Jan. 14, 1969 H. E. WHITING ET AL 3,422,317

THREE-PHASE BIMETAL OVERLOAD RELAY

Filed Oct. 18, 1966 Sheet 1 of 3

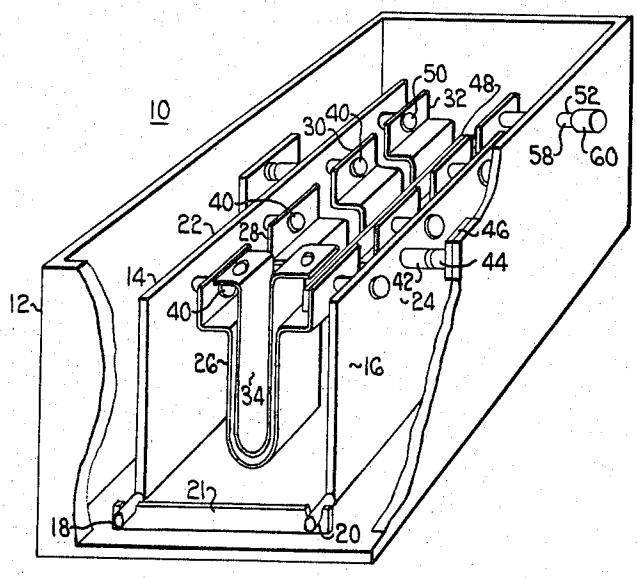


FIG. 1

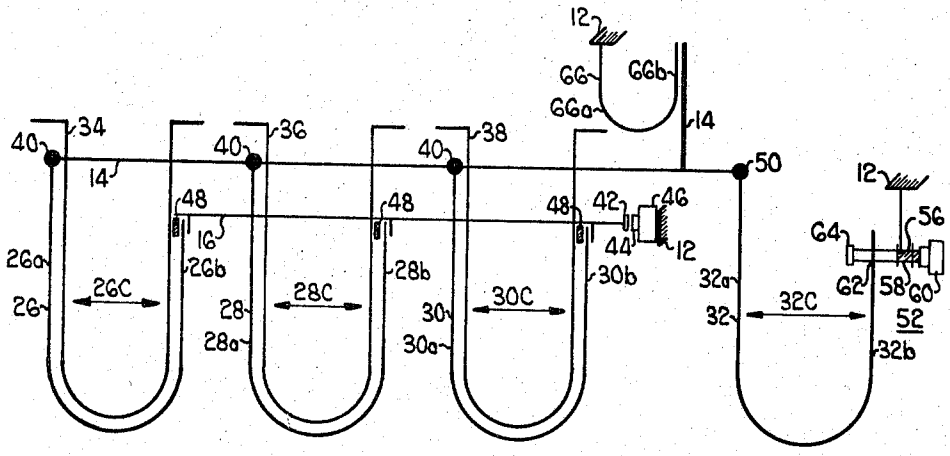


FIG. 2

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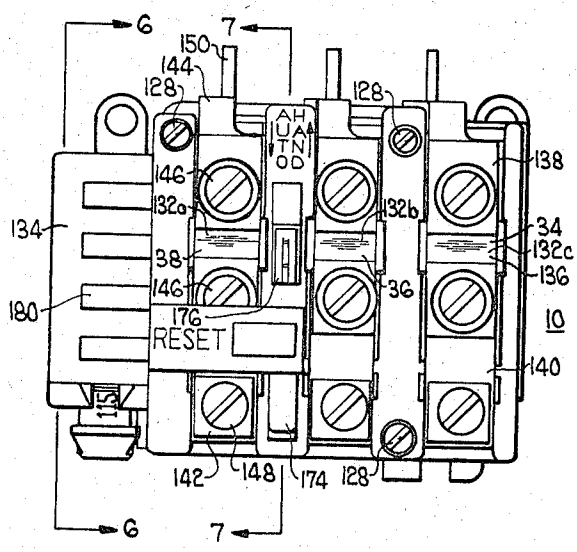


FIG. 3

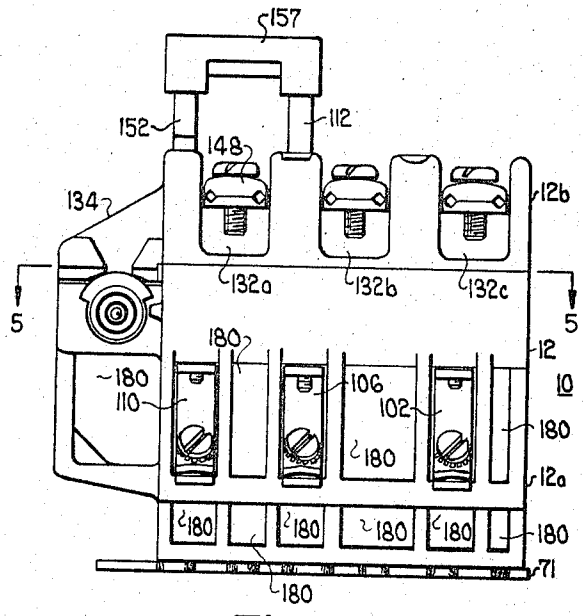


FIG. 4

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THREE-PHASE BIMETAL OVERLOAD RELAY

