July 8, 1969 H. G. WILLARD 3,454,831

QUICK-OPENING LOW COST CURRENT LIMITING CIRCUIT BREAKER

Filed Feb. 20, 1967 Sheet 1 of 2

FIG 1

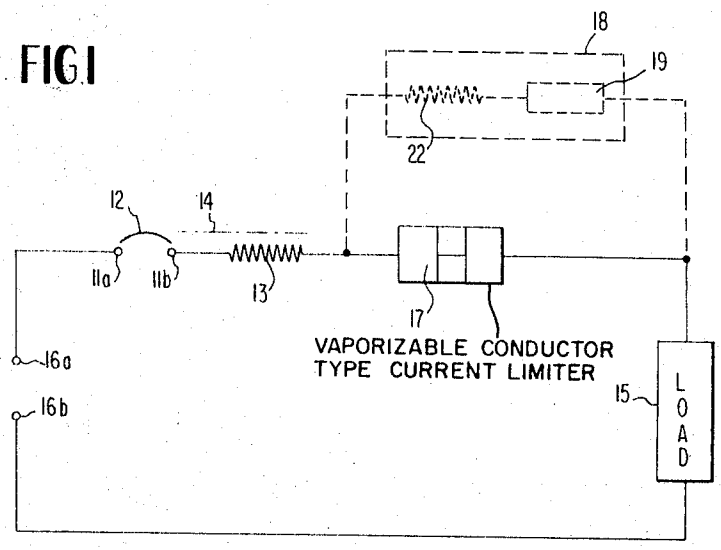
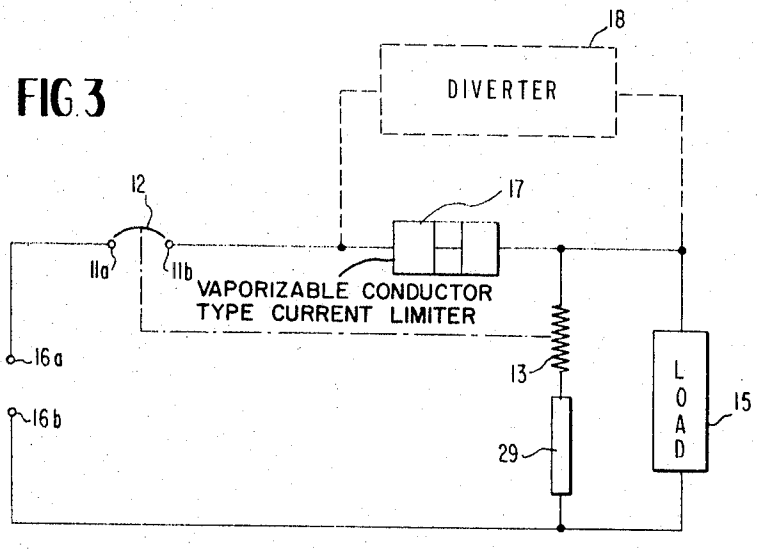


