May 28, 1957 FRITZ-HENNING BAADER ET AL 2,794,100

THERMAL RELAY

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FIG. 1

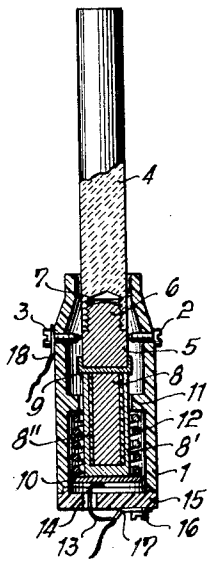


FIG. 2

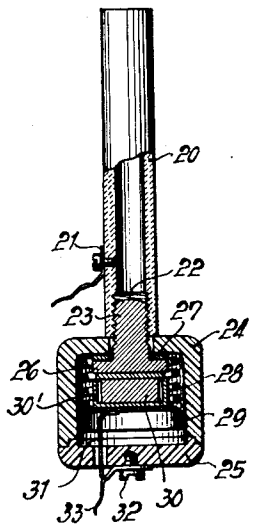


FIG. 3

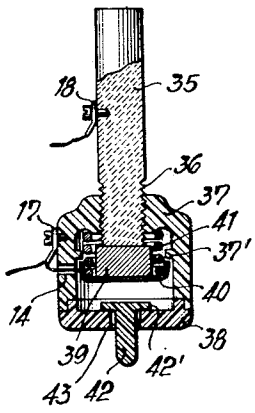


FIG. 4

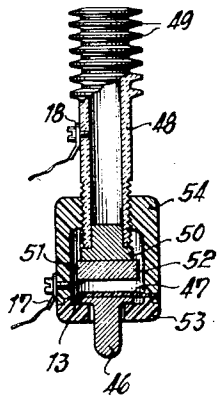
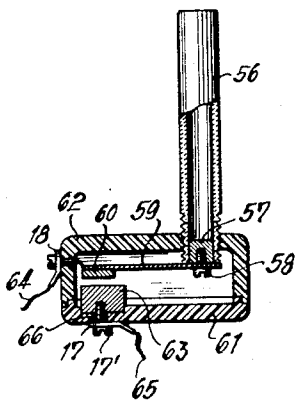


FIG. 5



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FIG. 6

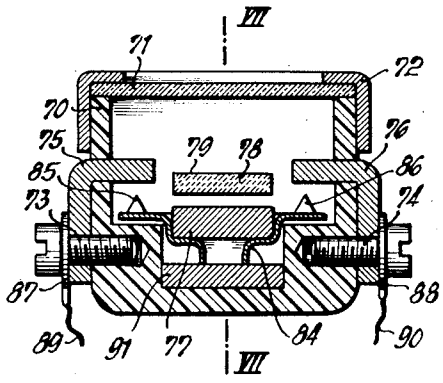


FIG. 7

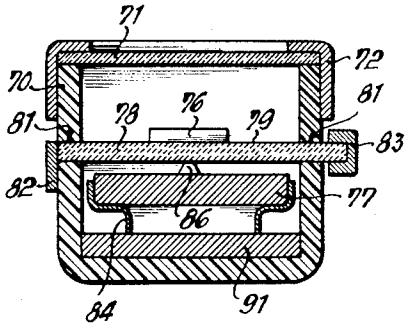


FIG. 8

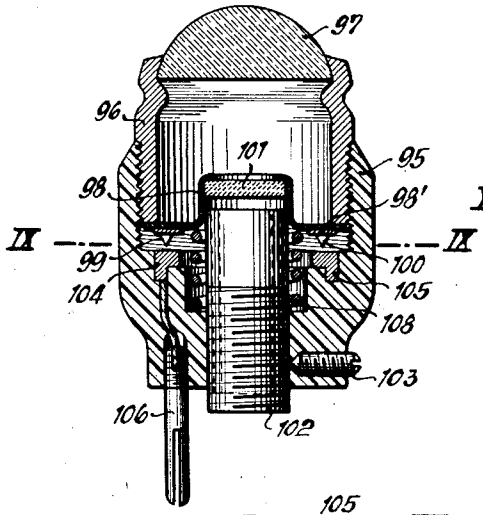


FIG. 10

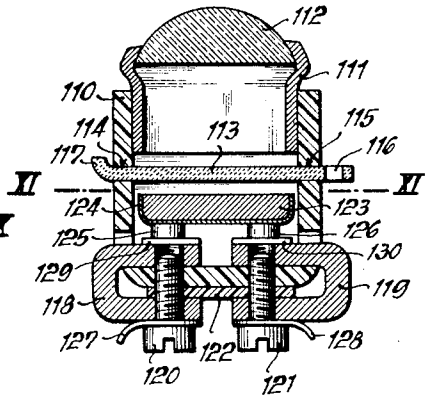


FIG. 9

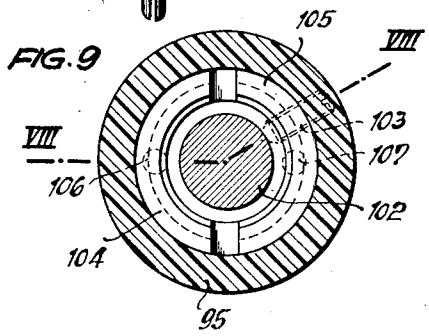
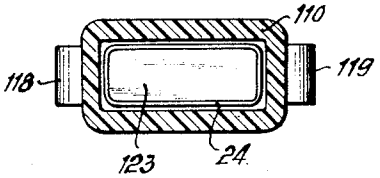


FIG. 11



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FIG. 12

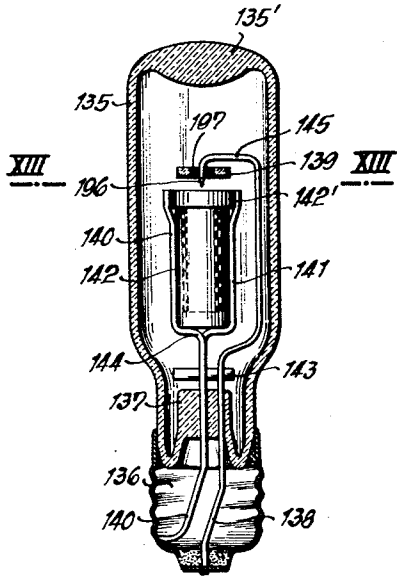


FIG. 13

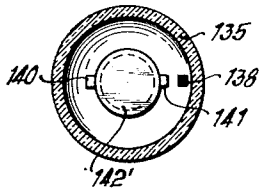


FIG. 14

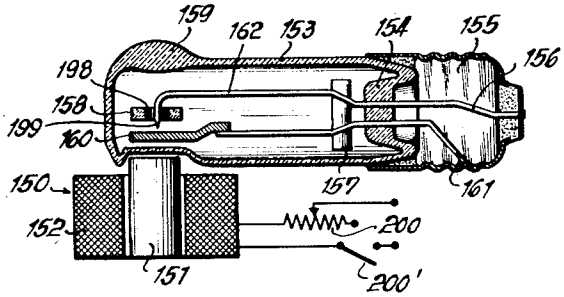
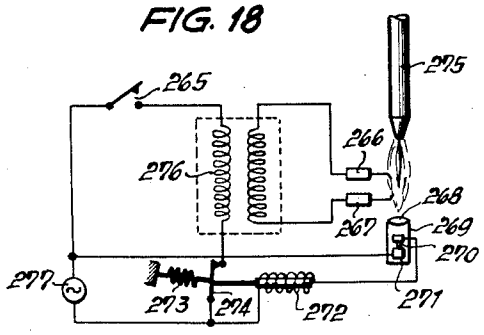


