Dec. 23, 1969 C. F. ALBAN 3,486,152
CIRCUIT BREAKER USING MAGNETOSTRICTIVE THERMOSTATIC
FLEXURE ELEMENT
Filed Aug. 21, 1967 2 Sheets-Sheet 1

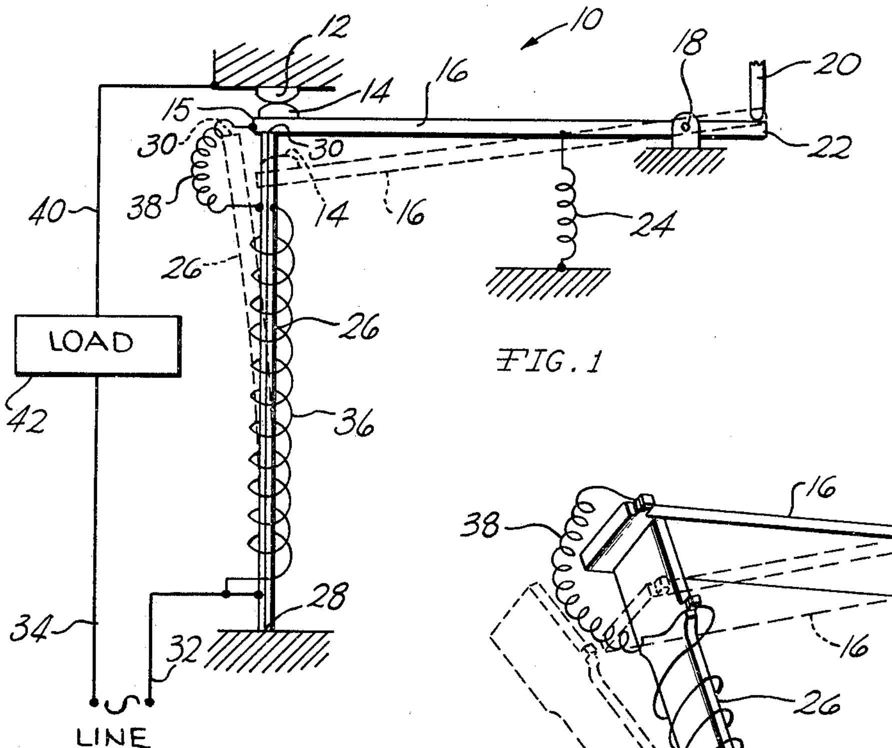

FIG. 1

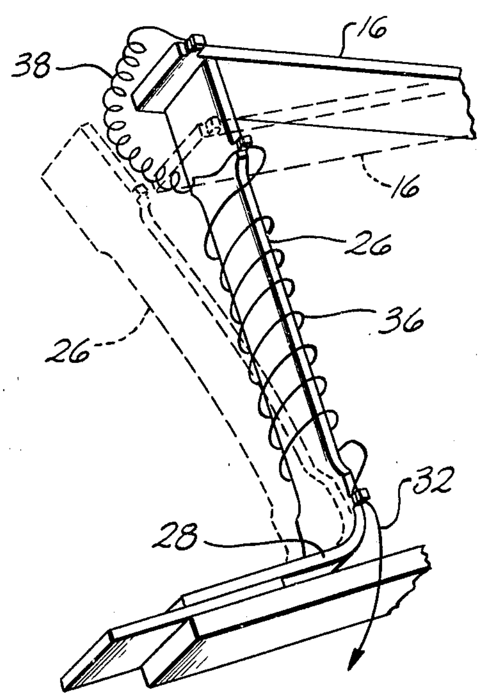

FIG. 2

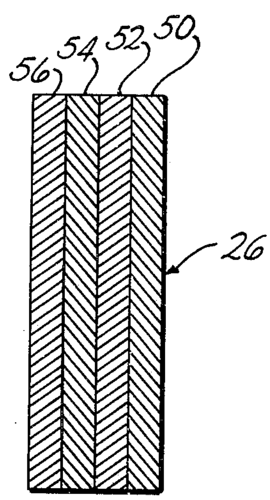

FIG. 3

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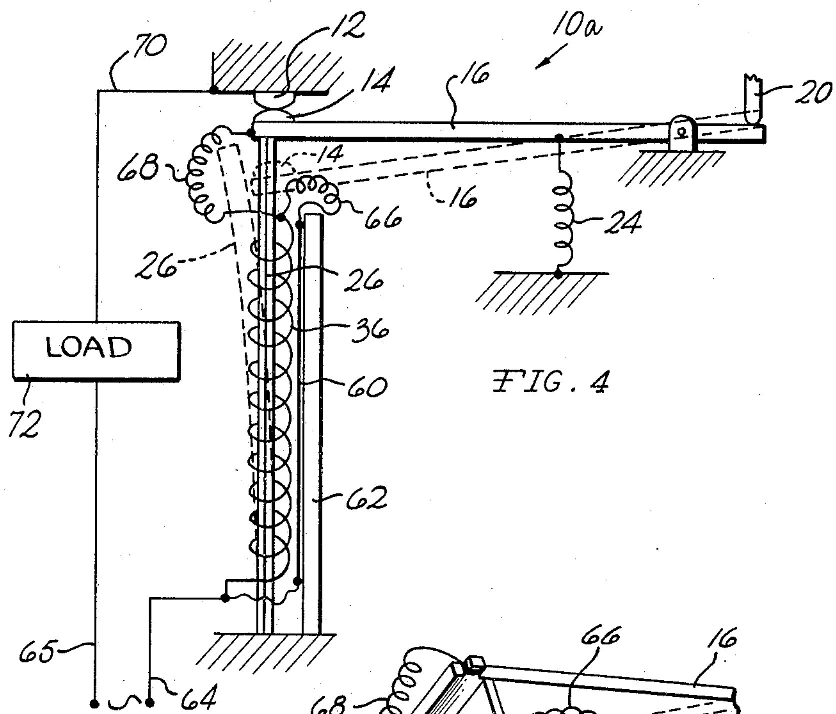

FIG. 4

