April 4, 1950 H. L. RAWLINS ET AL 2,502,992

CIRCUIT INTERRUPTER

Filed Dec. 16, 1943

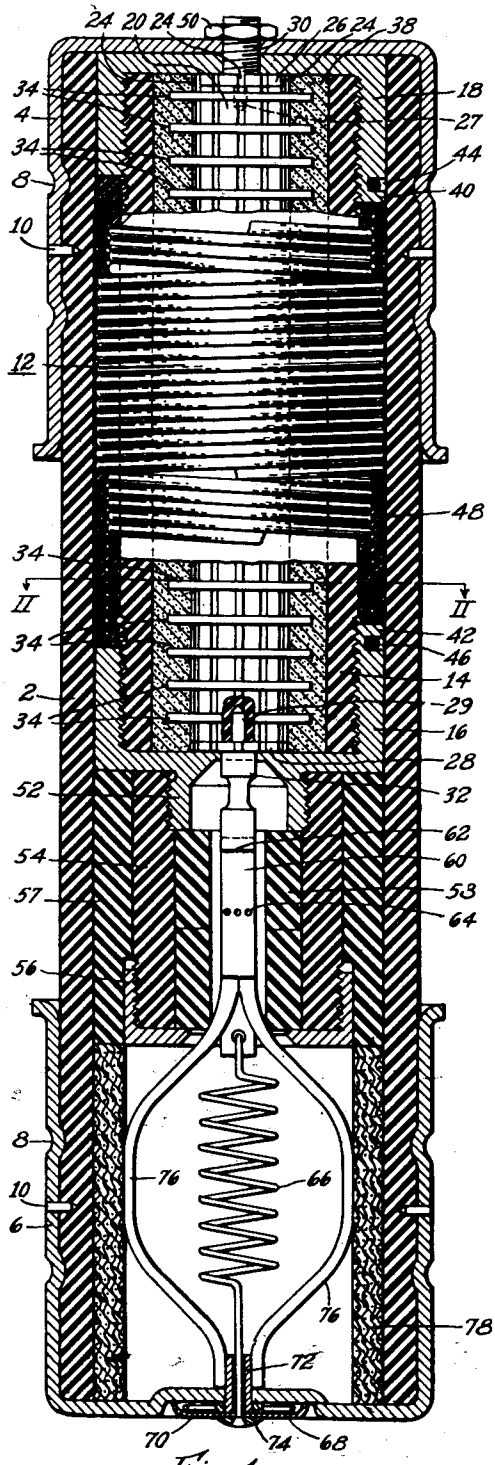



Fig. 1.

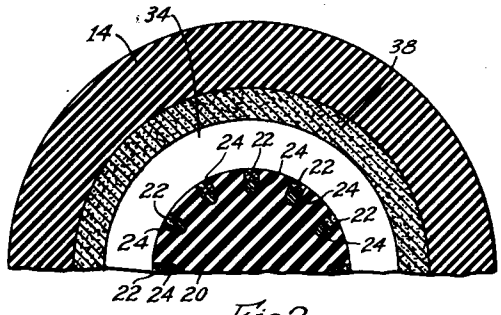



Fig. 2.

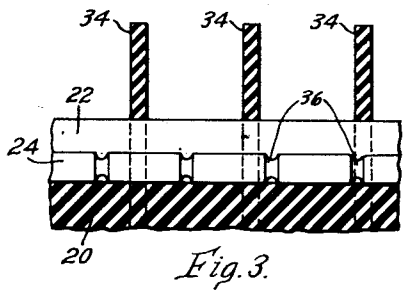



Fig. 3.

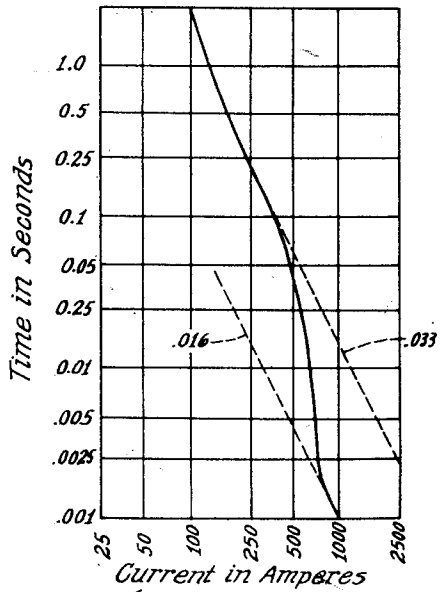



Fig. 4.

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# UNITED STATES PATENT OFFICE

2,502,992

## CIRCUIT INTERRUPTER

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Application December 16, 1943, Serial No. 514,502

25 Claims. (Cl. 175—294)

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This invention relates, in general, to electric circuit interrupting devices and, more particularly, to high voltage fuses which are especially adapted to limit the current and voltage at least upon interruption of heavy overloads and short circuits.

