Dec. 18, 1934. W. J. HUDSON 1,985,033

THERMAL RELAY

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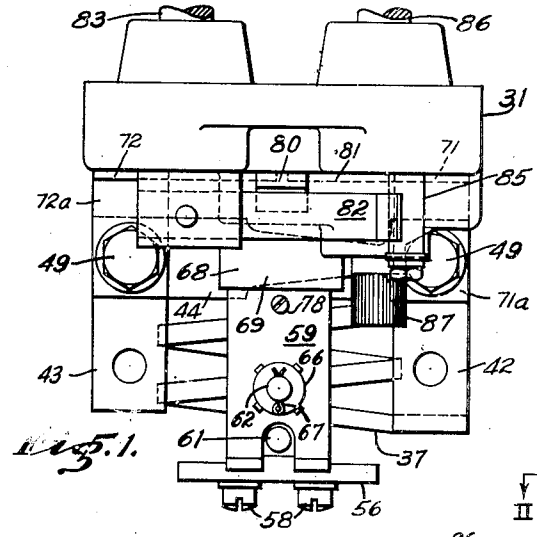


Fig. 1.

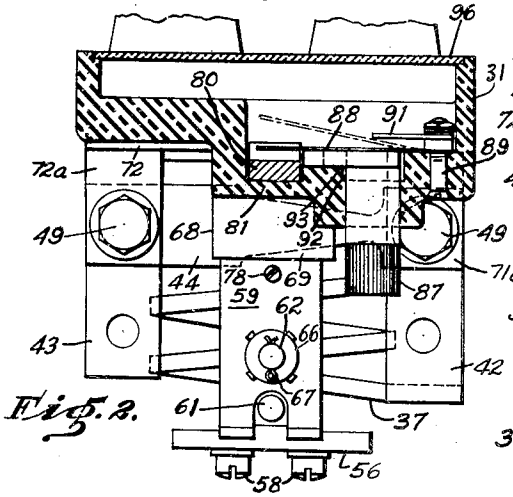


Fig. 2.

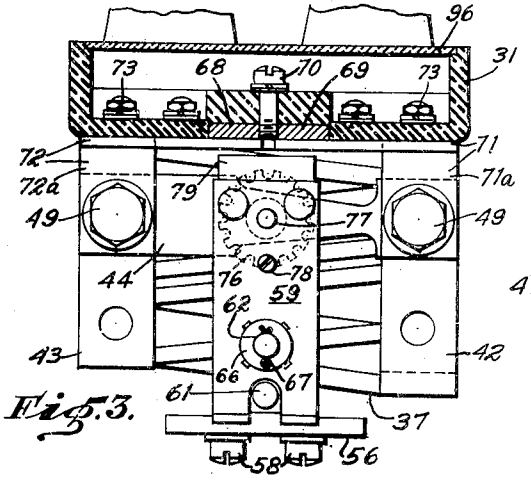


Fig. 3.

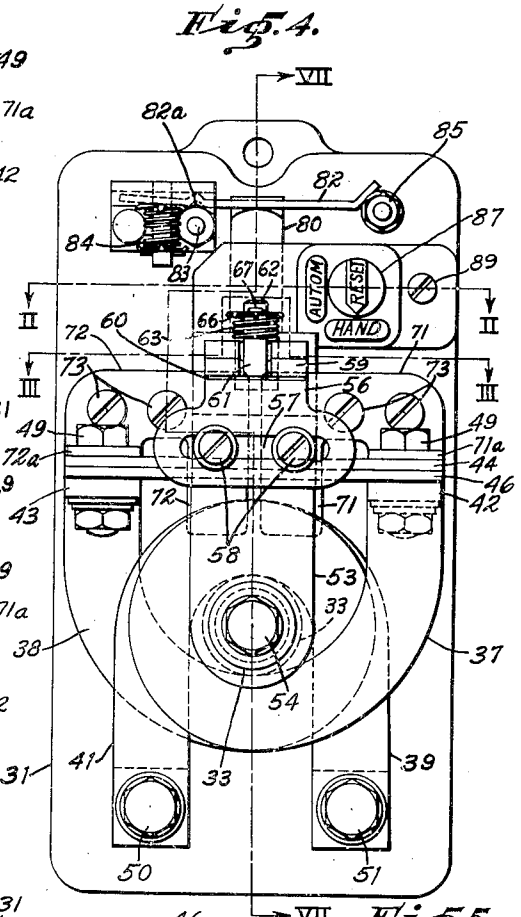


Fig. 4.

Fig. 5.

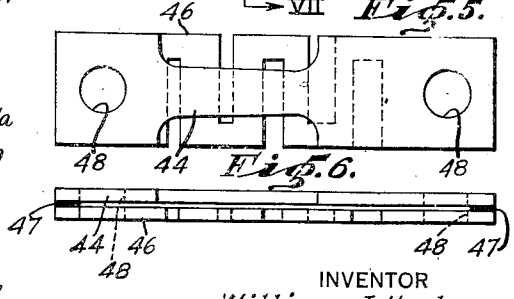


Fig. 6.

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THERMAL RELAY

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Fig. 7.

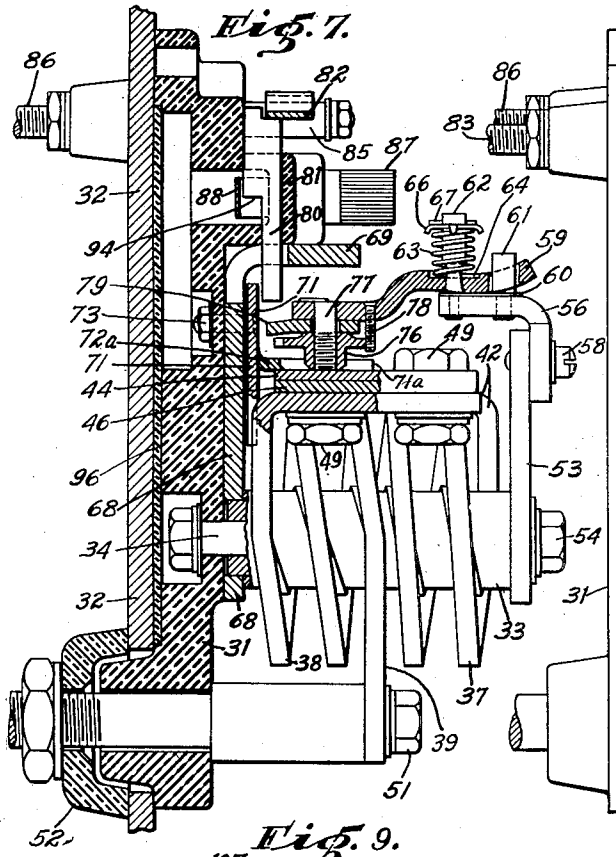


Fig. 8.

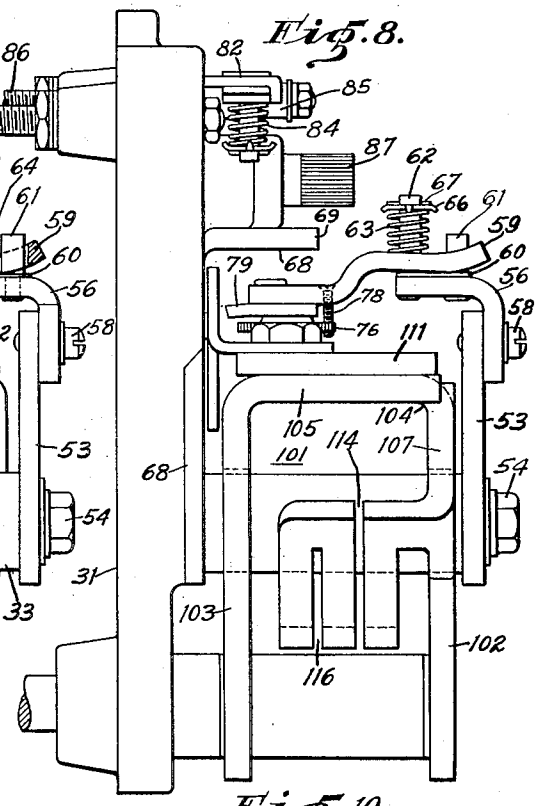


Fig. 9.