Filed Oct. 18, 1966 Sheet 3 of 3

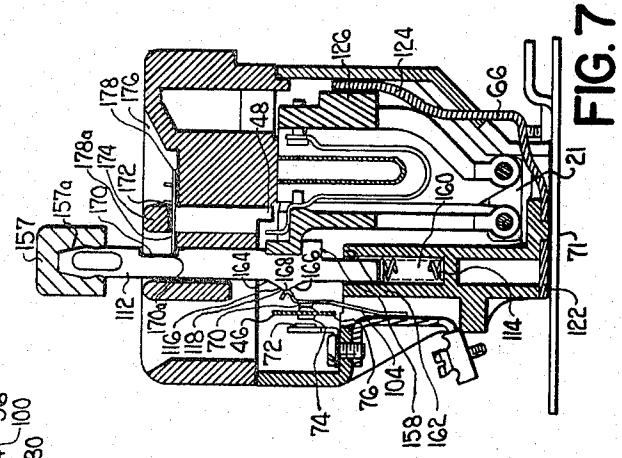


FIG. 7

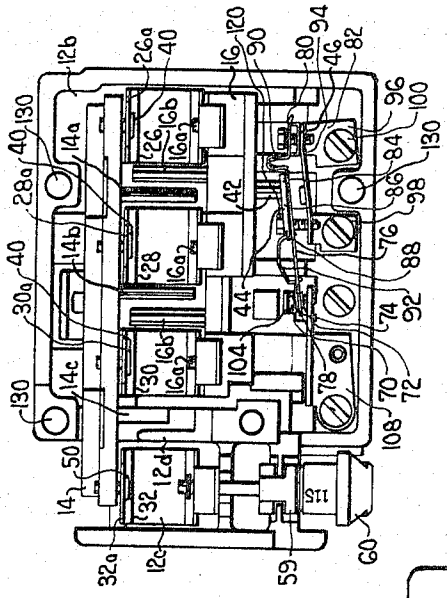


FIG. 5

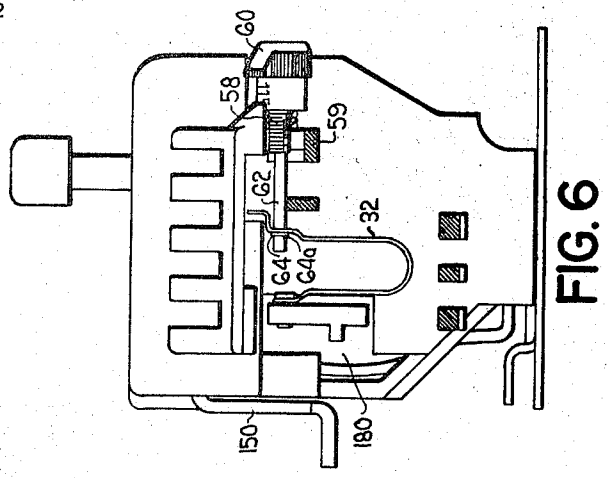


FIG. 6

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3,422,317

THREE-PHASE BIMETAL OVERLOAD RELAY

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U.S. Cl. 317—46 13 Claims
Int. Cl. H02h 3/00; H02h 3/28; H01h 71/16

This invention relates to thermally operated protective devices and more particularly to devices of the type used to open a circuit upon a current overload in any number of a plurality of circuits as may be used to supply a multiphase electric motor.

Thermally operated devices, known as overload relays, are used to protect electric apparatus, such as electric motors, against continued operation when the line current drawn is excessively high as may be caused by overloading the machine driven by the motor, excessively low line voltage, or single phase operation of a polyphase motor. As the overload relays and the apparatus protected thereby may be subjected to different environments, the switch according to the present invention is provided with means for compensating for the effect of ambient temperature whereby the switch will respond to the same overload conditions, regardless of variations in the temperature of the surrounding atmosphere. In addition, the switch according to the present invention is provided with a means to cause the switch to perform differently during conditions of high current overloads than during modest overload conditions with the means being arranged to cause the operation of the switch to be accelerated during high current overload conditions.

The switch according to the present invention also provides an advantage as the switch will operate when less than all of the operating bimetal elements are heated to a temperature that is lower than the temperature rise required to actuate the switch when all of the operating bimetal elements are heated. Thus the switch according to the present invention will operate in response to lower currents when a polyphase motor is operating as a single phase motor under conditions that would damage the motor than when all phases of the motor are energized.

Because of variations in materials and manufacturing tolerances, bimetal elements of different designs may not react alike to different temperature changes. Thus in manufacturing a switch wherein the shape and/or characteristics of the ambient compensating bimetal element is required to be different than the operating bimetal elements, difficulties will arise in matching the characteristics of the two different designs of bimetal elements to obtain a switch that may be readily calibrated and function properly throughout its entire current and temperature range. In the switch according to the present invention, as the operating bimetal elements and the ambient compensating bimetal element are identical, the selection of the bimetal elements and calibration of the switch during manufacture is simplified.

It is an object of the present invention to compensate the operation of a bimetallic type overload relay for variations in ambient temperature with a bimetal element that is identical to the current monitoring bimetal elements of the overload relay.

An additional object is to provide an overload relay with a plurality of heat responsive operating bimetal elements, a snap switch, a lever arrangement for transmitting movements of the bimetal elements to an operator of the snap switch when the bimetal elements are heated and a means for causing the snap switch to be actuated when less than all of the bimetal elements are heated to a temperature that is lower than the temperature required

to actuate the snap switch when all of the bimetal elements are heated.

A further object is to provide an overload relay with a plurality of heat responsive bimetal operating elements, a snap switch, a lever arrangement for transmitting movements of the bimetal elements to an operator of the snap switch when the bimetals are heated and a means for varying the time required to actuate the snap switch with variations in the rate at which the bimetals are heated.

Another object is to provide an overload relay with a plurality of identical heat responsive operating bimetal elements, a snap switch, a lever arrangement for transmitting movements of the operating bimetal elements to the operator of the snap switch when the operating bimetals are heated, and means including an additional bimetal element that is identical to the operating bimetal elements and has an operating connection with the transmitting lever arrangement for compensating the movement of the operating bimetal elements for variations in ambient temperature and for causing the snap switch to be actuated when less than all of the bimetal elements are heated to a temperature that is lower than the temperature required to actuate the snap switch when all of the bimetals are heated.

And another object is to provide an overload relay with a plurality of identical heat responsive operating bimetal elements, a snap switch, a lever arrangement for transmitting movements of the operating bimetal elements to the operator of the snap switch when the operating bimetals are heated, means including an additional bimetal element that is identical to the operating bimetal elements and has an operating connection with the transmitting lever arrangement for compensating the effect of movement of the operating bimetal elements for variations in ambient temperature, a means for causing the snap switch to be actuated when less than all of the bimetal elements are heated to a temperature that is lower than the temperature required to actuate the snap switch when all of the bimetals are heated, and a means for varying the time required to actuate the snap switch with variations in the rate at which the bimetals are heated.

