

Dec. 21, 1943.

H. L. RAWLINS

2,337,495

CIRCUIT INTERRUPTER

Filed Sept. 19, 1940

Fig. 1.

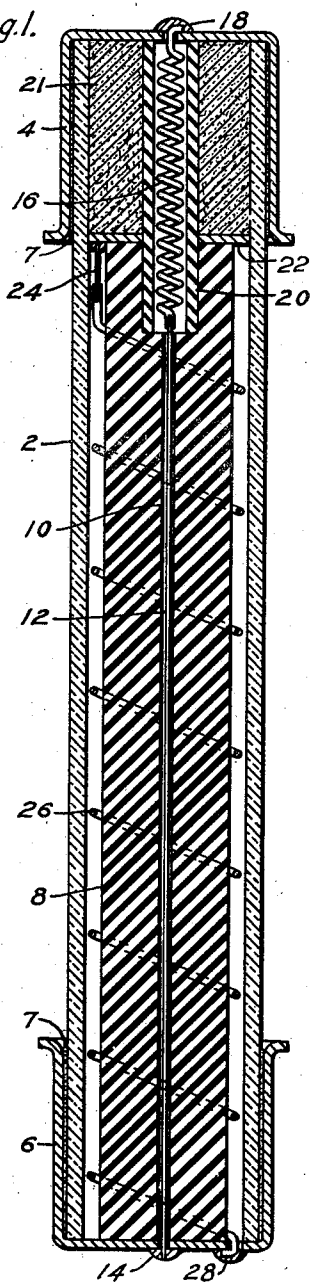
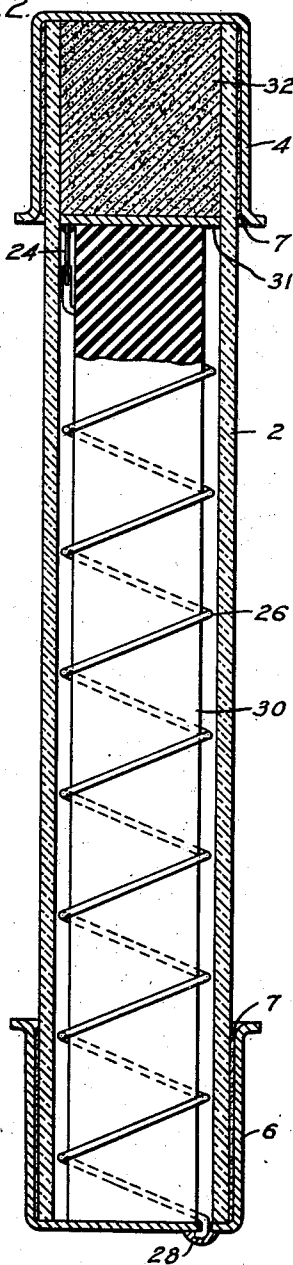


Fig. 2.



WITNESSES:

N. F. Sussner.
G. T. Stratton

INVENTOR

Herbert L. Rawlins.

BY *Ralph W. Swingle*
ATTORNEY

UNITED STATES PATENT OFFICE

2,337,495

CIRCUIT INTERRUPTER

Herbert L. Rawlins, Wilkinsburg, Pa., assignor to
Westinghouse Electric & Manufacturing Com-
pany, East Pittsburgh, Pa., a corporation of
Pennsylvania

Application September 19, 1940, Serial No. 357,393

34 Claims. (Cl. 200-120)

This invention relates generally to circuit interrupters, and more specifically to interrupters which are capable of automatically interrupting a circuit in response to the passage therethrough of currents above a predetermined value, and at the same time limit the value of the current interrupted. The invention will be more particularly disclosed in connection with a fuse which is capable of limiting the current when the fuse blows.