FIG 3



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METHOD OF FORMING AND DRIVING THIN WALL PIPE PILE AND BOOT

Filed Jan. 25, 1968 Sheet 2 of 2

FIG. 5E

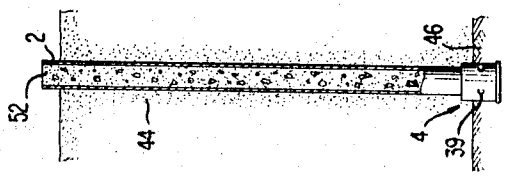


FIG. 5D

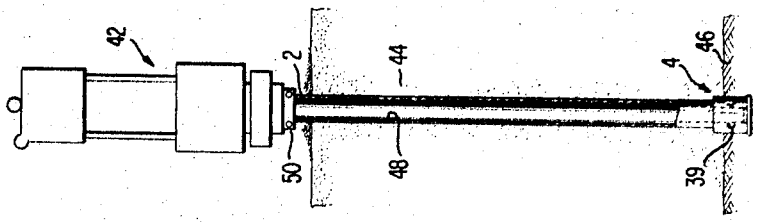


FIG. 5C

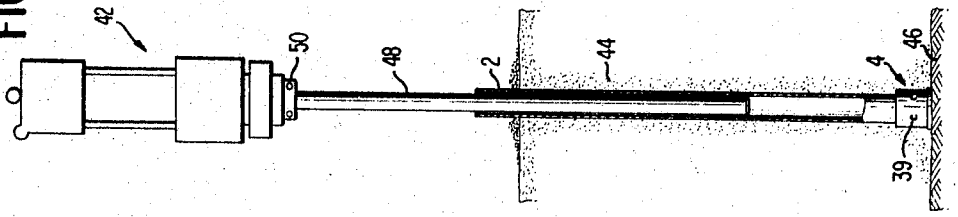


FIG. 5B

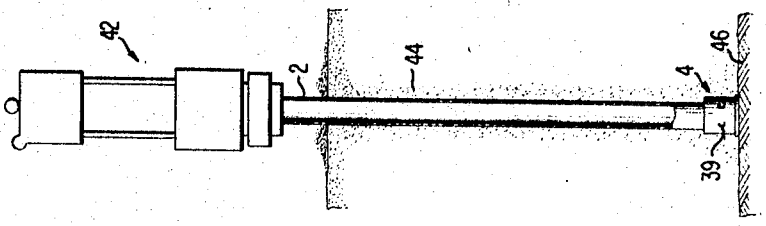
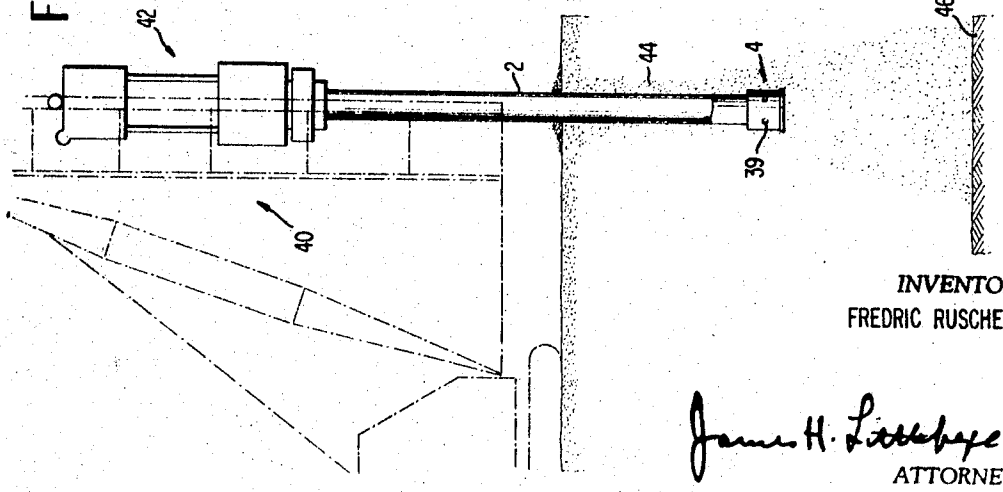


FIG. 5A



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QUICK-OPENING, LOW COST, CURRENT LIMITING CIRCUIT BREAKER

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Int. Cl. H02h 3/08
U.S. Cl. 317—11 5 Claims

ABSTRACT OF THE DISCLOSURE

A quick-opening low cost current limiting circuit breaker comprising a solenoid actuated mechanically operable contactor mechanism having a set of physically separable contacts connected in series circuit relationship with a source of electric potential. The solenoid actuated contactor mechanism is adjusted to open the supply circuit to a load automatically upon the occurrence of an overload above a predetermined rated value. A current limiter of the vaporizable conductor type is connected in series circuit with the physically separable contacts and is designed to carry a larger overcurrent than the solenoid actuated contactor mechanism. The current ratings of the solenoid actuated contactor mechanism and the current limiter are such that upon the occurrence of an overload condition, the solenoid actuated contactor mechanism is actuated first to commence current interruption by physically separating its contacts. Thereafter the current limiter is acuated to assist in extinguishing the arc normally established between the physically separated contacts upon being opened under load current carrying conditions, and simultaneously limits the current that can flow through the circuit breaker to a predesigned low value.

Background of the invention

This invention relates to a quick-opening, low cost current limiting circuit breaker.

More particularly, the invention relates to a quick-opening, low cost circuit breaker employing standard parts which is reliable in operation and, by reason of its quick-opening characteristic, both limits the current flow during, and cuts short the normal arcing period associated with the opening of the circuit breaker so as to greatly increase its operating life.

A circuit breaker is a control device normally connected in an electric power supply circuit to interrupt power flow through the circuit upon the occurrence of an abnormal or overload condition. Such abnormal or overload condition generally is exemplified by either an overcurrent or an overvoltage condition, and can result in damage to the equipment being supplied, as well as damage to the components of the power supply circuit if it is not interrupted within a short time period. From the foregoing description it will be appreciated that one essential characteristic of a satisfactory circuit breaker is that it be relatively quick acting. This characteristic is necessitated by the fact that the shorter the time period that an overload condition is allowed to exist, the less likelihood there is that damage will occur. It is also desirable that a circuit breaker limit the value of the overload current allowed to flow through the device. Further, it is desirable that the breaker be relatively low cost, reliable in operation and have a relatively long operating life.