Further objects and features of the invention will be readily apparent to those skilled in the art from the specification and appended drawings illustrating certain preferred embodiments in which:

FIG. 1 is a schematic perspective view of an overload relay mechanism according to the present invention.

FIG. 2 is a diagrammatic diagram of certain elements of the overload relay mechanism in FIG. 1.

FIG. 3 is a top plan view of an overload relay mechanism incorporating the elements illustrated in FIGS. 1 and 2.

FIG. 4 is a front elevational view of the overload relay mechanism shown in FIG. 3.

FIG. 5 is a top plan view of the overload relay mechanism with a top portion of a housing for the overload relay removed and taken along line **5—5** in FIG. 4.

FIG. 6 is a view partly in cross section taken along line **6—6** in FIG. 3.

FIG. 7 is a cross sectional view taken generally along line **7—7** in FIG. 3.

In FIGS. 1 and 2 a functional model of a thermally operated protective switch or device **10** according to the present invention is illustrated. The switch **10** has a housing **12**, of molded insulating material, wherein a pair of spaced levers **14** and **16** rotate about a pair of spaced and parallel pivot axes. As shown, the lever **14** is provided with a pivot **18** and the lever **16** with a pivot **20**. The pivots **18** and **20** are carried by a member **21** secured to a bottom wall of the housing **12**. An additional

similar member, not shown, carrying similar pivots, is provided at the other end of the housing **12** to permit relative independent movement between a free end portion **22** on the lever **14** and a free end portion **24** on the lever **16**.

Positioned between the levers **14** and **16** are four identical U-shaped bimetal elements **26, 28, 30** and **32**. Each of the bimetal elements **26–32** is formed of bimetal strip material to have a pair of spaced arms designated by suffices *a* and *b* that spread in the direction of indicating arrows **26***c*, **28***c*, **30***c* and **32***c* when the bimetal elements are heated. The bimetal elements **26–32** are arranged to have the bimetals **26, 28** and **30** act as operating bimetal elements each responding to the heating effects of currents through separate circuits and the bimetal element **32** provides ambient compensation for the switch **10**. The bimetals **26, 28** and **30** are respectively coupled with heating elements **34, 36** and **38**, as shown in FIG. 2.

In FIG. 1, for purposes of clarity, only a single heating element **34** is shown as coupled with the bimetal element **26**. When the switch **10** is used with a three-phase motor, not shown, the heating elements **34, 36** and **38** are connected to be heated by the current flow in the individual motor windings. The heating elements **34, 36** and **38** as shown are U-shaped and are positioned in heat radiating relation between the spaced arms of the U-shaped bimetal elements to heat the bimetal elements **26, 28** and **30** in response to current flow through the motor windings. The ends of arms **26***a*, **28***a* and **30***a* of the bimetals **26, 28** and **30** are secured to the portion **22** of the lever **14** as by rivets **40**. The ends of arms **26***b*, **28***b* and **30***b* of the levers **26, 28** and **30** are not fixed and rest against the portion **24** of the lever **16**. The lever **16** has a portion **42** engaging an operator **44** of a snap switch **46**. The snap switch **46** preferably is of the type requiring minimal movement of the operator **44** before moving its contacts with a snap action from a circuit closing position to a circuit opening position when a predetermined force is applied to the operator **44**.

The ends **26***b*, **28***b* and **30***b* are positioned between the portion **24** and fixed stops **48** formed as part of the housing **12**. As shown in FIG. 1, the stops **48** are located to limit the movement of ends **26***b*, **28***b* and **30***b* toward the lever **14**.

The ambient temperature compensating bimetal element **32** has arms **32***a* and **32***b* which spread in response to an ambient temperature increase. The arm **32***a* is secured to the lever **14** by a rivet **50**. The arm **32***b* is adjustably positionable relative to the housing **12** by an adjustment means **52**. The adjustment means **52** includes a rotatable member **56** having a threaded portion **58**, an adjustment knob **60**, a portion **62** extending through an opening in the arm **32***b* and a stop **64** on the end of portion **62**. The stop **64** is positioned to engage an inner surface of the arm **32***b* and limit movement of the arm **32***b* toward the arm **32***a*. The opening in the arm **32** receives the portion **62** with clearance permitting the arm **32***b* to move out of engagement with the stop **64**. The knob **60** is used to rotate the member **56** and because of a threaded connection between the housing **12** and the threaded portion **58**, the relative positions of the stop **62** and the arm **32***b* may be adjustably varied.

The switch **10** also includes an additional bimetal element **66**, known as a tripping accelerator bimetal. The bimetal element **66** may have a different shape and load characteristics than the bimetal elements **26, 28, 30** and **32** and has an arm portion **66***a* secured to the housing **12** and an arm portion **66***b* engageable with the lever **14**. The bimetal element **66** has the same deflection characteristics as the bimetal elements **26, 28, 30** and **32** and is constructed to have the ends of the arms **66***a* and **66***b* move toward each other when the bimetal element **66** is heated. The bimetal element **66** is positioned in the housing **12** to be heated by the heaters **34, 36** and **38** at a slower rate than the bimetal elements **26, 28** and **30**.

Referring to FIG. 2, the operation of the switch **10** will now be described. During normal ambient temperature and nonoperating conditions, the heating elements **34, 36** and **38** will not be subjected to current and the arms of the bimetal elements **26, 28** and **30** as well as the bimetal element **66** will be relaxed. Thus the levers **14** and **16** will not be subjected to any force and will in effect float in the housing **12** and the lever **16** will be free to engage either the actuator **44** or the arm portions **26***b*, **28***b* and **30***b* without exerting a force on either the arm portions or the actuator. Similarly, the lever **14** will be disengaged from the arm **66***b* and position the arm **32***b* a predetermined distance from the stop **64**.

