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2,337,504

CURRENT LIMITING FUSE

Filed Sept. 19, 1940

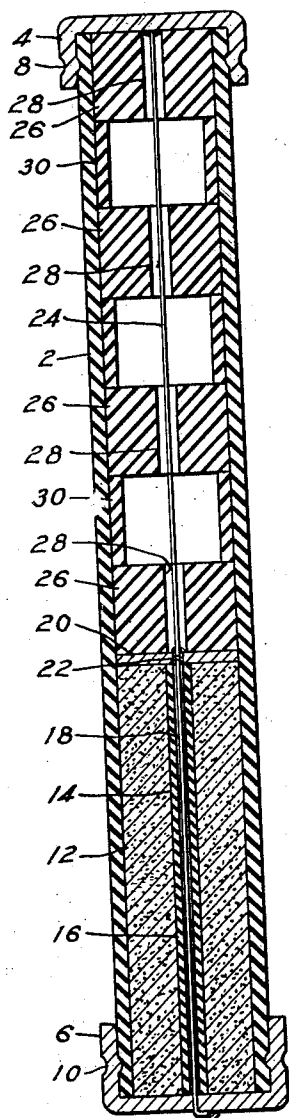


Fig. 1.

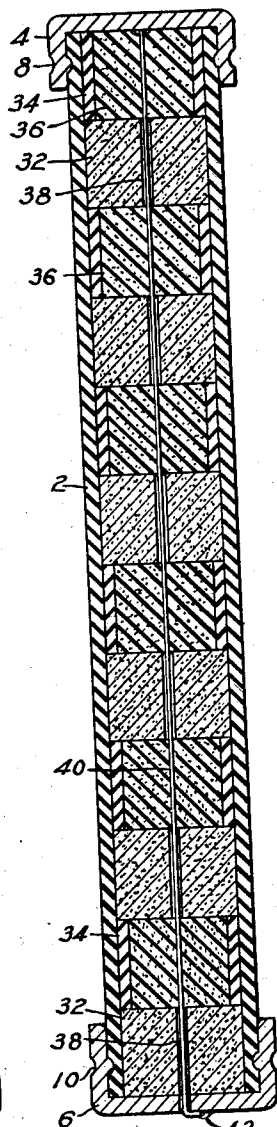


Fig. 2.

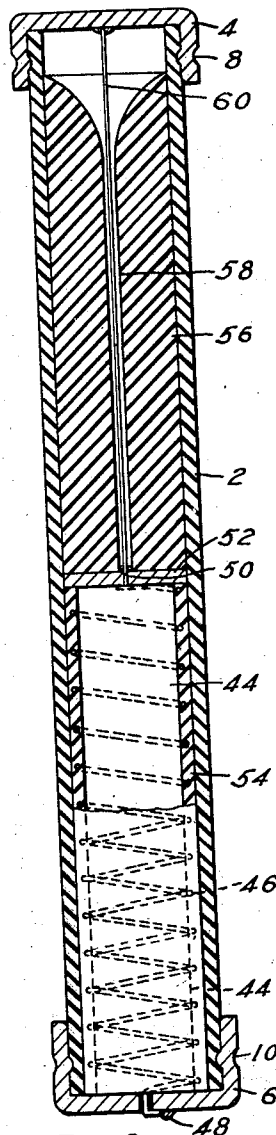


Fig. 3.

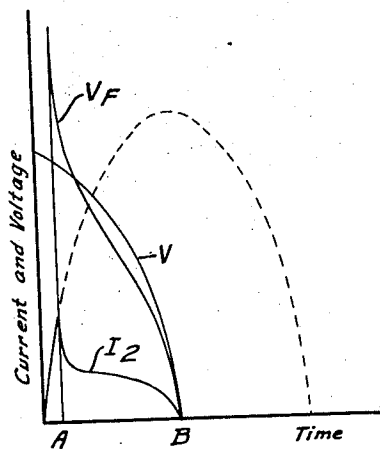


Fig. 4.

