

Oct. 6, 1953

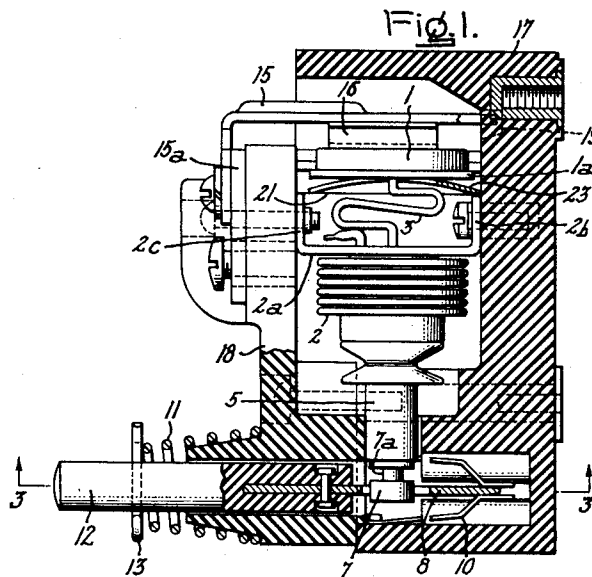
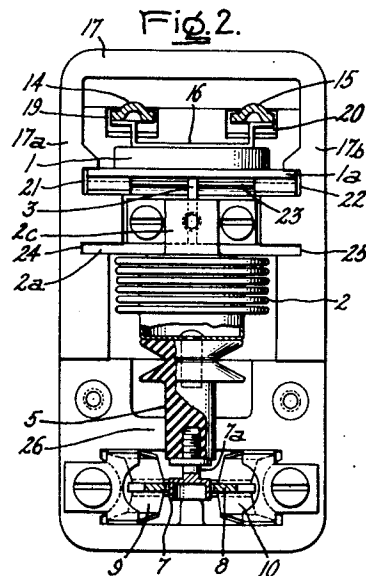
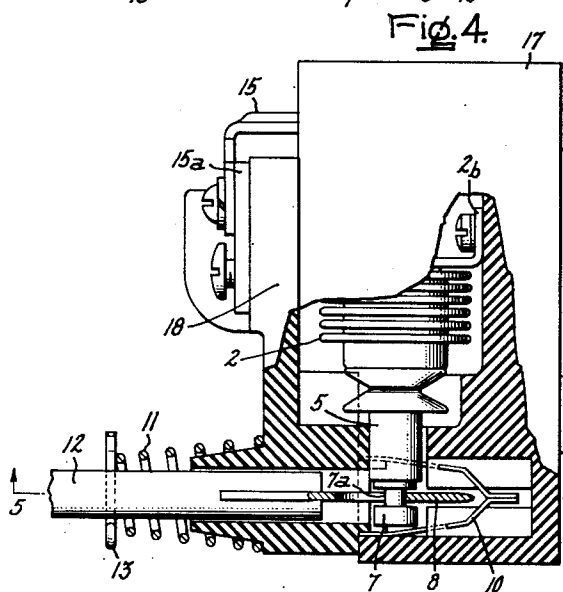
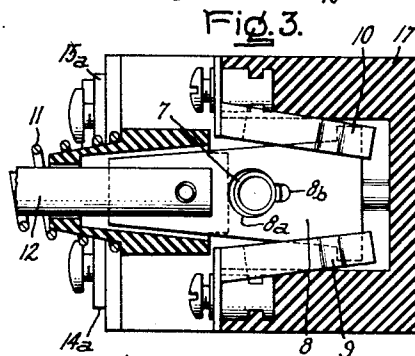
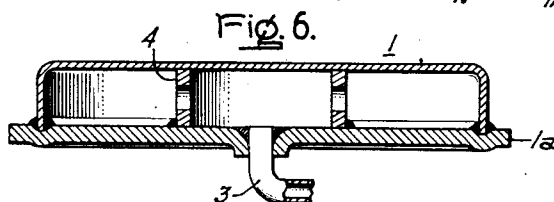
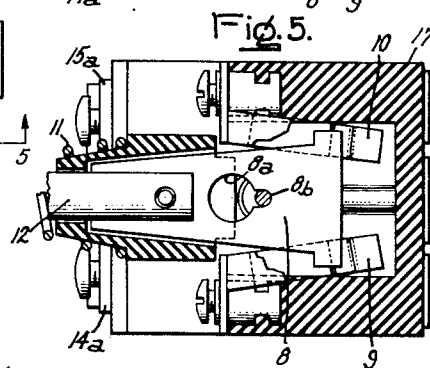
C. I. HALL

