July 13, 1965 F. L. CAMERON ETAL 3,194,923

CURRENT LIMITING FUSE

Filed Jan. 30, 1961 2 Sheets-Sheet 1

Fig. 1.

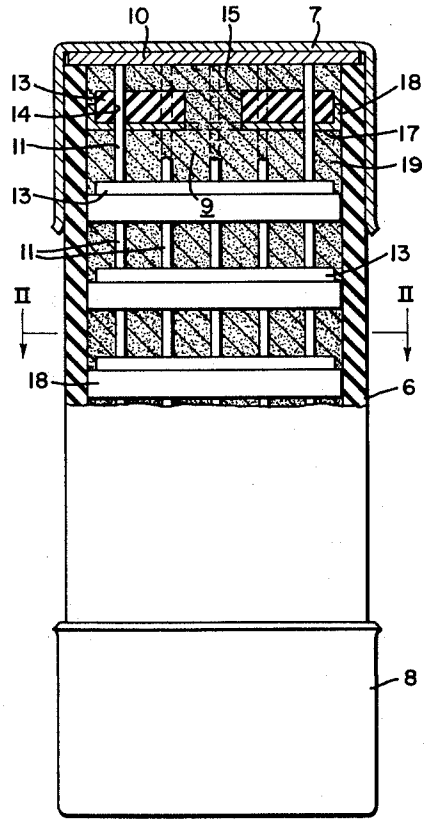
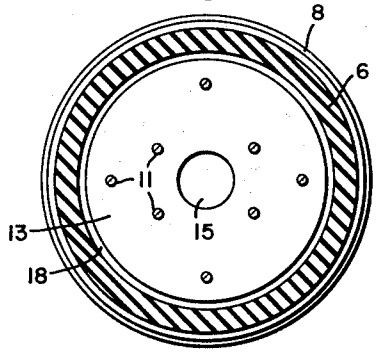


Fig. 2.



WITNESSES

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CURRENT LIMITING FUSE

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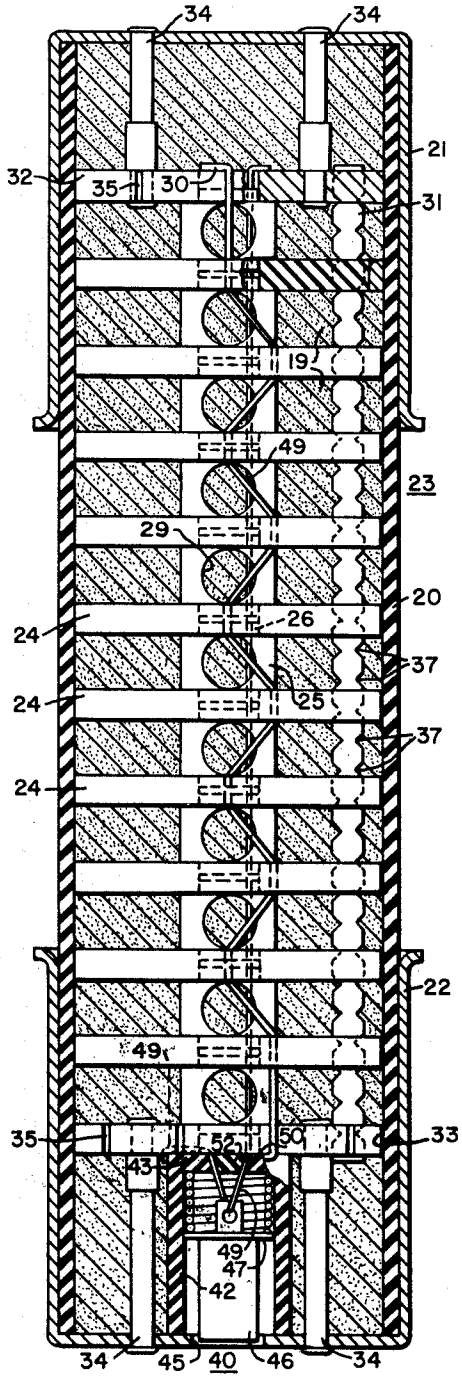


Fig. 3.

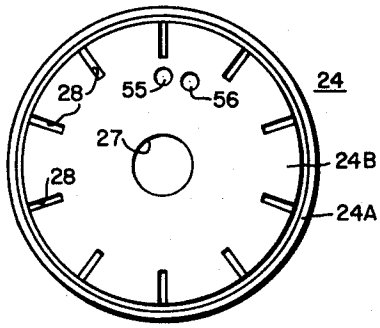


Fig. 4.