In order to limit current in a fuse to a value substantially smaller than the normal short circuit current, it is necessary to introduce a resistance or impedance within the fuse which is large compared to the impedance externally of the fuse. Such a resistance may be provided in the arc formed when the fuse blows, or the current may be forced to flow through a current limiting means in the fuse at the time of interruption. Resistance may be provided in the arc by restricting or confining the arc to raise the arc voltage. This method of limiting the current however, has certain disadvantages in that restriction of the arc may result in excessive energy liberation and destroy the arc boundary walls, and hence render control of such an arc extremely difficult. The resulting arc voltage or voltage surges that occur during the operation of fuses of this type, may also be so severe that flashovers will occur on adjacent apparatus.

In view of the foregoing, it is preferable to limit the current by causing it to flow through a current limiting means within the fuse. However, since it would not be desirable to provide a current limiting means such as a resistor in series in the circuit, it is necessary to provide a shunt circuit around the resistor, which, when the current rises above a predetermined value, will open very fast to shift the current through the resistor to thereby limit the current. It is desirable that the current be shifted to the resistor as rapidly as possible, preferably within a fraction of a half cycle, so that the resistor may be effective to limit the current.

This invention will be hereinafter particularly disclosed in a current limiting fuse of the last-mentioned type, and one object of the invention is to provide a current limiting fuse which is capable of functioning to interrupt a circuit in response to currents above a predetermined value, and which is also effective to limit the value of such currents.

A further object of this invention is to provide a circuit interrupter having arc establishing means in parallel with current limiting means

and arranged so that when an arc is struck at said arc establishing means, the current is substantially instantaneously shifted to said current limiting means.

5 A further object of this invention is to provide a circuit interrupter having means to establish an arc in an arc restricting passage, with current limiting means in parallel with said arc establishing means.

10 A further object of this invention is to provide circuit interrupting means having means for automatically interrupting a circuit in response to currents above a predetermined value and shift such currents to current limiting means in shunt relation thereto, with additional means for automatically interrupting a circuit in response to currents above a predetermined value arranged in series circuit relation with said current limiting means.

20 Another object of this invention is to provide a current limiting fuse having fusible means in a restricted passage in parallel with current limiting means, and other fusible means in series with said current limiting means.

25 Another object of this invention is to provide a novel type of current limiting fuse embodying a plurality of fusible means and current limiting means all arranged in a single structure in a novel manner.

30 Another object of this invention is to provide a novel fuse having a resistor element for both limiting the current and heating a fusible means in a novel manner.

35 Another object of this invention is to provide a novel construction of a time delay fusible circuit interrupter.

40 Still another object of this invention is to provide a circuit interrupter of a novel construction embodying readily visible indicating means to indicate the open and closed circuit conditions of the interrupter.

These and other objects of this invention will become more apparent upon consideration of the following detailed description of the preferred embodiments thereof, taken in connection with the attached drawing, in which:

45 Figure 1 is a longitudinal cross section view of a current limiting fuse embodying the principles of the invention; and

50 Fig. 2 is a longitudinal cross sectional view of a modified form of fuse embodying some of the parts of the fuse shown in Fig. 1.

Referring to the drawing, in Figure 1 there is shown a fuse including a fuse tube 2 of insulating material which is preferably a transparent

insulating material such, for example, as glass or a transparent resin. The fuse tube 2 is provided with metal end terminal caps 4 and 6 for the opposite ends thereof respectively, and these terminal caps are secured to the ends of the fuse tube by a plastic material 7 provided between the cap flanges and the tube. Within the fuse tube 2 and seated against the terminal cap 6, there is provided an insulating rod 8, which may be of any desired insulating material, preferably an insulating material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, such, for example, as fiber or a synthetic resin. The insulating rod 8 is provided with a relatively small central bore 10 which is of substantially the same size as a fuse wire 12 adapted to be positioned therein, and preferably the bore 10 has a diameter of $\frac{1}{8}$ inch or less, its minimum dimension being limited only by the size of fuse wire 12, all for a purpose to be hereinafter referred to.