2,654,813

OVERLOAD PROTECTIVE RELAY

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2 Sheets-Sheet 1



Inventor:
Chester I. Hall,

by *Clarence T. Miller*
His Attorney.

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2 Sheets-Sheet 2

Fig. 7.

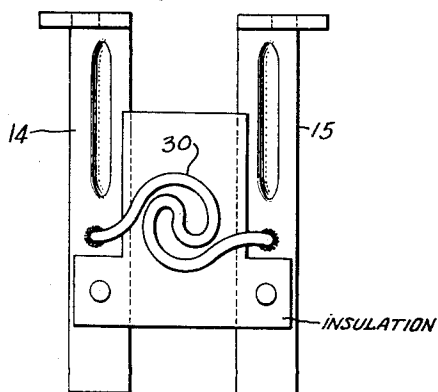
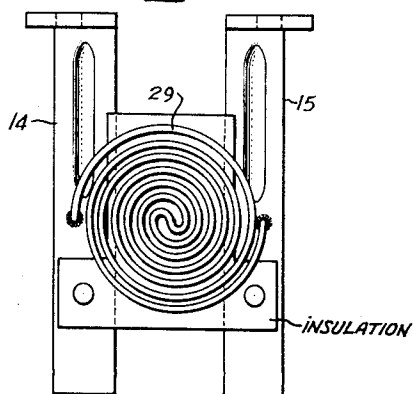
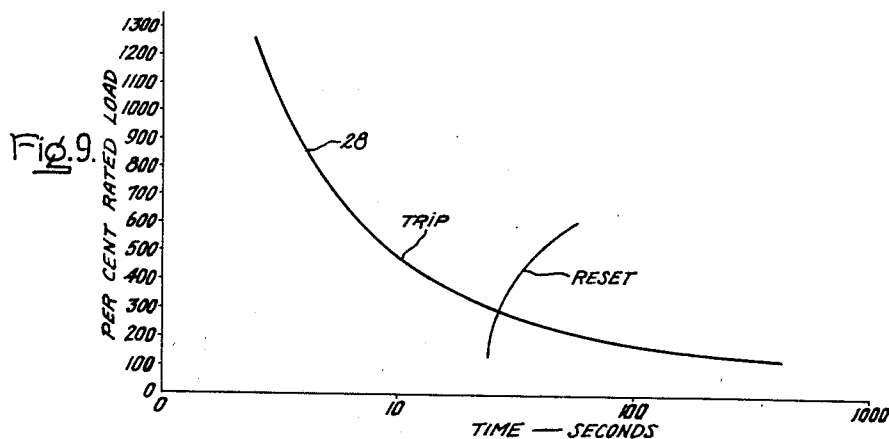
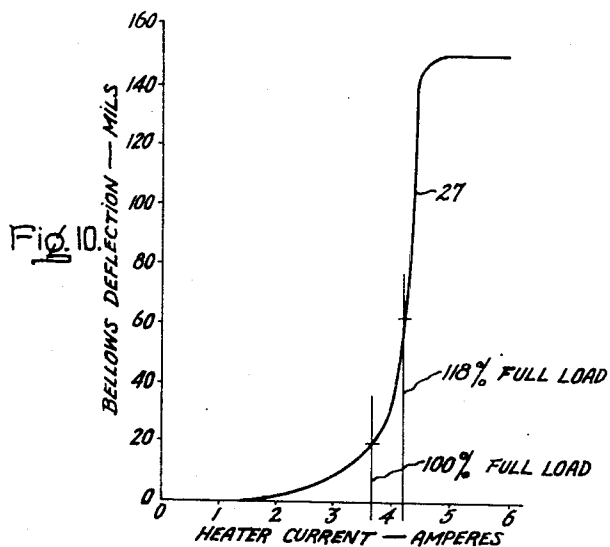


Fig. 8.