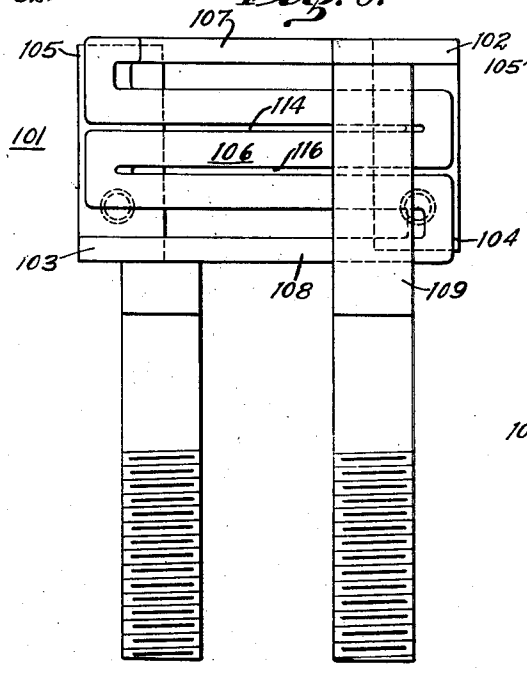
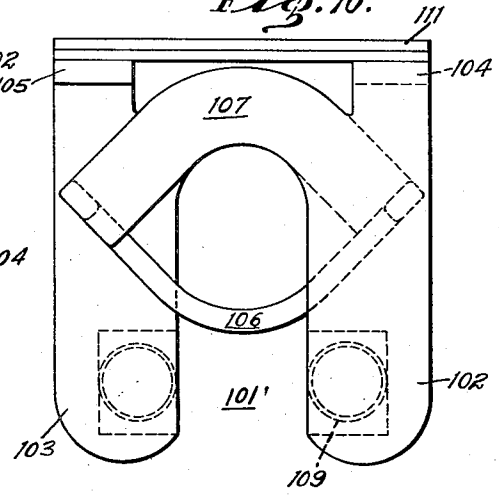


Fig. 10.



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Fig. 11.

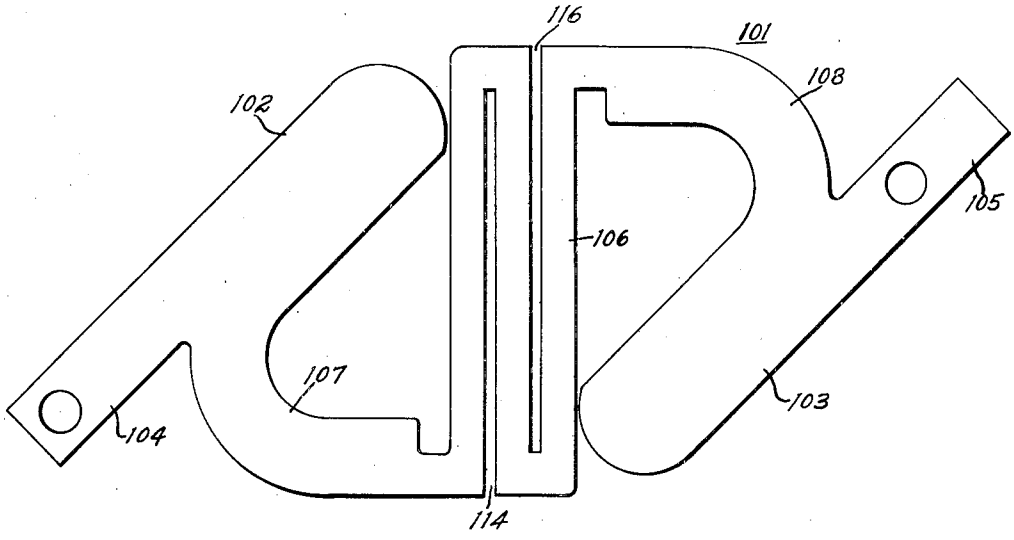
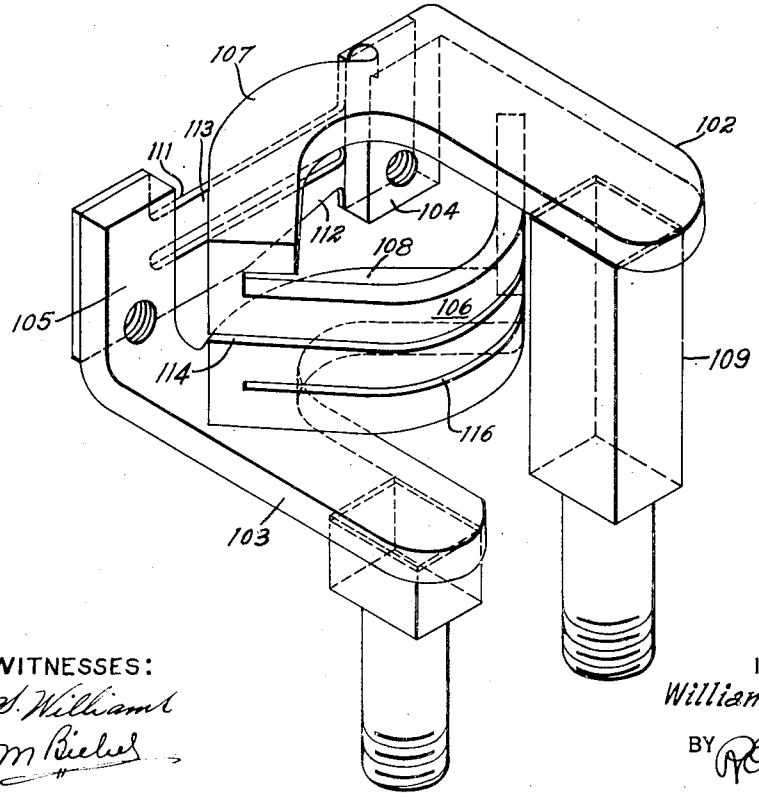


Fig. 12.



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Dec. 18, 1934. W. J. HUDSON 1,985,033

THERMAL RELAY

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Fig. 13.

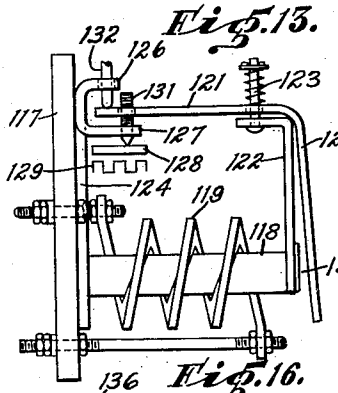


Fig. 14.

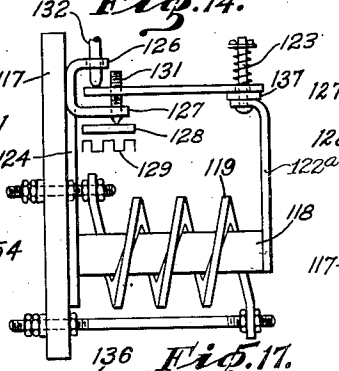


Fig. 15.

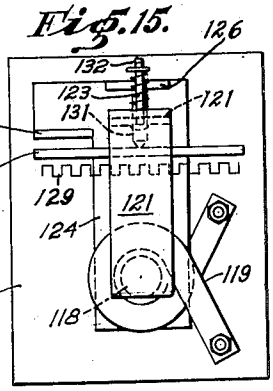


Fig. 16.

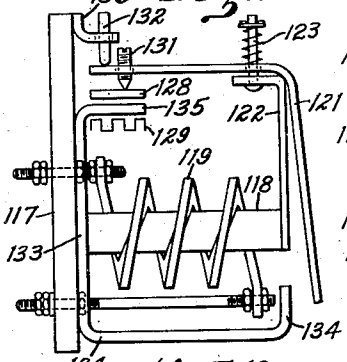


Fig. 17.

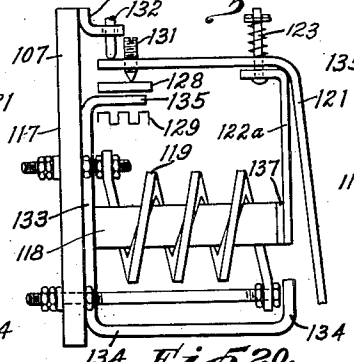


Fig. 18.

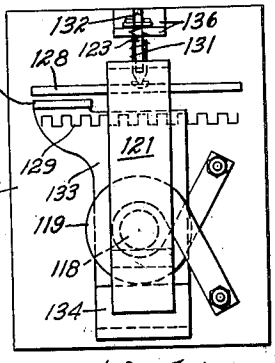
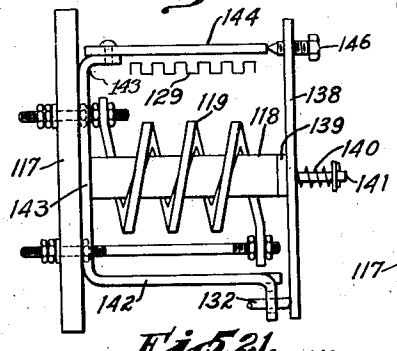


Fig. 19.



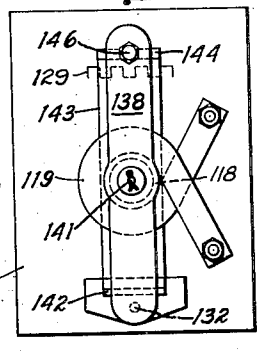
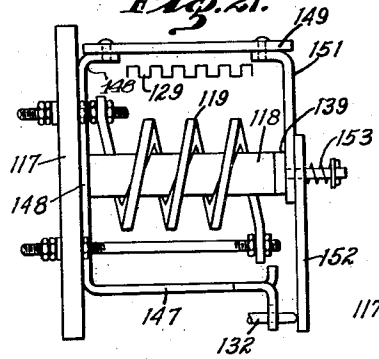


Fig. 21.