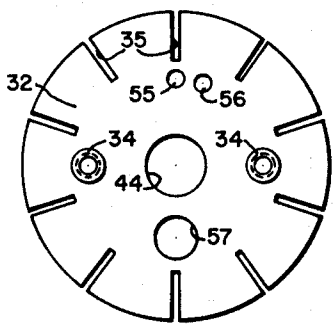


Fig. 5.

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3,194,923

CURRENT LIMITING FUSE

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7 Claims. (Cl. 200—120)

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

The current limiting fuse in general is an effective high current interruption device which operates extremely fast at high rates of current rise, but is less effective as a low current interrupter.

Accordingly, it is an object of this invention to provide a current limiting fuse which is an effective interrupter at all values of current from a value less than minimum melting to a maximum rating of the device.

It is a fundamental characteristic of current carrying fusible elements that the temperature distribution along the element is uneven so as to produce a hot spot at or near the center of the fusible element. Inasmuch as the limiting working temperature of the fuse is to some extent determined by the heat loss within the fuse, the rating of the fuse may be increased by effecting more uniform cooling of the fusible element throughout its length.

Accordingly, it is another object of this invention to provide in a fuse means for radially cooling the fuse elements so as to provide substantially more uniform heating of the element to increase the fuse rating.

In practicing this invention in one form, there is provided an enclosed current limiting fuse means having a plurality of spaced parallel fusible elements surrounded by suitable arc quenching material. A plurality of fibre discs are mounted in the fuse enclosure, with each disc extending transversely of the fuse enclosure and all the fusible elements and spaced along the length of the fusible elements. Each disc includes a plurality of spaced apertures, each aperture individually adapted to receive therethrough a different one of the fusible elements and wherein each aperture has a transverse dimension only slightly larger than the fusible element therein to effectively form a pressure pot interrupter chamber whereupon fusing of the fusible member within the confines of the chamber results in the arc voltage being maintained at a high level. Metal cup means supporting each fibre disc are provided to connect the discs to the fuse enclosure and at the same time provide for effecting radial cooling of the fuse element along its length by conduction of the heat from the fusible element transversely of the fuse holder to the wall of the fuse holder for radiation to the surrounding atmosphere.

In another embodiment of the invention, the fusible element means are notched to provide high arc voltages on high rate of current rise while at the same time fiber discs of the type described above are provided along the length of a fusible means as hereinbefore described to provide low current interrupting capabilities.

The invention will become more apparent upon consideration of the following description when taken in connection with the attached drawings, in which:

FIGURE 1 is a substantially central longitudinal section through one embodiment of the fuse constructed in accordance with this invention;

FIGURE 2 is a transverse cross sectional view of the fuse shown in FIGURE 1, taken substantially along the lines II—II of FIG. 1.

FIGURE 3 is a longitudinal sectional view of a fuse showing another embodiment of the invention;

FIGURE 4 is a top plan view of a fibre interrupter disc utilized in the construction of the fuse of FIGURE 3; and,

FIGURE 5 is a top plan view of a terminal disc used in the construction of the fuse of FIGURE 3.

Referring to FIGURES 1 and 2 of the drawing, there is shown one embodiment of the invention in a multilink fuse comprising a tubular fuse holder **6** of insulating material such as fiber or a synthetic resin. The tubular fuse holder **6** is provided with terminal caps **7** and **8** adapted to be secured over the opposite ends of the tubular holder **6**. Terminal caps **7** and **8** may be of any desired conducting material, such for example as copper or the like, and they may be secured in position over the tube **6** in any suitable manner known in the art such as by cementing, crimping or pinning.

The current limiting and arc-extinguishing structure is embodied in a unit **9** comprising a pair of connectors **10, 10** (only one shown) each mounted at one end of the tube **6** in abutting relationship with the end of the tube and fixedly held between the end of the tube **6** and a corresponding one of the end caps **7, 8**. The connectors **10, 10** may be comprised of conducting material, such as copper. A plurality of fusible wire elements **11**, which may be comprised of silver, are fixedly arranged within the tube **6** in spaced parallel relationship with respect to each other and extend the full length of the tube **6**, each element **11** having its opposite ends fixedly attached to the connectors **10, 10** by any suitable means such as soldering, brazing, welding, to provide a current path through each element **11** from one connector plate **10** to the other.