The fuse wire 12 may be of any desired fusible resistance material such, for example, as silver or copper alloys, and the lower end thereof extends through an opening in the end cap 6 to be soldered to the end cap as, for example, by the solder 14. The other end of fuse wire 12 is secured to one end of a coil tension spring 16, as by soldering or the like. Coil spring 16 is tensioned and the other end thereof is extended through an aperture in terminal cap 4, to be bent over and secured to the end cap, for example, as by solder 18. As shown in Fig. 1, the upper end of bore 10 through the insulating rod 8 is enlarged to receive an insulating sleeve 20 of fiber or the like, which is positioned between the bore 10 and upper terminal cap 4, about coil tension spring 16.

Positioned between the insulating sleeve 20 and fuse tube 2, there is an annular current limiting element 21, preferably a non-metallic resistance material such, for example, as carbon or the like. The resistor element 21 is confined between end cap 4 and a conducting metallic washer member 22 seated on the upper end of insulating rod 8.

As shown in the drawing, insulating rod 8 is substantially smaller than the interior diameter of fuse tube 2 so as to provide an annular space therebetween. In this annular space there is provided a second fuse wire which preferably melts at a lower current than does fuse wire 12, and which is capable of melting substantially instantaneously in response to predetermined conditions.

In order to obtain substantially instantaneous fusing of fuse wire 24, which should occur in less than a half cycle, this wire is preferably made of silver or a material having similar characteristics. The fuse wire 24 is secured to conducting washer 22 as by soldering or the like, and to a coil tension spring 26 in a similar manner. The coil tension spring 26 is provided with relatively large coils which lie in the annular space between fuse tube 2 and insulating rod 8 and the spring is tensioned with the lower end thereof extending through a second aperture in terminal cap 6 and bent over and secured thereto, as by solder 28 or the like.

It will now be apparent that in the structure in Fig. 1 of the drawing, there are provided two current carrying paths in parallel through the fuse. One path extends from terminal cap 4, through spring 16, fuse wire 12 to end cap 6. The other path through the fuse extends from terminal cap 4, resistor 21, conducting washer

22, fuse wire 24, and coil tension spring 26 to end terminal cap 6. Obviously, since the latter path includes the resistor 21 during the normal unfused condition of the fuse, the greater portion of the current will be carried by fuse wire 12 and substantially no current will pass through fuse wire 24 and resistor 21.

In the operation of the fuse illustrated in Fig. 1, upon the occurrence of heavy overloads and overloads on the order of short circuits, fuse wire 12 will be melted or will soften to such an extent as to permit coil spring 16 to insert a gap in the circuit and draw an arc in bore 10. Bore 10, however, is so small that as soon as arc voltage appears across the bore, the current will be substantially instantaneously shifted to the parallel circuit through resistor 21, fuse wire 24 and coil spring 26. The fuse wire 24 is designed, as previously stated, to melt substantially instantaneously preferably within a fraction of a half cycle, on any current capable of melting fuse wire 12, as limited by resistor 21. It will be apparent, therefore, that fuse wire 24 having a lower melting point than fuse wire 12 will accordingly melt at lower currents than fuse wire 12. As soon as the current shifts to the parallel circuit through resistor 21, it will be limited thereby, and the current thus limited will melt fuse wire 24, and this limited current arc is drawn out and easily extinguished in the annular slot between fuse tube 2 and insulating rod 8, by coil tension spring 26. The use of a small bore 10 to restrict the arc established by fusion of fuse wire 12, is especially important to instantaneously provide a high arc voltage to substantially instantaneously shift the current from bore 10 to the parallel circuit through resistor 21 and fuse wire 24.

The word "instantaneous" or term "at the same instant" as used herein and in the claims to indicate the time of operation, denotes a time of considerably less than a half cycle of a 60-cycle wave, and preferably a small fraction of a half cycle on the order of a few hundred microseconds.