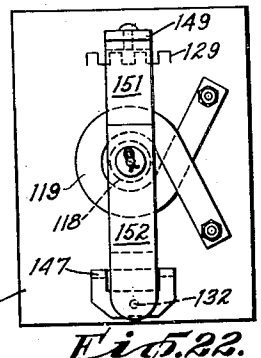


Fig. 22.

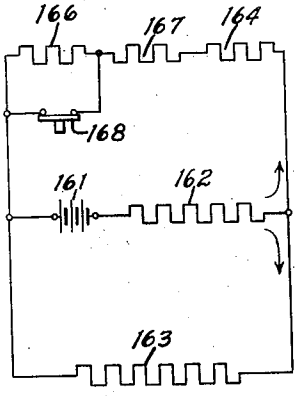


Fig. 23.

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Patented Dec. 18, 1934 1,985,033

UNITED STATES PATENT OFFICE

1,985,033

THERMAL RELAY

William J. Hudson, Wilkinsburg, Pa., assignor to Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania

Application February 19, 1932, Serial No. 593,994

43 Claims. (Cl. 175—336)

My invention relates to relays and particularly to thermal relays.

An object of my invention is to provide a relatively simple thermal relay having time delay and instantaneous operating characteristics under different current values.

Another object of my invention is to provide a thermal relay of the kind embodying a magnetically reversible control member that shall be highly sensitive and positive in operation and one which shall be accurate in its calibration.

Another object of my invention is to provide a thermal relay embodying a novel energizing coil structure.

Another object of my invention is to provide a thermal relay operating with time delay on moderate overloads by electro-thermal action and instantaneously on excessive overloads by electromagnetic action, that shall be highly sensitive in operation.

Another object of my invention is to provide a thermal relay that shall have a substantially instantaneous reset characteristic.

Other objects of my invention will appear from a description of the device and of its operating characteristics, as set forth in the specification and the claims or as will be specifically pointed out herein.

In practicing my invention, I provide an energizing coil, which may be of the series coil type and which may embody a plurality of sections each including a plurality of spaced turns, one end of each section extending longitudinally of the coil to support a magnetically reversible member therebetween which establishes an electrical connection between the coil sections. The magnetically reversible member is normally engaged by a movable armature which constitutes a part of a magnetic frame structure, one part of the frame structure being provided with a main gap traversed by substantially all of the magnetic flux generated by the energizing coil and including also two parallel-related portions, one of which is constituted in part by the magnetically reversible member. The armature is biased normally into engagement or into substantial engagement with the magnetically reversible member and is magnetically restrained from moving away therefrom at moderate overloads until its magnetic characteristic has changed because of an increase of temperature therein. At excessive overloads, however, the disengaging force exerted by another magnet pole on the armature increases relatively to the restraining force of the magnetically reversible member to a degree which is sufficient to overpower the restraining force without any thermal change in the magnetic characteristics of the magnetically reversible member.

In another form of my invention, I provide a relatively simple plural-turn energizing coil which is stamped out of a flat piece of metal to provide terminal portions at each end, lugs adjacent to the terminal portions to support the magnetically reversible member and an intermediate portion which may be provided with a differing number of alternately oppositely-extending lateral slots therein to provide an intermediate portion of relatively high ohmic resistance to constitute a shunt circuit for the magnetically reversible member supported on the lugs.

In the drawings,

Figure 1 is a top plan view of a device embodying my invention.

Fig. 2 is a view in horizontal section therethrough taken on the line II—II of Fig. 4,

Fig. 3 is a view in horizontal section therethrough taken on the line III—III of Fig. 4,

Fig. 4 is a view in front elevation of a device embodying my invention,

Figs. 5 and 6 are views in top plan and in front elevation, respectively, of a magnetically reversible member and heater,

Fig. 7 is a view partially in side elevation and partially in vertical section on a broken plane indicated approximately at VII—VII in Fig. 4,

Fig. 8 is a view in side elevation of a thermal relay embodying my invention and provided with a modified form of energizing coil,

Fig. 9 is a bottom plan view of an energizing coil, such as is shown in Fig. 8, the terminal studs being shown as secured thereto,

Fig. 10 is a front elevational view of the coil shown in Fig. 9,

Fig. 11 is a top plan view of a punched coil before shaping,

Fig. 12 is a perspective view of the coil shown in Figs. 9 to 11, inclusive, provided with terminal studs and an associated magnetically reversible member.

Fig. 13 is a schematic view in side elevation of the main elements of one form of device embodying my invention.

Fig. 14 is a schematic view in side elevation of a further modification of my invention.

Fig. 15 is a view in front elevation of the device shown in Fig. 13.

Fig. 16 is a schematic view in side elevation of

another modification of the device embodying my invention.

Fig. 17 is a view in side elevation of another modification of device embodying my invention.

Fig. 18 is a view in front elevation of the device shown in Fig. 16.

Fig. 19 is a view in side elevation of another modification of device embodying my invention.

Fig. 20 is a view in front elevation of the device shown in Fig. 19.

Fig. 21 is still another view in side elevation of another modification of the device embodying my invention.

Fig. 22 is a view in front elevation of the device shown in Fig. 21, and

Fig. 23 is a diagrammatic representation of an electric circuit to more clearly illustrate, by analogy, the magnetic circuits of the device shown in Figs. 12 to 22, inclusive.

The thermal relay embodying my invention may be mounted on a suitable base 31 of electric-insulating material, of substantially rectangular shape in outline and having an uneven front surface to assist in supporting the other elements of the relay in proper relative operative positions thereon, the outline of the front surface being shown more specifically in Fig. 7 of the drawings. The base 31 may be secured against a supporting plate 32 which, as shown in Fig. 7 of the drawings, may be of metal although this is not an important detail as the base may be mounted on a switchboard panel.

A magnetizable core member 33, which is shown in the drawings as being of solid magnetic material, is supported against the front surface of base 31 by a holding or clamping bolt 34 extending through an opening in the base.

An energizing coil for the core 33 and other magnetizable portions to be hereinafter specifically described includes two coils 37 and 38 each including a plurality of turns of copper or other suitable metal strip bent on edge, the individual turns of each coil section being spaced apart to assist, not only in cooling the conductor itself, in the usual manner, but also to assist in cooling another member to be hereinafter described. The two adjacent end portions of the coils 37 and 38 are located in the same transverse plane and are shown at 39 and 41 in Fig. 4, while the other end of each of the coil sections is so bent as to extend longitudinally of, and parallel to, the axis of the coil and of the core 33. Thus, the end 42 of the outer coil 37 extends toward the base 31 while the end 43 of the inner coil 38 extends away from the base 31, the two end portions 42 and 43, however, extending parallel to each other.

A bar of magnetically reversible material, such as invar, which may be of the general kind shown in Figs. 5 and 6 and there indicated by 44, is electrically connected to the ends 42 and 43 of the coil sections and is supported directly thereby. While I may use the bar 44 by itself, causing it to be heated by the action of an electric current traversing it, I may also, as shown in Figs. 5 and 6 of the drawings, provide an auxiliary heater strip 46 which may be of any suitable metal, only the end portions of which are electrically connected to the end portions of the bar 44 as by welding or brazing metal 47, indicated in Fig. 6. The bars 44 and 46 may be provided with holes 48 therein through which may extend clamping bolts 49 in order to ensure that the electrical connection between the magnetically reversible bar and the ends of the coil sections shall be as good as may be possible to obtain. In order to assist in reducing the ohmic resistance I may braze or solder the bars 44 and 46 to the ends 42 and 43 of the coils.

The other end portions 39 and 41 of the coil sections are suitably secured to terminal bolts or studs 50 and 51 which extend through suitable openings in the base 31 adjacent the bottom edge thereof and which also extend therebeyond to permit of connecting supply circuit conductors (not shown in the drawings) thereto and in order to provide proper insulation, I may use dished washers 52 of electric insulating material and I may also make the base 31 of greater thickness as is shown more particularly in Fig. 7 of the drawings.

The heater strip 46 may have a plurality of alternately oppositely-extending lateral slots therein as shown in Fig. 5 of the drawings and while the spacing and width of the slots may be the same throughout, I may vary both the spacing and the width of the slots as is shown in Fig. 5 of the drawings in order that the member 44, and particularly the intermediate portion thereof, may be heated non-uniformly. In order to assist this unequal heating of the bar 44 of magnetically reversible material, I may make it of different areas of cross section, as is shown in Fig. 5 of the drawings. If the lateral width of the intermediate portion of the bar 44 is made constant, it is obvious that the temperature rise of the bar 44, when used alone, will be a maximum at the midpoint thereof and that the temperature will decrease towards the ends of the bar 44.

A magnetizable frame structure cooperating with the core 33 includes a front frame 53 which may be of substantially bar shape and may have its lower end secured against the core 33 by a bolt 54. At the upper end of the front frame 53, I locate an armature bracket 56, of substantially L-shape, which may consist of a punched plate of magnetizable material which has a laterally extending slot 57 therein (see Fig. 4) so that the armature bracket 56 may be moved laterally relatively to the front frame 53 and be held in any predetermined position thereon by a plurality of clamping screws 58.