The copending application of H. H. Fahnoe on Circuit interrupters, Serial No. 511,562, filed November 24, 1943, now issued at Patent No. 2,483,577, dated October 4, 1949, and assigned to the same assignee of this invention represents a recent development in current and voltage limiting fuses, of the teachings of the copending application of H. L. Rawlins, Serial No. 357,393, filed September 19, 1940 now Patent No. 2,337,495, issued December 21, 1943, and the intermediate developments as represented in the copending application of A. P. Strom, Serial No. 357,395, filed September 19, 1940 now Patent No. 2,337,504, issued December 21, 1943, and H. L. Rawlins, et al. Patent No. 2,309,013, issued January 19, 1943, all assigned to the same assignee of this invention. This prior work teaches that an efficient current and voltage limiting fuse should comprise, in general, three main elements as follows: (1) a current limiting fusible element capable of producing a high arc voltage in a fraction of a half cycle, preferably in a few hundred microseconds after the fusible element melts, to limit the current at a low point in its rise, and to effect a transfer of the current to, (2) a resistor which is connected in parallel with the fusible element to limit the voltage and current to a predetermined value; and (3) a clean-up fusible element to interrupt the power follow current through the resistor.

While this general arrangement may be used throughout for fuses of all current ratings, this invention is primarily concerned with the solution of certain special problems encountered in fuses of this type for the higher current ratings, for example, in current ratings of about ten amperes and above. While a fuse of this type could be constructed in accordance with the prior disclosures mentioned above for such high current ratings, by merely enlarging these prior structures, the resulting fuse for ratings, for example, of one or two hundred amperes, would be excessively large in size and too costly. To build a fuse of this type in the higher current ratings by merely increasing the size of the current limiting fusible element, as by merely providing a plurality of parallel fuse wires, would necessitate a much larger structure for the absorption of metal vapors on melting the fusible

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element, and would require an excessively large parallel resistor to handle the higher currents.

It is, accordingly, one object of this invention to provide a current and voltage limiting fuse of the general type described, of a novel construction especially adapted for high current ratings, but which is small in size and economical of manufacture.

Another object of this invention is to provide a novel fusible element having a time characteristic especially adapted to fuses of this type.

Another object of this invention is to provide a novel structure for supporting a current limiting fusible element to obtain a high arc voltage in an extremely short time upon fusion of the element, with a minimum of disturbance.

Another object of this invention is to provide a novel unitary assembly of current limiting fusible means and shunt resistance means.

Still another object of this invention is to provide a novel power fuse assembly which is responsive to light continuing overloads as well as heavy overloads to efficiently interrupt the circuit.

These and other objects of this invention relating to certain novel details of fuse construction and assembly, will become more apparent upon consideration of the following description of a preferred embodiment of the invention, when taken in connection with the attached drawing, in which:

Figure 1 is a substantially central longitudinal section through a fuse constructed in accordance with this invention, with certain of the parts therein shown in elevation;

Fig. 2 is an enlarged partial transverse cross-section view of the limiter unit employed in the fuse shown in Fig. 1, taken substantially on the line II—II thereof;

Fig. 3 is an enlarged partial longitudinal section taken through one of the slots of the fuse supporting member shown in elevation in Fig. 1; and

Fig. 4 is a curve illustrating the melting characteristics of the fusible element employed in the structures shown in Figs. 1 to 3.

The particular embodiment of the invention disclosed is illustrated as being mounted within a tubular fuse holder 2 of insulating material, such as fiber or a synthetic resin. The tubular fuse holder 2 is provided with terminal caps 4 and 6 adapted to be secured over the opposite ends of the tubular holder. Terminal caps 4 and 6 may be of any desired conducting material, such, for example, as copper or the like, and they

are preferably secured in position on tubular holder 2 but having indentations 8 rolled therein, and staking pins 10 may be also provided to prevent relative rotation of the terminal caps and tubular holder.

The actual current and voltage limiting means disclosed are embodied in a limiter unit 12 adapted to be secured in position within one end of tubular holder 2. The limiter unit 12 includes a supporting tube 14 of suitable insulating material such as fiber or the like, provided with end terminal caps 16 and 18 threadedly engaged over each end of supporting tube 14. Terminal caps 16 and 18 of the limiter unit may be of any good electrical conducting material such as copper, brass, or the like. The particular current and voltage limiting means constituting this invention are adapted to be supported by supporting tube 14, with certain of the elements mounted within the tube, and others supported on the outside of the tube between terminal caps 16 and 18.

In order to effectively provide for current and voltage limitation on high overloads and short-circuits, it is necessary that the overload be limited before the maximum current is obtained in the first half cycle of the overload. If this is not done, the resulting surge on the first half cycle of fault current is capable of doing considerable damage to the circuit and especially to connected apparatus, such as transformers and the like. Accordingly, the main problem encountered in obtaining effective limiting action is to render whatever current limiting means employed, effective soon enough that it can operate to prevent the rise of the fault current to its maximum value in the first half cycle. This means that the current limiting means must be rendered effective in a small fraction of a half cycle of such overloads as it is desired to limit, on the order of time of a few hundred microseconds. This problem becomes acute in fuses having a continuous current rating above ten amperes, because considerable time is needed to melt the relatively large fusible elements required, and it is difficult to obtain a high enough arc voltage after fusion of the fusible element with sufficient speed to exert a limiting action on the current in a device of practical size. This invention comprehends one particular structure which is capable of limiting the current and voltage in the first half cycle of the fault, in a device which is small in size, and, therefore, capable of practical application.