It will be noted that by virtue of its connection to conducting washer 22, the fuse wire 24 is thereby placed in conducting relation with respect to resistor 21. This is important in the event fuse wire 12 is blown and the current drops before fuse wire 24 blows. Such a condition might occur on relatively light overloads, and in this event the heat generated by resistor 21 will be sufficient to melt fuse wire 24 and interrupt the circuit. Inasmuch as insulating rod 8 is of a material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, this action, both with regard to an arc struck in bore 10, or in the annular space between rod 8 and fuse tube 2, will aid in extinguishing these arcs. With respect to arcs struck in bore 10, the arc extinguishing action of gas evolved from insulation 8 will decrease the time required to transfer the current to the parallel path through resistor 21 and fuse wire 24, and with respect to arcs struck in the annular space between insulating rod 8 and fuse tube 2, the action of arc extinguishing gas evolved from insulating rod 8 aids in more quickly interrupting the circuit.

It should be noted that two stressed fusible means are provided in parallel relation in a single fuse cartridge together with a current limiting means, and that the fusible means for finally interrupting the circuit is provided in an annular slot subject to the action of an arc ex-

tinguishing gas. The arc passage in the form of an annular slot is advantageous inasmuch as the arc is thereby deformed, and made to conform to the shape of the passage, and this raises the arc voltage while at the same time causing the arc to contact a greater surface of the gas evolving material, and both of these actions together with attenuation of the arc by coil spring 26 provide a combined action on the arc to quickly extinguish the same and thereby interrupt the circuit.

In Fig. 2 there is shown a modified form of fuse embodying many of the features of the fuse shown in Fig. 1, and therefore, like reference numerals will be used to designate like parts. The fuse shown in Fig. 2 is substantially identical with that illustrated in Fig. 1, except that the insulating rod 30 within fuse tube 2 is solid, and the fuse wire 12, bore 10, and coil spring 16 are thereby eliminated. A solid block 32 of a resistance material which may be of the same material comprising resistor 21 shown in Fig. 1, is located between upper terminal cap 4 and conducting washer 31 and in contact therewith.

There is but a single circuit through the fuse shown in Fig. 2, and this extends from upper terminal cap 4 through resistor 32, conducting washer 31, fuse wire 24, coil tension spring 26 to end terminal cap 6. It can therefore be seen that the fuse of Fig. 2 embodies a resistance which is always in the circuit, and thereby serves to not only limit the current through the fuse, but also to heat fuse wire 24 on light continuing overloads to obtain a desirable time lag on these overloads, in the blowing of the fuse. On relatively high currents, such as short circuit currents, of course, the fuse wire 24 will melt substantially instantaneously and thereby interrupt the circuit faster on such overloads than on relatively light overloads. When the fuse wire 24 melts, of course, coil spring 26 is free to move towards terminal cap 6 and thereby draw out and elongate the arc to extinguish the same in the same manner described in connection with the fuse shown in Fig. 1.

In connection with both embodiments of this invention, it is apparent that the transparent fuse tube 2 will render the coil spring 26 and fuse wire 24 visible from the exterior and the condition of the fuse may be thereby readily ascertained.

In the foregoing there has been disclosed novel forms of fuses, one of which embodies current limiting means which is normally outside of the circuit through the fuse, but which acts to carry the current through the fuse in response to currents above predetermined values determined by a fuse wire 12. The current transfer from fuse wire 12 to the resistor or current limiting means is effected by the provision of fuse wire 12 in a parallel circuit, and in a restricted arc bore, to thereby obtain a high arc voltage when the fuse wire melts and effect a quick transfer of the current to the current limiting means. In both forms of the invention a current limiting means in the form of a resistor is employed which is in heat conducting relation with respect to a fusible element to thereby insure blowing of the fusible element, and interruption of the circuit in the embodiment of the invention shown in Fig. 1, and to provide a time delay in the blowing of the fuse in the embodiment of the invention shown in Fig. 2. These and the other features of the invention disclosed herein have been embodied in a particular type of apparatus wherein

they find particular novelty of cooperation and utility, it should be noted however that these features are also usable in connection with other types of fuses and circuit interrupters.