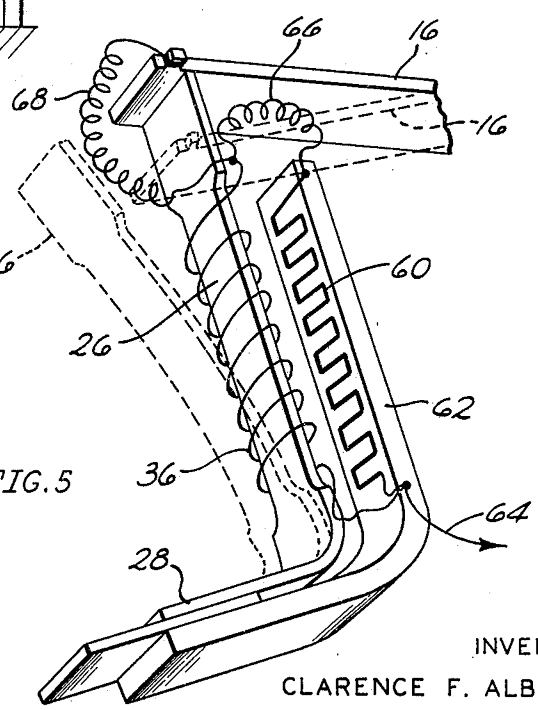

FIG. 5

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United States Patent Office

3,486,152
Patented Dec. 23, 1969

3,486,152

CIRCUIT BREAKER USING MAGNETOSTRICTIVE THERMOSTATIC FLEXURE ELEMENT

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Filed Aug. 21, 1967, Ser. No. 662,139
Int. Cl. H01h *61/013, 61/02, 71/16*
U.S. Cl. 337—106 5 Claims