Inventor:
Chester I. Hall,

by *Bank H. Mitt*
His Attorney.

UNITED STATES PATENT OFFICE

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OVERLOAD PROTECTIVE RELAY

Chester I. Hall, Vischer's Ferry, N. Y., assignor to
General Electric Company, a corporation of
New York

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7 Claims. (Cl. 200—116)

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This invention relates to overload protective devices for electric circuits, and it has for an object the provision of a simple, reliable, inexpensive and improved device of this character.

More specifically, the invention relates to electric circuit overload protective devices for use in locations in which high shocks may be encountered such, for example, as aboard naval vessels, and a further object of the invention is the provision of a device of this character which is capable of uniform and consistent operations under conditions of high shock.

Another object of the invention is the provision of an overload relay having an inverse squared load time of operation curve at overloads of the order of 1300% to 1500% of normal full load of the protected circuit.

A still further object of the invention is the provision of an overload relay having fail-safe operation, i. e., a failure of the device itself will initiate the same protective operation that is produced in response to an overload.

A still further object of the invention is the provision of an overload protective relay in which substantial changes in the ambient temperature produce relatively small changes in the critical value of the tripping current.

In carrying the invention into effect in one form thereof, a pair of circuit controlling contacts have closed and open operating positions. The contacts are biased to one of these two operating positions by suitable biasing means, and a detent serves to latch them in the other operation position against the force of the biasing means. The contacts are operated by means of a hermetically sealed thermally sensitive unit which comprises a boiler and a metallic bellows in communication therewith. A volatile liquid partially fills the bellows and boiler when the bellows is in the fully compressed condition thus retaining a slight vapor space under all conditions of operation. An electric heating element is energized in response to the load of the protected circuit and supplies heat to the boiler with respect to which it is mounted in heat transfer relationship. The bellows is normally retained in a substantially, but not fully, compressed condition owing to the vacuum produced within the boiler and bellows. In response to overload on the protected circuit, the heater vaporizes a portion of the liquid in the boiler and forces the liquid out of the boiler. The resulting expansion of the bellows moves an operating member to actuate the detent to permit the biasing means to move the contacts to initiate the circuit protective operation. Failure of the device such, for example, as development of a leak in the thermally sensitive unit allows the bellows to expand and move the operating member in the direction in which it moves when an overload

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occurs thereby producing "fail-safe" operation. Substantially shock proof operation is produced as a result of a load versus deflection characteristic of the bellows such that at normal full load of the device which is to be protected e. g. a motor, the amount of deflection is small in comparison with that which takes place in response to a small increase in load above 100% of full load.

For a better and more complete understanding of the invention, reference should now be had to the following specification and the accompanying drawings in which Fig. 1 is a side elevation, partly in section of the protective device with the contacts in the closed position; Fig. 2 is a front elevation with the cover removed; Fig. 3 is an end section taken on the line 3—3 of Fig. 1 looking in the direction of the arrows; Fig. 4 is a side elevation with parts broken away, and with the contacts in the open position; Fig. 5 is an end section taken on the line 5—5 of Fig. 4; Fig. 6 is an enlarged sectional view of the boiler; Figs. 7 and 8 are plan views of heating elements having different ratings; and Figs. 9 and 10 are charts of characteristic curves which facilitate an understanding of the operation of the invention and its advantages.