When all of the heaters **34, 36** and **38** are heated by normal motor current, the arms **26***a*–**26***b*, **28***a*–**28***b* and **30***a*–**30***b* will spread, causing a movement of the arms **26***a*, **28***a*, **30***a* to the left and a movement of the arms **25***b*, **28***b* and **30***b* to the right. The movement to the right of the arms **26***b*, **28***b* and **30***b* causes the lever **16** to move to the right and impress a force against the actuator **44**. The force on the actuator **44** is resisted by the mechanism of the snap switch **46**. As previously stated, the snap switch **46** is selected to require a predetermined applied force on actuator **44** before the contacts will move with a snap action from a circuit closing to a circuit opening position and the snap action of the contacts will occur upon a minimal distance of travel of the actuator **44**.

As the lever **16** is prevented from movement to the right by the opposing force supplied by the actuator **44**, the arm portions **26***a*, **28***a* and **30***a* will move lever **14** and the bimetal element **32** to the left to a position wherein the arm **32***b* engages the stop **64**. The foregoing movement of the lever **14** and the bimetal element **32** will be unopposed by the bimetal element **32** because of the lost motion connection provided by the distance the arm **32***b* is required to move on the portion **62** before engaging the stop **64**. Further movement of the lever **14** to the left after engagement of the arm **32***b* with the stop **64** is resisted by the bimetal element **32** which acts as a resilient means having identical spring characteristics as the bimetal elements **26, 28** and **30**. The movement to the left of the lever **14** continues until the force exerted by the bimetals **26, 28** and **30**, that is resisted by the bimetal **32**, stabilizes at a value less than the force required to move the operator **44** and actuate the snap switch **46**.

When a current higher than normal occurs in each of the heaters **34, 36** and **38**, the force exerted by the bimetals **26, 28** and **30**, as resisted by the bimetal **32**, progressively increases to the value required to move the operator **44** and actuate the switch **46**.

In the event of failure of one of the phases of the motor protected by the switch **10**, two of the heating elements will be heated and the remaining heating element will not be heated. Assuming a condition wherein the circuit connected to the heating element **38** is open and not carrying current and the circuits connected to the heating elements **34** and **36** are subjected to an excess current, the switch **10** will operate as follows. The heating effect of the abnormal excess current through the heating elements **34** and **36** causes movement of the arms **26***a* and **28***a* to the left and movement of the arms **26***b* and **28***b* to the right. The movement to the right of the arms **26***a* and **28***b* causes the lever **16** to move to the right and impress a force against the actuator **44**. As the movement of the lever **16** is opposed by the actuator **44**, the arm portions **26***a* and **28***a* will urge the lever **14** and the bimetal element **32** toward the left. The motion of the lever **14** to the left is instantly opposed by the bimetal element **30** as the arm portion **30***b* engages the stop **48**. After the lever **14** has moved a predetermined distance to the left to a position wherein the arm **32***b* engages the stop **64**, further movement of the lever **14** to the left will be resisted by both bimetal elements **30** and **32** each acting as a resilient means having identical spring charac-

teristics as the operating bimetals **26** and **28**. The movement to the left of the lever **14** will continue until the force exerted by the bimetal elements **26** and **28**, as resisted by the bimetal elements **30** and **32**, equals the force required to move the operator **44** to actuate the snap switch **46**.

While useful in other types of motor circuits, the switch according to the present invention is particularly suited for use in a circuit wherein a Y-delta transformer provides a supply for a three-phase motor. In event of failure in one of the phases of the primary side of the transformer, two of the phases of the motor will be excited with a slightly increased current while the remaining phase will be excited with current in excess of twice the normal value. Thus under conditions wherein a three-phase motor supplied by Y-delta transformer is operating under a load significantly less than its rated load, and a failure occurs in one of the phases of the primary side of the transformer, two of the phases of the motor will be supplied with less than the normal currents required to trip the switch **10** while the third phase will be supplied with currents in excess of the normal currents. In the event the switch **10** has its heating elements **34**, **36** and **38** connected in circuits having an excess current in one of the circuits and less than normal current in the two remaining circuits, one of the heating elements will be heated excessively and the two remaining heating elements will be heated less than normal. Assuming a condition wherein the circuits connected to the heating elements **36** and **38** are carrying less than normal currents and the circuit connected to the heating element **34** is subjected to an excess current, the switch **10** will operate as follows: the heating effect of the excess current through the heating element **34** will cause movement of the arm **26***a* to the left and movement of the arm **26***b* to the right. The movement to the right of the arm **26***c* causes the lever **16** to move to the right and impress a force against the actuator **44**. As the movement of the lever **16** is opposed by the actuator **44**, the arm portion **26***a* will urge the lever **14** and the bimetal element **32** toward the left. This motion of the lever **14** to the left is opposed by the bimetal elements **28** and **30** as the arm portions **28***b* and **30***b* engage the stop **48**. After the lever **14** has moved a predetermined distance to the left to a position wherein the arm **32***b* engages the stop **64**, further movement of the lever **14** to the left will be resisted by bimetal elements **28**, **30** and **32** each acting as a resilient means having identical spring characteristics as the operating bimetal **26**. The movement to the left of the lever **14** will continue until the force exerted by the bimetal element **26**, as resisted by the bimetal elements **28**, **30** and **32**, equals the force required to move the operator **44** and actuate the snap switch **46**.