WITNESSES:

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2,337,504

CURRENT LIMITING FUSE.

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Application September 19, 1940, Serial No. 357,395

34 Claims. (Cl. 200—120)

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

An interrupter of this general type is disclosed in the copending application of H. L. Rawlins, Serial No. 357,393, filed September 19, 1940, and assigned to the assignee of this invention.

The invention of the instant application is directed to improved constructions of a current limiting fuse, and one object of the invention is to provide a novel fuse which is capable of interrupting the circuit in a fraction of a half cycle, while limiting the current and voltage interrupted.

Another object of this invention is to provide a novel type of fuse having fusible means and a relatively large current limiting resistor element all arranged in a single fuse cartridge in a novel manner.

Another object of this invention is to provide a novel arrangement of current limiting resistor and shunt fuse to obtain a quick transfer of current to the resistor when the fuse blows.

Another object of this invention is to provide in a current limiting fuse of the type wherein current limiting means and fusible means are arranged in parallel circuit relation, additional fusible means arranged in series with said parallel circuit for interrupting the circuit in response to currents above a predetermined value.

Another object of this invention is to provide in a fuse having a fusible means, a novel arrangement of current limiting means, and arc extinguishing means, to limit the current interrupted and extinguish the resulting arc.

Another object of this invention is to provide a novel type of current limiting fuse utilizing a plurality of spaced current limiting elements, and fusible means adapted to establish a plurality of arcs in series so as to transfer the current to said elements to thereby limit the current, together with means for finally extinguishing the arcs and interrupting the circuit.

Another object of this invention is to provide in a current limiting fuse having current limiting means and fusible means arranged in shunt relation, novel means cooperating with said fusible means for providing a high arc voltage upon

fusion thereof, to obtain a very rapid transfer of the current to said current limiting means.

A still further object of this invention is to provide a fuse of a novel design, having a novel and efficient arrangement of parts rendering the fuse both efficient in operation, and economical to manufacture.

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

Figure 1 is a central longitudinal cross-sectional view of a current limiting fuse embodying certain features of the invention.

Fig. 2 is a central longitudinal sectional view of a modified form of current limiting fuse.

Fig. 3 is a central longitudinal cross-sectional view of a still further modified form of current limiting fuse, and

Fig. 4 illustrates certain performance curves of a current limiting fuse constructed in accordance with this invention.

Referring to Figure 1 of the drawing, there is illustrated a fuse which includes an insulating fuse tube 2 which may be of any desired insulating material such, for example, as fiber or synthetic resin. The fuse tube 2 is provided at opposite ends thereof with terminal caps 4 and 6, respectively, which are secured to the fuse tube 2 by having portions 8 and 10, respectively, punched inwardly to engage the material of fuse tube 2.

In the lower portion of the fuse tube 2 there is shown a substantially cylindrical current limiting member in the form of a resistor 12, which may be of any desired resistance material, preferably a carbon or carborundum rod or the like. This type of resistor, when constructed of finely divided particles of carbon or other resistance material intimately bonded together will have some valve characteristics on high voltages due to breakdown and consequent discharge between particles and this feature is preferable for a purpose to be described. As shown, the resistor 12 is provided with a central bore 14, in which is received a tubular insulating sleeve 16, which may be of any desired insulating material, such, for example, as fiber. A fuse wire 18 is extended through the bore in insulating sleeve 16, and has one end thereof extended through a central aperture in terminal cap 6 to be bent over and soldered thereto as shown at 19. The other end of fuse wire 18 is soldered in an aperture 22, provided in a conducting, metal terminal partition

disk 20, located at the other end of resistor 12.