Referring now to the drawing, the overload protective relay device comprises a thermally sensitive unit which uses the principle of a liquid-vapor system. The thermally sensitive unit is hermetically sealed and comprises a boiler 1 and a metallic bellows 2 which is in fluid communication with the boiler. In the illustrated embodiment the communication between the boiler and the bellows is provided by means of a capillary tube 3.

As shown in Fig. 6, the boiler is flat in general appearance, i. e., its height is small in comparison with its other dimensions. It is illustrated as being cylindrical in form. It is preferably made in two portions comprising the cylindrical portion having an upper closed end and a lower open end, and a supporting plate 1a to which the wall of the open end is fastened by a suitable method such as brazing with silver solder.

The cylindrical portion of the boiler is made of any suitable good heat conducting material such as copper or Phosphor bronze, and its end surface, which after assembly is in heat transfer relationship but not in actual physical contact with a heating element, is blackened to provide good heat absorption qualities. The supporting plate 1a is preferably made of a metal having high strength and rigidity and relatively poor thermal conductivity such, for example, as stainless steel. An annular internal supporting member 4 prevents collapse of the boiler when operating under conditions of partial vacuum.

The bellows 2 is made of a suitable strong flex-

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ible metal such as brass or Phosphor bronze. Its upper end is closed by means of a supporting plate 2a which is preferably made of stainless steel of sufficient thickness to impart to it substantially rigidity. Stainless steel is suitable for this element owing to its relatively poor thermal conductivity. At its rear edge, i. e., the edge which is remote from the cover, the plate 2a is provided with an upturned lug 2b provided with holes through which machine screws extend into threaded engagement with the wall of the enclosing casing or housing. Similarly the front edge of the plate is provided with an upturned lug 2c having a threaded opening for receiving a screw passing through the cover of the enclosing casing.

The capillary tube 3 enters openings in the supporting plates 1a and 2a and is fastened thereto by silver soldering to provide tightly sealed joints.

The chemical composition of the boiler fluid affects the critical temperature of operation of the relay. When this temperature is high with respect to the ambient temperature, the effect of the ambient temperature upon relay operation is small. However the power requirements are high. Preferably the boiler fluid should have a low freezing point so that low ambient temperatures do not affect it. It must be chemically stable and must not combine chemically with the boiler or the bellows. Although several liquids produce satisfactory operating results, it is preferred to use para-cymene $\text{CH}_3\text{C}_6\text{H}_4\text{CH}(\text{CH}_3)_2$. Para-cymene has a boiling point of 177° C. Other liquids which may be used and which provide successful operation are aniline, o-dichlorobenzene and chloro-methylbenzene. These liquids have boiling points of 184.4° C., and 180.6° C. and 162.6° C. respectively.

In order that the operating characteristics shall be consistent in successive operations, it is necessary that the boiler fluid shall be in contact with its own vapor. This condition is achieved by filling the boiler and bellows with the bellows fully compressed and then sealing the unit at 100° C. When released after filling and sealing, the external atmospheric pressure maintains the bellows substantially compressed. However, the spring restoring force of the compressed bellows produces a slight expansion which is sufficient to cause the bellows to produce a small negative pressure in the boiler with the resultant formation of a vapor pocket. Without this vapor pocket, the operating characteristics are erratic.

To the movable closed end of the bellows is securely fastened a rod-like operating member 5 which is preferably made of a suitable plastic insulating member which does not deteriorate at relatively high temperatures, e. g., temperatures of the order of 115° C. At its opposite or lower end the operating member 5 is provided with a trip detent 7 having a circumferential slotted portion 7a which provides for movement of a contact bridging member 8 out of contact-making relationship with stationary control contacts 9 and 10 in response to the force of a biasing spring 11 as the detent is moved downward in response to expansion of the bellows. As shown, the contact bridging member is provided with a circular opening 8a in which the enlarged portion of the detent rests when the bellows is fully contracted, and this circular opening is further extended toward the contact and the bridging member to provide a slot 8b which coacts with the slotted portion of the detent.