The particular means for obtaining current and voltage limitation in limiter unit 12, comprises a supporting rod 20, which extends longitudinally within supporting tube 14 and is preferably of an insulating material which is capable of evolving an arc extinguishing gas when in proximity with an electric arc, such, for example, as fiber or a synthetic resin. It will be noted that supporting rod 20 is considerably smaller than the internal diameter of supporting tube 14 and is centrally positioned therein so as to be spaced from the inner walls of the supporting tube. Supporting rod 20 is provided with substantially central bores at each end, for a purpose to be described. A plurality of longitudinally extending slots 22 are provided in supporting rod 20, angularly spaced around the periphery of the rod. These slots 22 are for the purpose of receiving fuse wires 24, which are connected at their ends to terminal disks 26 and 28. Terminal disks 26 and 28 have integral centrally located positioning pins 27 and 29, respectively, adapted to be



received in the bores at the ends of rod 20. These terminal disks are of a good electrical conducting material, such for example, as copper or the like, and are slotted to correspond with the slots 22 in supporting rod 20 for receiving the fuse wires 24 which are secured in the slots of the disks, for example, as by soldering or the like. Terminal disk 26 is provided with an integral threaded stud 30 for a purpose to be described, and the other terminal disk 28 is provided with an integral terminal extension 32 having a diametrically extending slot in the outer end thereof, which will be hereinafter referred to. A plurality of washers 34 are telescoped over supporting rod 20 and are disposed in spaced relation along the length of the supporting rod, for a purpose to be described. Washers 34 may be of any desired insulating material, such, for example, as fiber or the like.

As stated above, the most important factor in obtaining efficient current limitation is the speed at which the current limiting operation is brought into play, at least on overloads which it is desired to limit. Since the first thing that must occur on such heavy overloads is the fusion of the fusible element to establish an arc, it is absolutely necessary that the fusible element in a fuse of this type be capable of fast action, especially on those heavy overloads where it is desired to exert a current limiting action. In the above-mentioned patent of H. H. Fahnoe, No. 2,483,577, the limiter fuse wires are disclosed as being a material such as silver which has a high electrical conductivity and low specific heat to obtain fast melting time on high overcurrents. Another advantage of this material is that it has a relatively high temperature coefficient of resistance so that the resistance will increase at a relatively rapid rate just prior to melting. Although ordinary fuse wires of uniform diameter, made of silver or other materials having comparable characteristics, are suitable for use in a current limiting fuse having a low current rating, for example, ten amperes or less, fuses of higher current ratings, which must be designed with a greater amount of fusible material to carry such higher currents, require that the individual fusible elements operate considerably faster than the ordinary fuse wire in order that the total melting time be fast enough to effectively limit the current. Referring to Fig. 3, it will be seen that the particular fusible elements employed in the fuse of this invention are especially constructed to provide a faster action at least on the higher currents. To this end, the fuse wire itself is chosen to be of substantially the same size as that required to carry the rated current without undue heating, and which will melt on currents above the rated current. Such a wire is then provided with a plurality of reduced area sections 36, such, for example, as by rolling these sections. It has been found that by making the fuse wire with sections 36 reduced in area, the fusion time of the wire is speeded up to correspond to that of a wire of substantially the same diameter as the reduced sections for high values of current. This speeding up effect has been found to be roughly proportional to the ratio between the areas of the large portions of fuse wire 24 and reduced portions 36. As a practical matter, this ratio may be made as high as possible, being limited only by mechanical strength consideration. Such a fuse wire retains all the normal time-current characteristics desired in a fuse for time values in excess of

approximately two cycles without appreciable reduction in current carrying ability. Reduction in current carrying ability varies roughly directly in proportion to the length of sections 36, so it is desirable that these sections be made as short as possible. For short times of less than one-fourth cycle, fuse wire 24 has an exceptionally fast melting time. This will be clear from a consideration of Fig. 4 of the drawing wherein the characteristic time-current curve of a fuse wire constructed in accordance with this invention is shown in full lines. The particular fuse element having the characteristic curve shown in Fig. 4 has a diameter of .036 inch and reduced portions 36 of .0145 inch. Fig. 4 illustrates the time current curve extended in dotted lines for a fuse wire of uniform diameter and like material having a diameter of .033 inch, and the other dotted line curve illustrates the time current characteristic for a fuse wire of a uniform diameter of .016 inch. It will be observed that by providing the reduced sections 36, the fuse wire still retains substantially the same time-current characteristic on low currents up to about 400 amperes as a fuse wire of a uniform diameter substantially equal to the large diameter of the fuse wire constituting this invention. However, on currents above 400 amperes, fuse wire 24 is much faster, and departs abruptly from the characteristic of the large diameter wire and becomes substantially coincident with the characteristic of a fuse wire having a uniform diameter substantially the same as the reduced section 36 of fuse wire 24. This means that a fuse wire constructed with reduced sections 36 will have its continuous current carrying ability substantially unimpaired, and even its time current characteristic on light overloads will be substantially unchanged. However, on heavy overloads, and this is particularly important and useful with current limiting fuses where it is desired to limit such heavy overloads; on such overloads, the fuse wire constructed in accordance with this invention operates much faster, and, accordingly, it is possible to bring the current limiting means into action soon enough, so that it may be effective at an early point in the first half cycle of fault current. While the particular fuse wire disclosed has a special cooperation in a current limiting fuse in order to permit early limitation of the current, it may, of course, find application in connection with other fuse structures of general utility.