FIG. 18



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FIG. 15

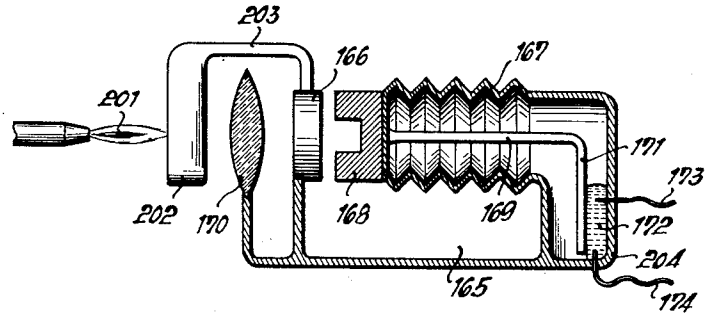


FIG. 16

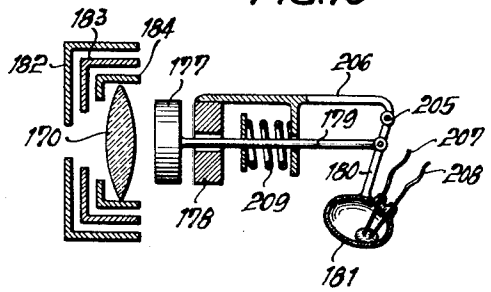
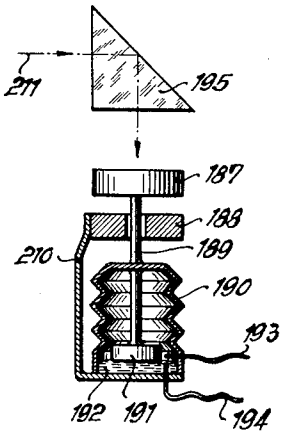


FIG. 17



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2,794,100

THERMAL RELAY

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Application December 6, 1955, Serial No. 551,402

Claims priority, application Germany August 16, 1955

19 Claims. (Cl. 200—136)

This invention relates to a thermal relay of the type adapted to perform certain control functions as a result of changes of temperature, and has special reference to a device adapted to act as a switch in an electric circuit closing the circuit at a predetermined controlling temperature and opening the circuit at another predetermined controlling temperature.

Hitherto, various thermal relays are known, such as relays operating with bimetallic strips and switches operated by vapor under pressure.

The bimetallic switches in general include a bimetallic strip bent in the form of a spiral or of any other curve whose curvature changes as a result of heating so that the change of temperature is transformed into a motion releasing the switching operation. Such bimetallic switches, however, occupy a relatively large space and are slow in operation, whereby a long reaction time is resulting. Moreover, owing to the slow and "creeping" movement of the operative parts, additional devices are required for achieving a prompt contact making and contact breaking action. Furthermore, these switches after an extended service and in case of overheating show fatigue of material and structural changes owing to thermal influences, so that the response temperature of the switch is changed in an uncontrollable way.

The mercury switches in which the switching operation is effected by a mercury column expanding under action of heat, are extremely bulky, sensitive to vibrations and expensive. The switches operating by vapor pressure cause great sealing difficulties, are extremely sensitive to vibrations and cannot be used for technical purposes, more particularly in devices exposed to intensive vibrations.

It is an object of the present invention to provide a thermal relay avoiding these difficulties and drawbacks, being of very small size, requiring low manufacturing and operating costs and ensuring a reliable and permanent operation even after a long time of service.

A special object of the invention is to provide a thermal switch which is not sensitive to vibration and has a very short reaction time, making and breaking contact by a snap action and avoiding a creeping contact.

Still another object of the invention is to provide a thermal relay of the type referred to which can be easily adjusted, preferably by remote control, as to its response at different temperatures and as to its reaction time.

A still further object of the invention is to provide a thermal relay which can be fitted and interchanged by a simple manipulation.

With these and further objects in view, our novel thermal relay or switch comprises a magnet and an armature in the form of a control element which is movable in relation to the magnet and includes a material whose permeability is subject to considerable variations in dependence upon the variations of the controlling temperature to which the thermomagnetic material is exposed—such a material hereinafter being referred to as a "thermomagnetic material" for the sake of brevity—whereby the control element is moved in relation to the magnet in dependence upon said variations of the temperature and of the variable magnetic forces thereby exerted upon it, thereby releasing any desired controlling function and, more particularly, closing or opening an electric circuit between two or more contact members.

It is preferred to use in a relay of this kind a ferromagnetic element having a very small mass in such a way that the mass forces produced by vibrations or shocks are very small and that the ferromagnetic element follows very quickly any changes of the controlling temperature.

It will be understood that owing to the characteristic of magnetic attraction, varying with the square of the distance between the two magnetic parts attracting each other, both the contact making and the contact breaking action take place very quickly, i. e. if the two parts have reached a certain distance from each other, a very small increase of the magnetic attraction causing a slight reduction of the distance between the two parts will be sufficient to cause an instant relative motion of the two parts towards each other into the contact making position, and again, once the magnetic attraction after establishment of the contact making position falls below a certain critical amount, permitting a slight increase of the distance between the two parts attracting each other, the movable part will fall off entirely, thereby instantly interrupting the circuit, under action of a return force opposed to the magnetic attraction. This characteristic, of course, is highly advantageous for making and breaking electrical contact in such a way that arcing and oxydation phenomenons are safely avoided.