ABSTRACT OF THE DISCLOSURE

A circuit breaker incorporating a flexure element movable between circuit "make" and "break" positions and a coil positioned adjacent to or surrounding the element and connected to a source of current so as to continually subject the element to a magnetic field. The flexure element is constructed so that it will flex in response both to an ambient magnetic field and to heating so that the magnetic response of the element can be used to break the static frictional force on the flexure element and thereby improve the ability of the element to quickly flex, when it is heated, to its "break" position. In cases in which the coil is connected to A.C. current, the element continually oscillates at small amplitude to thereby decrease the coefficient of friction between the flexure element and the part of the breaker which it engages from the static to the kinetic value, and in cases in which the coil is connected to a D.C. source a high current overload condition immediately results in magnetically induced movement of the flexure element while it is being heated to also reduce the coefficient of friction from the static to the kinetic value.

Background of the invention

Many of the circuit breakers presently in use incorporate a thermostatic bimetal element which, in the absence of an overload in the circuit, is positioned so that it holds a movable member in a position in which a contact thereon is engaged with a fixed contact in the breaker. The bimetal element thus holds the circuit breaker in the "make" position. An overload in the circuit causes heating of the bimetal element with a resultant flexure thereof to a position in which the element permits movement of the movable contact carrying member so as to break the contacts. In the usual case, the bimetal element is frictionally engaged with the movable member. As a result, movement of the bimetal element in response to an overload is dependent upon a buildup in the bimetal element of a thermally induced moment of sufficient magnitude to overcome the static frictional force between the bimetal element and the movable breaker element. This necessity for overcoming this frictional force results in an undesirably high response time of the circuit breaker to an overload condition. At present, applicant is unaware of any satisfactory solution to the problem created by this static frictional force.

Cross reference to related application

Application Ser. No. 652,436, filed July 11, 1967 discloses a laminated material particularly adapted for use in making the flexure element in the circuit breaker which is the subject matter of this application.

Summary of the invention

The circuit breaker of this invention incorporates a flexure element formed so that it will respond to both an increase in tempearture due to the Joule effect and the presence of a magnetic field. A coil, which is connected to a source of alternating current in one form of the

invention, is positioned in close proximity to or surrounding the flexure element so that when there is current in the circuit in which the circuit breaker is located, the flexure element is continually subjected to the resulting alternating current magnetic field induced by the coil. This produces a small pulsing flexural moment in the flexure element which occurs at twice the frequency of the current alternation. This results in a continual very small amplitude oscillation of the end of the flexure element which is frictionally engaged with the movable member in the circuit breaker. The coefficient of friction between the flexure element and the movable breaker element is thus reduced from the static to the kinetic value. As a result, once the flexure element becomes heated because of an overload or short-circuit condition, the frictional force which impedes flexure of the element and which must be overcome, is reduced, thereby resulting in a reduced response time of the circuit breaker. This reduction in response time is one of the most important considerations in circuit breaker design.

The desirable reduction in response time is also achieved in the circuit breaker of this invention when the coil is connected to a direct current source in the event the circuit breaker installation makes this desirable or necessary. The direct current field resulting from normal current flow through the coil causes flexure of small magnitude of the flexure element. When a high current overload condition occurs the increased magnetic field strength causes immediate increased flexure of the flexure element during the time the thermal moment necessary to move the element to its "break" position is being developed in the element. The thermal inertia of the element delays development of this moment for a short time. The magnetically induced moment is thus effective to put the flexure element in motion ahead of the time that the element responds to heat, so as to reduce the frictional force on the element which must be overcome by the thermal moment. As a result, a smaller thermal moment, which is more quickly developed, is needed to move the flexure element to its "break" position.

The ability of the flexure element to respond to both a magnetic field and Joule effect temperature changes is achieved by forming the element with a plurality of laminations, some of which have widely different coefficients of thermal expansion, so as to achieve temperature response, and some of which have widely different coefficients of magnetostriction so as to achieve response to a magnetic field.

