to attract said armature upon a first flux reversal and said other of said end walls serving to attract said armature upon a second reversal.

10. In a magnetically switching device the combination of a pair of spaced end walls serving as a portion of a switch housing and as an electrical terminal and a magnetic pole piece, a third pole piece, a magnetic member connecting said third pole piece to one of said end walls, an armature, a member for pivotally supporting said armature serving as an electrical conductor, a permanent magnet disposed between said third pole piece and said conductor member, a variably magnetizable switching element disposed between one of said end walls and said third pole piece, said switching element having a low magnetization below a predetermined temperature and a high magnetization above the temperature, said switching element upon sensing the predetermined temperature increasing the flux concentration in said one of said end walls in excess of the flux concentration in the other of said end walls to attract said armature thereagainst to complete an external electrical circuit including said one end wall, said armature and said electrical conductor member, said switching element reversing the flux pattern between the end walls below the predetermined temperature to increase the flux concentration at the other end wall above that at said one end wall whereby the armature is attracted to said other

end wall and separated from said one end wall to open the first electrical circuit and complete another electrical circuit including the other end wall, the armature and the electrical conductor member.

11. In the combination of claim 10, said pole pieces, electrical conductor member, magnet and switching elements being arranged colinearly in a compact manner, and means for interconnecting said colinearly arranged parts.

12. In a temperature responsive magnetically operated switch the combination of, a first permanent magnet, a second permanent magnet, first and second variably magnetizable switching elements, a plurality of support plates of magnetizable material located in spaced parallelism with one another, one of said permanent magnets and one of said switching elements supported in juxtaposition relationship between first and second of said plates, another of said permanent magnets and another of said switching elements being supportingly received in juxtaposition relationship between the second and a third of the spaced plates, means for integrally connecting said plates, switching elements and permanent magnets as a compact, modular unit, an armature, said second plate serving to pivotally support said armature for movement with respect to said first and third plates, said permanent magnets producing a predetermined relative flux concentration between said first and third plates for attracting said armature toward one of said plates, said switching elements upon sensing a predetermined temperature having a substantial magnetization to effect a reversal of flux concentration in said second and third plates for attracting the armature toward another of said first and third plates, and coacting means on said armature and switch means operatively connected with said armature for effecting a predetermined switching action upon such movement of said armature.

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