In order to provide a high arc voltage upon the fusion of fuse wire **11**, there is provided within the tube **6** a plurality of circular interrupter plates **13**. The plates are comprised of gas evolving material, such as fibre. Each of the plates **13** is positioned transversely of the tube and has a diameter slightly less than the inside diameter of tube **6** for reasons to be discussed hereinafter. The plates **13** are spaced from each other longitudinally of the tube **6** through the supporting action of a granular arc-quenching filler material **19**, such as silica sand. The plates **13** are provided with suitable apertures **14**, each aperture having a diameter only slightly larger than the fuse elements and appropriately placed in each disc to provide passage of all the fuse wires **11** through each disc **13**. A large centralized aperture **15** is provided in each plate **13** for receiving the filler material **19** dispersed throughout the tube and which may be comprised of granular sized silica sand.

The plates **13** have a predetermined thickness selected to provide each aperture with optimum length so that it performs the function of an individual pressure pot. Each plate **13** is spaced sufficiently from the adjacent plates so that upon the melting of a wire **11**, there will be formed a plurality of serially related high voltage areas having a summation of arc voltages providing a greater arc voltage than would be provided by a single arc in the absence of the interrupter plate. Tests have indicated that fibre discs having a thickness on the order of about ¼ inch and spaced about ½ inch apart provide this desired action. It has been observed that a thickness of the fibre disc less than ¼ inch provides a significantly reduced relatively unsatisfactory pressure pot effect. The tests have indicated that the arcing occurring within the confines of the small diameter hole in the interruptor plates generates a high pressure gas. This gas blows the silver vapor into the relatively cool surrounding medium of the sand **19**, tending to rapidly cool the arc, as well

as removing the conductiing silver vapors. The provisions of Paaschen's Law, which generally state that an increase in dielectric strength accompanies an increase in gaseous pressure, also plays a part in the effective interruption, that is, an increase in gas pressure within the chamber provides an increased arc voltage. The interrupter plates 13 and their arc pressure chambers are effective on high current as well as low current. The physical confinement of the arc within the plate results in the arc voltage being maintained at a high level, thus providing highly successful operation to limit the let-through current at high rates of current rise.

In order to carry heat away from the fusible elements 11 to the outer fuse tube 6 where the heat may be radiated to the surrounding atmosphere, there is provided a close fitting metal cup 17 having a lip portion 18 for each fibre disc and serving as a seat for the disc. The lip portions 18 of the cups 17 are in contact with the inner wall of the tube 6 and the outer periphery of the fibre disc 13. The cups are characterized as cooling fins which serve as cooling and momentary heat storage wells, allowing the fuse to have a higher rating than would otherwise be the case. Secondly, this provision for effectively conducting the heat away radially means that the importance of the actual heat distribution along the element is less. Stated another way, the fuse elements are more prone to reach a uniform temperature before melting, rather than melting in the center which is ordinarily the hot spot of the conductor. Thus it is seen that the fuse rating is a function of the number of the radially arranged heat condutcor caps 17.

Referring now to FIGURES 3, 4 and 5 of the drawings, a second embodiment of the invention is illustrated as being mounted within a tubular fuse holder 20 of insulating material, such as glass melamine or fibre. The tubular fuse holder 20 is provided with terminal caps 21, 22 adapted to be secured over opposite ends of the tube 20. The terminal caps 21, 22 and may be of any desired conducting material, such for example as copper or the like, and they may be secured in position in any suitable manner as by cementing or other suitable means known to the art.

The current limiting and arc-extinguishing structure comprises a unit indicated generally at 23. This unit comprises a stack of circular interrupter plates 24 of the general type hereinbefore described, and comprised of insulating material, such for example as fibre which is capable of evolving an arc-extinguishing gas when in proximity to an electrical arc. Each disc 24 has a diameter substantially equal to the inside diameter of the tube 20 and is spaced longitudinally along the inside of the tube with respect to the other plates by means of tubular spacers 25, each spacer having a reduced neck portion 26, 26 at each end for seating within a mating aperture 27 in the center of the adjacent interrupter plate 24, thus providing convenient means for varying the size of an interrupter stack as desired. Each spacer 25 is provided with a bore 29 transversely through its longitudinal axis to allow access for a suitable granular insulating filler 19, such as silica sand. The spacers may be comprised of insulating material, such as fibre.