Although the resistance element in the embodiment of the invention disclosed herein is referred to both here and in the claims as "current limiting means," it is apparent that the high arc voltage, which occurs instantaneously upon fusion of the fusible element shunting the resistance element, will limit the rise of current prior to its transfer to the resistance element, and thus exert an initial current limiting effect. The resistance element is effective as soon as transfer of the current to it occurs, to limit the current to a predetermined value, and this current is then finally interrupted by the series fuse element at the first current zero. The instantaneous transfer of current to the resistance element will, obviously, also limit the voltage to a value determined by the current flowing through the resistance element.

Having described preferred embodiments of the invention in accordance with the patent statutes, it is desired that the invention be not limited to the particular embodiments disclosed, inasmuch as it will be obvious, particularly to persons skilled in the art, that many changes and modifications may be made in these particular structures without departing from the broad spirit and scope of this invention. Therefore, it is desired that the invention be interpreted as broadly as possible and that it be limited only by the prior art and by what is expressly set forth in the following claims.

I claim as my invention:

1. In a fuse including a tubular fuse holder having terminals adjacent opposite ends thereof, fusible means and current limiting resistor means in said holder and connected in series between said terminals, additional fusible means in said holder in shunt relation with at least said resistor means and located in a long, narrow, arc restricting insulating passage having solid walls, and said passage being sufficiently long and narrow as to cause the voltage of an arc struck therein to rise instantaneously to a value at which the current will be transferred to the shunt circuit comprising said resistor means and said first-mentioned fusible means.

2. In a fuse including a tubular fuse holder having terminals adjacent opposite ends thereof, fusible means and current limiting resistor means in said holder and connected in series between said terminals, additional fusible means in said holder in shunt relation with at least said resistor means and located in a long, narrow, arc restricting insulating passage having solid walls, said passage having at least inner wall portions thereof of a material capable of evolving an arc extinguishing gas when in proximity to an electric arc, and said passage being sufficiently long and narrow as to cause the voltage of an arc struck therein to rise instantaneously to a value at which the current will be transferred to the shunt circuit comprising said resistor means and said first-mentioned fusible means.

3. In a fuse including a tubular fuse holder having terminals adjacent opposite ends thereof, fusible means and current limiting resistor means in said holder and connected in series between said terminals, resilient means biasing a terminal of said fusible means to elongate the arc formed upon fusion thereof, additional fusible means in said holder in shunt relation with at least said

resistor means and independently located in a long, narrow, arc restricting insulating passage having solid walls, and said passage being sufficiently long and narrow as to cause the voltage of an arc struck therein to rise instantaneously to a value at which the current will be transferred to the shunt circuit comprising said resistor means and said first-mentioned fusible means.

4. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from at least a portion of said tube wall to form an arc passage in air therebetween, said means of insulating material having a bore therethrough, separate fusible means in said bore and passage, respectively, said fusible means connected between said terminals, and current limiting means connected only between said fusible means in said passage and one of said terminals.

5. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from at least a portion of said tube wall to form an arc passage in air therebetween, said means of insulating material having a bore therethrough, separate fusible means in said bore and passage, respectively, said fusible means connected between said terminals, current limiting means connected between said fusible means in said passage and one of said terminals, and said bore being small to restrict the arc and having a diameter of $\frac{1}{8}$ inch or less.

6. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from the inner walls thereof to form an annular air space therebetween, means connected between said terminals including fusible means and resilient means located in said space, said resilient means stressing said fusible means for separating the terminals of said fusible means upon fusion thereof, said insulating means having an arc restricting bore therethrough, and a second fusible means in said bore and also connected between said terminals.

7. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from the inner walls thereof to form an annular arc chamber therebetween, means connected between said terminals including fusible means and resilient means located in said chamber and current limiting means, said resilient means stressing said fusible means for separating the terminals of said fusible means upon fusion thereof, said insulating means having an arc restricting bore therethrough, and a second fusible means in said bore and also connected between said terminals.

8. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from the inner walls thereof to form an annular arc chamber therebetween, means connected between said terminals including fusible means and resilient means located in said chamber, said resilient means stressing said fusible means for separating the terminals of said fusible means upon fusion thereof, said insulating means having an arc restricting bore therethrough, a second fusible means in said bore and also connected between said terminals, and a second resilient means for biasing apart the unfused por-

tions of said last mentioned fusible means in response to fusion thereof.

9. In a fuse, a fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from the inner walls thereof to form an annular arc chamber therebetween, means connected between said terminals including fusible means and resilient means located in said chamber and current limiting means, said resilient means stressing said fusible means for separating the terminals of said fusible means upon fusion thereof, said current limiting means including a resistor element positioned to be in heat conducting relation with respect to said fusible means, said insulating means having an arc restricting bore therethrough, and a second fusible means in said bore and also connected between said terminals.

10. In a fuse, a fuse tube having terminals adjacent opposite ends thereof, means of insulating material in said tube and of a size to form an annular arc chamber therebetween, resistor means positioned adjacent one end of said tube and connected to one of said terminals, and fusible means in said chamber and positioned to be heated by said resistor means and connected between said resistor means and the other of said terminals.

11. In a fuse, a fuse tube of a transparent insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and of a size to form an annular arc chamber therebetween, resistor means positioned adjacent one end of said tube and connected to one of said terminals, and fusible means in said chamber and positioned to be heated by said resistor means and connected between said resistor means and the other of said terminals.

12. In a fuse, a fuse tube having terminals adjacent opposite ends thereof, means of insulating material in said tube and of a size to form an annular arc chamber therebetween, resistor means positioned adjacent one end of said tube and connected to one of said terminals, fusible means in said chamber and positioned to be heated by said resistor means and connected at one end to said resistor means, and a helical spring in said chamber for biasing said fusible means towards and electrically connecting it to the other of said terminals.

13. In a fuse, a transparent fuse tube of insulating material having terminals adjacent opposite ends thereof, means of insulating material in said tube and spaced from the inner walls thereof to form an annular arc chamber therebetween, means connected between said terminals including fusible means and resilient means located in said chamber, said resilient means being of helical form to surround said insulating means and stressing said fusible means for separating the terminals of said fusible means upon fusion thereof, whereby said helical resilient means provides a readily visible indication of the condition of said fuse.

14. In a current limiting fuse, a length of fusible wire of uniform cross section, solid means of insulating material defining a long arc passage for receiving said wire, the cross section area of said passage conforming to and substantially the same as the cross section of said wire to provide a high arc voltage upon fusion of said wire, and current limiting means connected in parallel circuit relation with said length of fuse wire.

15. Apparatus for limiting heavy overload and short circuit currents comprising current limit-

ing means, means responsive to heavy overload and short circuit currents for automatically establishing an arc in parallel with said current limiting means, solid means of insulating material forming an arc passage for said arc to provide an arc voltage at least of a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, and said arc passage being of such length and restricted cross-section as to cause the arc voltage to rise to said predetermined value in less than a half cycle after an arc is struck therein, whereby the current is transferred to said current limiting means to limit said current and arc voltage in less than a half cycle.

16. In a current limiting fuse, a length of fusible wire, solid means of insulating material defining a long arc passage for receiving said wire, at least one transverse dimension of said passage being substantially the same as a transverse dimension of said wire to provide an instantaneous high arc voltage upon fusion of said wire, and current limiting means connected in parallel circuit relation with said length of fuse wire.

17. In a current limiting fuse, a length of fusible wire, solid means of insulating material defining a long arc passage for receiving said wire, the cross-section area of said passage conforming to and being substantially the same as the cross-section of said wire to provide a high arc voltage upon fusion of said wire, and current limiting means connected in parallel circuit relation with said length of fuse wire.