In order that the thermomagnetic material need not be exposed to the direct action of the controlling temperature, the control element is preferably provided with a thermal detector. Either the magnet or the ferromagnetic control element may be the movable part of the relay system. In the second case the control element is attracted by the magnet in cold condition and springs off automatically, for instance under action of the pressure of a spring, if the temperature and the permeability of the ferromagnetic material is changed in a predetermined manner, while in the first case the magnet is moved, under action of a spring or of another magnet, in relation to a stationary control element. In some instances, the weight of the control element or of the magnet may be sufficient to act as a counterforce to the magnetic attraction between the two parts. Where a magnet is used as a source of force for releasing the motion between the magnet and the control element effecting the switching operation, advantageously an intermediate layer of low magnetic conductivity is provided between the first and the second magnet so as to permit removal of the second magnet from the first magnet when the first magnet and the control element again attract each other. This intermediate layer of low magnetic conductivity may take the form of a spring causing, or at least assisting in, the removal of the first magnet from the second magnet. In some instances the intermediate layer may consist of a material of high electric conductivity thus forming one of the switch contacts. The magnet may take the form of a pot-shaped magnet whose outer pot formation may simultaneously accommodate the spring and serve for guiding the magnet in the switch casing. Also, the spring in the form of a helical spring may itself form the outer return path of the pot-shaped magnet.

Our novel switch can be easily adapted to the actual requirements by adjustment of the control element and/or of the magnet in such a way that the distance between the control element and the magnet is changed. By way of alternative, or in addition thereto, the spring tension may be variable, for instance by inserting the

spring between the temperature detector, which is connected with the control element, and the magnet and arranging the temperature detector so as to be adjustable in the casing, for instance by a threadable engagement therein. According to another modification, the temperature detector may be connected with the control element through a springy connecting member of high thermal conductivity. The temperature detector may be of tubular shape and provided with cooling ribs or the like permitting quick response to temperature changes.

In the above described embodiments at least the temperature detector of the thermal relay must be exposed to the temperature. If the temperature is produced by hot gases, for instance by the hot exhaust gases of a heating device to be controlled by the thermal relay, the danger exists that the temperature detector or the entire thermal relay are sooted. Since soot is a very poor heat conductor, the reliability and more particularly the accuracy of response of the thermal relay may be deteriorated considerably by such depositions of soot. Therefore, where an intensive formation of soot is to be expected, according to a further feature of the invention the control element may be exposed to the heat action indirectly, i. e. preferably in such a way that at least partly radiant heat acts upon the thermomagnetic material of the control element. It is particularly advantageous to concentrate this heat radiation to the control element by a condenser lens or a concave reflector. In some instances it may be advantageous to mount the control element in such a way that it is not directly hit by the radiant heat of the controlling, for instance glowing, body or gas. In this case a deflection device, for instance a prism, mirror or the like is provided by which the heat radiation is deflected to the control element. If desired, the control element may be provided with a lug or the like projecting into the path of the rays of the thermal radiation and being adapted in such a way that the transmission of heat from the radiant body to the control element takes place partly by radiation and partly by conduction, and possibly by convection, of heat.

A diaphragm may be provided in front of the control element in order to adjust the amount of controlling heat transmitted to the control element in the unit of time, for varying the sensitivity and the accuracy of control. This diaphragm may be adjustable, or a plurality of diaphragms of different aperture may be selectively attachable to the device. In most instances and especially where the thermal relay is to be exposed to rough operating conditions such as those occurring in a heating device, it will not be advisable to provide an iris diaphragm which is adjustable as to its aperture, but in such cases a plurality of diaphragm elements of different aperture will be provided which can be telescoped upon each other or interchanged against each other in such a way that the desirable aperture can be obtained by removing or interchanging various diaphragm elements.

Since in this modification of our novel thermal relay the same is exposed to the heating effect directly, it is possible in certain cases to use mercury switches controlled by our novel thermal relay. For instance the control element or the magnet may be put on a bellows having in its interior a rigid element permitting to raise or lower the mercury level in such a way that the contacts projecting into the mercury chamber in case of a rising mercury level are bridged by the mercury or in case of a falling mercury level are separated from each other. It is also possible to use the motion of the control element or of the magnet purely mechanically by providing a corresponding lever gear which for instance in its turn operates a mechanical switch or a mercury inclination switch.

It will thus be understood that it is possible by our novel control device to produce mechanical movements in dependence upon changes of temperature for causing switching operations in a switch which is arranged separately from the relay device.

A special advantage of our novel device consists in the fact that it occupies very small space and therefore can be accommodated in a small closed casing. Thus, for instance, all elements of the thermal relay may be fitted in a bulb of glass or of a suitable synthetic material which may be evacuated or filled with a suitable inert gas, if desired, for preventing a flashover at the contact points. In this arrangement it is possible to provide a thickened portion of the glass body of the bulb in the form of a lens situated in the path of the rays impinging upon the control element, in such a way that a concentration of the thermal radiation acting upon this element is achieved. A further diminution of the arrangement can be achieved by accommodating only the two contact elements within the bulb while a magnet, and preferably an electromagnet is arranged outside thereof in a corresponding connection.

Other and further objects, features and advantages of the invention will be pointed out hereinafter and appear in the appended claims forming part of the application.

In the accompanying drawings some now preferred embodiments of the invention are shown by way of illustration and not by way of limitation.

Fig. 1 is an axial section of a relay embodying the invention, provided with a pot-shaped magnet and a return spring,

Fig. 2 is a similar section showing a modification with a flat pot-shaped magnet.

Fig. 3 is an axial section of a modification provided with a simple magnet and a spring and adapted especially as a simple circuit closer or as a circuit breaker,

Fig. 4 is an axial section of a relay similar to Fig. 3 but being provided with a magnet in place of a spring for producing a return force,

Fig. 5 is an axial section of a modification in which the control element is connected to the temperature detector through a heat-conducting leaf spring,

Fig. 6 is an axial section showing a modification in which the control element is exposed to radiant heat, the magnet being the movable part,

Fig. 7 is a section on line VII—VII of Fig. 6,

Fig. 8 is an axial section substantially on line VIII—VIII of Fig. 9 showing an embodiment with a lens and a movable control element,

Fig. 9 is a section on line IX—IX of Fig. 8,

Fig. 10 is an axial section of a modification with movable magnet,

Fig. 11 is a section on line XI—XI of Fig. 10,

Fig. 12 is an axial section of an embodiment in which the relay is accommodated in a glass bulb provided with a screw base,

Fig. 13 is a section on line XIII—XIII of Fig. 12,

Fig. 14 is an axial section of a modification in which an electromagnet is arranged outside of the bulb enclosing the control element and the contacts,

Figs. 15, 16, and 17 are diagrammatic axial sections of three different forms of mercury switches operable by thermal relays in accordance with the present invention, and

Fig. 18 is a diagram of connection of a burner control.

Identical reference numerals denote identical parts in the different views.

The relay or switch shown in Fig. 1 comprises a casing 1 in which the temperature detector 4 with a ferromagnetic control element 5 is inserted and secured by means of set screws 2, 3.

The control element 5 is secured in an axial bore of the detector bar 4 by threadable engagement of its screw-threaded end in the bore and consists of a "thermomagnetic" material whose permeability is subject to substantial variations in dependence upon the temperature to which it is exposed, within the controlling range.

Various suitable ferromagnetic materials are available on the market for the various ranges of temperature in question.