It is therefore a primary object of the present invention to provide a new and improved quick opening, low cost circuit breaker which employs standard commercially available components arranged in a new circuit breaker configuration in a manner so as to rapidly limit overcurrents and shorten the arcing period normally associated with opening of the breaker contacts under load current carrying conditions. As a consequence of the limited current and shortened arcing period the operating life of the breaker is extended and its reliability in operation improved.

Summary of the invention

In practicing the invention, a new and improved quick-opening, low cost circuit breaker is provided having the above set forth characteristics and comprises a solenoid actuated mechanically operable contactor mechanism having a set of physically separable contacts connected in series circuit supply relationship with a load and a source of electric potential. The solenoid actuated contactor mechanism is adjusted to automatically open the supply circuit to the load upon the occurrence of an overload above a predetermined rated value. A current limiter of the vaporizable conductor type is connected in series circuit with the physically separable contacts and the load with the current limiter being capable of carrying a larger overcurrent than the solenoid actuated contactor mechanism. The current ratings of the solenoid actuated contactor mechanism and the limiter are such that upon the occurrence of an overload condition, the solenoid actuated contactor mechanism is actuated first to commence current interruption by physically separating its contacts. Thereafter the current limiter is actuated to rapidly limit the current to a predesigned low value and assist in extinguishing the arc normally established between the physically separated contacts upon being opened under load current carrying conditions, and simultaneously limiting the current that can flow through the circuit breaker to a predesigned limited value.

Other objects, features and many of the attendant advantages of this invention will be appreciated more readily as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings.

Description of the drawings

In the drawings, like parts in each of the several figures are identified by the same reference character, and:

FIGURE 1 is a schematic circuit diagram of a new and improved quick opening, low cost, current limiting circuit breaker constructed in accordance with the invention;

FIGURE 2 is a characteristic curve illustrating the current versus time operating characteristic of the circuit breaker shown in FIGURE 1; and

FIGURE 3 is a schematic circuit diagram of a modified form of a quick opening, low cost, current limiting circuit breaker constructed in accordance with the invention.

Description of the preferred embodiments

FIGURE 1 is a schematic circuit diagram of a quick-opening, low cost, current limiting circuit breaker constructed in accordance with the invention. The circuit breaker shown in FIGURE 1 comprises a solenoid actuated, mechanically operable contactor mechanism formed by a pair of physically separable contacts **11***a*, **11***b* and **12** and a solenoid actuating winding **13**. The dash dot line shown at **14** indicates that the solenoid actuating winding **13** operates to open the movable contact **12** so that it no longer forms a closed electrically conducting path through the fixed contacts **11***a*, **11***b*. The mechanically operable contactor mechanism may comprise a conventional commercially available low cost magnetic contactor arrangement such as that described on page 39 of the textbook entitled "Controllers for Electric Motors" by James and Markle, published by the McGraw-Hill Book Company, copyrighted 1945. While any kind of

mechanically operable contactor can be employed, it is preferred that the contactor have the conventional magnetic blow out coil and arc chute arrangement such as is described in the above mentioned reference text. Additionally, it is desired that the contactor be designed in a manner such that the circuit can be actuated by manually closing the movable contact **12** on the fixed contacts **11***a* and **11***b*. Thereafter should an overcurrent condition occur, the increased current above design rating flowing through the solenoid winding **13**, causes the movable contact **12** to be opened, thereby physically separating the contact **12** from the fixed contacts **11***a* and **11***b* and interrupting current flow through the contacts. Such magnetically operable contactors are available commercially from a large number of manufacturers such as the General Electric Company at a cost ranging from one dollar up depending upon the design of the contactor. Alternatively, the mechanically operable contactor mechanism **11***a*, **11***b*, **12** and **13** may comprise a thermally actuated switching arrangement utilizing bimetallic elements, or may comprise a combined magnetic-thermal actuated mechanism such as that disclosed in U.S. Patent No. 3,117,203 to be described more fully hereinafter. If a combined magnetic-thermal actuated contactor mechanism such as that disclosed in U.S. Patent 3,117,203 is employed, its current carrying characteristics are preferably adjusted to be in accordance with the teaching of this disclosure.