It is an object of this invention, therefore, to provide an improved circuit breaker.

Further objects, feature and advantages of this invention will become apparent from a consideration of the following description, the appended claims, and the accompanying drawing in which:

FIGURE 1 is a diagrammatic view of one form of the circuit breaker of this invention in which the flexure element is heated by the passage of current therethrough, showing the breaker in assembly relation in an alternating current circuit;

FIGURE 2 is a fragmentary perspective view of a portion of the circuit breaker shown in FIG. 1;

FIGURE 3 is a longitudinal sectional view of the flexure element in the circuit breaker shown in FIGS. 1 and 2;

FIGURE 4 is a diagrammatic view of another form of the circuit breaker of this invention in which the flexure element is heated by an adjacent heating element, showing the breaker in assembly relation in a circuit connected to a direct current source; and

FIGURE 5 is a fragmentary perspective view of a portion of the circuit breaker shown in FIG. 4.

With reference to the drawing, one form of the circuit breaker of this invention, indicated generally at **10**, is illustrated in FIG. 1 as including a fixed contact **12**, and a movable contact **14** mounted on one end **15** of a movable lever member **16**. The movable member **16** is illustrated as being mounted intermediate its ends on a pivot **18** for movement between the "make" position shown in solid lines and a "break" position shown in broken lines. A reset member **20** is engageable with the opposite end **22** of the movable member **16** for resetting it to its solid line position after it has been moved to its broken line position. A tension spring **24** is illustrated connected to the movable member **16** between its end **15** and the pivot **81** for moving the member **16** to its broken line "break" position.

An elongated flexure element **26**, fixedly supported at one end **28**, has its opposite end **30** frictionally engaged with one side of the movable member **16**, adjacent the end **15** thereof, when the member **16** is in its solid line "make" position. When the flexure element **26** has been heated to a predetermined temperature, corresponding to the overload or short-circuit condition which the breaker **10** is designed to terminate, the flexure element **26** will flex to its broken line position in which it is out of the path of movement of the movable member **16** when it is being moved to its broken line position by the spring **24**. In the absence of this condition causing heating of the element **26** above its critical temperature, the element **26** is in the illustrated solid line position in which the end **30** thereof frictionally engages the movable member **16** so as to latch it in a circuit making position.

The circuit breaker **10** is positioned in an alternating current circuit which includes a pair of leads **32** and **34** connected to a source of alternating current. The lead **32** is connected to the element **26** adjacent the end **28** thereof and is also connected to a coil **36** which is extended about the element **26** over substantially the full length thereof. The coil **36** is also connected to the element **26** adjacent the end **30** thereof so that the coil **36** and element **26** are in parallel, although they could also be in series. The element **26** is connected to a pigtail-type conductor **38** which is in turn connected to the movable member **16** to provide current for the movable contact **14**. The fixed contact **12** is connected by a conductor **40** to the load, indicated diagrammatically at **42**, which is in turn connected to the conductor **34**.

In the operation of the circuit breaker, assume that the movable member **16** is in its "make" position shown in solid lines in FIG. 1. Current then continually flows through the coil **36** so as to subject the element **26** to an alternating current magnetic field. The element **26** is constructed so that it will flex in the presence of a magnetic field, and, as a result, the alternating current magnetic field causes the element **26** to flex back and forth as the polarity of the field is reversed and the field strength passes through zero, as explained in the aforementioned application. This results in a very small amplitude high frequency oscillation of the end **30** of the element **26** which is frictionally engaged with the movable member **16**. The frequency of oscillation is equal to the frequency of the flexural moment produced in the element **26** which is in turn equal to twice the frequency of the current alternation. This substantially reduces the total frictional force applied to the end **30** of the element **26** by the movable member **16**, since the coefficient of friction between these members is now reduced from the static to the kinetic value.