The armature bracket 56, just mentioned, carries a movable armature 59 which is of substantially straight but slightly laterally-deformed shape, as is shown more particularly in Fig. 7 of the drawings, and which is pivotally mounted on the armature bracket 56. The pivotal action is obtained by bending the outer end into an arc which rolls on a flat non-magnetic spacer 60 which is used to avoid the interfering action of residual magnetism and also for other purposes hereinafter described. A pin 61 is fitted rigidly into the bracket 56 and a second pin 62 is also fitted rigidly into the rear inner end of the bracket 56. A compression spring 63 surrounds the pin 62 and fits into a recess 64 in the upper surface of armature 59, a washer 66 and a cotter pin 67 cooperating with the pin 62 to yieldingly hold the armature 59 in a predetermined position.

A rear frame 68 of magnetizable material and of substantially L-shape is clamped against the front surface of base 31 by the bolt 34 and the core 33, and its upper, forwardly extending end 69 is secured against the base 31 by a machine screw 70, as shown in Fig. 3 of the drawings.

At a point immediately back of the movable armature 59, the rear frame 68 carries a pair of

aprons 71 and 72, for which see particularly Figs. 3, 4 and 7 of the drawings. The aprons 71 and 72 are of substantially plate form and have extensions 71*a* and 72*a* bent forwardly so as to lie parallel to, and spaced from, the respective end portions 42 and 43 of the coils 37 and 38. The body portions of the aprons 71 and 72 are secured to the insulating base 31 by screws 73, and the forwardly extending tabs 71*a* and 72*a* are secured to the coil terminals 42 and 43 by the bolts 49. The two aprons 71 and 72 thus serve to support the two ends of the invar strip 44, which is secured to the coil-terminals 42 and 43.

One of the aprons, such as 72, is of magnetic material, so as to carry flux from the rear end of the magnet-core 33, through the rear plate 68, to one end of the invar strip. The other apron 71 is non-magnetic.

Flux is taken off of the invar strip by means of the movable armature 59, and thence to the front plate 53 and the front end of the magnet-core 33.

The inner or rear end of the movable armature 59, which is magnetically related to the invar strip, is provided with means for varying the air gap between the armature and the invar strip 44, and this means may include a non-magnetic adjusting nut 76 on an iron, or magnetizable, screw-threaded stud 77 which is welded, or otherwise rigidly secured, to the movable armature 59. The adjusting nut 76 has a serrated peripheral flange which is engaged by a locking pin 78 to hold it in any predetermined position. This particular adjusting element of the thermal relay constitutes no part of my present invention but is disclosed in a copending application, Serial No. 574,317, filed by W. M. Ellingson on November 11, 1931, and assigned to the Westinghouse Electric and Manufacturing Company.

The iron stud 77 at the rear end of the movable armature 59 is normally nearly in engagement with the invar strip 44, where it is held by magnetic attraction, aided slightly by the spring 63. When the invar strip 44 is heated, by excessive current-flow, to a critical temperature which may be of the order of 200° C., it loses its magnetic properties enough for the rear end of the movable armature to be lifted by the magnetic pull of the horizontal flange 69 of the rear plate 68.

The rear end of the armature is provided with a striker plate 79 which will thus be caused to strike the bottom end of an actuating rod 80, which rod is of substantially rectangular shape in lateral section and moves in a forwardly projecting portion 81 of base 31.

The upper end of the actuating rod 80 engages a switch arm 82 which is pivoted at 82*a* on a terminal stud 83 and is biased by a compression spring 84 to have its free end normally in engagement with a contact terminal 85 which has a terminal stud 86 extending back through the base 31 and its support. This switch may be connected in series circuit relation with a source of electric energy and with a device to be controlled, such as the actuating coil of a relay or of a circuit breaker. The controlled means or circuit has not been shown, as devices of this general kind are old in the art and the device embodying my invention may cooperate with any one of a number of different devices or controlled means of this general kind.

Means are provided in the relay, either to make the switch arm 82 automatically return to its initial closed position wherein its free end engages the contact terminal 85, or to make it remain in its open position so that it will be necessary for an operator to manipulate a part of the relay to cause resetting or reclosing of the switch 82. The last-mentioned means is shown on the drawings, and it includes a reset knob 87 movable manually in a direction laterally of the base 31 and engaging a leaf-spring 88 (see Fig. 2), one end of which is secured in the inside of the casing-portion 81 by a machine screw 89. A small rigid or unyielding strip of metal 91 is provided to limit the rearward movement of the leaf-spring 88 when it is actuated by the reset knob 87. The inner end of the reset knob 87 is provided with a laterally projecting lug 92 and by turning the reset knob 87, the lug 92 may be caused to fit into a recess in front of the leaf-spring 88, or it may engage a shoulder portion 93 (see Fig. 2) to hold the reset knob in its actuated position where the inner end thereof occupies the position shown in broken lines in Fig. 2 of the drawings.

The actuating rod 80 is provided with a shoulder 94 (Fig. 7) which may be engaged by the upper edge of the leaf-spring 88 if the spring is not held out of its path of movement by the reset knob 87. Thus, if the inner end of the reset knob 87 occupies the position shown by the broken lines in Fig. 2 of the drawings, the spring 88 will be bent inwardly to the position shown by the broken lines of Fig. 2 and the actuating rod 80 may move freely up and down in accordance with the movements of the armature 59. If, however, the reset knob occupies the position shown by the full lines in Fig. 2, the switch arm 82 will remain in its disengaged position when it has been moved thereto by the upward movement of actuating rod 80.

Referring to Figs. 2 and 7 of the drawings, I have there illustrated the use of a sheet 96 of electric insulating material between the rear surface of the base 31 and the supporting member 32 so that the possibility of electrical breakdown from the head of the bolt 34 shall be reduced as much as possible.

In Figs. 8 to 12, inclusive, I have illustrated a simple and easily manufactured plural-turn energizing coil which I have found particularly advantageous in the construction of my improved relay. Referring first to Fig. 11 of the drawings, I have there illustrated the general shape of a punched plate 101 which I utilize in making a plural-turn energizing coil. The energizing coil 101 of Fig. 11 includes terminal portions 102 and 103, lug portions 104 and 105 immediately adjacent to the terminal portions 102 and 103, an intermediate portion 106 and arcuate connecting portions 107 and 108.

Fig. 12 of the drawings shows a view, in perspective, of the completed coil and it may be noted that, in the completely shaped or finished coil structure, the lug 104 is bent substantially at right angles to the terminal portion 102 which terminal portion has connected thereto a terminal stud 109, it being noted that the method of connection of the terminal stud 109 to the terminal portion 102 of the coil is immaterial and is here shown as including a brazed joint. The other lug, 105, is also bent substantially at right angles to the terminal portion 103 and in the reverse direction to that in which lug 104 is bent. The outer surfaces of the lugs 104 and 105 are parallel to each other and a current-

traversed magnetically-reversible bar 111 may be secured against the outer surface of the lugs, either by brazing alone, or by brazing and bolts extending therethrough in a manner well known in the art.

It may here be noted that the magnetically reversible members 44 and 111 may be made up of any one of a number of different materials but I prefer to use a nickel-steel alloy known as invar, having on the order of 35% nickel, which has the property of being magnetizable at ordinary room temperatures but of losing its magnetic characteristics upon an increase of the temperature to a predetermined value. Nickel-steel containing approximately 35 to 36% of nickel loses its magnetic characteristics when heated to approximately 210° C. while a nickel-steel alloy containing a slightly larger percentage of nickel loses its magnetic characteristics at somewhat higher temperatures. I prefer to use a material which has a thermally variable magnetic characteristic such that it loses its magnetizable character at a temperature on the order of 210° C. or even slightly above this value.

As shown in Fig. 12 of the drawings, the invar member 111 includes relatively large end portions and one intermediate portion 112 which is of varying area in lateral section, as well as a second intermediate portion 113 which is of uniform area in lateral section, but other sizes and shapes of bars designed to provide the same characteristics for other ratings may be used.

Referring more particularly to Figs. 11 and 12, and to the intermediate portion 106 of the blank 101, as shown in Fig. 11, I call attention to the alternately oppositely-extending lateral slots 114 and 116 which so divide the intermediate portion 106 as to provide a circuitous path for the current traversing the coil, which path is of relatively high ohmic resistance, as compared to the ohmic resistance of the terminal portions 102 and 103. I may use any desired even number of alternately oppositely extending, lateral slots in the intermediate portion 106, to obtain different resistances of the intermediate portion of the coil structure, whereby it is possible to correspondingly vary the value of the current, or rather the portion of the current, traversing the magnetically reversible member 111.

It will be noted by reference to Fig. 12 of the drawings that the coil structure there shown provides a two-turn coil which is relatively open and well ventilated so that it can carry a relatively large current without undue heating. The open construction is also advantageous in assisting in cooling the ends of the invar strip 111.