The physically separable contacts **11***a*, **11***b* and **12** are connected in series circuit relationship with a load **15** across a source of supply potential whose terminals are shown at **16***a* and **16***b*, and which may comprise a source of either direct current or alternating current. A current limiting device **17** is connected in the series circuit comprising the load **15**, power supply terminal **16***a*, **16***b* and physically separable contacts **11***a*, **11***b* and **12**. The current limiting device **17** preferably is of the vaporizable conductor type such as that described in U.S. Patent No. 3,117,203—R. L. Hurtle, inventor, entitled "Circuit Protective Devices and Circuits" issued Jan. 7, 1964, and assigned to the General Electric Company. For a more complete description of the construction and operation of the current limiter device **17**, reference is made to this patent. However, for the purpose of the present disclosure it is believed that the following description of the nature and operation of the limiter device **17** will suffice. The current limiting device **17** is a rapidly operable current limiting protective device for power circuits which maintains electrical continuity both during and after its current limiting action. The device comprises a body of strong and inelastic, non-porous, ceramic insulating material having one or more capillary passages formed therein. The capillaries are filled end to end with a vaporizable conducting material which is in contact with terminal members insulated from one another and extending to the outside of the enclosure. The conductive material in the capillaries is capable of carrying a predetermined amount of current without substantial loss or without substantial change in its electrical properties. However, when the device is subjected to excessive currents of a sufficient magnitude to vaporize all or part of the vaporizable conductive material within the capillaries, an extremely high pressure, high resistance steady state arc is established in the capillaries which limits and reduces the current flow through the device to some predetermined low level. Upon the overcurrent being removed, the device will cool back down and the vaporizable conductive material in the capillaries will reassume its conducting state so that it is possible for the current limiting device to be cycled through a number of current limiting operations without adversely affecting its operating characteristics in either the normal current conducting mode or the overcurrent mode of operation.

In preferred forms of the invention, it is desirable that a current diverter shown in dotted outline form at **18**, be connected in parallel circuit relationship with the current limiter **17**. The current diverter **18** preferably comprises a resistor **19** and an inductor **22** connected in series circuit relationship. The resistor **19** could comprise a positive temperature coefficient resistor and for some applications a capacitor could be added to the circuit. In one specific form of the diverter, the resistor had a value of one ohm and the inductor a value of ten microhenries.

During normal operation of the circuit breaker shown in FIGURE 1, the circuit can be placed in operation by manually closing the movable contact **12** on the fixed contacts **11***a*, **11***b* of the solenoid actuated mechanically operable contactor mechanism. Thereafter for so long as normal load current flows to the load **15** through the power supply terminal **16***a*, **16***b*, the circuit will remain in this condition. However, in the event of an overcurrent condition, the overcurrent flowing in the solenoid winding **13** will cause the movable contacts **12** to be actuated so as to physically separate movable contactor **12** from fixed contacts **11***a* and **11***b*. This occurs before the current limiter **17** operates due to the fact that the current limiter **17** has a larger current rating, and hence by design can tolerate a larger overcurrent than the solenoid actuator contactor mechanism. Hence, the overcurrent first will actuate the solenoid actuator contactor mechanism causing its movable contact **12** to be physically separated from the fixed contacts **11***a*, **11***b* and causing an arc to be formed between the movable and fixed contacts. Because of the existence of this arc, the overcurrent condition will continue until the arc is extinguished. This continued overcurrent condition will thereafter actuate the current limiter **17** which, upon being placed in its vaporized state severely limits the current to a predesigned low value. This predesigned low value is sufficiently low that it will no longer sustain the arc appearing between the movable contact **12** and the fixed contacts **11***a*, **11***b* of the solenoid actuated contactor mechanism. As a consequence this arc will be rapidly extinguished in an extremely short period of time on the order of 100 to 300 microseconds resulting in complete interruption of current flow to the load **15**. If it is employed the current diverter **18** assists this operation by diverting some of the current away from the current limiter.

FIGURE 2 of the drawings is a characteristic curve plotting current versus conduction period over a number of electrical degrees of a large half sinusoidal current pulse imposed on the circuit shown in FIGURE 1 of the drawings. The half sinusoidal shaped solid line curve **25** illustrates the character of the prospective overcurrent that could be imposed on the circuit of FIGURE 1 from the available supply, as well as the current which would flow through the load **15** if the circuit were designed to carry currents of this magnitude. The solid line curve shown at **26** illustrates the operating characteristics of the combined 25 amp regulating current limiter and 15 amp solenoid actuated magnetic contactor employed in the circuit of FIGURE 1. From a consideration of curve **26**, it will be appreciated that the circuit of FIGURE 1 is effective to almost immediately limit the current to a value of about 1,700 amperes and thereafter terminates current flow within substantially 10 electrical degrees of the imposed half sinusoidal waveshape overload current **25**. If the solenoid actuated contactor **11***a*, **11***b*, **12** and **13** by itself were employed to interrupt such an overcurrent, the time that would be required to completely interrupt the current is illustrated by the dotted line curve **27**. By comparing curve **27** to curve **26** it will be seen that the time required to accomplish complete interruption is almost four times as long for a conventional mechanically operable contactor mechanism as that required with the instant invention. It might also be noted that while the contactors **11***a*, **11***b*, **12** and **13** operate to immediately limit the current, this is not a required characteristic of the contactor. Even if the current continued to increase

after the contactor opened, the regulating current limiter **17** could still drive the current to zero in the short time interval indicated.