The bore through insulating sleeve 16 should be very small, and its minimum dimension is limited only by the size of fuse wire 18 and in general should not be much greater in diameter than the diameter of the wire. The fuse wire 18 is preferably constructed of a material having a relatively high melting point and a high temperature coefficient, such, for example, as silver, for a purpose to be hereinafter described. The bore through insulating sleeve 16 needs to be quite small in order to restrict the arc formed when fuse wire 18 melts, to thereby provide a high arc voltage, so that the current path may be quickly shifted to resistor 12, between terminal cap 6 and terminal disk 20. As stated above, the insulating sleeve 16 may be of any desired insulating material, although preferably of a material such as fiber which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, to thereby further aid in providing a high arc voltage for an arc struck within insulating tube 16. This is an important feature, because, in order to effectively limit the current, it is necessary that it be transferred to the resistor in a small fraction of a half cycle, after fuse wire 18 melts and before the current has had an opportunity to build up to a high value, and before the energy developed by the arc reaches a value which might cause damage to the fuse.

In the upper portion of the fuse tube 2, as seen in Fig. 1, there is provided a fuse wire 24, having one end secured in aperture 22 of terminal disk 20, as by soldering or the like, and the other end thereof is secured to terminal cap 4 in a like manner. The fuse wire 24 is preferably of a material which will melt on lower currents than fuse wire 18 and may, for example, be of a lead-tin alloy. Spaced along the length of fuse wire 24, there are provided blocks 26, of a material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, such, for example, as boric acid, gypsum, or a synthetic resin. As shown, these blocks 26 are provided with substantially central bores 28 therethrough, which are substantially larger than fuse wire 24, and insulating spacer sleeves 30 are provided between blocks 26 to maintain the blocks in spaced relation. The spacing sleeves 30 may be of any desired insulating material, such for example, as fiber or the like.

The circuit through the fuse shown in Fig. 1 may now be traced from terminal cap 4, fuse wire 24, to terminal disk 20, and thence in parallel paths, one of which extends through fuse wire 18 to terminal cap 6, and the other of which extends through resistor 12 to terminal cap 6. Obviously, under normal load conditions all of the current passing through the fuse will flow through fuse wire 24, and the major portion of the current will continue through fuse wire 18 to terminal cap 6. Only a relatively minor portion of the current, if any, will normally flow through resistor 12.

Normally upon the occurrence of a short circuit, fuse wire 24, having the lower melting point, will be melted first and substantially instantaneously thereafter fuse wire 18 will also blow. Melting of fuse wire 18 will create an arc in insulating sleeve 16, and because of the high arc voltage obtained in the manner described above, the current flow will be transferred within a fraction of a half cycle to resistor 12 which will thereby limit the current, and this limited cur-

rent will be easily interrupted in the upper end of the fuse by the action of the un-ionized gases evolved by blocks 26 and by melting of fuse wire 24, creating an elongating arc gap. Fuse wire 24, of course, is chosen to be of a size depending upon the current rating of the fuse. On the other hand, fuse wire 18 need not melt until a current value is reached which it is desired to limit. Accordingly, and by way of example, fuse wire 24 may melt in response to currents of one or two amperes, whereas fuse wire 18 may not melt unless the current reaches a value of 80 amperes. It follows from this example that on currents below the value of currents which it is desired to limit, that is, in the example given, 80 amperes, fuse wire 18 may not melt and the current will be interrupted easily within the upper end of the fuse as shown in Fig. 1 by the action of un-ionized gases evolved from blocks 26.

When resistor 12 also has a valve characteristic, this feature is made use of to limit the maximum voltage across the fuse to a safe value which may be, for example, about twice normal line voltage. Upon the occurrence of a short circuit having exceptionally high current, the arc voltage in bore 14 might go above this safe value, unless a resistor is employed which decreases in resistance at said safe high voltage. The valve effect of the resistor therefore, should operate to reduce the resistance thereof at a predetermined high voltage, which may be, as in the above example, about twice line voltage.