It will be understood that the control element 5 in this case is heated through the temperature detector 4 which is directly exposed to the controlling heat. Mounted below the control element 5 is a pot-shaped permanent magnet consisting of a central bar 8 and an outer pot-shaped member 8', the hollow space between the outer shell of the portion 8' and the bar member 8 being filled up by a non-magnetic sleeve 8'' in per se known manner. The upper end of the pot-shaped magnet 8, 8' is covered by a cap 9 which may be secured to the magnet 8 or to the control element 5, by means of its upturned rim, as shown, for preventing the control element 5 from sticking to the magnet. It will be understood that the thickness of the cap 9 must be made very small so as to ensure a reliable magnetic attraction sufficient to establish a good electrical contact where it is intended to pass the electric current directly from the magnet to the control member, through said cap which, of course, must be electrically conductive in this case.

A foot plate 10 is secured to the lower end of the pot member 8', and a helical compression spring 12 is inserted between said foot plate and an inner flange 11 of the casing 1, thus tending to force the movable pot-shaped magnet 8 away from the control element 5. Through a wire 13 extending through a bore 14 in an insulating cover 15 of the casing 1 the foot plate is connected to a terminal 17 secured to the insulating cover 15 by a terminal screw 16. The other terminal 18 is electrically connected to the control element 5 through the screw 3 as shown. It will be understood that the various parts are connected together and insulated from each other in such a way that an electric circuit can be closed and opened in dependence upon the electrical contact between the parts 5, 9, and 8.

The thermal relay shown in Fig. 1 operates as follows:

In a cold condition of the thermal detector 4 and of the control element 5 the ferromagnetic attraction between the ferromagnetic piece 5 and the magnet 8 exceeds the counteracting force of the compression spring 12, so that the electric circuit is closed between the terminals 17 and 18. Now, if the temperature detector 4 is heated to a predetermined critical temperature by action of the controlling temperature upon the detector 4, the control element 5 is heated to said temperature, whereby its permeability is reduced to such an extent that the force of the compression spring becomes larger than the magnetic attraction force between the members 5 and 8, with the result that the magnet 8 is instantly moved to its lower end position and the electric connection between 17 and 18 is interrupted. If the controlling temperature now falls by a certain amount, the permeability of the control element 5 is increased again to such an extent that the magnet 8 is able to overcome the force of the spring 12 and the parts 5, 9, 8 are re-engaged with each other by an instant movement of the magnet 8.

As mentioned above the cap 9 reduces the magnetic adhesion between the magnet and the control member so that the spring can be made weaker and the relay becomes more sensitive. In other words, the control interval becomes smaller without having to reduce the spacing between the control element 5 and the magnet 8. A too small spacing would mean that the relay would be more sensitive against vibrations. By means of the screws 2, 3 the control element 5 can be adjusted in the casing 1 for regulating the reaction temperature of the relay.

By way of example, one of the following thermomagnetic materials may be used:

1. "Thermoflux" type 90/100S of Vacuumschmelze AG., Hanau a.M. having a magnetic flux density, in dependence upon the temperature, at a magnetic field strength of 100 oe. as follows: At 20° C. about 5250 gauss, at 80° C. about 900 gauss, at 110° C. about 0 gauss. The curve of magnetic flux density plotted against field strength is approximately linear between 20° C. and 80° C. Depending upon the force of the spring the separation between the magnet 8 and the control element 5 will take place between 70° C. and 90° C.

2. "Thermoflux" type 65/100G of Vacuumschmelze AG. having a magnetic flux density, in dependence upon the temperature, at a magnetic field strength of 100 oe. as follows: At 20° C. about 3000 gauss, at 70° C. about 0 gauss.

3. "Hyperox" type E1 of Krupp Widiafabrik, Essen—its initial permeability is characterized by a jump from about 2500 to about 100 gauss between 80° C. and 90° C.

4. "Hyperox" type E2 of Krupp Widiafabrik—its initial permeability is characterized by a jump from about 2000 to about 0 gauss between 140° C. and 150° C.

5. "Hyperox" type C2 of Krupp Widiafabrik—its initial permeability is characterized by a jump from about 1400 to about 0 gauss between 180° C. and 185° C.

The construction and operation of the relay shown in Fig. 2 differs from that shown in Fig. 1 inasmuch as the temperature detector 20 in this case is constructed as a tube and one of the terminals 21 corresponding to the terminal 18 in Fig. 1 is attached directly to the detector 20. The tubular form of the detector is intended to reduce the mass which is subject to changes of the temperature, so as to ensure a very prompt reaction to changes of the temperature with a minimum amount of time lag. The lower end of the temperature detector 20 is formed with an internal thread 22 threadably engaged with the screw threaded end 23 of a ferromagnetic control element 26 arranged within a casing 24 whose lower end is closed by a cover 25 of insulating material secured to the casing 24 by an adhesive or by threadable engagement. Interchangeable annular washers 27 of different thickness between the casing 24 and the control element 26 serve to adjust the position of the element 26 in the casing for adjusting the compression force of the compression spring 28 whose upper end bears against the upper end wall of the casing 24, while its lower end bears on a cup shaped member 29 of non-magnetic material secured to the lower face of the pot-shaped outer shell 30' of a magnet 30. Again a layer 9 of non-magnetic but electrically conductive material secured either to the magnet 30 or to the control member 26 serves to separate the two parts 26 and 30 from each other magnetically while permitting electric connection therebetween. The cup-shaped member 29 serves to guide the movable unit 29, 30, 30' in the casing 24 and has soldered to it a length of wire 31 leading through a bore in the insulating cover 25 to a terminal 32, to which a connecting wire 33 is connected.

The operation of the relay shown in Fig. 2 is the same as that of the relay shown in Fig. 1 except that the reaction to changes of temperature is quicker owing to the reduced mass of the hollow thermal detector 20. Moreover, the adjustment of the reaction temperature is facilitated compared to Fig. 1.

Fig. 3 shows a cut-in or cut-out relay of very simple construction. In this case the temperature detector 35 itself consists of a "thermomagnetic" material. The detector 35 can be screwed upwards and downwards in an insulating casing 37 owing to the threadable engagement of its screw threaded lower part 36 with a femal thread in the central bore of the casing 37, for adjustment of the operating temperature. Arranged below the member 35, 36 is a magnet 39 acted upon by a compression spring 41 whose upper end bears against the upper wall of the casing 37 while its lower end bears against a cup-shaped ferromagnetic end plate 40 of the magnet 39. In this case the magnet 39 is not provided with an outer pot member but the cup 40 and the spring 41 consist of a ferromagnetic

material so that the magnetic circuit again is closed by a path of relatively low magnetic resistance. A push button 42 having an upper end flange 42' is movable in a central bore 43 of the insulating cover 38, for the purpose which will be hereinafter described. The relay can be connected to a circuit by a terminal 17 secured to the insulating casing 37 and connected to the magnet 39 by a flexible member and by a terminal 18 secured to the temperature detector.