Now assume that an overload or short-circuit condition exists in the load circuit **42**. Since the flexure element **26** is a current carrying member, it quickly becomes heated by the high current passing therethrough to induce a moment therein tending to move the element **26** to its broken line position. When the high current situation takes place, the magnetic effect in the element **26** quickly saturates at low field strength while the thermal effect continues to increase in magnitude. As a result, the magnetic effect cannot seriously impede the thermally induced movement of the element **26** even if it tends to produce motion in the opposite direction. Since the frictional force on the end **30** of the element **26** which must be overcome is relatively low, due to the fact that the kinetic coefficient of friction is relatively low, the element **26** quickly flexes to its broken line position allowing the spring **24** to move the member **16** to its "break" position in which the contacts **12** and **14** are separated and the circuit is broken. The element **26** then cools so that it tends to return to its solid line position. As soon as the reset member **20** is depressed so as to move the movable member **16** to its "make" position, the flexure element **26** resumes its solid line latching position so that the above cycle can be repeated.

The element **26** is formed so that it will respond to both temperature changes and the existence of a magnetic field by forming the element **26** of a laminated construction in which two of the laminations have widely different coefficients of thermal expansion and two have widely different coefficients of magnetostriction. Materials are selected for these laminations which are characterized by their extreme properties. In other words, one of the laminations will have an extremely high coefficient of thermal expansion and the other lamination will have an extremely low coefficient of thermal expansion, the high expansion lamination being disposed on the right hand side of the element **26** in FIG. 1. Response to the presence of a magnetic field is obtained by forming one of the laminations so that it will have an extremely high positive coefficient of magnetostriction and another lamination will have an extremely high negative coefficient of magnetostriction. The element **26** can thus be formed with two laminations providing materials can be selected having these properties, and it is thus within the purview of this invention to make the element **26** of two, three, or more layers, as appropriate.

Since the corresponding extremes of thermal expansion and magnetostriction do not ordinarily occur in any single material, the element **26** in the illustrated embodiment of the invention, consists of at least four laminations, as illustrated in FIG. 3. The lamination **50** has a high thermal coefficient of expansion, such as an alloy consisting essentially of 22% Ni, 3% Cr. and balance Fe. The lamination **52** is characterized by its extremely low coefficient of thermal expansion, an example being an alloy consisting essentially of 36% Ni and balance Fe. The lamination **54** has an extremely high negative coefficient of magnetostriction such as a 100% nickel lamination, and the lamination **56** is characterized by its extremely high positive coefficient of magnetostriction, such as an alloy consisting essentially of 50% Ni and balance Fe. If desired, a fifth lamination having proper electrical characteristics can be included, preferably between the laminations **52** and **54** for modifying the current carrying capabilities of the element **26**. It is to be understood that the laminations can be relatively arranged in any desired sequence so long as the thermally responsive layers are retained in the same relative positions.

Another form of the circuit breaker of this invention, indicated generally at **10*a***, is illustrated in FIGS. 4 and 5. The circuit breaker **10*a*** is similar to the circuit breaker **10** described above, so corresponding reference numerals with the letter subscript "*a*" are employed in connection with the circuit breaker **10*a*** to indicate parts corresponding to identical parts in the breaker **10** without repeating the description of these parts. The breaker **10*a*** differs from the breaker **10** in that the flexure element **26** is heated by a resistance-type electric heating element **60** and the coil **36** is connected to a direct current source.

As shown in FIGS. 4 and 5, the heater element **60** is mounted on a support **62**, formed of insulating material, disposed in close proximity to the flexure element **26**. The support **62** is shown spaced further from the element **26** than would be the case in actual practice for purposes of clarity in the drawing. The breaker **10***a* is positioned in a direct current circuit which includes a pair of leads **64** and **65** connected to a source of direct current. The lead **64** is connected to one end of the coil **36** and also to one end of the heating element **60**. A first pigtail conductor **66** connects the opposite ends of the coil **36** and the heating element **60** and a second pigtail conductor **68** connects the coil **36** and the conductor **66** to the movable member **16** to provide current for the movable contact **14**. The fixed contact **12** is connected by a conductor **70** to the load, indicated diagrammatically at **72**, which is in turn connected to the conductor **65**.