A modified form of the invention is illustrated in Fig. 2 of the drawing, and inasmuch as certain parts of the fuse shown in Fig. 2 are like those previously described in connection with Fig. 1 of the drawing, like reference numerals will be used to designate like parts. In the fuse illustrated in Fig. 2, there is provided a plurality of spaced resistor blocks 32 distributed along the entire length of fuse tube 2. These blocks 32 may be of the same material as resistor block 12 described in connection with the embodiment of the invention shown in Fig. 1. The blocks 32 are maintained in spaced relation along fuse tube 2 by insulating spacer sleeves 34 positioned between the blocks, and which may be of any desired insulating material, such, for example, as fiber or the like. Within each spacer sleeve 34 there is provided arc extinguishing material 36 which may be in the form of a powder of inert material, but preferably is material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, like the material comprising blocks 26 in the embodiment of the invention shown in Fig. 1, only in powder form. Obviously, arc extinguishing material in solid block form with quite large bores therethrough, so as not to confine fuse wire 40, like blocks 26 of Fig. 1, may be used if desired.

As shown, each resistor block 32 is provided with a small substantially central bore 38, through which is threaded a fusible wire 40, secured at one end to terminal cap 4, as by soldering or the like, and having the other end thereof extended through an aperture in end cap 6 to be bent over and secured to the cap as at 42. Fuse wire 40 may be of any desired fusible material having a relatively low melting point such, for example, as a lead-tin alloy. It will be noted that the fuse wire 40 extends through relatively small openings in resistor blocks 32 similar to the opening in resistor block 12 for fuse wire 18

in the embodiment of the invention shown in Fig. 1.

In operation, when an overload appears in the circuit, fuse wire 40 is first melted within one or more of the passages 38 through resistor blocks 32, because in these passages the fuse wire is confined by solid walls, and accordingly, there is less dissipation of heat from the portions of fuse wire 40 within bores 38 than from the portions of the fuse wire between resistor blocks. Wire 40, having fused in one or more of passages 38 to form an arc, which will have a high arc voltage since it is restricted to the small passages 38, will cause the arc current to be substantially instantaneously transferred through adjacent resistor blocks 32. As soon as current passes through one or more resistor blocks 32, these obviously will function to limit the current, and the current thus limited will be easily interrupted by the arc extinguishing material 36 between resistor blocks 32. In connection with this embodiment of the invention it will be noted that on high currents a plurality of arcs will be formed in series which may produce a still higher arc voltage than would be possible if but a single arc were formed. In other words, the sum of the arc voltages of a plurality of series arcs may be greater than the arc voltage for a single arc. This obviously will promote still quicker transfer of the current to the resistor elements, and limit the current at an earlier point in its ascending curve. Although but a single fuse wire is shown in connection with this embodiment of the invention, it is obvious that different fuse wires may be provided in restricted bores 38 than in the spaces outside resistors 32, in the manner disclosed in connection with Fig. 1.

Referring now to Fig. 3 of the drawing, a still further embodiment of the invention is shown, and inasmuch as many of the parts illustrated in this embodiment of the invention are identical with those illustrated in connection with the species shown in Figs. 1 and 2, like reference numerals will be used to designate like parts.

In Fig. 3 there is shown a solid resistor rod 44 positioned in the lower part of the fuse, and this resistor rod may be of the same material as resistors 12 and 32 previously described. A fuse wire 46 preferably of a material similar to the fuse wire 18, described in connection with the embodiment of the invention shown in Fig. 1, is wrapped around resistor rod 44 in substantially a spiral fashion, and has one end thereof extended through an aperture in terminal cap 6 and bent over to be secured thereto as at 48, and the other end thereof is secured in an aperture 50, in a conducting, metal terminal partition disk 52 positioned at the opposite end of resistor rod 44. The end of fuse wire 46 may be secured in aperture 50 in any desired manner, such, for example, as by soldering or the like. Fuse wire 46 is preferably closely surrounded by walls of insulating material, and may even be embedded in insulating material 54 as shown on the drawing. Although good results have been obtained by using enameled wire, for example, and covering this with one or more layers of cellulose acetate tape or a tape impregnated with water-glass, it is preferred that the fuse wire 46 be entirely embedded in an insulation material which may be in the form of a plastic, such as a viscous paint made of a solution of cellulose acetate, or ethyl cellulose, or synthetic resin or the like, which is capable of evolving an arc extinguishing gas when in proximity to an electric arc. The purpose of em-