Actual current limitation is effected in this fuse by providing a high arc voltage upon fusion of fuse wires 24, which arc voltage is built up substantially instantaneously to thereby exert a limiting or choking effect on the overload current and prevent its rise beyond a predetermined value. In order that the length of the fuse may be kept down to a reasonable amount, it is necessary that the arc volts per inch of length of the arc be made a high value, not only to obtain a high value of arc voltage but to cause this high value of arc voltage to be attained with the greatest possible speed. One way of increasing the arc voltage per inch of arc length, is to provide a relatively large number of reduced sections 36 in fuse wire 24, so that when these reduced sections melt, a plurality of serially related arcs will be struck, and the summation of the arc voltages of these series arcs will then be greater than the arc voltage across a single arc. Generally speaking, the arc voltage per inch is directly proportional to the number of



series arcs or restrictions 36 per inch. This suggests that to obtain maximum arc voltage, there should be provided as many restrictions per inch as physically possible. However, this is not literally true, because as the number of restrictions 36 per inch are increased a point is eventually reached where a further increase results in a decrease in current carrying ability. This appears to be due to the resulting reduction in length of the large diameter fuse wire portion to the point where they no longer have sufficient mass to absorb enough of the heat generated in the restrictions 36 to maintain the temperature of the restrictions below the fusion point. It has been found that at least for voltages above 600 volts at least two restrictions 36 per inch of fuse wire 24, or a total of 10 should be provided to obtain an effective rise in arc voltage in a fuse wire which is not of excessive length. This corresponds approximately to a spacing of restrictions 36 not to exceed about 15 times the large diameter of the fuse wire. It is desirable, however, to use the maximum number of restrictions possible without substantially impairing the current carrying ability of the fuse wire. Such a desirable number of restrictions will depend on the size of fuse wire employed. In the particular example previously given, with a wire having a diameter of .036 inch, the restrictions 36 should be spaced about one-eighth of an inch apart, for best results. This particular spacing of reduced sections 36 corresponds roughly to 3.5 times the largest diameter of the fuse wire. This is an optimum spacing, however spacings as low as about twice the largest diameter of the fuse wire may be employed with good results. The specific example given above is for a fuse wire designed for a fuse to have a continuous current rating of 200 amperes at 2500 volts. Such a fuse will employ eight fuse wires 24 connected in parallel between the terminal caps 16 and 18 of limiter unit 12.

Another aid in rapidly building the arc voltage up to a high enough value to exert a current limiting effect, is the narrow slots 22 in which fuse wires 24 are located. The width of slots 22 is made as small as possible, being limited only by the size of fuse wires 24, and in practice the slots may be made not more than .010 inch larger than the fuse wires. This clearance will provide a snug fit of the wires in the base of the slots, and since the slots are preferably made about twice as deep as the diameter of the fuse wires, it is apparent that the wires will closely contact the slot on three sides, that is, at the bottom and opposite sides of the slot. The use of such narrow slots in which the arc is struck upon melting of the fusible elements, physically restricts the lateral boundaries of the arc, thereby raising the arc voltage at the instant the arc is formed.

Because fuse wires 24 are in intimate engagement with the walls of slots 22 in the supporting rod, and since the rod is of a material capable of evolving an arc extinguishing gas, it will be apparent that the arc formed upon fusion of reduced sections 36 will be in close proximity on three sides with the walls of the slots so that considerable quantities of arc extinguishing gas will be evolved, and this gas will blast laterally through the arc to perform three functions, all of which act to increase the arc voltage. First, the blast of arc extinguishing gas through the arc acts to sweep metal vapor out of the arc

stream to thereby increase the resistance and, consequently, the voltage across the arc. This metal vapor is swept out of the slots by the arc extinguishing gas and into the material 38 filling the space between supporting rod 20 and supporting tube 14. Material 38 is preferably an inert granular insulating material, such, for example, as sand or the like, and this acts to disperse and condense the metal vapors into separated particles insulated from each other by the particles of sand, so that a high resistance path is maintained outside the slots. Secondly, the blast of arc extinguishing gas transversely of the arcs in the slots, also acts to supply unionized gas to the arc path, which obviously increases the resistance of the arc path and, consequently, the voltage drop across it. A third function of the transverse gas blast is to cause the series arcs to be looped outwardly toward the filling material 38, thereby lengthening the arc path and, consequently, increasing the resistance thereof and the voltage drop across it. The function of washers 34 on supporting rod 20 will now be apparent, as permitting looping of the series arcs outwardly of slots 22, but preventing these arcs from entirely escaping from the slot and, consequently, from proximity with the gas evolving material, and from the restricting action of the narrow slot, while preventing the arcs from restriking as a single arc outside of the slots. It is apparent that washers 34 provide spaced points along the slots where the arcs cannot escape from the slots, so that any looping of the arcs outwardly of the slots must occur between washers 34. Washers 34 function the same way on extremely high currents when the fuse wires may be entirely consumed and the arc in each narrow slot may become a single long arc.