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The contact bridging member is mounted on a rod 12 made of insulating material. This rod is provided with a pin 13 against which the biasing spring 11 presses to bias the movable contact bridging member toward the contact opening position.

A heating element for the boiler is illustrated as comprising a pair of heater supports 14 and 15 and a strip of resistance material 16 which is bent up at each end to provide a channel-shaped cross section. The ends of the resistance strip are silver soldered to the heater supports so that the supports are held in spaced apart relationship. The heater supports may be made of any suitable material having relatively high thermal resistivity and relatively low electrical resistivity. For heater currents of less than 25 amperes, the heater supports are preferably made of monel metal which contains approximately 67% nickel, 28% copper and 5% other elements such as iron and manganese. The heater element strip 16 may be made of a suitable material such as a Nichrome V alloy containing 80% nickel, 20% chromium. As shown, the protruding ends of the heater supports are bent down at right angles to engage with the terminal plates 14a and 15a with which they are maintained in contact by suitable means such as machine screws.

The heater element and the thermally sensitive unit are mounted in a suitable molded housing member made of an insulating compound which is illustrated as a generally rectangular box-shaped member 17 which is provided with a cover 18. A pair of ledges 19 and 20 formed on the inside rear surface of the casing member provide support for maintaining the heating element in the upper end space above such ledges.

Beneath these ledges, the opposite walls 17a and 17b are provided with slots 21 and 22 for receiving the boiler supporting plate 1a. A U-shaped curved leaf spring 23 between the lower surface of the plate and the lower surfaces of the slots maintains the top surface of the boiler against the heating element. The boiler is electrically insulated from the heating element by means of a sheet of mica (not shown) approximately 10 mils in thickness which is inserted between the upper surface of the boiler and the lower surface of the heating element. A second pair of slots 24 and 25 in the side walls receive the supporting plate 2a of the bellows and serve to support the bellows in an intermediate position within the housing. Near the bottom end of the housing, a partition member 26 serves to define the upper wall of a chamber within which the stationary control contacts 9 and 10 are mounted and provides a guide for operating member 5.

In operation, the heater terminals are connected to the circuit which is to be protected and which for the purposes of illustration may be assumed to be a motor circuit. The connection is made with the heating element connected directly in series relationship with the motor. The bellows is normally partially decompressed as a result of its spring tension which expands the bellows a slight amount from the fully compressed condition until a condition of equilibrium is produced between the spring tension of the bellows and the compressive force of the atmosphere. In this normal condition, the detent 7 on the operating member 5 maintains the movable contact 8 in bridging position with respect to the stationary control contacts 9 and 10 which are preferably connected in the control

circuit of a protective device for the motor such, for example, as a circuit breaker.

As long as the motor current is less than the critical full load value at which the relay is set to trip, the liquid in the boiler is below the boiling point, and the relay remains in the normal partially decompressed condition. If the motor current increases to the critical full load value, a small portion of the liquid in the boiler is vaporized. The vapor being trapped at the upper surface of the boiler forces the unvaporized liquid out of the boiler through the capillary tube into the bellows and causes expansion of the bellows.

As a result of the expansion of the bellows, the operating rod 5 moves downward until the edge of the detent 7 passes below the bottom surface of the movable contact bridging member 8. This permits the biasing spring 11 to move the rod 12 toward the left so that the restricted portion 8b of the opening 8a is moved into the slot in the detent member. The contact 8 is thus moved out of bridging engagement with the stationary contacts 9 and 10. The opening of the control contacts 9 and 10 results in opening the main circuit to the motor and in deenergizing the heating element 16 thus permitting the thermally responsive system to cool.

When the vapor in the boiler was condensed, the liquid which was transferred to the bellows is returned to the boiler. The bellows therefore is constrained by external atmospheric pressure to collapse but is prevented from doing so by the contact carrying rod 8 which prevents upward movement of the detent 7. Depression of the manually resettable contact carrying arm 12 permits the detent 7 to move upward and thus permits the bellows to collapse to its initial partially decompressed position.