18. In a circuit interrupter, arc establishing means, current limiting means connected in a parallel circuit with said arc establishing means, means positioned to act on said arc to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, and said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck to cause instantaneous transfer of the current to said current limiting means.

19. In a circuit interrupter, arc establishing means, current limiting means, means positioned to act on said arc to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck and said arc establishing means being associated with said current limiting means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said current limiting means.

20. In a circuit interrupter, fusible means, current limiting means, and means positioned about said fusible means to act on the arc formed when said fusible means melts to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck and said fusible means being asso-

ciated with said current limiting means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said current limiting means.

21. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

22. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, said means of insulating material forming a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current, and circuit interrupting means in series circuit relation with said current limiting means.

23. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, said means of insulating material forming a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current, circuit interrupting means in series circuit relation with said current limiting means, and said arc establishing and circuit interrupting means being automatically operable in response to the passage of currents therethrough above a predetermined magnitude.

24. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a long narrow passage for the arc which is enough smaller than the cross-section of the arc to restrict the lateral confines of the arc and is of sufficient length to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

25. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to pro-

vide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise in a small fraction of a half cycle to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

26. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise in a few hundred micro-seconds to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

27. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a narrow passage for the arc, said passage having at least one transverse dimension not greater than $\frac{1}{4}$ of an inch to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

28. In a circuit interrupter, current limiting means, arc establishing means in shunt relation with said current limiting means, means of insulating material positioned to cooperate with an arc struck by said arc establishing means to provide an arc voltage high enough to transfer all of the current to said current limiting means, and said means of insulating material forming a bore therethrough the greatest transverse dimension of which does not exceed $\frac{1}{4}$ inch to form a narrow passage for the arc to restrict the lateral confines of the arc sufficiently to cause the arc voltage to rise instantaneously to said high value and thereby transfer the current to said current limiting means early enough to limit the crest of the first half cycle of arcing current.

29. In a circuit interrupter, arc establishing means, current limiting means, means positioned to act on said arc to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck, said arc establishing means being associated with said current limiting means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said current limiting means, and means responsive to a current limiting operation of said interrupter to insert a gap in series with said current limiting means to finally interrupt the circuit.

30. In a circuit interrupter, fusible means, current limiting means, and means positioned about said fusible means to act on the arc formed when said fusible means melts to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck, said fusible means being associated with said current limiting means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said current limiting means, and other fusible means connected in series with said current limiting means for interrupting the circuit after current limitation.

31. In a circuit interrupter, fusible means, current limiting means, and means positioned about said fusible means to act on the arc formed when said fusible means melts to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck, said fusible means being associated with said current limiting means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said current limiting means, and other fusible means connected in series with said current limiting means for interrupting the circuit after current limitation, said other fusible means adapted to fuse in response to lower currents than the first-mentioned fusible means.

32. In a circuit interrupter, arc establishing means, current limiting means connected in a parallel circuit with said arc establishing means, means positioned to act on said arc to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck to cause instantaneous transfer of the current to said current limiting means, and means responsive to a current limiting operation of said interrupter to insert a gap in series with said current limiting means in said parallel circuit, to finally interrupt the circuit.

33. In a circuit interrupter, fusible means, a parallel circuit about said fusible means having current limiting means and other fusible means connected in series, means positioned to act on the arc formed upon fusion of said first-mentioned fusible means to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value at the same instant an arc is struck to cause instantaneous transfer of the current to said current limiting means, and said other fusible means adapted to finally interrupt the circuit.

34. In a circuit interrupter, arc establishing means, resistance means, means positioned to act

on said arc to cause the voltage of said arc to attain at least a predetermined value which is greater than the voltage drop through said resistance means for any instantaneous value of current flowing in the circuit, said means acting on the arc constructed and arranged to cause said arc voltage to rise to said predetermined value

at the same instant an arc is struck, and said arc establishing means being associated with said resistance means in such a manner that said instantaneous arc voltage causes instantaneous transfer of the current to said resistance means.

HERBERT L. RAWLINS.