The relay shown in Fig. 3 operates as follows:

As long as the control element 35, 36 has a temperature below the operating temperature of the relay, the magnetic attraction between the magnet 39 and the control element 35, 36 is sufficient to hold the two parts tightly engaged with each other against action of the compression spring 41. As the operating temperature is reached, the permeability of the member 35, 36 is reduced to such an extent that the spring 41 is able to separate the magnet 39 from its armature 35, 36, whereby the electrical contact established between the terminals 17 and 18 through the members 35, 36, 39 is interrupted. The distance between the lower face of the detector 35, 36 and the magnet 39 in this case is preferably made so large that the magnetic force is insufficient to overcome the force of the spring 41 even after cooling down of the element 35. Therefore, in order to close the circuit after response of the relay, the push button 42 has to be forced into the casing by hand, whereby the magnet 39 is again engaged with the element 35, 36. This type of relay can be used, for instance, where human attendance is required in order to remove the causes by which the temperature of the element 35, 36 had reached its critical value. It will be understood that the push button 42 may be provided with a weak spring tending to hold the push button in its normal position shown in Fig. 3.

If desired the upper end position of the magnet 39 may be defined by an inner collar or flange 37' of the casing 37 cooperating with the cup member 40 so as to form an air gap between the elements 35, 36 and 39 if the detector 35, 36 is readjusted in the casing 37 by the thread 36. It will be understood that in this case a contact spring (not shown) must be provided between the members 35, 36 and 39 in order to bridge the air gap electrically.

In the thermal relay as per Fig. 4 the spring 41 is omitted and instead the push button consists of a ferromagnetic material 46 whose upper face is covered by a plate 47 of an elastic magnetically insulating material. The member 47 is secured to the casing 54 in such a way that the push button 46 is urged into its lower end position as shown in Fig. 4. The magnet 51 is guided in the casing 54 and in a cold condition of the thermomagnetic control member 50 sticks to the same. The heat detector 48 is threaded in the casing 54 and the control member 50 is screwed into the lower end thereof as shown, while the upper end of the tubular detector 48 is formed with ribs 49 facilitating the interchange of heat between the detector and the surrounding medium.

The terminals of the relay are shown at 17 and 18, the former terminal being connected to the magnet 51 by a wire 13 extending through a bore in the casing 54 which again consists of insulating material, the same as its cover 53, or is formed with an insulating sleeve for passage of the wire 14, respectively. The operation of the relay shown in Fig. 4 is the same as described above with reference to Fig. 3, except that the force tending to move the magnet 51 away from its armature 50 in this case is exerted by the ferromagnetic member 46 which simultaneously serves to re-engage the magnet 51 with its armature 50 by pressing the member 46 into the casing 54, like a push button, and is then moved back to its normal position by the spring action of the plate spring 47. If the temperature of the thermal detector 48 and of the control element 50 has not yet decreased below the predetermined operating temperature range, the magnet 51 will fall off again and interrupt the circuit for a second time.

Fig. 5 illustrates a modification in which a plug 57 is screwed into the end of a thermal detector 56 for threadable engagement by a screw 58 serving for fixing to the detector a leaf spring 59 which consists of a material having a high coefficient of thermal conductivity, and carries at its extreme end a control element 60 of a thermomagnetic material. Opposed to the control element 60 is a magnet 63 secured to the lower insulating cover 61 of the casing 62 of the relay. It will be understood that the spring 59 may consist of the same material as the control element 60 provided that the latter has a high coefficient of thermal conductivity. The casing 62 consists of an electrically conductive material and serves for connection of a wire 64, by means of a terminal 18, while the second connecting wire 65 is connected to a terminal 17 which is connected to the magnet 63 by a screw 17' extending through a bore 66 in the cover 61.

The relay shown in Fig. 5 operates as follows:

Normally the control element 60 is attracted by the magnet 63 so that electrical connection is established between the terminals 18 and 17 through the control element 60, the magnet 63 and the screw 17'. If the thermal detector 56 is exposed to a certain critical temperature and transmits this temperature to the control element 60 through the leaf spring 59, the force of the spring will exceed the magnetic force and separate the parts 60 and 63 from each other. If the thermal detector 56 cools down, the armature 60 is attracted again and the circuit is closed.

The screw 58 is arranged in such a way that the thermal detector 56 can be screwed into, and out of, the casing 62 for adjusting the distance between the parts 60 and 63, which determines the operating temperature, while the spring 59 is prevented from taking part in the rotary movement of the detector 56 by engagement with the lateral walls of the rectangular casing 62.

It will be understood that the insertion of a temperature detector between the control element and the source of heat controlling the function of the relay prevents changes of the structure of the thermomagnetic control element due to overheating and corrosion thereof, especially where the relay is to be used in apparatus for processing aggressive liquids or gases. If desired, the parts exposed to corrosive action may be coated with a corrosion-resisting varnish or the like.

Some of the constructional features of the embodiments shown in Figs. 1 to 5 may also be used in other combinations. Thus, for instance, ribs like those shown in Fig. 4 may also be provided on the thermal detectors of Figs. 1, 2, 3 and 5 and the thermal detectors shown in Figs. 1 and 3 may also be provided in tubular form if desired, for reducing the time-lag between changes of the controlling temperature and operation of the relay.

On the other hand, in many instances it is desirable to reduce both, the moving mass and the heated mass to the very minimum for minimizing the influence of vibrations or shocks upon the cell and for obtaining an instant response to changes of the controlling temperature (for instance circuit-closing operation less than 25 seconds after the upper operating temperature has been reached and circuit-breaking operation less than 10 seconds after the lower operating temperature has been reached). In order to meet with this requirement, according to a modification of our thermal relay cell the control element is directly exposed to the controlling temperature, by thermal radiation, so as to be protected against deposition of dust or soot or corrosive attack. Some embodiments of this kind will be hereinafter described.

Referring at first to Figs. 6 and 7 it will be seen that the casing 70 of the cell is closed at its upper side by a window 71 of transparent material secured to the casing 70 by means of a cap 72. The contact members 75 and 76 are secured to the casing 70 of insulating material by means of screws 73 and 74, in such a way that one leg

of each of the L-shaped contact members 75 and 76 projects into the interior of the casing 70 through an aperture provided therein. Moreover a plate or strip 78 of thermomagnetic material extends through the casing and is seated in slots 80 and 81 in the casing, being secured therein after its insertion by a metal sheet 82 at one end and by a clamp 83 attached to the opposite end. Preferably the surface 79 of the strip 78 is blackened in order that the rays impinging through said window are not reflected. The magnet 77 is mounted in a cup-shaped member 84 provided with diametrically arranged contacts 85 and 86. The cell is connected to the circuit to be controlled by lugs 87 and 88 secured to the contact members 75 and 76 by the screws 73 and 74, respectively, and having the connecting wires 89 and 90 soldered to them. A further ferromagnetic plate 91 is secured to the bottom of the casing 70.