A thermal relay embodying the energizing coil illustrated in Figs. 9 to 12 inclusive, is shown in side elevation in Fig. 8 of the drawings and as all of the other parts of the relay are the same as shown in Figs. 1 to 7, inclusive, these other elements have been given the same numerals as the parts in Figs. 1 to 7, inclusive.

While I have illustrated and described a specific embodiment of a frame structure including a movable armature, I do not desire to be limited to any particular form thereof, and in order to show some of the various forms which my apparatus may take, I illustrate a number of such forms in Figs. 13 to 22, inclusive, which will now be described.

Referring to Fig. 13, I have illustrated a base 117, a magnet-core 118 and an energizing coil 119 which is here shown as including only one section, but which may take either the form shown in Fig. 7 of the drawings or that shown in Fig. 8 of the drawings. The coil is provided with terminal members either as set forth hereinbefore or in a manner usual in the art.

A movable armature 121 may be of magnetizable material and of substantially L-shape and it may be pivotally supported on a non-magnetic frame 122 upon which the armature is yieldingly held in a predetermined position by a spring 123 in a manner well known in the art. A rear frame structure 124 is provided, the upper portion of which is provided with two spaced pole pieces or pole faces 126 and 127, in a manner substantially the same or similar to that hereinbefore set forth in connection with Figs. 1 to 7, inclusive. A magnetically reversible bar 128 is suitably supported and may be heated either by the current traversing it or by an auxiliary heater 129, the magnetically reversible bar or the heater, as the case may be, being connected in series circuit with the coil 119 to be traversed by the load current. The magnetically reversible member 128 coresponds to the bar 44 of Fig. 7 or to the bar 111 of Fig. 8, and the heater 129 of Fig. 13 corresponds to the bar 46 of Fig. 5.

An adjusting screw 131 is mounted on the inner end of movable armature 121. The armature actuates a push rod 132 which corresponds to the actuating rod 80 and may be used to actuate a switch. It is to be particularly noted that the lower end of the screw 131 is made of conical shape in order that it may have small-area engagement with the magnetically reversible bar 128. It may be noted further, that the outer or lower end of the armature 121 is normally spaced away from the outer end of the magnetizable core 118.

Referring now to Fig. 14, the mechanical construction there shown is the counterpart of that shown in Figs. 1 to 7, inclusive and I have, therefore, numbered the different elements thereof, insofar as possible, the same as in Figs. 1 to 7, inclusive. While I have shown a single coil 119, it is to be noted that in actual practice either a plural-section coil, as shown in Fig. 7, or a modified coil, as shown in Figs. 8 to 12, inclusive, may be used.

Referring to Fig. 16 of the drawings, I have there shown a relay embodying a coil 119, a core 118, a movable armature 121 supported by a non-magnetic frame 122 and a rear frame 133 which has a lower portion 134 of L-shape extending forwardly from the base 117 and an upper forwardly-extending portion 135. A magnetically reversible bar 128 is provided and a heater 129, as was hereinbefore set forth in connection with Fig. 13. A push rod 132 moves in a guide 136.

Referring to Fig. 17, I have there illustrated a modification of the device shown in Fig. 16 except that the front frame 122*a* is of magnetic material and a non-magnetic spacer 137 is provided between the front frame 122*a* and the armature core 118.

In Fig. 19 of the drawings, I have illustrated a still further modification of a device embodying my invention including a coil 119 surrounding a core 118, and a movable armature 138 which is pivotally mounted against a non-magnetic insert 139 and yieldingly held in its initial or normal position by a compression spring 140 on a

pin 141. The rear magnetizable frame includes a lower portion 142 extending forwardly from the base, a back portion 143 extending parallel to the base and a magnetically reversible bar 144 which may be supported by the upper end of the back portion 143. An adjusting screw 146 is provided at the upper end of armature 138 and has a conical inner end to engage one edge of bar 144.

Referring to Fig. 21 of the drawings, I have there shown a still further modification of a thermal relay embodying a core 118, a coil 119 and a rear magnetizable frame having a lower frame-portion 147 extending forwardly at the base and a portion 148 extending parallel to the base. A magnetically reversible bar 149 is provided, as well as a heater 129. A front frame 151 of magnetizable material may be utilized to support the magnetically reversible member 149, being itself supported from the core 118. A non-magnetic spacer 139 is located between the core 118 and the front frame 151. A movable armature 152 has one end pivotally mounted on and engaging one end of the front frame 151, being yieldingly held in its normal position by a spring 153. The armature 152 is held in such position that it is spaced from the outer end of the lower portion 147 of the rear frame and is so disposed as to actuate a push-rod 132.

I will now set forth in greater detail the fundamental principles of the magnetic action and the magnetic characteristics of the frame structure and the movable armature which are made use of, in the operation of my improved relay, to obtain a highly sensitive operation under varying current conditions. I have shown, in Fig. 23, an electric circuit analogy by which it is expected to make clear the principles upon which my improved relay is based.

Thus, it may be noted, by reference to Fig. 13, that there is an air gap 154 in the magnetic circuit between the armature 121 and the front end of the magnetizable core 118, and this air gap is designed to have a relatively high magnetic reluctance and to be traversed by substantially all of the flux generated by the energizing coil 119. It is to be understood that, by substantially all of the flux, I mean that there is provided no parallel path in this part of the magnetic circuit and that, therefore, only those flux-lines usually called leakage flux lines, will not traverse this gap and the armature 121. Tracing the path of the flux lines as they leave the core 118, it will be found that they will traverse the armature 121 to the upper inner end thereof, where two parallel magnetic circuits are provided, constituted as follows:

First, the portion 126 (Fig. 13), which is constituted by the forwardly extending upward end portion 69 of the rear frame 68 as is shown in Fig. 7 of the drawings. Second, the members 127 and 128 (Fig. 13), which, in the device illustrated in Figs. 1 to 7 inclusive, are constituted by the forwardly extending portion 72*a* of the magnetizable apron 72 and the bar 44 which has a thermally variable magnetic characteristic as has been hereinbefore set forth. The flux will therefore divide, a part thereof flowing from the armature 121 to the frame-portion 126 and the other part thereof (aside from the leakage flux) flowing through the magnetizable screw 131 into the invar bar 128 and thence to the frame-portion 127. The total flux will then flow through the rear frame 124 and back to the core 118.

This general statement of the flux paths and the two parallel-related magnetic reluctance portions connected in series circuit with the main reluctance portion will hold for all the devices shown in the drawings, except that the high-reluctance main gap corresponding to the gap 154 in Fig. 13 is provided by the non-magnetic insert 60 in Figs. 7 and 8, and by the non-magnetic insert 137 in Figs. 14 and 17 and by the non-magnetic insert 139 in Figs. 19 and 21. Furthermore, the flux paths corresponding to the air-gap between the parts 121 and 126 in Fig. 13 is replaced by the lower gap between the parts 121 and 134 in Figs. 16 and 17, between the parts 138 and 142 in Fig. 19 and between the parts 152 and 147 in Fig. 21.

Thus in Figs. 16 and 17, the flux will divide in armature 121, a part thereof flowing downward and passing from the lower end of the armature 121 to the frame portion 134 and the other portion flowing upward to the inwardly extending horizontal end of armature 121 and thence through the magnetizable screw 131, and back to the core by a path similar to that described for Fig. 13. The flux from the air gap 121—134 will, of course, return to the core 118 through the lower frame portion 134. In Figs. 19 and 20 the flux divides in armature 138 at the end of core 118 into a downwardly flowing portion which passes from the lower end of 138 across an air gap into frame portion 142 and an upwardly flowing portion which passes from the upper end of 138 through an adjustable magnetizable screw 146 and a thermally variable magnetic member 144 into the upper portion of frame 143. In Figs. 21 and 22 the construction is the same as Figs. 19 and 20 except that the upper portion of armature 138 is made rigid as part 151 and the lower portion of armature 138 alone is mobile and is shown as part 152.

Referring to Fig. 23, I have indicated, by the source of electric energy 161, the magnetomotive source, (the energizing coil of the relay), which source of electric energy 161 sends a current through a main resistor 162, analogous to the main gap 60 in the thermal relay. From here the current divides, a part thereof flowing through a resistor 163 which corresponds to the magnetic reluctance between armature 121 and the fixed member 126 of Fig. 13, which gap may be designated as the pull-in gap. A parallel-related reluctance path in the frame structure of the relay is represented in Fig. 23 as including a resistor 164 corresponding to the reluctance of the small but unavoidable air gaps in the frame structure, a second resistance 166 corresponding to the relatively high magnetic reluctance of the magnetically reversible bar 128 when hot, and a third resistance 167 corresponding to the relatively low magnetic reluctance of the adjusting screw 131. A shunt circuit is shown across the resistor 166, said shunt circuit being normally bridged by a short-circuiting bar 168 which corresponds to the relatively very low magnetic reluctance of the invar member 128 or its counter part, which member has a low magnetic reluctance at low temperatures and is magnetizable, but which loses its magnetic characteristic upon being heated to a predetermined temperature under certain operating conditions of the thermal relay.