bedding the fuse wire 46 in such a material, is to provide a very small arc passage when the fuse wire melts, to thereby obtain a high arc voltage to quickly transfer the current to resistor rod 44. Obviously, if insulating material 54 is of the gas evolving type, the arc voltage will be higher than if the insulation 54 is of an inert type. Positioned above terminal partition disk 52, as shown in Fig. 3, there is provided a lining 56 for the fuse tube 2 which is preferably of a gas evolving material like the blocks 26 described in connection with Fig. 1. The gas evolving material 56 is provided with a bore 58 therethrough, for receiving a fuse wire 60 which is secured between terminal disk 52 and end cap 4, in any desired manner, such, for example, as by soldering or the like, and is of a material like fuse wire 24 previously described, which melts on lower currents than fuse wire 46.

The electrical circuit through the fuse shown in Fig. 3 is similar to that described in connection with the fuse shown in Fig. 1, and comprises a series circuit extending from one cap 4 through fuse wire 60 to terminal disk 52. From there, there are two circuits in parallel to end cap 6, one extending by way of fuse wire 46 and the other by way of resistor rod 44. Normally, of course, resistor rod 44 will carry little, if any, of the current, and the main current path through the fuse will be from end cap 4, through fuse wire 60, terminal disk 52, and fuse wire 46 to end cap 6.

Upon the occurrence of a short circuit, fuse wire 60 which is of a different material, and has different characteristics than fuse wire 46, and is preferably of a material like that of fuse wire 24, described in connection with Fig. 1 of the drawing, will melt and substantially instantaneously thereafter fuse wire 46 will also melt to establish an arc in the very small bore in insulating material 54. It will be noted that not only is this bore extremely small, but that it is also quite long due to the coiled arrangement of fuse wire 46, and this also helps to provide an extremely high arc voltage, so that the current will be substantially instantaneously shifted to resistor rod 44, to thereby limit the current, and permit the current as thus limited to be interrupted within bore 58 through gas evolving material 56. It will be noted that the operation of the fuse shown in Fig. 3 is much like that of the fuse shown in Fig. 1, and therefore will not be described again in detail to avoid repetition. However, certain features of the fuse shown in Fig. 3 are important, especially the feature which enables the use of a longer parallel fuse wire to thereby attain a desirable high arc voltage when this fuse wire melts, to obtain quick transfer of the current to the current limiting resistor element.

All three of the embodiments of the invention disclosed have the advantage that with these constructions a relatively large resistor may be employed, since, as shown, the resistor may occupy substantially one-half the total space within the fuse tube. This results in a larger current carrying capacity without excessive heating. Also the overall length of the fuse may be reduced, because, with the constructions disclosed herein, portions of the fuse elements may be passed through or parallel to the resistor elements, and this is of advantage with these constructions of current limiting fuses since it is highly desirable to locate such portions of fuse elements in very small passages, to restrict the arc formed when they blow. All three embodiments of the invention also utilize current limiting resistor elements

having a valve action, to limit the voltage to a safe maximum.

It should also be noted that in the constructions herein disclosed it is impossible for the current to transfer to any element which might short circuit the resistors, so that the current limiting resistors must always be cut in the circuit when the fuse blows, especially on currents above predetermined values for limiting the maximum value of such currents.

In Fig. 4 of the drawing there is illustrated typical voltage and current curves plotted with respect to time, and which provide a graphic example of the performance of a fuse constructed in accordance with this invention. In Fig. 4, the dotted line curve designates the normal short circuit current if it were not limited. Curve V designates the circuit voltage, point A designates the point at which the fuse blows, curve I_2 designates the current as limited by applicant's fuse, curve V_f indicates the voltage across the fuse, and point B indicates the time when interruption occurs.