The switch **10** has its levers and bimetal elements arranged to actuate the snap switch **46** when any number less than all of operating bimetal elements **26**, **28** and **30** are heated to a temperature that is less than when all of the operating bimetal elements **26**, **28** and **30** are heated. This can be mathematically demonstrated in the following examples wherein:

F—pounds of force required to trip the snap switch
ΔT_n—temperature change required to heat operating bimetal elements to trip switch
d—total distance bimetal arms **26***a*, **28***a* and **30***a* move to provide force to trip snap switch
r—distance ambient compensating bimetal arm **32***a* moves when operating bimetals are heated
i—distance bimetal arms **26***a*, **28***a* and **30***a* move to take up lost motion connection between the arm **32***a* and stop **64**
a—force constant in lbs./degrees F of the bimetals **26**, **28**, **30** and **32**
c—motion constant in inches/degrees F of the bimetals **26**, **28**, **30** and **32**
K—bimetal spring constant a/c=lbs./inch

Three operating bimetal elements heated

The three operating bimetal elements **26**, **28**, and **30** each are equally heated and equally share the required force F. Thus to develop the required force F the bimetal elements **26**, **28** and **30** must be heated $F/3a$. Further, the three operating bimetal elements **26**, **28** and **30** must be additionally heated to deflect the unheated bimetal **32** a distance sufficient to provide the force F.

Therefore

$$\Delta T_3=\frac{F}{3a}+\frac{i}{c}+\frac{r}{c}$$

substituting for *r*

$$\Delta T_3=\frac{F}{3a}+\frac{i}{c}+\frac{F}{a}$$

Solving

$$\Delta T_3=\frac{4F}{3a}+\frac{i}{c}$$

Bimetal element **32** supplies entire force F

$$\therefore F=rK$$

Solving for *r*

$$r=F/K$$

Substituting a/c for K

$$r=Fc/a$$

Two operating bimetal elements heated (assume bimetal elements 26 and 28 heated)

The two operating bimetal elements **26** and **28** each equally share the required force F and to develop the required force F must be heated $F/2a$. Further, the two operating bimetal elements **26** and **28** must be additionally heated to deflect the bimetal elements **30** and **32** a sufficent distance to provide the force F.

$$\Delta T_2=\frac{F}{2a}+\frac{i}{c}+\frac{r}{c}$$

Substituting for *r*

$$\Delta T_2=\frac{F}{2a}+\frac{i}{c}+\frac{F}{2a}-\frac{i}{2c}$$

Solving

$$\Delta T_2=\frac{F}{a}+\frac{i}{2c}$$

Bimetal elements **32** and **30** share force F

$$\therefore F=rK+(i+r)K$$

Solving for *r*

$$r=\frac{F}{2K}-\frac{i}{2}$$

Substituting a/c for K

$$r=\frac{Fc}{2a}+\frac{i}{2}$$

One operating bimetal heated (assume bimetal element 26 heated)

$$\Delta T_1=\frac{F}{a}-\frac{i}{c}+\frac{r}{c}$$

Substituting for *r*

$$\Delta T_1=\frac{F}{a}+\frac{i}{c}+\frac{F}{3a}-\frac{2i}{3c}$$

Solving

$$\Delta T_1=\frac{4F}{3a}+\frac{i}{3c}$$

Bimetal elements **32**, **30** and **28** share force F

$$\therefore F=rK+(i+r)K+(i+r)K$$

Solving for r

$$r=\frac{F}{3K}-\frac{2i}{3}$$

Substituting for K

$$r=\frac{Fc}{3a}-\frac{2i}{3}$$

In previous designs of bimetal overload switches the speed with which the switch is actuated when excess current occurs is a function of the degree of excess current and the rate of heat transfer from the heating elements through which the excess current flows and the bimetal responsive elements. In the switch according to the present invention the speed is accelerated by the action of the bimetal **66** which functions as follows.

When the heating elements are carrying normal currents, as previously described, a portion of the heat generated is transferred by convection around the actuating bimetals **26**, **28** and **30** to the accelerating bimetal **66**. The accelerating bimetal **66** reacts by deforming the ends of the arms **66***a* and **66***b* moving toward each other with the arm **66***b* retreating from the lever **14** at at least the same rate as lever **14** is advanced by the actuating bimetal elements **26**, **28** and **30**. Thus the bimetal **66** will not influence the operation of the switch **10** during normal operating conditions.

If, however, the switch is in a cold, unoperative state and a sudden abnormal excess current, such as six times normal current, is caused to flow through the heater elements **34**, **36** and **38** over an abnormal period of time, bimetal elements **26**, **28** and **30** will be fully exposed to heating effects of the current for the entire period of current flow and respond by deflecting while the convection heat will be delayed in reaching the accelerator bimetal **66**. Accordingly, the accelerator bimetal **66** will not materially deflect. Therefore lever **14**, which under the normal conditions previously described was restrained only by bimetal **32**, now under abnormal conditions as caused by a sudden flow of excess current for an abnormal period through the heating elements **34**, **36** and **38**, is additionally restrained by bimetal **66**. Thus a lower temperature difference and less time is required to cause sufficient force to be developed by the bimetal elements **26**, **28** and **30** on operator **44** to actuate switch **46**. Also, if desired, the arm **66***a* may be adjustably attached to housing **12** to provide an adjustable lost motion space between arm **66***a* and lever **14**. When this adjustment, not shown, is provided, the effect of bimetal **66** under abnormal conditions of excess current may be varied to permit the operating time response of the switch **10** to conditions of sudden abnormal excess current to be adjusted to compensate for different types of loads that may be imposed on the motor.

In FIGS. 3–7 an operative embodiment of the switch incorporating the features of the present invention as described in connection with the embodiment in FIGS. 1 and 2 is shown wherein the elements corresponding to similar elements in FIGS. 1 and 2 are similarly designated.

The housing **12** of the switch **10** in FIGS. 3–7 is formed of two molded parts designated as a base **12***a* and a cover **12***b*. The base **12***a* is secured to a mounting plate **71** by means of the screws extending through the mounting plate **71** and the bottom wall of the base **12***a* into the members **21**. The base **12***a* has an internal cavity. As shown in FIG. 5, the cavity is divided into two cavity portions **12***c* and **12***b* by a barrier **12***d*. The barrier **12***d* serves as a heat barrier and isolates the cavity **12***c*, wherein the ambient compensated bimetal **32** is received, from the cavity **12***b* wherein the operating bimetals **26**, **28** and **30** are received. Positioned within the cavity **12***b* is the lever **16**. The lever **16** has spaced projections **16***a* thereon extending with clearance through suitable openings in the arms **26***b*, **28***b* and **30***b* of the operating bimetal elements permitting the lever **16** to be moved by one or more of the arms **26***b*, **28***b* and **30***b* independently of the remaining arms. The lever **16** additionally has a pair of spaced projections **16***b* thereon which act as heat barriers and are located to effectively divide the cavity **12***b* into three compartments each having a bimetal **26**, **28** and **30** positioned therein. Additionally, the portion **42** on the lever **16** engaging the actuator **44** of the snap switch **46** is adjustable.