From the foregoing, it is apparent that efficient current limitation of the first half cycle of the fault current may be obtained with the structure disclosed because: (1) the fusible element itself is capable of melting to establish an arc at least on the high currents which it is desired to limit, in a very short time, that is, in a very small fraction of a half cycle; (2) as soon as the arc is established, it is subjected to all of the factors enumerated above which create an arc voltage at the instant an arc is formed which is high enough to prevent any further rise of fault current. It has been found that the factors enumerated, produce such a high arc voltage in an extremely short period of time, so that the current is actually limited in a small fraction of the first half cycle of fault current, on the order of time of a few hundred microseconds.

While the current is limited essentially by the high arc voltage instantaneously produced by the fuse structure contained within supporting tube 14, this arc voltage must at the same time be prevented from creating a surge on the circuit which might cause flashover damage to other apparatus connected in the circuit and to line insulation. Accordingly, this voltage is prevented from rising to a dangerously high value by the provision of a resistance in parallel with the fuse structure within supporting tube 14. This resistance is preferably in the nature of a resistance wire 48 wound on the outside of the supporting tube and connected to terminal caps 16 and 18. For this purpose, each of the terminal caps is provided with an integral semicircular extension, such as the extension 40 on



cap 18 and extension 42 on cap 16. These cap extensions are provided with peripheral grooves 44 and 46, respectively, for receiving an end portion of the resistance wire 48. These grooves 44 and 46 have the inner wall thereof substantially aligned with the outer end of the remaining portion of their respective cap flanges, so that the end turn of resistance wire 48 may abut the cap flanges at one side and lie in groove 44 or 46 at the other side. Resistance wire 48 is provided with a very thin coating of insulating material, such, for example, as a glass composition, and is preferably of a material which is substantially non-magnetic and has a positive temperature coefficient of resistance, such, for example, as a copper-nickel alloy. Actually the resistance wire 48 comprises but a single wire which is wound, for example, with one end placed in groove 46 of terminal cap 16, in an inner layer along tubular holder 14 until terminal cap 18 is reached, whereupon one half turn is laid in slot 44 and an outer layer is then wound over the first layer of winding, and this will obviously be wound in a direction opposite to the first winding, to thereby cancel the inductance of the two windings. The outer winding is then continued until terminal cap 16 is again reached, and the end of wire 48 may also be laid in groove 46, groove 46 is illustrated in Fig. 1 with one end of wire 48 therein. The resistance wire 48 may be secured in grooves 44 and 46 as by soldering or the like, or by peening over the outer end wall of the slots.

Such a resistance being connected in parallel with the fuse elements within tubular support 14, and being non-inductively wound, will stabilize the voltage that occurs during interruption. The maximum voltage that can appear across the fuse is simply the IR drop through the resistor, because as soon as the voltage reaches this value the current will transfer to the resistance circuit. Since the arc voltage in slots 22 builds up at an extremely rapid rate, as previously pointed out, transfer of the current to the resistance will occur in a small fraction of a half cycle. Thus, knowing the instantaneous peak current permitted by the current limiting structure within tubular holder 14, which can be determined from curves made from experimental data, the value of resistance 48 may be chosen to limit the voltage to any desired figure. In addition to controlling the voltage surge during interruption, the resistance very materially reduces the duty on the current limiting fuse elements, because the total energy which is required to be absorbed by the current limiting fuse elements has been found to be less than 15% of the energy that it would absorb without any parallel resistance. This also contributes to making possible a very compact structure, and is a very material factor in the small overall size of the complete fuse.

The limiter unit 12 may be secured in position within tubular holder 2, by the stud 30 at the upper end thereof, which extends through an aperture provided in terminal cap 4 of the fuse holder 2, and is provided with a nut 50 for securing the limiter unit 12 in operative position with its terminal cap 18 in conductive relation with terminal cap 4 of the fuse holder 2. Terminal cap 16 of limiter unit 12 is provided with an integral extension 52 of reduced size, which is externally threaded for cooperation with internal threads provided in one end of a tube 54 of insulating material, such, for example, as