An important feature of this invention is the relationship between load current in the protected circuit and the expansion of the bellows and deflection of the detent member 7. This relationship is illustrated in Fig. 10 by the curve 27 of which ordinates represent deflection of the detent and abscissae represent heater current or motor circuit load current. It will be noted from this curve that at normal full load on the motor, i. e., 100% full load, the detent is deflected approximately 20 mils, and that at 118% full load the detent is deflected more than 60 mils which represents a deflection more than 3 times the deflection at 100% load. In other words, at normal full load of the motor, the amount of deflection of the detent is small in comparison with the ultimate deflection for a very small increase above full load. This assures full locking condition of the detent for all normal loads on the motor which in turn enables the relay to withstand high shock without producing false operation.

A further advantage of this invention is that the relay fails safe. For example, if a leak should develop in the thermally sensitive unit while the relay is in the contact closed position, the bellows would expand and move the detent in the same direction as that in which it is moved in response to an overload condition.

Heaters of different construction may be used to provide different ratings for the relay. A spirally wound heater 29 of the type illustrated in Fig. 8 may be used with a protected circuit in which 100% full load is within the range of 1 to 8 amperes. The heater 30 illustrated in Fig. 7 may be used in the 8 to 30 ampere range

and the strip resistor illustrated in heating relationship with boiler 1 of Fig. 1 may be used in the 31 to 50 ampere range.

A still further advantage of the invention is that the timing of operation of the relay in response to overloads of the order of 1300% to 1500% of normal full load varies in inverse relationship to the square of the load as illustrated in Fig. 9 by the curve 28 in which ordinates represent percentages of full load and abscissae represent operating time. The curve is plotted on semilogarithmic coordinates. The explanation of this phenomenon is that at low loads the slow rate of heat transfer from the heating element to the boiler, owing to the heat transfer through the liquid and the metal of the boiler, elevates the entire thermally sensitive system including the liquid to the boiling point of the liquid before vaporization occurs. On the other hand, at high loads vaporization is produced at the top surface of the liquid in the boiler before the temperature of the main body of the liquid has increased appreciably and forces the liquid into the bellows to effect expansion and releases the detent.

Although in accordance with the provisions of the patent statutes, this invention is described as embodied in concrete form and the principle thereof has been explained together with the best mode in which it is now contemplated applying that principle, it will be understood that the elements shown and described are merely illustrative and that the invention is not limited thereto since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or from the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electric circuit overload protective device comprising in combination, a thermally sensitive unit comprising a boiler, a bellows having communication with said boiler, a vaporizable liquid filling said unit in the fully compressed condition of said bellows and at a predetermined temperature of said liquid thereby to provide a negative pressure within said unit in a partially decompressed condition of said bellows and at a temperature of said liquid substantially lower than said predetermined temperature, contacts having open and closed operating positions and operable from one of said positions to the other in response to expansion of said bellows from said partially decompressed condition, and a heating element mounted in heat transfer relationship with said boiler and having input terminals for connection with a circuit to be protected.

2. An electric circuit overload protective device comprising in combination, a housing member, a thermally sensitive unit mounted within said housing member comprising a shallow boiler, a bellows, means providing communication from the space immediately above the bottom of said boiler to the space within said bellows, a vaporizable liquid filling said unit in the full compressed condition of said bellows and at a predetermined temperature of said liquid substantially above room temperature thereby to provide a negative pressure within said unit at room temperature and in a partially decompressed condition of said bellows, contacts having open and closed operating positions and operable from one of said positions to the other in response to expansion of said bellows from said partially de-

compressed condition, and a heating element mounted above said boiler and having its lower surface in heat transfer relationship with the top surface of said boiler and having input terminals for connection with a circuit to be protected.