The lever **14** extends across compartments **12***b* and **12***c* and includes three spaced projections **14***a*, *b* and *c*. The projections **14***a* and **14***b* are positioned adjacent the projections **16***b* and cooperate with the projections **16***b* to provide a heat insulating barrier between the compartments wherein the bimetal elements **26**, **28** and **30** are located. The projection **14c** is positioned adjacent the barrier **12***d* and cooperates with the barrier **12***d* to provide a heat barrier between the ambient compensated bimetal element **32** and the heating elements for operating bimetal elements **26**, **28** and **30**. The arms **26***a*, **28***a* and **30***a* each are secured to the lever **14** by the rivets **40**. Similarly, the arm **32***a* of the bimetal **32** is secured to the lever **14** by the rivet **50**. As shown in FIG. 6, the adjustment means **52** for the bimetal **32** includes the knob **60**, the threaded portion **58**, which is threadedly received in a nut **59** carried by the housing part **12***a*, and the portion **62** carrying the stop **64**. In the embodiment shown, the stop **64** is formed as a clip **64***a* that is received in a suitably formed groove in the portion **62**.

Referring to FIGS. 5 and 7, the snap switch **46**, which per se is not part of the present invention, includes a pair of spaced stationary contacts **70** and **72** and a movable contact **74** carried on a resilient member **76** to alternately engage the contacts **70** and **72**.

The resilient member **76** is formed to have a pair of parallel slots extending between an end **78** carrying the movable contact **74** and an end **80** secured to a support **82**. The slots divide the member **76** to provide the member **76** with a pair of outer legs **84** extending between the ends **78** and **80** and a central leg **86**. The central leg **86** extends from the end **80** to present a free end **88** spaced from the end **78**. The resilient member **76** also has portions of the outer legs **84** and the central leg adjacent the end **80** formed as folded portions **90** to permit the length of the legs **84** and the leg **86** to independently vary. Interconnecting the free end **88** and the end **78** is a C-shaped member **92**. The member **92** constantly causes the leg **86** to be subject to a compressive force while the legs **84** are under tension. Thus the resilient member **76** and the member **92** act as a toggle mechanism alternately resiliently forcing the leg **86** either in one direction to a position wherein the contact **74** engages the contact **70**, or in an opposite direction to a second position wherein the contact **74** engages the contact **72**.

The support **82** is formed of a conducting metal part having a body portion **94** extending perpendicular to a pair of spaced feet **96** and **98**. The feet **96** and **98** are secured to portions of the base **12***a* by screws **100**. The screw **100** securing the foot **96** electrically connects the support **82** to a terminal and wire clamping member **102** shown in FIG. 4. As shown in FIG. 7, a flexible strip **104** has the stationary contact **70** secured at one end and its other end secured to a terminal and wire clamping member **106** shown in FIG. 4. The stationary contact **72** is carried in spaced relation to the contact **70** on the opposite side of the resilient member **76** by a support **108**. The support **108** also is connected to a terminal and wire clamping member **110** shown in FIG. 4.

When the contact **74** engages the contact **70** the switch will be in a condition known as the tripped position, wherein a circuit between the terminals **102** and **110** is completed through the support **82**, the resilient member **76**, the contacts **74** and **70** and the support **108**. As shown in FIG. 7, the components of the snap switch **46** are placed in the reset condition by depressing a plunger **112** against the force of a return spring **114** to a position wherein a projection **116** on a side wall of the plunger **112** engages

a bearing surface **118** on the strip **104** and causes movement of the contact **70** and the contact **74** toward the contact **72**. The movement of the contact **74** causes the member **76** and the C-shaped member **92** to move to an over-center position whereby the member **76** automatically moves with a toggle action to a reset position and resiliently maintains the engagement between the contact **74** and the contact **72**. Further travel of the central leg **86** after the contacts **72** and **74** are engaged is limited by a stop **120** provided by the head of a screw having a threaded shank extending through an opening in the central leg **86** and adjustably threaded into an opening in the body portion **94**. The operator of the snap switch **46** corresponding to the operator **44** in FIGS. 1 and 2 is provided by the portion **42** having one end engageable with a portion of the central leg **86** located intermediate the stop **120** and the folded portion **90**. The portion **42** is adjustably threaded into an insert in the lever **16** whereby the point of operating engagement of the operator **44***a* and the central leg **86** may be adjusted when the lever **86** is moved toward the reset condition.

The accelerating bimetal element **66**, as shown in FIG. 7, is formed as an L-shaped member having a base portion **122** positioned in a groove in a bottom outside surface of the base **12***a* between the base **12***a* and the mounting plate **71** and an arm **124** spaced from the bimetals **26**, **28** and **30** extending between the lever **14** and the walls forming the cavity **12**. The arm **124** has a portion located to engage a projection **126** on the lever **14**. The material forming the bimetal element **66** is selected to have the arm **124** move away from the projection **126** when the bimetal **66** is heated to function as previously described in connection with FIGS. 1 and 2.