fiber or the like. A cap 56 is provided for the other end of tube 54, and a spacer tube 57 is adapted to fit in the space between tube 54 and fuse tube 2. Tube 54 has supported therein, between extension 52 and cap 56, a lining comprising blocks 58 of a material which is capable of evolving an arc extinguishing gas when in proximity with an electric arc, such, for example, as boric acid, synthetic resin, or the like. These blocks 58 of gas evolving material have a central bore therethrough for receiving a strip of fusible material 60, adapted to be connected to terminal 32 of the limiter unit 12. The strip of fusible material 60 is adapted to fit into the slot provided in the outer end of terminal 32, and to be secured therein by a low melting point solder 62. The strip of fusible material 60 is adapted to have a portion reduced in area, as by the provision of apertures 64 therein to define a melting point for excess currents. The current carrying capacity of fusible strip 60, at least at the section at apertures 64, is somewhat less than fuse wires 24 so that the fusible strip 60 will always operate first, at least on lower values of overload current. A coil tension spring 66 has one end hooked through an aperture in the outer end of fusible strip 60, and has the other end anchored to an indicator disk 68 held in a depression at the outside of holder terminal cap 6, by spring 66. The indicator disk 68 is biased outwardly by a relatively weak coil compression spring 70, reacting between the disk and terminal cap 6. A bushing 72 of a good electrical conducting material, such as copper or brass, is provided for the aperture through which the outer end of spring 66 extends, and this bushing is provided with a nut 74 at the outside of the cap by which it is held in position. Fusible strip 60 is electrically connected with holder terminal cap 6 by flexible shunts 76 of copper or the like, which may be brazed or otherwise secured to the fusible strip and to bushing 72. The space at the end of tubular holder 2 occupied by tension spring 66 is preferably lined with a metallic fabric or screening 78, to provide means for condensing gases emitted from gas evolving material 58.

In the operation of the fusible element described above, it will be observed that it is electrically connected in series between holder terminal caps 4 and 6, with the parallel arrangement of limiter fusible elements 24 and resistance wire 48. The series fuse may operate upon the occurrence of relatively light overloads which continue for relatively long preiods of time by melting of solder 62, due to heat conducting thereto from the fusible element 60. On higher overloads and short circuits, the fusible e'ement 60 will melt at the point defined by apertures 64, and in either case the outer end of the fusible element will be withdrawn by tension spring 66 through the passage formed by gas evolving material 58, to thus lengthen the arc and subject it to the action of arc extinguishing gas evolved from material 58. Preferably this gas evolving material is one which evolves a readily condensable gas, such as water vapor, so that upon expulsion of this gas into the lower end of the fuse tube, it will contact the relatively cool surfaces defined by metallic material 78, and be condensed to thereby avoid the building up of high pressures within the fuse holder.

The operation of the complete device may now be summarized, and it will be apparent that the fuse may operate in either of two ways, depending upon the magnitude of fault current. On relatively light overloads, the series fuse will operate by melting of solder 62 and the resulting arc will be lengthened and extinguished by the deionizing action of gases evolved from material 58, while the metallic material 78 condenses the evolved gas. During this process, the current limiting fusible elements 24 do not fuse because of their higher current carrying capacity, and consequently play no part in the interruption.



On heavy overloads or short circuits where it is desired to limit the current, the series fuse will operate in a small fraction of a half cycle, and the current limiting fuse elements will melt substantially simultaneously at a very rapid rate, as previously described. The fusion of the current limiting fuse elements 24 and the action of the resultant series arcs in the restricted fiber slots all act to rapidly produce an arc voltage high enough in value to prevent further increase in the fault current. This occurs in a small fraction of a half cycle, and transfer of the current to the resistance 48 is effected at the same time. The condensing action of the granular insulating material 38 within the current limiting unit 12 has the effect of reducing pressures which would otherwise be present within the current limiting unit, not only by the condensation of metal vapors from the fuse wires themselves, but also by the cooling action thereof on the gases evolved from the inner walls of slots 22. On such operation of the current limiting unit, the current is effectively limited, and the resistance wire 48 prevents a rise in the voltage beyond a predetermined value. The series fuse will arc through the current limiting action, which, as pointed out previously, requires only a very short time on the order of a few hundred microseconds, and the series fuse then interrupts the current through the resistance at the first current zero. Since this current is limited by the resistance, it has a high power factor, and, consequently, it is very easily interrupted.

From the foregoing, it will be apparent that this invention not only provides a current limiting fuse which is capable of efficiently limiting the value of current in the first half cycle for fuses having high current ratings, but that there is also disclosed herein a novel construction of fuse wires to obtain unusually fast action thereof, at least on high values of current. This invention also comprehends a novel combination of means for obtaining a high arc voltage in a very short time, to thereby obtain its particularly efficient current limiting operation. These particular novel features are combined with a parallel resistance to limit the voltage and also prevent any further rise in current, with this parallel arrangement all supported in a novel manner in a relatively small and compact arrangement in a tubular holder of practical size having an additional fuse element connected in series therewith to interrupt the circuit on light overloads, and to finally interrupt the current as limited by the current limiting structure on heavy overloads. The whole construction disclosed is totally enclosed so that no external display or venting of arc products occurs.

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

We claim as our invention:

1. In a circuit interrupter, a supporting rod of insulating material, a plurality of spaced generally longitudinally extending slots in the outer surface of said rod, means for striking an arc in each of said slots, and a plurality of washer-like members of insulating material mounted in spaced relation on said rod to prevent escape of corresponding portions of said arcs from said slots.