Thus, when the energizing coil is traversed by a current of normal value, a relatively large amount of flux will flow from the armature 121 through the gap to portions 127 and 128 of Fig. 13, which gap may be termed the hold-out gap.

It is therefore, evident that by far the greatest drop in magnetic potential will exist across main gap 154 (Fig. 13) whose counterpart is the resistance 162 of Fig. 23. As the pull-in portion of the magnetic circuit, that is, the gap between armature 121 and member 126 of Fig. 13 is bridged or shunted by the relatively low reluctance circuit including more particularly the magnetically reversible member 128, the magnetic pull across the pull-in circuit acting on the armature 121 is, therefore, much lower than it would be if the structure providing main gap 154 were not present. The magnetic reluctance of the hold-out gap is smaller than the magnetic reluctance of the main gap but the magnetic reluctance of the pull-in gap is much larger than the magnetic reluctance of the main gap.

It will thus be seen that all of the various modifications shown in Figs. 13 to 22 are characterized by the feature that an electrically produced magnetomotive force passes a flux across a main non-magnetic gap, which may be an air gap and directly useful in producing magnetic pull to move the armature as in Figs. 13 and 16, or it may be a non-magnetic spacer which is only indirectly useful in producing force to move the armature by its influence on the magnetic distribution of other parts of the system as in Figs. 14, 17, 19 and 21. A second characteristic feature of all modifications is the provision of a divided return of the magnetic flux after it passes the non-magnetic main gap into two portions which are magnetically in parallel with each other but in series with the main gap; any change in the reluctance of one of the two parallel paths will produce a change in the flux passing through the other parallel path by change of the m. m. f. drop in the main gap, which is in series with both. It is characteristic of all modifications that one return path (known as the pull-in gap) is an air gap between an armature portion and a magnetic frame portion and the flux across this gap is solely or partly instrumental in producing motion of the armature when impediments to such motion in other parts of the relay are removed. It is characteristic of all modifications that the other return path (known as the lockout path) is mainly in iron and in a magnetically reversible member and the amount of its flux is controlled by the special ferro-magnetic properties of those substances to prevent or allow motion of the armature according to the size of the current and the time it flows. In all modifications except Figs. 21 and 22 the impediment to motion exerted by the flux in the lockout path combines a mechanical force directly exerted on the armature with the controlling effect of the series-parallel arrangement of magnet gaps. In Figs. 21 and 22 the lockout path does not produce any mechanical force directly but governs motion of the armature entirely by shunting more or less of the main flux away from the pull-in gap 152—132. The flux across the pull-in gap is never zero but for lower values of flux the armature is biased to its inoperative position by a spring 153.

Referring to Fig. 17, all of the flux passes into bracket 122—*a* and upward to the hinge point. At the hinge point the total flux divides and one portion flows downward to the lower end of 121 where it passes across the "pull-in" air gap to frame portion 134. There is no magnetic potential to produce pull between 122—*a* and 121 but there is a large magnetic potential difference between 121 and 134.

If now the magnetic conditions in the parallel related magnetic circuit portions are changed, as will occur upon heating of the magnetically reversible bar, the normally existing short circuit of the pull-in gap is removed, analogous to opening of contact bar 168 in Fig. 23, and the magnetic pull on the armature 121 is greatly increased because the pull-in gap now has a higher reluctance than the main gap 154. It may be noted, further, that as soon as the armature 121 of Fig. 13 moves, the main gap 154 is reduced and the pull-in gap is also reduced so that the reluctance of the main gap is decreased as is also the reluctance of the pull-in gap whereby a relatively strong pull upon the armature is effected resulting in quick turning or pivotal movement thereof and movement of the actuating rod 132 of Fig. 13.

It may be here pointed out that the relay will operate even though the magnetic reluctance of the magnetically reversible bar is not thermally changed and this is effected by the ferromagnetic properties of the adjusting screw 131 of Fig. 13 and the magnetically reversible member 128. Thus, if an excessive overload current should traverse the coil 119, a very greatly increased flux would be generated thereby and it would traverse the magntic frame and the adjusting screw 131 and particularly the point thereof, and the contact area of its engagement with bar 127 would be highly saturated. The reluctance of the adjusting screw and the magnetically reversible member would increase by magnetic saturation irrespective of any temperature change in the invar strip, which is analogous to an increase of resistance in portion 167 of Fig. 23. As the area of the flux path (air gap) between the armature 121 and the portion 126 is relatively large and does not vary with the amount of flux traversing it, the pull-in torque will exceed the hold-out torque, so that the armature will move upwardly substantially instantaneously and irrespective of any temperature rise of the magnetically-reversible bar.

I have found it very advantageous, in the operation of the device, to provide the main gap hereinbefore described, as it tends to greatly increase the sensitivity of the device and make it operate more quickly and definitely at certain current values without departing therefrom to any appreciable extent.

It may be noted that, since the armature bracket 56 is adjustable on the front frame, the point of engagement between the gap-adjusting screw 77 of Fig. 7 and the magnetically reversible bar 44 may be varied longitudinally along the bar, and if the area of cross-section of the bar is uniform, the highest temperature will exist in the mid-portion and decrease towards each end thereof so that it is only necessary to adjust any given relay so that the armature is either centrally located thereof or to one side of the central line to obtain operation at different current values. By using a magnetically reversible member of the type shown in Fig. 12 and designated by 111, a number of different current settings may be obtained and the temperature will be highest adjacent to one end portion and decrease toward the other end portion. This feature is disclosed and claimed in a copending application, Serial No. 565,744, filed Sept. 29, 1931 by C. H. Hodgkins and assigned to the Westinghouse Electric and Manufacturing Company.

As the member having a thermally variable

magnetic reluctance is supported substantially out of engagement with the base and on an open-turn coil, I have found that my improved relay has a very desirable characteristic, namely, that it has what may be called a substantially instantaneous reset characteristic. By this, I mean that if the relay has operated because of an excessive overload, it is possible to reclose it substantially immediately and maintain it, or rather the switch-arm 82, in closed position. This is because of the fact that, if the bar 44 is heated so that it becomes non-magnetic, it will be cooled very quickly by reason of its being connected to and supported by the open-turn energizing coil which is of such shape as to have not only a relatively low inherent ohmic resistance but also a relatively large heat-radiating surface so that heat in the member 44 is conducted away therefrom very rapidly. The aprons 71 and 72, secured to the front surface of the base 31 and also to the magnetically reversible bar 44 at its ends are also effective in radiating heat generated in the bar 44. As was hereinbefore set forth, the relay is operated by electro-thermal action alone, under one condition of operation, that is, when the coil and the bar 44, or the heater 46, are traversed by a current representing a moderate overload. In this case, the member 44 gradually heats, and loses its magnetic characteristic after a certain time delay, causing the relay, or more particularly the armature, to be actuated as has already been hereinbefore set forth.

In case of a sudden excessive overload the relay will have an instantaneous characteristic, that is, it will open without any time delay, and this is accomplished because of the ferromagnetic saturation of a part of the hold-in magnetic circuit. It may here be pointed out that, in addition to the increased reluctance of the lockout pin and of the magnetically-reversible bar caused by these parts being traversed by an increased main flux, the magnetically reversible bar has its magnetic reluctance increased additionally as follows. When the magnetically reversible bar, which has a ferromagnetic characteristic is traversed by an excessive overload current, the current traversing the magnetic material will generate local flux lines within the bar which exist without dependence on the magnetization of the main magnetic circuit and are sufficient of themselves to cause a high degree of saturation of the bar. On extreme overloads the internally produced saturation in the bar is added to the effect of the externally produced saturation (by the flux generated by the coil) in the bar and in the lockout pin to give a greatly increased reluctance of the lockout gap, while the reluctance of the pull-in gap is practically unchanged (it being mainly an air circuit). The pull-in torque thus increases much more rapidly than the lock-out torque and effects instantaneous operation of the armature at high overloads irrespective of the temperature of the magnetically reversible bar. It may be noted that a local flux circuit (in the magnetically-reversible bar) and an external flux circuit (in the core and magnetic frame and the bar) are present and are inter-linked.

It may be noted that, in the form of relay illustrated in Figs. 1 to 7, inclusive, the magnetically reversible current-conducting member 44 is not only supported by the ends of the coil sections but also electrically connects them in series circuit relation, the location of the magnetically reversible member relatively to the turns of the coil being such that the ampere turns generated by the current traversing it are additive to those generated by the coil structure.

Attention may here be directed to the cooperation between the magnetic apron 71 and a magnetically reversible bar 44 having a varying area of cross section, such as shown in Fig. 5. It is obvious that the portion of the bar 44 which has the smallest area of cross section will lose its magnetic characteristic first when a predetermined current has traversed it for a predetermined length of time, or it has been heated by an auxiliary heater. When this occurs the flux traversing the armature 59 and the lock-out pin 77 will continue to flow through the wider parts of bar 44 and into the apron 72, thus making it possible to obtain proper operation of the relay at different current values by adjusting the armature (and particularly the lock-out pin 77) to engage the bar 44 at different points along its length.