The cover **12***b* is secured to a top wall of the base **12***a* by screws **128** extending through suitable openings in the cover **12***b* into threaded engagement with threaded inserts **130** in the base **12***a*. The cover **12***b* has three spaced open ended compartments **132***a*, **132***b* and **132***c* extending across its top surface to be respectively vertically aligned with the bimetal elements **26**, **28** and **30** and a portion **134** providing a top wall for the cavity **12***c*. The compartments **132***a*, **132***b* and **132***c* are substantially identical and each have openings **136** therein vertically aligned with the space between the arms *a* and *b* of the bimetal elements **26**, **28** and **30** and the ledges **138** and **140** extending on opposite sides of the openings **136**. The ledges **138** and **140** are provided with a suitable means for securing conductor members **142** and **144** in the respective compartments on opposite sides of the openings **136**. The conductor members **142** and **144** have suitable threaded openings for receiving screws **146**. The screws **146** provide an attachment for connecting opposite ends of the heater elements **34**, **36** and **38** between the conductor members **142** and **144**. Each heater element **34**, **36** and **38** is U-shaped, having arm portions extending from the members **142** and **144** downwardly through the openings **136** in spaced relation with the arm portions *a* and *b* of the bimetal elements **26**, **28** and **30**. The heater elements thus are heated by current flow between the members **142** and **144** and are arranged to heat the bimetals **26**, **28** and **30** in response to the current flow. The member **142** has a threaded opening receiving a fastening screw of a wire clamping assembly **148**. The wire clamping assembly **148** is arranged to secure bared ends of an electrical conductor extending from the electrical load to be monitored and not shown. The member **144** has a portion **150** extending outwardly of a side wall of the switch **10** and is preferably arranged to be clamped in a wire clamping member on an electrical switch known as a contactor, in a manner disclosed in an application for U.S. patent, Ser. No. 472,599, filed July 16, 1965, and assigned by the inventors Joseph J. Gribble and Kenneth J. Marien to the assignee of the present invention.

Extending downwardly from the bottom surface of the cover **12***b* and located to be engaged by the arms **26***b*, **28***b* and **30***b*, as shown in FIG. 7, are three spaced stops **48** each integrally formed on the cover **12***b* and extending into the cavities wherein the bimetals **26**, **28** and **30** are positioned. The stops **48** limit movement of the arms **26***b*, **28***b* and **30***b* as described in connection with FIGS. 1 and 2. Extending downwardly through the cover **12***b* are a pair of spaced openings wherein a leg **152** and the plunger **112** of a reset button are movable. The leg **152**, which is integrally formed with the button portion **157** acts as a guide and is sized not to extend into the base **12***a*, when the button **157** is fully depressed. The plunger **112** has an end received in a socket **157***a* in the button portion to maintain the button portion **157** and the plunger **112** assembled.

A stop portion **158** extending from a sidewall on the plunger **112** is engageable with a bottom surface of the cover **12***c* to limit upward movement of the plunger **112** in the switch **10** by the spring **114**. The spring **114** is positioned in a socket **160** vertically aligned with the opening in the cover **12***b* through which the plunger **112** extends. The socket **160** is formed in the material of the base **12***a* to receive a portion of the plunger **112** to guide the plunger **112** during its movements and to present a surface **162** that is engaged by the portion **158** to limit the downward movement of the plunger **112**. The projection **116** is formed as a pair of inclined surfaces **164** and **166** intersecting at an apex **168**. The inclined surfaces **164** and **168** are arranged so the bearing surface **118** engages a portion of the plunger **112** above the inclined surface **164** when the stop portion **158** engages the stop surface **162** and a portion of the plunger **112** below the inclined surface **166** when the stop portion **158** engages the bottom surface of the cover **12***b*. As previously described, the apex **168** on the projection is arranged to engage the bearing surface **118** for the purpose of moving the flexible mounting strip **104** to a position whereby the member **76** automatically moves with a toggle action to the reset position. The plunger **112** additionally is provided with a notch **170** aligned with a slot **172** in the barrier **174** between the compartments **132***a* and **132***b*. A recess **176** in the barrier **174** having a bottom wall forming an extension of the slot **172** receives a slide **178**. The slide **178** has a portion **178***a* extending into the slot **172** and is movable between two extreme positions in the recess **176**. When the slide **178** is in one position its portion **178***a* is out of the path of movement of the plunger **112**. When the slide **178** is in its second position, as shown in FIG. 7, the portion **178***a* will be received in the notch **170** whereby a bottom edge **170***a* of the notch **170** engages the portion **178***a* and maintains the plunger **112** in a position wherein the apex **168** constantly engages the bearing surface **118**. When the plunger **112** is thus maintained in position by the slide **178**, the flexible mounting strip **104** will position the contact **70** to cause the toggle action of the member **76** to occur automatically. Thus when the switch **10** operates in response to an overload condition wherein the lever **16** causes movement of the member **76** to the tripped position wherein the contact **74** engages the contact **70**, a subsequent cooling of the bimetals **26**, **28** and **30** will remove the force exerted by the lever **16** on the member **76** and the member **76** will automatically move with a toggle action to the reset position wherein the contact **74** engages the contact **72**. In normal practice the contact **72** is connected in circuit with an operating magnet coil of an electromagnetically operated switch having contacts controlling circuits through the heating elements **34**, **36** and **38**. The contact **70** is connected in circuit with an alarm or other indicating device. Thus when the contact **74** engages the contact **72**, completing the circuit to the operating coil for operating the electromagnetic switch to complete the circuits through the heating elements **34**, **36** and **38** as well as the load circuits monitored by the switch **10**, if the overload condition previously sensed by the switch **10***h* has ceased to exist, the switch **10** will remain in a reset condition. However, should the

overload condition continue, the excess current through the heaters **34**, **36** and **38** will cause movement of the bimetal elements **26**, **28** and **30** and levers **14** and **16** and actuate the snap switch **46** to a position wherein the contact **74** moves out of engagement with the contact **72** and into engagement with the contact **70**. As the contact **72** is in circuit with the operating coil of the electromagnetic switch controlling the load circuit, the load circuit will be interrupted and the engagement of contact **74** with contact **70** will energize an alarm circuit indicating the occurrence of an overload condition in the load monitored by the switch **10**. Thus when the slide **178** is positioned to have the portion **178***a* within the notch **170**, the switch **10** will be adjusted to operate automatically.