The thermal relay cell shown in Figs. 6 and 7 operates as follows:

As long as the plate 78 is cold, the magnet 77 engages the same under action of the magnetic forces between 78 and 77, whereby the contacts 85 and 86 engage the contact members 75 and 76, thus providing an electric connection between the wires 89 and 90 through lugs 87 and 88, contact members 75 and 76, contacts 85 and 86 and cap member 84. When the plate 78 is heated to a predetermined operating temperature, its permeability is reduced to such an extent that the magnetic attraction between the second ferromagnetic plate 91 and the magnet 77 preponderates and the contacts 85, 86 are withdrawn from the contact members 75, 76. As soon as the control member 78 cools down, the magnet 77 is against attracted to it, since the distance between the magnet 77 and the plate 78 is smaller than the distance between the magnet 77 and the second ferromagnetic plate 91.

It is also contemplated, according to a further feature of the invention, to increase the effect of the controlling source of heat upon the ferromagnetic control member by condensing the thermal radiation by lens means. An embodiment of this kind is shown in Fig. 8. In this case a casing 95 is closed at its upper end by a cover or socket 96 holding a lens 97 and being screwed into a female thread of the casing 95. The lower face of the socket 96 serves as a stop or abutment for a pot- or cup-shaped member 98 of insulating material accommodating a ferromagnetic control member 101 in its upper tubular part and having a ring 98' of metallic material secured to its lower face which ring in its turn carries contacts 99, 100 in a diametrical position. The ferromagnetic plate or disc 101 may be secured in the cup 98 by frictional engagement. A pot-shaped magnet 102 projects into the depression of the cup member 98 by an amount which can be adjusted by a set screw 103 and/or by threadable engagement of the magnet 102 in the central bore of the casing 95. The contacts 99 and 100 cooperate with semi-circular annular contact members 104 and 105 which are inserted in the circuit to be controlled by the relay through conductors 106 and 107 taking the form of plugs as shown in the left-hand half of Fig. 8. A compression spring 108 tends to hold the contacts 99, 100 away from the contact rings 104, 105.

The thermal relay cell shown in Fig. 8 operates as follows:

Normally, in its cold condition the control member 101 is in its lower end position, defined by engagement of the contacts 99, 100 with the contact rings 104, 105, so that the circuit is closed between the plugs 106 and 107. If the control member 101 is heated to the operating temperature of the cell, by thermal rays impinging upon the control member 101 through the lens 97, the magnetic attraction is reduced to such an extent that the force of the spring 108 prevails and moves the member 98, 99, 100, 101 to its upper end position in which the contacts 99, 100 are separated from their contact rings 104, 105, whereby the circuit is interrupted. As soon as the control member 101 cools down to the lower operating temperature, it will again be attracted by the magnet 102 against action of the spring 108 and the contact is restablished. The upper and lower operating temperatures of the relay can be adjusted by adjustment of the magnet 102 by means of its thread and the set screw 103.

It will be seen from Fig. 8 that the contacts 99, 100 are arranged in such a way that contact is established before the ferromagnetic control member 101 would be able to engage the magnet 102 so that the separating layer between the control member 101 and the magnet 102 in this case consists of air rather than consisting of a metallic material such as shown in Figs. 1, 2 and 4. This offers the advantage that physical adhesion between the members 101 and 102 is prevented and moreover, that the transfer of heat from the member 101 to the member 102 is prevented which would influence the operating temperatures of the relay in an undesirable and uncontrollable manner. Furthermore, owing to the complete separation between the contact making members 99, 100, 104, 105 and the magnetic members 101, 102, which in this case do not form part of the electric circuit, uncontrollable thermal influences caused for instance by arcing between contact faces is completely avoided. Also it will be understood that the cell shown in Fig. 8 offers the advantage that the moving mass in this case is very small so that the influence of vibrations and shocks to the function of the cell is minimized.

The relay shown in Fig. 8 may have an actual length of about 4 cms. and a diameter of 2.5 cms. The actual size of the control element 101 depends on the desired reaction times, the material, the lens arrangement and the distance of the control element from the source of the rays. In order to attain short reaction times, the volume of the control element 101 in case of the above mentioned material Thermoflux 90/100S should not exceed 150 $mm.^3$. Very good results can be obtained with control elements having a volume of less than 75 $mm.^3$ In case of the material Thermoflux 65/100G the corresponding values would be about 33% higher.

The thermal relay cell shown in Figs. 10 and 11 comprises a casing 110 which is closed by a lens 112 held in a lens socket 111. The plate 113, consisting of a thermomagnetic material is inserted in slots 114, 115 of the casing 110, similarly to the plate 78 in Figs. 6 and 7 and is held therein by a pin (not shown) engaged in the bore 116 and by an upwardly bent portion 117 at its opposite end. U-shaped contact members 118 and 119 are secured on the casing 110 by screws 120, 121 and can be adjusted in the casing by providing one or more spacing members 122 of different thickness between the lower face of casing 110 and the lower legs of the U-shaped members 118, 119, for adjusting different operating temperatures. A magnet 123 is arranged in a cup member 124 of an electrically conductive material having contacts 125 and 126 secured to its lower face and engaging in the lower position of the magnetic 123 contact foils or coatings 129, 130 applied on the upper faces of the contact members 118, 119 and consisting of a material of high electric conductivity. Lugs 127 and 128 screwed to the contact member 118, 119 serve to connect the cell in the circuit to be controlled.

The cell shown in Figs. 10 and 11 operates as follows:

In a cold condition of the plate 113 the magnet 123 is attracted to it and the circuit between the contacts 125 and 126 is thus interrupted. If the plate 113 is heated to the operating temperature of the relay by the thermal radiation impinging upon it through the rectangular lens 112, its permeability is reduced and the magnet 123 drops off into its lower end position whereby the circuit is closed through lug 127, contact member 118, contact foil 129, contact 125, cup member 124, contact 126, contact foil

130, contact member 119 and lug 128. This relay thus operates in a reverse manner of the relays shown in Figs. 1–9, i. e. the circuit is closed as a certain operating temperature is surpassed and opened as the controlling temperature falls below a certain amount. If desired, the entire thermal relay or at least its contacts may be arranged in a chamber which is under vacuum or filled with an inert gas so as to reduce arcing phenomenons and corrosion on the contacts. Two embodiments of such vacuum or gas filled cells are shown in Figs. 12 and 13 or 14, respectively.