In the operation of the breaker **10***a*, with the movable member **16** in its solid line position, normal current flows through the coil **36** so as to subject the element **26** to a magnetic field causing it to flex a small distance in one direction without moving it out of latching engagement with the member **16**. The direction of flexing is not important. When a high current overload condition occurs in the circuit, the magnetic field strength is immediately increased to thereby immediately increase the magnetically induced moment in the element **26** to cause it to flex an additional amount. This quick movement of the element **26** breaks the static frictional force between the element **26** and the member **16** so that the coefficient of friction therebetween is reduced to the kinetic value. During this time the element **26** is being rapidly heated up by heat from heating element **60** so that a thermal moment of a magnitude sufficient to flex the element **26** to its "break" position shown in broken lines is quickly built up in the element **26**. Thus the magnetically induced moment in the element **26** is utilized to reduce the response time of breaker **10***a* to a high current condition.

The reason that the direction of deflection of element **26** caused by the magnetic field is relatively unimportant is because the magnetic field will saturate while the thermal response of element **26** is not limited. Thus the primary purpose of the magnetically induced response of element **26** is to produce some motion of element **26** immediately so as to reduce the frictional force on element **26** while it is heating up.

From the above description, it is seen that this invention provides improved circuit breakers **10** and **10***a* in which the thermally responsive latch element **26** quickly responds to an increase in temperature by virtue of immediate magnetically induced movement of the element **26** when a high current condition occurs. As a result, the trip time for the circuit breakers **10** and **10***a* is reduced, it being understood that the invention can be incorporated in countless variations of the illustrated breaker **10** which is intended to be representative of a wide class of resettable circuit breakers wherein the coil can be in either series or parallel with the flexure element. It is also to be understood that the flexure element **26** can be heated either by current flowing therethrough or by a heater element **60** and can be connected to either a D.C. or an A.C. source in both of the described breakers **10** and **10***a*, and that the coil and the heating means can be connected in either series or parallel in each case, as desired.

It will be understood that the circuit breaker using magnetostrictive thermostatic flexure element which is herein disclosed and described is presented for purposes of explanation and illustration and is not intended to indicate limits of the invention, the scope of which is defined by the following claims.

What is claimed is:

1. A circuit breaker adapted for connection between

two terminals of an electric circuit, said breaker comprising:

a first contact fixed in position and adapted for coupling to one of said terminals;

a second movable contact;

an elongated flexure element having said second contact at one end, the contact bearing end being movable, the other end being fixed, the fixed end being adapted for coupling to the other of said terminals, said element having a first position of flexure at which said contacts are connected and having a second position of flexure at which said contacts are physically separated, said element having a laminar structure of at least four successive elongated parallel layers which extend in the direction of elongation of said element, two adjacent layers having high and low coefficients of thermal expansion respectively whereby the flexing of said element is ambient temperature responsive, the remaining two layers having negative and positive coefficients of magnetostriction respectively whereby flexing of said element is ambient magnetic field responsive; and

a coil electrically connected between the movable contact and the fixed end of said element, said coil being concentrically disposed about said element whereby when the element is in the first position, current flowing through the contacts creates a magnetic field within the coil to produce magnetic flexing of said element, the temperature flexing of said element being determined by the ambient temperature, the combined effect of magnetic field and temperature flexing determining which position of flexure is established.

2. A breaker as set forth in claim **1** further including means to supply an alternating voltage between said terminals whereby magnetic flexing of small amplitude occurs at a frequency twice that of said voltage and the coefficient of static friction between said contacts is essentially zero.

3. A breaker as set forth in claim **1** further includes means to apply a direct voltage between said terminals.

4. A breaker as set forth in claim **3** further including an electrical resistance heater disposed adjacent said element and connected in circuit therewith.

5. A breaker as set forth in claim **4** wherein said heater is connected in parallel with said coil.

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