From a consideration of the above descripion, it will be appreciated that due to the shorter time period allowed for arcing, the deterioration of the contacts as a result of each opening is greatly reduced thus assuring greater reliability in operation as well as greatly extending the operating life of the circuit breaker. Because the circuit breaker arrangement of FIGURE 1 can be fabricated from conventional commercially available elements such as a solenoid actuated contactor mechanism and the regulating current limiter device **17**, its cost of fabrication is relatively low in comparison to circuits whch would require specially designed components. Additionally, while the arrangement shown in FIGURE 1 has been described as comprising a separate mechanically operable contactor mechanism and a separate current limiter, the two devices could be incorporated in a single unitary structure such as that described in the Hurtle Patent No. 3,117,203 by appropriate design. Further, while a 15 ampere rated contactor has been combined with a 25 ampere regulating current limiter in the example cited other combinations of rating values clearly are possible to provide any desired combined circuit operating characteristics.

FIGURE 3 of the drawings schematically illustrates a modified form of the circuit shown in FIGURE 1. In the circuit arrangement of FIGURE 3, the actuating winding **13** of the solenoid actuated mechanically operable contactor mechanism is connected in series circuit relationship with a limiting impedance **29** across the load **15**. Otherwise the circuit is entirely similar to the circuit arrangement of FIGURE 1 and operates somewhat in the same manner.

In operation, the circuit of FIGURE 3 will sense the voltage developed across the load **15**. As long as the voltage developed across the load **15** is normal, load current will be supplied to the load through the closed contacts **11***a*, **11***b* and **12**. However, in the event of an overvoltage condition being developed across load **15**, the winding **13** will sense the overvoltage condition and open the movable contact **12** in the above described manner. Thereafter, the circuit functions in the same manner as described above to quickly interrupt the current flow to load **15**.

From the foregoing description it can be appreciated that the invention provides a new and improved quick opening, low cost current limiting circuit breaker which employs standard commercially available components arranged in a new circuit breaker configuration. This new circuit breaker configuration results in shortening the arcing period normally associated with opening of the breaker contacts under load current carrying conditions, and as a consequence of the shortened arcing period, the operating life of the breaker is extended, and its reliability in operation is improved.

Having described several embodiments of a new and improved quick opening, low cost current limiting circuit breaker constructed in accordance with the invention, it is believed obvious that other modifications and variations of the invention are possible in the light of the above teachings.

I claim:

1. A quick-opening low cost current limiting circuit breaker including in combination a mechanically operable contactor mechanism having a set of physically separable contacts connected in series circuit relationship with a source of electric potential, said mechanically operable contactor mechanism being adjusted to automatically open the supply circuit to a load upon the occurrence of an overcurrent above a predetermined rating value, and a current limiter of the vaporizable conductor type connected in series circuit relation with said physically separable contacts, the current ratings of said mechanically operable contact mechanism and said limiter being such that upon the occurrence of said predetermined value, said mechanically operable contactor mechanism is actuated first to commence current interruption by physically separating its contacts and thereafter said current limiter is actuated to limit the current rapidly to a predesigned low value and assist in extinguishing the arc normally established between said physically separated contacts.

2. A circuit breaker according to claim **1** wherein the mechanically operable contactor mechanism is a solenoid actuated contactor mechanism having its solenoid actuating winding connected in a series circuit comprising the physcially separable contacts, the current limiter and the source of electric potential.

3. A circuit breaker according to claim **2** wherein a current diverter is connected in parallel circuit relationship with the current limiter.

4. A circuit breaker according to claim **3** wherein the current diverter comprises a resistor and an inductor connected in series circuit relationship.

5. A circuit breaker according to claim **4** wherein the solenoid actuated contactor mechanism includes a magnetic blow-out coil for blowing out the arc normally established between the physically separated contacts upon being opened under load current carrying conditions.

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3,238,418	3/1966	Heft	317—33

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J. D. TRAMMELL, *Assistant Examiner.*

U.S. Cl. X.R.

307—136; 317—20, 33