The coil structure illustrated in Figs. 8 to 12, inclusive, provides a relatively simple and highly efficient means for varying the operating current of the relay, in that it is possible to laterally slot the intermediate portion of the coil structure in different manners during the manufacture of the coil, so that a larger number of current ratings are, therefore, obtainable. This coil structure may be easily and quickly punched from a flat sheet of metal and then bent to shape substantially, as shown in the drawings.

The magnetic circuit structure hereinbefore described, and illustrated in the drawings, and various modifications coming within the scope thereof, permit a relatively delicate balance between the pull-in torque and the hold-out torque, which balance is obtained by adjustment of the position of the inner end of armature 59 by means of the adjustable nut 76. This means that, if the armature is properly adjusted for normal current conditions in the relay, it will respond properly when an increased current traverses the coil, thus providing a relatively sensitive relay. However, it is to be noted that the constructional details hereinbefore set forth and including the use of a main reluctance gap traversed by substantially all of the flux and other details of the magnetizable frame structure assist greatly in increasing the sensitivity of operation of my relay.

Various modifications may be made in the device embodying my invention without departing from the spirit and scope thereof and I desire, therefore, that only such limitations shall be placed on my invention as are imposed by the prior art or set forth in the appended claims.

I claim as my invention:

1. A thermal relay including a movable armature, a magnetically-reversible bar heated by the relay current, to control the position of the armature, means including a pair of open-turn coil sections having one end of each section secured to the ends of the magnetically-reversible bar for assisting in dissipating the heat therein and supporting means for the coil sections and the bar secured to the other end of each coil section.

2. A thermal relay including a plural-section open-turn coil, end portions of each section being located in spaced alinement, a magnetically reversible member electrically connecting the said alined end portions of the coil sections, means for introducing and removing the flux

generated by said coil at spaced points in said magnetically reversible member, the magnetomotive force generated by the current traversing said magnetically reversible member being additive to that generated by the coil sections in said magnetically reversible member, and a movable armature controlled by said magnetically reversible member.

3. A thermal relay including an energizing coil, an armature magnetized by, and movable relatively to, the coil, and a magnetically reversible member supported by, and electrically connected to, said coil in parallel-circuit relation therewith for controlling the position of the armature.

4. A thermal relay including a movable magnetic armature, a magnetically reversible member for controlling the position of the armature, and an energizing coil having integral portions for directly supporting the magnetically reversible member and connecting it in shunt-circuit relation to the coil, said coil embodying a portion of higher resistance between said supporting portions.

5. A relay including a movable armature and an energizing coil therefor, said coil having terminal portions and an intermediate portion which is alternately oppositely slotted to provide a current path of higher electrical resistance than the terminal portions.

6. A relay including a movable armature and an energizing coil therefor, said coil having terminal portions and an intermediate portion which is alternately oppositely slotted to provide a circuitous path of relatively high resistance.

7. A thermal relay including a movable armature, an energizing coil therefor, said coil consisting of shaped sheet metal bent to form a loop embodying terminal portions, lugs adjacent the terminal portions and an intermediate resistor portion, and means supported by the lugs for controlling the position of the armature.

8. A thermal relay including a movable armature, an energizing coil therefor having terminal portions of relatively low electrical resistance, lugs adjacent to the terminal portions and a resistor portion of relatively high electrical resistance between the terminal portions, and a magnetically reversible member electrically connected to, and supported by, the lugs and controlling the position of the armature.

9. A thermal relay including an energizing coil comprising a source of magnetomotive force, a movable armature, and a frame structure cooperating with the movable armature to provide a magnetic circuit for the flux and including a main reluctance portion magnetized by said coil, and two parallel-related reluctance portions in series magnetic circuit with the main reluctance portion, one of the two parallel-related portions including a magnetically reversible member controlling the position of the armature by the variation of its magnetic permeability.

10. In a thermal relay having an energizing coil, a flux-carrying structure magnetized by said coil and including fixed and movable members providing parallel-related magnetic circuit portions, and a main magnetic circuit portion in series relation to the parallel-related portions, one of the parallel-related magnetic-circuit portions having a thermally-variable magnetic characteristic and controlling the position of the movable member, a part of the main magnetic circuit portion having a relatively high magnetic reluctance to increase the sensitivity of operation of the relay.

11. A thermal relay including a movable armature, a member having a thermally variable magnetic characteristic controlling the position of the armature, and means including a pair of open-turn coil sections each secured at one end to the thermally variable member and supported at the other end, for establishing a predetermined temperature gradient in the thermally variable member.

12. In a thermal relay including a movable armature, a magnetic circuit structure for controlling the position of the movable armature and including a main gap and a pull-in gap in series relation, a hold-out magnetic circuit portion shunting the pull-in gap and having normally a relatively low magnetic reluctance to substantially short circuit the pull-in gap and hold the armature in a predetermined position.

13. In a thermal relay having an energizing coil traversed by a varying current, and a movable armature, a magnetic circuit structure for controlling the position of the movable armature and including a main gap and a pull-in gap in series relation and a hold-out magnetic circuit portion shunting the pull-in gap and having a relatively low magnetic reluctance at less than a predetermined current value in the coil to substantially short circuit the pull-in gap and normally hold the armature in a predetermined position.

14. In a thermal relay having an energizing coil traversed by a varying current, and a movable armature, a magnetic circuit structure for controlling the position of the movable armature and including a main gap and a pull-in gap in series relation and a hold-out magnetic circuit portion shunting the pull-in gap and including a member in electric circuit with the coil and having a thermally variable magnetic characteristic normally having a relatively low magnetic reluctance to substantially short circuit the pull-in gap and hold the armature in a predetermined position at less than a predetermined current value.

15. In a thermal relay having an energizing coil traversed by a varying current, and a movable armature, a magnetic circuit structure for controlling the position of the movable armature and including a main gap and a pull-in gap in series relation and a hold-out magnetic circuit portion shunting the pull-in gap and including a member in electric circuit with the coil and having a thermally variable magnetic characteristic normally having a relatively low magnetic reluctance to substantially short circuit the pull-in gap and hold the armature in a predetermined position at less than a predetermined current value, the reluctance of the member having the thermally variable magnetic characteristic increasing greatly at current values in the coil above said predetermined value to thereby cause energization of the pull-in gap and effect movement of the armature.

16. In a thermal relay having a variable-current-traversed coil and a movable armature, a magnetic circuit structure for the flux generated by the coil including a main gap having a predetermined reluctance and a pull-in gap having a greater reluctance than the main gap in series relation therewith, and a hold-out magnetic portion short circuiting the pull-in gap

and having normally a relatively low magnetic reluctance which increases with increase of temperature of the portion whereby the short circuit across the pull-in gap is substantially removed at a predetermined temperature of said hold-out portion thereby energizing the pull-in gap and effecting movement of the armature.

17. In a thermal relay having an energizing coil, a movable armature energized by the coil, and a frame structure cooperating with the armature to provide a flux path traversed by the main flux produced by said coil, and two parallel-related flux paths in series circuit with the path traversed by the main flux, one of said parallel-related flux paths comprising means for effecting movement of the armature with a time delay on moderate overloads in the coil and for effecting instantaneous movement of the armature on excessive overloads in the coil.

18. In a thermal relay having an energizing coil, a movable armature energized by the coil, and a frame structure cooperating with the armature to provide a flux path traversed by the main flux produced by said coil, and two parallel-related flux paths in series circuit with the path traversed by the main flux, one of said parallel-related flux paths comprising means for effecting movement of the armature by electro-thermal action of said means when the coil is traversed by a current representing a moderate overload and by electro-magnetic action of said means when the coil is traversed by a current representing an excessive overload.

19. In a thermal relay having an energizing coil, a movable armature energized by the coil, means for normally biasing said armature to open position, and a frame structure cooperating with the armature to provide a flux path traversed by the main flux produced by said coil, and two parallel-related flux paths in series circuit with the path traversed by the main flux, one of said parallel-related flux paths comprising means for normally magnetically short-circuiting the other parallel-related path to hold the armature in its initial position and for removing said short circuit to effect movement of the amature on overload currents in the coil, said other parallel-related path operating to produce a pull-in force on the movable armature.

20. In a thermal relay having an energizing coil, a movable armature energized by the coil, means for normally biasing said armature to open position, and a frame structure cooperating with the armature to provide a high reluctance flux path traversed by the main flux produced by said coil, and two parallel-related flux paths in series circuit with the path traversed by the main flux, one of said parallel-related flux paths comprising means for normally magnetically short circuiting the other parallel-related path to hold the armature in its initial position and for removing said short circuit with a time delay on moderate overloads in the coil and instantaneously on excessive overloads in the coil to effect movement of the armature, said other parallel-related path operating to produce a pull-in force on the movable armature and also having a high reluctance.