It will be obvious upon consideration of these curves that circuit interruption occurs within a fraction of a half cycle after the fuse blows, or a predetermined time after the current reaches a value predetermined by the size of the fuse wire employed, and the current is limited as soon as the parallel fuse wire melts to a very small fraction of the normal short circuit current, and even the voltage across the fuse is not much higher than line voltage. As the system short circuit capacity increases, the time at which current limitation occurs also decreases, as does the ratio of the limited current to the system capacity, because the current will be shifted to the resistor at an earlier point. The reason for the relatively low voltage across applicant's fuse is that although a high arc voltage may result from the arc structure in insulating tube 16 of Fig. 1, resistor bores 38 of Fig. 2 or insulating material 54 of Fig. 3, this causes transfer of the current to the resistors, and the voltage can rise only to a value high enough to transfer all of the current to the resistors, and this occurs in a very few microseconds. Of course, the size and characteristics of the parallel fuse wire accounts for the low peak in the I_2 curve, and since the fuse has only to interrupt a current which is limited by the resistor means, interruption is quickly accomplished in a small period of time as illustrated by way of example in Fig. 4. The time for interruption of the circuit is decreased materially in a fuse of this type, due to the fact that the current after transfer to the resistor is at almost unity power factor, thereby advancing current zero so that interruption occurs in a small fraction of a half-cycle.

Where the word "instantaneously" or term "at the same instant" is used herein and in the claims to denote a time of operation, this means a time of less than a half cycle of a 60 cycle wave, and preferably in a small fraction of a half cycle on the order of a few hundred micro-seconds.

In the foregoing there has been specifically disclosed various embodiments of an invention specifically relating to current limiting fuses wherein a fuse wire is provided paralleling a resistor element, with both electrically and mechanically related in various novel combinations, and further arranged in conjunction with arc extinguishing means, to provide a current limiting fuse which is particularly efficient in opera-

tion, while being relatively small and compact in construction, and economical to manufacture.

Although the resistance elements in each of the embodiments of this invention are referred to herein 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 each 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, and this action is enhanced by the use of a resistance element having valve characteristics, as previously described.

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 specifically disclosed herein, 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 circuit interrupter, current limiting means, means for automatically establishing an arc in response to currents above a predetermined value arranged in shunt relation with respect to said current limiting means, means positioned to act on said arc to provide an arc voltage 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, said means acting on the arc being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the arc is struck to cause instantaneous transfer of the current to said current limiting means, and means for automatically interrupting the circuit in response to currents above a predetermined value and connected in series with said current limiting means and arc establishing means.

2. In a current limiting fuse device, current limiting means having a passage substantially coextensive with said current limiting means, fusible means in said passage and arranged in shunt relation with respect to said current limiting means.

3. In a circuit interrupter, current limiting means, means for automatically establishing an arc in response to currents above a predetermined value, means positioned to act on an arc established by said arc establishing means to provide an arc voltage 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, said means acting on the arc being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the 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 for automatically interrupting the circuit in response to currents above a predetermined value and arranged in series circuit relation with said current limiting means and arc establishing means at least during a current limiting operation.

4. In a circuit interrupter, current limiting means, means for automatically establishing an arc in response to currents above a predetermined value arranged in shunt relation with respect to said current limiting means, solid means of insulating material positioned to restrict said arc to provide an arc voltage 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, said means acting on the arc being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the 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 for automatically interrupting the circuit in response to currents above a predetermined value and connected in series with said current limiting means and arc establishing means, and including solid means in proximity thereto of a material capable of evolving an arc extinguishing gas when in proximity to an electric arc.

5. In a circuit interrupter, current limiting means, means for automatically establishing an arc in response to currents above a predetermined value arranged in shunt relation with respect to said current limiting means, solid means of insulating material capable of evolving an arc extinguishing gas when in proximity to an electric arc forming a narrow passage for restricting an arc established by said arc establishing means to provide an arc voltage 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, said means acting on the arc being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the 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 for automatically interrupting the circuit in response to currents above a predetermined value and connected in series with said current limiting means and arc establishing means.