3. An electric circuit overload protective device comprising in combination, a pair of contacts having closed and open operating positions; a detent for latching said contacts in a first of said positions; means biasing said contacts to a second of said positions; a thermally sensitive unit comprising a boiler, a bellows having communication with said boiler and a vaporizable liquid fillable liquid filling said unit in the fully compressed condition of said bellows to provide a negative pressure within said unit in a partially decompressed condition of said bellows at room temperature; an operating member connected to said bellows for retaining said detent in its latching position in said partially decompressed condition of said bellows and movable in response to further decompression of said bellows to actuate said detent to effect movement of said contacts to said second position; and a heating element mounted in heat transfer relationship with said boiler and having input terminals for connection with a circuit to be protected.

4. An electric circuit overload protective device comprising in combination, a pair of contacts having closed and open operating positions; a latch for retaining said contacts in a first of said positions; means biasing said contacts to the second of said positions; a thermally sensitive unit comprising a boiler, a bellows member, a tubular member providing communication between said boiler and said bellows, and a volatile liquid completely filling said boiler; said tubular member and said bellows in the compressed condition of said bellows at a predetermined temperature to provide within said boiler in the released condition of said bellows a liquid pressure less than atmospheric at a temperature substantially lower than said predetermined temperature; an operating member of insulating material connected to said bellows for releasing said latch to effect movement of said contacts to said second position in response to expansion of said bellows, and a heating element mounted in heat transfer relationship with said boiler and having input terminals for connection with a circuit to be protected.

5. An electric circuit overload protective device comprising in combination, a pair of contacts having closed and open operating positions; means biasing said contacts to a first of said operating positions; a detent for latching said contacts in the second of said operating positions against the force of said biasing means; a sealed thermally sensitive unit comprising a boiler, a bellows having communication with said boiler and a vaporizable liquid completely filling said unit in the substantially fully compressed condition of said bellows at a temperature of said liquid of 100° C. to provide a negative pressure within said unit in a partially decompressed condition of said bellows at a room temperature substantially lower than 100° C.; a heating element having input terminals for connection with a circuit to be protected and mounted in heat transfer relationship with said boiler to effect ex-

pansion of said bellows from said partially decompressed condition, and an operating member of insulating material mechanically connected to one end of said bellows for retaining said detent in the latching position in said partially decompressed condition of said bellows and movable in response to expansion of said bellows from said partially decompressed condition to actuate said detent to effect movement of said contacts to said second position.

6. An electric circuit overload protective device comprising in combination, a pair of contacts having closed and open operating positions; a detent for latching said contacts in a first of said positions; means biasing said contacts to the second of said positions; a thermally sensitive unit comprising a boiler, a bellows member having communication with said boiler and a vaporizable liquid filling said unit at a predetermined temperature in a fully compressed condition of said bellows to provide a negative pressure within said unit in a partially decompressed condition of said bellows at a temperature substantially less than said predetermined temperature; a heating element having input terminals for connection with a circuit to be protected and mounted in heat transfer relationship with said boiler to effect further decompression of said bellows from said partially decompressed condition, and an operating member connected to said bellows for retaining said detent in its latching position in said partially decompressed condition of said bellows and movable in response to said further decompression of said bellows to actuate said detent to effect movement of said contacts to said second position and to provide fail safe operation of said device in response to a leak in said thermal sensitive unit.

7. An electric circuit overload protective device comprising in combination, a thermally sensitive unit comprising a boiler having spaced apart top and bottom end walls and an enclosing wall joining said end walls to provide an enclosed space; a bellows member disposed in spaced apart relationship with said boiler; a tubular member providing communication between said bellows and said boiler through said bottom end wall; a vaporizable liquid filling said unit in the fully compressed condition of said bellows and at a predetermined temperature of said liquid thereby to provide a negative pressure within said unit in a partially decompressed condition of said bellows and at a temperature of said liquid substantially lower than said predetermined temperature; contacts having open and closed operating positions and operable from one of said positions to the other in response to expansion of said bellows from said partially decompressed condition; and a heating element mounted in heat transfer relationship with said top end wall of said boiler and having input terminals for connection with a circuit to be protected.

CHESTER I. HALL.

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