21. In a thermal relay having a movable armature and a member having a thermally variable magnetic characteristic for controlling the position of the armature and effective to cause movement of the armature upon a predetermined temperature rise of the member, and means for effecting a substantially instantaneous reset of the switch including a pair of open-turn energizing coils directly connected to and supporting the member to assist in dissipating heat therefrom.

22. In a thermal relay having a movable armature and a member having a thermally variable magnetic characteristic for controlling the position of the armature and effective to cause movement of the armature upon a predetermined temperature rise of the member, and means for effecting a substantially instantaneous cooling of said armature-controlling member including an energizing coil directly connected to, and supporting, said armature-controlling member.

23. In a thermal relay having a movable armature and a member having a thermally variable magnetic characteristic for controlling the position of the armature and effective to cause movement of the armature upon a predetermined temperature rise of the member, means for effecting a substantially instantaneous cooling of said armature-controlling member including an energizing coil directly connected to, and supporting, said armature-controlling member, and additional supporting means for the armature-controlling member, said additional supporting means having a relatively large area of heat radiating surface.

24. A thermal relay including a source of magnetomotive force, a movable armature energized thereby and means for controlling the position of the armature, including a heated magnetically reversible bar having a temperature gradient in only one direction thereof and means including a magnetic member adjacent to the low temperature end of the bar for directing the flux in the magnetically reversible bar to the low-temperature part thereof.

25. A thermal relay including an energizing coil comprising a source of magnetomotive force, a flux-carrying structure having a fixed portion and a movable portion carrying substantially all of the flux produced by said coil, and two parallel-related flux-carrying portions in series circuit with fixed and movable portions, one of said parallel-related portions including an air gap of relatively large area of cross section and the second parallel-related portion including a variable-reluctance element.

26. A thermal relay comprising a magnet having a pull-in pole-piece and a hold-out pole-piece, a current-heated, thermally responsive, magnetically variable, magnetizable element longitudinally disposed in magnetic series relation to the flux in said hold-out pole-piece, said element being of a material which loses its magnetic quality at a predetermined temperature, and a movable armature associated with said magnet and subject to the opposing attractions of said pole-pieces, being normally attracted by said hold-out pole-piece.

27. The invention as defined in claim 26, characterized by said pull-in and hold-out pole-pieces being of the same polarity, whereby the magnetic flux-paths thereof are in parallel-circuit relation.

28. A thermal relay comprising a current-energized electromagnet having a pull-in pole-piece, a movable armature associated with said magnet and subject to the attraction of said pull-in pole-piece, and means for normally holding the armature away from said pull-in pole-piece so as to be separated therefrom by an air-

gap, characterized by a magnetic path shunting said air-gap and comprising a current-heated, thermally responsive, magnetically variable, magnetizable element which substantially loses its magnetizable quality at a predetermined temperature, said magnetic shunting path also including a portion which becomes substantially saturated on extremely large flux densities corresponding to extremely large overcurrents.

29. A thermal relay comprising a current-energized electromagnet having a pull-in pole-piece and a hold-out pole-piece, a current-heated, thermally responsive, magnetically variable, magnetizable element being in magnetic series relation to the flux in said hold-out pole-piece, said element being of a material which loses its magnetic quality at a predetermined temperature, a magnetic-path-section being also in magnetic series circuit relation to the flux in said hold-out pole-piece and having the property of becoming first substantially saturated on extremely large flux densities corresponding to extremely large overcurrents, and a movable armature associated with said magnet and subject to the opposing attractions of said pole-pieces, being normally attracted by said hold-out pole-piece.

30. The invention as defined in claim 29, characterized by said pull-in and hold-out pole-pieces being of the same polarity, whereby the magnetic flux-paths thereof are in parallel-circuit relation.

31. A relay comprising a magnet having a pull-in pole-piece and a hold-out pole-piece, and a movable armature associated with said magnet and subject to the opposing attractions of said pole-pieces, being normally attracted by said hold-out pole-piece, characterized by a saturable magnetizable member in magnetic series relation to the flux in said hold-out pole-piece, and means responsive to the relay current for bringing about a saturated condition in said magnetizable member on excessive overloads.

32. The invention as defined in claim 31, characterized by said pull-in and hold-out pole-pieces being of the same polarity, whereby the magnetic flux-paths thereof are in parallel-circuit relation.

33. A relay comprising a magnet having a pull-in pole-piece and a hold-out pole-piece, and a movable armature associated with said magnet and subject to the opposing attractions of said pole-pieces, being normally attracted by said hold-out pole-piece, characterized by a saturable magnetizable member in magnetic series relation to the flux in said hold-out pole-piece, and means for causing a current to traverse said magnetizable member, in response to said relay current, for bringing about a saturated condition in said magnetizable member on excessive overloads.

34. The invention as defined in claim 33, characterized by said pull-in and hold-out pole-pieces being of the same polarity, whereby the magnetic flux-paths thereof are in parallel-circuit relation.

35. A relay comprising a current-responsive electromagnet having a pull-in pole-piece and a hold-out pole-piece, and a movable armature associated with said magnet and subject to the opposing attractions of said pole-pieces, being normally attracted by said hold-out pole-piece, characterized by a saturable magnetizable member in magnetic series relation to the flux in said hold-out pole-piece, said magnetizable member being included in the coil of said electromagnet, whereby the current traversing the same assists in effecting a saturated condition therein on excessive overloads.

36. The invention as defined in claim 35, characterized by said pull-in and hold-out pole-pieces being of the same polarity, whereby the magnetic flux-paths thereof are in parallel-circuit relation.

37. In a thermal relay having an energizing coil, a movable armature energized by the coil, means for normally biasing said armature to open position, and a frame structure cooperating with the armature to provide a high-reluctance flux path traversed by the main flux produced by said coil, and two parallel-related flux paths in series circuit with the path traversed by the main flux, one of said parallel-related flux paths comprising means for normally magnetically short-circuiting the other parallel-related path to hold the armature in its initial position and for removing said short circuit to effect movement of the armature on overload currents in the coil, said other parallel-related path operating to produce a pull-in force on the movable armature and also having a high reluctance.

38. A relay comprising a source of magnetomotive force, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap of relatively high reluctance, and means for normally biasing said armature to open position, characterized by said magnetic flux structure comprising a main flux path of relatively high reluctance, and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap of relatively high reluctance, and the other of said parallel-related flux paths comprising a variable-reluctance means which is normally of relatively low reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, and means for, at times, changing said variable-reluctance means so as to cause it to have a relatively high reluctance.

39. A relay comprising a source of magnetomotive force, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap of relatively high reluctance, and means for normally biasing said armature to open position, characterized by said magnetic flux structure comprising a main flux path of relatively high reluctance, and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap of relatively high reluctance higher than said main flux path, and the other of said parallel-related flux paths comprising a variable-reluctance means which is normally of relatively low reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, and means for, at times, changing said variable-reluctance means so as to cause it to have a relatively high reluctance higher than said parallel-related pull-in flux path.

40. A relay comprising a current-responsive energizing coil, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap of relatively high reluctance, and means for normally biasing said

armature to open position, characterized by said magnetic flux structure comprising a main flux path of relatively high reluctance and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap of relatively high reluctance, and the other of said parallel-related flux paths comprising a variable-reluctance means which is normally of relatively low-reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, and means for, at times, changing said variable-reluctance means so as to cause it to have a relatively high reluctance.

41. A relay comprising a current-responsive energizing coil, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap of relatively high reluctance, and means for normally biasing said armature to open position, characterized by said magnetic flux structure comprising a main flux path of relatively high reluctance, and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap of relatively high reluctance higher than said main flux path, and the other of said parallel-related flux paths comprising a variable-reluctance means which is normally of relatively low reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, and means for, at times, changing said variable-reluctance means so as to cause it to have a relatively high reluctance higher than said parallel-related pull-in flux path.

42. A relay comprising a current-responsive energizing coil, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap, and means for normally biasing said armature to open position, characterized by said magnetic flux structure comprising a main flux path and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap, and the other of said parallel-related flux paths comprising a variable-reluctance means which is normally of relatively low reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, said variable reluctance means comprising a thermally responsive magnetically reversible element and a saturable element in series, and current-responsive means for heating said magnetically reversible element, whereby, on moderate overloads, the thermally responsive element will remove the short-circuit on the pull-in flux path so as to effect movement of the armature after a time delay, whereas, on excessive overloads, the saturable element will remove the short-circuit on the pull-in flux path so as to effect substantially instantaneous movement of the armature.

43. A relay comprising a current-responsive energizing coil, a magnetic flux structure energized thereby and including a field member and a movable armature normally separated from the field member by a pull-in gap, and means for normally biasing said armature to open position, characterized by said magnetic flux structure comprising a main flux path and two parallel-related flux paths in series with said main flux path, one of said parallel-related flux paths including said pull-in gap, and the other of said parallel-related flux paths comprising a variable reluctance means which is normally of relatively low reluctance, so as to magnetically short-circuit said parallel-related pull-in flux path, said variable reluctance means comprising a saturable and thermally responsive magnetically reversible element in electrical circuit relation to said coil.

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