In the embodiment shown in Figs. 12 and 13 the complete relay is accommodated in a bulb 135 consisting of glass or of a synthetic material permitting the passage of thermal radiation and being evacuated or filled with an inert gas, said bulb being secured to a screw base 136. A connecting wire 138, 145 leads to the control element 139 and further connecting wires 140, 141 lead to the magnet 142, through the pinched base 137 of the bulb 135, a spacing member 143 serving to align the leads 138, 140, 141 in the proper way. The leads 140, 141 are joined at 144 and enclose the magnet 142 between one another. The lead 138, 145 bears at its free end a control element 139 of a thermomagnetic material, said element 139 being arranged in such a way that the thermal radiation impinging through the lens-shaped thickened portion 135' impinges directly upon the control element 139. The lead 138 is elastical in its upper part 145 in such a way that it tends to remove the control element 139 from the magnet 142.

The magnetic member 139 is secured to a contact pin 196 fixed to the end of the elastic part 145 of the lead 138, by means of a sleeve 197 of a material of low thermal conductivity inserted between the pin and the disc 139 so as to prevent the latter from being heated up by the contact pin in case of any arcing between the contact pin 196 and the upper contact surface of the magnet 142.

The cell shown in Figs. 12 and 13 operates as follows:

As long as the armature 139 is at a temperature below the operating temperature of the relay, its contact pin 196 engages the upper contact surface of the pot-shaped magnet 142, thus closing the circuit between the wires 140, 141 and the lead 138, against the spring action of the upper end 145 of the latter. As the radiant heat impinging upon the control member 139 through the condenser lens 144 heats the control member to the operating temperature, its permeability is reduced to such an extent that the elastic counter force of the springy member 145 preponderates and opens the contact. Again with decreasing temperature the armature 139 is re-attracted and the contact is closed again.

Fig. 14 shows a modification permitting a still more compact arrangement of the contact parts. In this case the magnet which in the above described embodiment has been shown in the form of a permanent magnet—although an electromagnet could be used in these embodiments as well—takes the form of an electromagnet 150 having a core 151 and a winding 152 and being arranged outside of the bulb 153 consisting of glass or of a suitable synthetic material and being mounted by means of its squash 154 in a screw base 155 or preferably in a bayonet union (not shown) so as to ensure a definite position of the cell in its socket. A lead 156 passes from the central tip of the base through the squash and a spacing member 157 to a control member 158 of thermomagnetic material which is secured, by means of a sleeve of insulating material 198, on a contact pin 199 formed at the elastic end 162 of the lead 156. A thickened portion 159 of the bulb in the form of a lens serves to condense the thermal radiation on the thermomagnetic material 158. A second lead 161 passes from the threaded metal shell of the screw base 155 through the squash 154 and the spacer 157 to a contact element 160 opposed to the contact pin 199 and being interposed between the armature 158 and the core 151 of the electromagnet which projects into a depressed portion of the bulb 153 so as to reduce the distance between the magnetic core 151 and its armature 158. The plate 160 consists of a material of low magnetic conductivity and high electric conductivity.

The cell shown in Fig. 14 operates in the same manner as that shown in Figs. 12 and 13 and the bulb may be evacuated or filled with a suitable gas. However, it will be understood that the provision of an electromagnet offers considerable advantages compared to a permanent magnet. The control member 158 can be made very small in view of the strong magnetic field of the electromagnet and it is possible to provide a remote adjustment of the operating temperature of the relay by controlling the current passing through the winding 152 and energizing the core 151, as by a variable resistance 200. Furthermore, a remote control can be effected by connecting or disconnecting the winding 152, as by a switch 200'.

In some instances and especially where the relay is held in a well defined horizontal position, it may be advantageous to combine the thermal magnetic control system with a mercury switch ensuring a reliable contact even for the passage of currents of a higher amperage. Three embodiments of this kind are shown in Figs. 15 to 16 and 17.

In the embodiment shown in Fig. 15 a plate 166 of thermomagnetic material is fixedly connected to a frame or casing 165 and exposed to the heat of a flame or other source of heat 201 by thermal radiation through a lens 170 and by thermal conduction from a lug 202 exposed to direct action of the heat of the flame 201 and connected to the control member 166 through a strip 203 of high thermal conductivity. The lug 202 is arranged in such a way that the thermal radiation through the lens 170 is not substantially shielded thereby. Mounted on the end of a bellows 167 is a permanent magnet 168 forming a magnetic circuit together with the armature 166. The mercury level between the end wall 204 of the casing 165 and a movable wall 171 is controlled by a rod 169 connected to the end of the bellows where the magnet 168 is secured to it. Connecting wires 173 and 174 extend into the space occupied by the mercury.

The relay shown in Fig. 15 operates in such a manner that the magnet 168 is attracted to its armature 166 in a cold condition of the latter, against the elastic retracting action of the bellows, whereby the mercury level is lowered to such an extent that the connection between the wires 173 and 174 is interrupted. If the armature 166 is heated to the operating temperature of the relay, by thermal radiation through the lens 170 and thermal conduction through the lugs 202 and the connection 203, the retracting force of the bellows 167 will exceed the magnetic attraction so that the wall 171 is instantly moved into the position as shown and the mercury level is raised in such a way that it reaches the end of the wire 173, thus making contact between the two wires.

In the arrangement shown in Fig. 16 a thermomagnetic control member or armature 177 cooperates with an annular magnet 178, a rod 179 of the armature 177 being jointed to a level 180 pivoted at 205 on a bar 206 carrying the magnet 178 for inclining the casing 181 of a mercury switch and making or breaking the contact between the wires 207 and 208 as shown. Again a condenser lens 170 is arranged in front of the control member 177 and a plurality of diaphragms 182, 183, 184 of different aperture can be put before the lens in order to change the behaviour of the relay in dependence upon the controlling temperature. A spring 209 tends to move the armature 177 away from its magnet 178.

It will be understood that depending on the arrangement of the mercury switch 181 on the lever 180 the circuit between the wires 207 and 208 may be either closed in hot condition of the armature 177 as shown in the figure, or in a cold and attracted condition of the arma-

ture 177, and the response of the relay will be the quicker, the larger the smallest aperture of the diaphragms applied on the lens 170. In this manner the relay can be adapted to the actual requirements in practical operation. If desired, a single adjustable iris diaphragm 184 may be provided in place of a plurality of diaphragms with different apertures.

In the embodiment shown in Fig. 17 a thermomagnetic control member or armature 187 is again movable and cooperates with an annular magnet 188 fixedly secured by a frame 210 above a bellows 190 which is connected to the plate 187 through a rod 189 carrying at its lower end an immersing body 191 by which the level of the mercury 192 can be varied for making and breaking contact between the wires 193 and 194 projecting into the space within the bellows. The thermal radiation 211 arrives in a horizontal direction and is deflected by a prism or mirror 195 into a vertical direction for heating the armature 187. The bellows 190 tends to move the armature 187 away from the magnet 188. It will thus be understood that the mercury will connect the wires 193 and 194 in an attracted position of the armature 187 while the circuit will be interrupted if the permeability of the armature 187 is reduced by thermal radiation, since the elastic force of the bellows 190 in this case will preponderate and move the armature into its upper end position.