6. In a current limiting fuse device, current limiting means having a passage substantially coextensive with said current limiting means, fusible means including a portion in said passage connected in shunt relation with said current limiting means, said fusible means having another portion outside said passage, and arc extinguishing means arranged in cooperative relation at least with the portion of said fusible means located outside said passage.

7. In a current limiting fuse device, current limiting means having a passage substantially coextensive with said current limiting means, fusible means in said passage and arranged in shunt relation with respect to said current limit-

ing means, and additional fusible means located outside said passage and arranged in series relation with respect to said current limiting means and fusible means in said passage.

8. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion but not all of the space along said tube with one end of said resistor means electrically engaged with one of said terminals, and fusible means connected between said terminals and having a portion thereof occupying substantially the same extent of said tube as said resistor means and connected in shunt circuit therewith, and said fusible means having another portion in the remainder of said tube.

9. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, spaced current limiting resistor means in said tube and occupying a substantial portion of the space in said tube, and fusible means connected between said terminals and including fusible portions extending along said resistor means and across at least certain of the spaces between said resistor means.

10. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, spaced current limiting resistor means in said tube and occupying a substantial portion of the space in said tube, fusible means connected between said terminals and including fusible portions extending along said resistor means and across at least certain of the spaces between said resistor means, and arc extinguishing means located in at least said certain of said spaces between said resistor means.

11. In a fuse, current limiting resistor means having a bore therethrough, and fusible means in said bore and connected in parallel circuit relation with said resistor means.

12. In a fuse, current limiting resistor means having a bore therethrough, fusible means in said bore and connected in parallel circuit relation with said resistor means, and additional fusible means outside said bore and connected in series with said parallel circuit.

13. In a fuse, current limiting resistor means having a bore therethrough, fusible means in said bore and connected in parallel circuit relation with said resistor means, and said bore being of a size to restrict the arc formed upon fusion of said fusible means to thereby create a high arc voltage and cause rapid transfer of the current to said resistor means.

14. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube with one end of said resistor means electrically engaged with one of said terminals, a fuse wire connected between said terminals and having a portion thereof extending along said resistor means, and said portion of said fuse wire being closely surrounded by insulating material to provide a small bore for the arc formed when said fuse wire melts.

15. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube, with one end of said resistor means electrically engaged with one of said terminals, a fuse wire connected between said terminals and having a portion thereof extending along said

resistor means, and said portion of said fuse wire being closely surrounded by insulating material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc to provide a small bore for the arc formed when said fuse wire melts.

16. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube with one end of said resistor means electrically engaged with one of said terminals, a fuse wire connected in shunt relation with said resistor means and closely surrounded by means of insulating material to form a restricted arc passage, and another fuse wire connecting said resistor to said other terminal and having a lower melting point than said first mentioned fuse wire.

17. In a fuse, current limiting resistor means, and a fuse wire substantially spirally wound about said resistor means and connected in shunt relation with said resistor means.

18. In a fuse, current limiting resistor means, a fuse wire substantially spirally wound about said resistor means and closely confined in a passage of substantially the same cross-section as said wire, and said wire being connected in shunt relation with said resistor means.

19. In a fuse, current limiting resistor means, a fuse wire substantially spirally wound about said resistor means and closely confined in a passage of substantially the same cross-section as said wire, said wire being connected in shunt relation with said resistor means, and at least inner wall portions of said passage comprising a material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc.

20. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube with one end of said resistor means electrically engaged with one of said terminals, and fusible means coiled about said resistor and connected in shunt relation therewith, and additional fusible means connecting said resistor means to the other of said terminals.

21. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, partition means including terminal means dividing said tube into at least two compartments, current limiting means and a closely confined shunt fusible means in one of said compartments and connected between said terminal means and one of said terminals, and a second fusible means having different characteristics located in another of said compartments and connecting said terminal means and the other of said terminals.