2. In a circuit interrupter, a supporting rod of insulating material, a plurality of spaced generally longitudinally extending slots in the outer surface of said rod, a fuse wire in each of at least a plurality of said slots adapted to automatically fuse and establish an arc in each such slot in response to the passage of currents above a predetermined value therethrough, and a plurality of washer-like members of insulating material mounted in spaced relation on said rod to prevent escape of corresponding portions of said fuse wires and arcs from said slots.

3. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having at least two spaced sections per inch of length which are reduced in area to render said element faster acting at least on heavy overloads, and means positioned to act on the arcs formed by fusion of said fusible element to cause the arc voltage to attain said high value at said rapid rate.

4. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in area which are of a size and spacing to render said element faster acting on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, and means positioned to act on said arcs to raise the arc voltage comprising the sum of said series arcs at least to said high value and at said rapid rate.

5. In a device of the type described having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having at least two spaced sections per inch of length which are reduced in area and of a size to render said element faster acting at least on heavy overloads but not on light overloads.

6. In a device of the type described having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in



area of such size as to render said element faster acting at least on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, said reduced area sections being spaced apart a distance of from about 2 to 5 times the large diameter of said element.

7. In a current limiting fuse, a limiter unit comprising a tube of insulating material, terminal caps for each end of said tube, a longitudinally extending supporting rod of insulating material in said tube and spaced from the inner walls of said tube, a plurality of spaced generally longitudinally extending slots in the outer surface of said rod, a fuse wire in at least one of said slots and electrically connected between said terminals, spaced disks of insulating material telescoped over said rod to prevent escape of said fuse wire and the arc formed upon fusion thereof entirely from said slots, and an inert granular insulating material filling the space between said rod and tube.

8. In a current limiting fuse, a limiter unit comprising a tube of insulating material, terminal caps for each end of said tube, a longitudinally extending supporting rod of insulating material in said tube and spaced from the inner walls of said tube, a plurality of spaced generally longitudinally extending slots in the outer surface of said rod, a fuse wire in at least one of said slots and electrically connected between said terminals, at least inner wall portions of said slots being of a material which is capable of evolving an arc extinguishing gas when in proximity with an electric arc, spaced disks of insulating material telescoped over said rod to prevent escape of said fuse wire and the arc formed upon fusion thereof entirely from said slots, and an inert granular insulating material filling the space between said rod and tube.

9. In a current limiting fuse, a limiter unit comprising a tube of insulating material, terminal caps for each end of said tube, fusible means in said tube connected between said terminals, each of said caps having its flange extended at one side, a wire receiving groove on the outer periphery of each flange extension, and a resistance wire coil wound on the outside of said tube with end portions of said coil being secured in said grooves.

10. In a current limiting fuse, a limiter unit comprising a tube of insulating material, terminal caps for each end of said tube, fusible means in said tube connected between said terminals, each of said caps having its flange extended at one side, a wire receiving groove on the outer periphery of each flange extension, each of said grooves having the inner side in the same plane as the outer edge of its cap flange, and a resistance wire coil wound on the outside of said tube with end portions of said coil being secured in said grooves.

11. In a current limiting fuse, a limiter unit comprising a tube of insulating material, terminal caps for each end of said tube, fusible means in said tube connected between said terminals, each of said caps having its flange extended at one side, a wire receiving groove on the outer periphery of each flange extension, a continuous resistance wire wound on said tube in two layers with the respective layers wound in opposite directions, the ends of said wire at one end of said windings being secured in one of said grooves, and an intermediate portion of said wire at the

other end of said windings being secured in the other of said grooves.

12. A high voltage fuse which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having at least one section of relatively high resistance to render said element faster acting at least on heavy overloads but not on light overloads, means positioned to act on the arc formed by fusion of said fusible element to cause the arc voltage to attain said high value at said rapid rate, and resistance means connected in a parallel circuit with said fusible element at least after said fusible element melts, said resistance means being of a value such that the current will transfer to it when said arc voltage attains a predetermined magnitude at least sufficient to effect said current limitation, whereby the arc voltage is prevented from rising beyond said predetermined magnitude, and additional fusible means connected in series with said parallel circuit for finally interrupting the circuit, said additional fusible means including a second fusible element adapted to fuse prior to said first mentioned fusible element, and a low melting point alloy connection in heat conducting relation to said second fusible element for interrupting the circuit on light overloads which remain on the circuit for a predetermined time.

13. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in area to render said element faster acting at least on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, said reduced area sections being so short as not to substantially effect the time-current characteristic of said element at least for light overloads, and means positioned to act on said arcs to raise the arc voltage comprising the sum of said series arcs at least to said high value and at said rapid rate.

14. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in area and of such size and spacing as to render said element faster acting at least on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, said element having at least 10 of said reduced area sections, and means positioned to act on said arcs to raise the arc voltage comprising the sum of said series arcs at least to said high value and at said rapid rate.



15. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in area and of such size and spacing as to render said element faster acting at least on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, said reduced area sections being spaced apart a distance of between from about 2 to 5 times the large diameter of said element, and means positioned to act on said arcs to raise the arc voltage comprising the sum of said series arcs at least to said high value and at said rapid rate.

16. A high voltage fuse having a definite continuous current rating and which is capable of producing an arc voltage high enough in value and with sufficient rapidity to prevent the rise of current interrupted above a predetermined value, comprising, in combination, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections reduced in area and of a size to render said element faster acting at least on heavy overloads but not on light overloads, and to provide a plurality of spaced series arcs upon fusion of said reduced area sections, said reduced area sections being as short and of as small cross section as mechanically possible and being spaced apart a distance of between from about 2 to 5 times the large diameter of said element, and means positioned to act on said arcs to raise the arc voltage comprising the sum of said series arcs at least to said high value and at said rapid rate.

17. In a device of the type described, having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of sections which are reduced in area and are of such size and spacing as to render said element faster acting at least on heavy overloads but not on light overloads.

18. In a device of the type described having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of spaced sections which are reduced in area and substantially as short as mechanically possible to render said element faster acting at least on heavy overloads.

19. In a device of the type described having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a pluarlity of sections which are reduced in area and of such size and spacing as not to

substantially alter the time-current charcteristic of said element on overloads up to a predetermined value above which the melting time of said element is substantially decreased.

20. In a device of the type described having a definite continuous current rating, an elongated fusible element, the cross section area of said element being of a size capable of carrying the rated current of said fuse but which will fuse on currents above said rated current, said element having a plurality of sections which are reduced in area and of such small size and sufficient spacing as not to substantially alter the time-current characteristic of said element on overloads up to a predetermined value above which the melting time of said element is substantially decreased.

21. Current limiting cirucit interrupting means comprising, means of a solid insulating material forming an elongated arc passage, means for striking an arc in said passage, said passage being sufficiently narrow to restrict the cross section of the arc, said arc passage closely surrounding the arc throughout its length on at least three sides, with the fourth side of said passage being open at longitudinally spaced points, to permit correspondingly spaced portions of said arc to loop outwardly through said openings and the escape of arc products while maintaining intermediate portions of the arc in the restrictive passage, and a layer of inert granular means of insulating material over said openings for cooling and dispersing products of the arc.

22. Current limiting circuit interrupting means comprising, means of a solid insulating material forming an elongated arc passage, means for striking an arc in said passage, said passage being sufficiently narrow to restrict the cross section of the arc, said arc passage closely surrounding the arc throughout its length on at least three sides, with the fourth side of said passage being open at longitudinally spaced points, to permit correspondingly spaced portions of said arc to loop outwardly through said openings, at least inner wall portions of said passage being of an insulating material which is capable of evolving an arc extinguishing gas when in proximity to an electric arc, so that when said arc is struck said arc extinguishing gas will flow laterally across the arc to escape through said openings and thereby cause looping of at least spaced portions of the arc toward said openings and the escape of arc products while maintaining intermediate portions of the arc in the restrictive passage, and a layer of inert granular means of insulating material over said openings for cooling and dispersing products of the arc.

23. In a circuit interrupter, arc establishing means, a mass of inert insulating material of granular form having a high thermal capacity, means supporting said insulating material in proximity to at least one side of the path of an arc struck by said arc establishing means, said insulating material being directly exposed to substantially the entire length of said path, means of a solid insulating material capable of evolving an arc-extinguishing gas when in proximity to an electric arc supported in proximity with at least the opposite side of said arc path along substantially the entire length thereof to cause a blast of unionized gas to flow through substantially the entire length of the arc in a direction toward said granular insulating material to disperse the metal vapor in the arc through said granular insulating material where it is condensed in finely divided form outside the arc path, and spaced means of solid insulating material for maintaining correspondingly spaced portions of said arc in proximity with said gas evolving material, whereby portions of the arc intermediate said spaced means may be looped outwardly toward said granular material by the passage therethrough of said evolved gases, but the arc is prevented from moving bodily away from said gas evolving material by said spaced means of insulating material.

24. In a current limiting fuse, a fusible wire, supporting means of a solid insulating material surrounding said wire at a plurality of spaced points, said material having at least inner wall portions capable of evolving an arc extinguishing gas when in proximity to an electric arc and having one internal dimension which is small enough to restrict the cross section of the arc formed upon fusion of said wire to thereby limit the arc current, and a finely divided inert insulating material in proximity to said fusible wire intermediate said spaced points.

25. In a circuit interrupting means, means of a solid insulating material forming an elongated arc passage, means for striking an arc in said passage, said passage being sufficiently narrow to restrict the cross section of the arc, said arc passage closely surrounding the arc throughout its length on at least three sides, with the fourth side of said passage being open at longitudinally spaced points, thereby permitting correspondingly spaced portions of said arc to loop outwardly through said openings and the escape of arc products while maintaining intermediate portions of the arc in the restrictive passage, a layer of inert granular means of insulating material over said openings for cooling and dispersing products of the arc, and said means of solid insulating material including barriers extending laterally outwardly at points intermediate said vent openings.

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