As shown in the drawings, the cover **12***b* and the base **12***a* are provided with a maximum number of openings **180** exposing to a maximum extent the internal parts of the switch **10** including the bimetal elements **26**, **28**, **30** and **66**, as well as the heating elements **34**, **36** and **38**. The openings **180** exposing the bimetal **32** permit the switch **10** to more faithfully follow changes in ambient temperatures. The openings exposing the heating elements **34**, **36** and **38** as well as the bimetal elements **26**, **28**, **30** and **66**, as well as the other elements within the interior of the switch **10**, prevent the transfer of heat to the bimetal element **32** and decrease the interval required to reset the switch **10** after the switch **10** has responded to an overload condition.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

What is claimed is:

1. A thermally operated protective device for use in a plurality of circuits wherein N equals the number of circuits, comprising: a fixed stop, a pair of levers movable relative to the stop, a snap switch having an operator engaging a first of said pair of levers for actuating contacts of the switch when a predetermined force is applied to the operator by the first lever, N number of identical, heat-responsive, resilient U-shaped bimetal elements, each of said elements having a pair of ends that move in opposite directions when the element is heated and having a first of said pair of ends attached to a second of said pair of levers and second of said pair of ends positioned to alternately engage the stop and the first lever and provide a force for moving the levers in opposite directions and the first lever in a direction for actuating the snap switch when the bimetal element is heated, N number of heating units each connected to be heated by current flow in one of the circuits and positioned to heat one of the bimetal elements, and means including a resilient element for resiliently opposing and absorbing movement of the second lever by the bimetal elements in response to the heating of the bimetal elements by the heating units, said means, second lever and stop being arranged for causing the second end of any unheated bimetal element to engage the stop when any other bimetal element is heated and for preventing movement of the first lever by any heated bimetal element until the force absorbed by the resilient means equals the predetermined force required to move the operator.

2. The combination as recited in claim **1** wherein the resilient element is identical to the bimetal elements and provides a means for compensating the operation of the device for variations in ambient temperature.

3. The combination as recited in claim **1** including a heat responsive means having an operating connection with at least one of the levers and located to be heated by the heating means at a rate different than the bimetal elements for varying the time required to actuate the switch with variations in the rate of heating of the bimetal elements.

4. The combination as recited in claim **1** wherein the resilient element is identical to the bimetal elements and provides a means for compensating the operation of the device for variations in ambient temperature and including a heat responsive means having an operating connection with at least one of the levers and located to be heated by the heating means at a rate different than the bimetal elements for varying the time required to actuate the switch with variations in the rate of heating of the bimetal elements.

5. The combination as recited in claim **1** wherein the pair of levers are each pivoted on a portion of a housing for the device.

6. The combination as recited in claim **5** wherein the pair of levers are parallel and the bimetal elements and resilient element are positioned between the pair of levers.

7. The combination as recited in claim **1** wherein the resilient means has a pair of ends with one of the ends being attached to the second lever and the other of said ends being attached to a housing for the device and at least one of the pair of attached ends is attached through a lost motion connection whereby the second lever moves a predetermined distance before the resilient means initially opposes further movement of the second lever.

8. The combination as recited in claim **1** wherein the snap switch has a member movable between two operative positions and includes means responsive to movement of the operator for moving the member to a first of said two positions and the device includes a member guided by a housing for the device that has a portion engageable with the snap switch means for moving the member to a second of said two positions.

9. The combination as recited in claim **4** wherein the heat responsive means includes a bimetal element having characteristics different than the resilient element and having a portion engageable with the second lever.

10. The combination as recited in claim **1** including means for causing the first lever to move and actuate the snap switch when any number less than all of the bimetal elements are heated to a temperature that is lower than the temperature required to actuate the snap switch when all of the bimetal elements are heated.

11. A thermally operated protective device comprising: a fixed stop, a switch having a movable operator for actuating contacts of the switch when a predetermined force is applied to the operator, a first lever movable relative to the stop and having a portion engaging the operator, a second lever movable relative to the stop independently of the first lever, a plurality of bimetal elements each having a first end attached to the second lever and a second end engageable with the stop when the second end moves in a first direction and engageable with the first lever and supplying a force for moving the first lever and the operator when the second end moves in a second direction, means individual to each bimetal element for heating said elements in response to current flow in individual circuits and causing movement of the ends of the bimetal elements, and resilient means having an end engaging the second lever and resiliently opposing and absorbing movement of the second lever and thereby preventing movement of the first lever by the bimetal elements when the bimetal elements are heated by the heating means until the force absorbed by the resilient means equals the predetermined force required to move the operator and actuate the switch contacts.

12. In a thermally operated protective device for use in a plurality of circuits wherein N equals the number of circuits, the combination comprising: a snap acting switch having a movable operator for actuating contacts of the switch when a predetermined force is applied on the operator, a fixed stop, a pair of levers each movable independently relative to the stop, N number of identical, heat-responsive, resilient U-shaped, bimetal elements, each of said bimetal elements having a pair of ends movable in opposite directions when the bimetal is heated with a first

of said pair of ends being attached to a first of said pair of levers and a second of said pair of ends being positioned to engage the stop when the second end moves in a first direction and to engage the second of said pair of levers when the bimetal is heated and the second end moves in a second direction, N number of heating elements each connected to be heated by current flow in one of the circuits and positioned to heat one of the bimetal elements, a resilient means having resilient characteristics identical to the resilient characteristics of the bimetal elements, said resilient means having an end engaging the first of said levers for resiliently opposing and absorbing movement of the first lever and thereby preventing movement of the second lever by the bimetal elements when the bimetal elements are heated by the heating elements until the force absorbed by the resilient means equals the predetermined force required to move the operator.

13. An ambient compensated overload relay for use in a plurality of separate circuits wherein N equals the number of circuits comprising N plus one identical, heat-responsive resilient U-shaped bimetal elements and N number of identical heating units each connected to be heated by current flow in one of the circuits and positioned to heat one of the bimetal elements.

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