Fig. 18 shows a diagram of connection in which our novel thermomagnetic relay is used to control the ignition of a burner. In this case the two electrodes 266 and 267 of an electric ignition device arranged adjacent to the mouth of a burner 275 are connected to the secondary winding of a transformer 276 which is connected to a source of alternating current 277 through a switch 265 and a relay 274 whose energizing winding 272 is connected to the source of current 277 through a thermomagnetic relay 268, 269, 270, 271.

The arrangement shown in Fig. 18 operates as follows:

In cold condition of the thermomagnetic relay 269, the control member 270 thereof is attracted by the permanent magnet 271, in such a way that the contact is closed between 270 and 271 and the winding 272 is energized, whereby the contact arm 274 of the relay is held in its closed position against action of a tension spring 273. Now, the relay 269 may be adjusted in such a way that the heat of the ignition spark between the electrodes 266 and 267, concentrated on the thermomagnetic control element 270 by the lens 268, causes the thermomagnetic relay to open the circuit of the winding 272, whereby the transformer 276 is de-energized and the ignition device is put out of operation. Nevertheless the thermomagnetic relay is held in its open position by the heat of the flame of the burner 275, provided that the ignition has been properly effected. On the other hand, if the ignition has not been accomplished or if the flame goes out for lack of fuel or any other reason, the control member 270 will cool down and close the circuit of the winding 272, which thereby closes the relay 274 and puts the ignition device into operation. The further operation is as mentioned above.

It will be understood that in the same manner the motor of the fuel pump or any other part of the burner system may be connected or disconnected in dependence upon operation of the thermomagnetic relay. If desired, the thermomagnetic relay may be arranged in the manner shown in Figs. 3 and 4, so that manual operation is required to close the relay again after it has been opened. Of course, in this case re-ignition will not take place automatically.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention it will be understood by those skilled in the art after understanding the invention that various changes and modifications may be made without departing from the spirit and scope of the invention and it is intended, therefore, to cover all such changes and modifications in the appended claims.

We claim:

1. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon variations of temperature, means for transmitting the controlling heat to the control element predominantly in the form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

2. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon variations of temperature, means including a lens for transmitting the controlling heat to the control element predominantly in the form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

3. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon variations of temperature, means including a ray deflector for transmitting the predominant part of the controlling heat to the control element in the form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

4. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variation in dependence upon variations of temperature, means for transmitting the greater part of the controlling heat to the control element in the form of radiant heat, a diaphragm of variable aperture arranged in the path of the heat radiation, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

5. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon variations of temperature, means for transmitting the controlling heat to the control element predominantly in the form of radiant heat, a diaphragm

including a plurality of elements of different apertures arranged in the path of the heat radiation, means opposing the magnetic attraction between the magnet and the ferromagentic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperatures of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

6. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon variations of temperature, means for transmitting the predominant part of the controlling heat to the control element in the form of radiant heat, the side of the control element exposed to the radiation being blackened, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, and means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes.

7. A thermal relay, comprising a magnet, an armature for the magnet, said armature consisting of a ferromagnetic material whose permeability is subject to considerable variations in dependence upon variations of the controlling temperature to which the armature is exposed, means for transmitting the controlling heat to said armature predominantly in form of radiant heat, means opposing the magnetic attraction between the magnet and its armature, in such a way that the distance between the magnet and the armature is changed as a result of changes of the temperature of the armature, a liquid switch, and means for controlling said liquid switch in dependence upon said distance changes.

8. A thermal relay as per claim 7, in which the liquid switch is a mercury switch.

9. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon the variations of the controlling temperature to which the ferromagnetic material may be exposed, means for transmitting the controlling heat to said armature predominantly in form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes, and means for enclosing at least said contact members in an evacuated space.

10. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon the variations of the controlling temperature to which the ferromagnetic material may be exposed, means for transmitting the controlling heat to said armature predominantly in form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes, and a glass bulb enclosing at least said contact members.

11. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon the variations of the controlling temperature to which the ferromagnetic material may be exposed, means for transmitting the controlling heat to said armature predominantly in form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes, and a standardized base adapted to be detachably secured in a standardized socket and carrying at least the contact members.

12. A thermal relay, comprising a magnet, a first contact member, a second contact member cooperating therewith, a control element including a ferromagnetic material which is situated in the field of the magnet and has a permeability which is subject to considerable variations in dependence upon the variations of the controlling temperature to which the ferromagnetic material may be exposed, means for transmitting the controlling heat to said armature predominantly in form of radiant heat, means opposing the magnetic attraction between the magnet and the ferromagnetic material, in such a way that the distance between the magnet and the ferromagnetic material is changed as a result of changes of the temperature of the ferromagnetic material, means for making and breaking the electrical contact between the two contact members in dependence upon such distance changes, a standardized base adapted to be detachably secured in a standardized socket, and a bulb tightly sealed on said base by a squash and enclosing at least the contact members.

13. A thermal relay comprising a magnet, an armature opposite said magnet, said armature and said magnet being displaceably mounted with respect to one another, said armature being made of a ferro-magnetic material having a permeability which is subject to considerable variations in dependence upon variations of the controlling temperature to which said armature is exposed, means adapted to transmit the controlling heat to said armature predominantly in form of radiant heat, means tending to separate said armature from said magnet, stationary contact means and contact means movable with respect to and cooperating with said stationary contact means, said stationary and said movable contact means being respectively associated with said magnet and said armature in such a manner that said movable contact means and said stationary contact means are brought to and out of engagement by the mutual displacements of said magnet and said armature caused by the change in the permeability of said armature due to changes in temperature and under control of the magnetic force of said magnet attracting said armature at a lower temperature and of said means separating said armature from said magnet at a higher temperature, when the force of said separating means overcomes said magnetic force.

14. A thermal relay according to claim 13, wherein said armature has a volume of less than 150 cubic millimeter.

15. A thermal relay according to claim 13, wherein a layer of an inferior magnetic conductor between said magnet and said armature separates the latter when said armature attracts said magnet at said lower temperature.

16. A thermal relay according to claim 13, wherein spacer means are provided between said magnet and said armature to prevent a direct engagement of said latter when said magnet attracts said armature.

17. A thermal relay according to claim 16, wherein said spacer means are contact points formed on said contact means.

18. A thermal relay according to claim 13, wherein means are provided to adjust the mutual position of said magnet and said armature.

19. A thermal relay according to claim 13, wherein said armature is stationary and said magnet is displaceable with respect thereto, and wherein said means to separate said armature from said magnet is a ferromagnetic member spacedly mounted at the opposite side of said magnet where said armature is arranged.

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