22. In a circuit interrupter, means for establishing an arc, means cooperating with said arc to provide an instantaneous high arc voltage, and current limiting means, the resistance of which decreases when subjected to voltages above a predetermined value arranged in shunt relation with said arc establishing means for limiting the current and voltage.

23. In a circuit interrupter, current limiting valve means, arc establishing means in shunt relation with said current limiting means, means cooperating with an arc established by said arc establishing means to substantially instantaneously raise the arc voltage thereof to a value above that necessary to transfer the current to said current limiting means, and said current

limiting means being responsive to voltages above said value to reduce its current limiting effect and thereby limit such voltages.

24. In a fuse, a resistor block, a fuse wire spirally wound about said resistor means and connected in shunt relation with said block, and insulating means between said wire and resistor means.

25. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, closed partition means including terminal means dividing said tube into at least two compartments, current limiting means and a closely confined shunt fusible means in one of said compartments and connected between said terminal means and one of said terminals, and a second fusible means having different characteristics located in another of said compartments and connecting said terminal means and the other of said terminals.

26. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, transverse partition means dividing said tube into a plurality of compartments, current limiting means and shunt fusible means in one of said compartments and connected to the adjacent terminal, series fusible means in another of said compartments and connected to the other of said terminals, and connections extending through and sealed in said partition means for connecting said fusible means and current limiting means.

27. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube with one end of said resistor means electrically engaged with one of said terminals, fusible means connected between said terminals and having a fusible portion thereof extending along said resistor means, and said portion of said fusible means being closely surrounded by insulating material to provide a small bore for the arc formed when said fusible portion melts.

28. In a fuse, a fuse tube having insulated terminals adjacent opposite ends thereof, current limiting resistor means in said tube and occupying a substantial portion of the space in said tube with one end of said resistor means electrically engaged with one of said terminals, a fuse wire connected in shunt relation with said resistor means and closely surrounded by means of insulating material to form a restricted arc passage, another fuse wire connecting said resistor to said other terminal, and means of a material capable of evolving an arc-extinguishing gas occupying substantially all of the remaining space in said tube and forming an arc passage for said other fuse wire.

29. In a fuse, current limiting means and fusible means connected in shunt relation, means for restricting the arc formed upon fusion of said fusible means to provide an instantaneous high arc voltage, and one of said first two mentioned means being in the form of an elongated strip of material spirally arranged about the other.

30. In a fuse, current limiting means and fusible means connected in shunt relation, and one of said means being in the form of an elongated strip of material spirally arranged about the other.

31. In a fuse, current limiting means and fusible means connected in shunt relation, one of said means being in the form of an elongated strip of material spirally arranged about the

other, and insulating means between said first two mentioned means.

32. In a circuit interrupter, current limiting means, fusible means, means positioned to act on the arc formed upon fusion of said fusible means to provide an arc voltage 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, said means acting on the arc being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the arc is struck, said fusible means 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 a second fusible means connected in series with said first-mentioned fusible means.

33. In a circuit interrupter, current limiting means, fusible means, means positioned to act on the arc formed upon fusion of said fusible means to provide an arc voltage at the instant said arc is struck which is greater than the voltage drop through said current limiting means for any instantaneous value of current flowing in the circuit, said fusible means 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 a second fusible means having a lower melting point than said first-mentioned fusible means and connected in series with said first-mentioned fusible means.

34. In a circuit interrupter, resistance means, means for automatically establishing an arc in response to currents above a predetermined value, means positioned to act on an arc established by said arc establishing means to provide an arc voltage of 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 being constructed and arranged to cause the arc voltage to rise to said predetermined value at the same instant the arc is struck, 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, and means for automatically interrupting the circuit in response to currents above a predetermined value and arranged in series circuit relation with said resistance means and arc establishing means at least during a current limiting operation.

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