The interrupter plates 24 are identical and as shown in FIG. 4 are provided with ten radially disposed equally spaced narrow slots 28 adjacent the outer edge of each plate 24. The fibre discs 24 may be of a unitary structure or, as shown, may be comprised of two separate elements, the second element comprising a portion of disc 24 and consisting of a fibre ring 24A tightly fitted over the outer periphery of the disc core 24B, thus allowing the slots to be cut radially into the periphery of the disc 24B whereafter assembly of the ring 24A about the core 24 adds the outer side to the slots 28

In the assembly of the fuse, each slot 28 in the interrupter plate 24 is initially aligned longitudinally of the fuse holder with a corresponding slot 28 in the adjacent plate by means of an aperture 55 in each plate for receiving an aligning rod, not shown, whereupon a plurality of ribbon type fuse elements or links are threaded through the aligned slots in parallel relationship, only two of such ribbons 30, 31 being shown, the other eight ribbon elements being omitted for the sake of clarity in the drawings.

In order to provide fatigue strength to the fuse elements 30, 31 and all the fuse elements not shown, so they do not break under the stresses of expansion and contraction imposed by alternate heating and cooling of the elements as loading varies, particularly where the fuse is utilized in motor starting equipment, the fuse elements are regularly indexed or staggered throughout their lengths, as for example, fuse element 30 which has been threaded from interrupter plate to interrupter plate on a symmetrically staggered basis, as shown. This staggered arrangement is achieved by rotating alternate ones of discs 24 half the angular distance between adjacent slots by means of a second aperture 56. Thus, after the fuse elements 30, 31 are initially threaded as described above, the holes 56 in alternate discs 24 are brought into alignment with holes 55 in the remaining discs whereupon an aligning rod, not shown, inserted in the aligned apertures 55, 56 maintains the fuse elements in the staggered arrangement, as shown. Accordingly, where a straight fuse element will bend at only one or two weak points under contraction or expansion, thus effecting a relatively large amount of flexing at the weak points for a given amount of expansion effecting an early break in the fuse elements, in the present arrangement, each of the indexed or prebent points bends only slightly under the same amount of expansion or contraction thus distributing the stress uniformly along the fuse element with the result that the variation in stress intensities at any one point of loading is kept within the endurance range of the metal, and the element does not break.

The prebending or indexing of fuse elements to provide fatigue proofing is disclosed and claimed in copending case Serial No. 85,872, now Patent No. 3,134,874, filed concurrently with the present application, by Frank L. Cameron and assigned to the same assignee.

The fuse elements 30, 31 are of a well known type which may be comprised of silver and which are notched at intervals, as at 37, to provide a series of reduced portions which melt in response to a high rate of current rise associated with large fault currents, thus forming a plurality of serially related arcs, the summation of which arc voltages will then be greater than the arc voltage across a single arc to thus effect a current limiting action.

In order to provide for electrically connecting the parallel fuse elements 30 and 31 to the end caps 21, 22, there is provided a pair of electrically conducting terminal elements 32, 33, one at each end of the previously described insulating stack and spaced from the stack by means of spacers 25 of the type previously described. The terminal elements 32, 33, are disc shaped and have an outwardly extending pair of studs or connectors 34, 34 which are connected by brazing or other known means to the corresponding end cap 21, 22. The terminal discs are slotted at 35 on their outer periphery to align the slots 35 with the slots 28 in the interrupter plate 24. The opposite ends of each fuse link 30, 31 are fitted in appropriate slots 35 where they may be fastened by any suitable means, such as by soldering or the like. The discs 32 and 33 each have an off center opening 57 therethrough to facilitate insertion and dispersion of the filler 19 throughout the tube holder.

In order to provide visual indication of fuse operation, there is provided a fuse operation indicator at one end of the fuse tube 20 and indicated generally at 40. The operation indicator comprises a tubular housing 42 having a shoulder 43 at one end abutting the terminal disc 33 and having a tubular neck portion extending beyond the shoulder 43 within aperture 44 in the terminal plate 33. The

opposite end of the housing 42 is open and extends outwardly of plate 33 into abutting relationship with the inside edge of an aperture 45 in the end cap 22, the aperture 45 having a diameter slightly smaller than the inside diameter of the tubular housing 42 for reasons which will be immediately apparent. Slidably mounted within the housing 42 is a cylindrical indicator 46 having a diameter slightly less than the diameter of aperture 45 and having a flange portion 47 at the inner end thereof having a diameter substantially the same as that of the inside of housing 42 and greater than the diameter of aperture 45. The length of the cylinder indicator is such that it may be fully enclosed within the housing 42 to thus indicate the absence of fuse operation. A compression spring 48 is mounted in the housing 42 between the restricted end of the housing at shoulder 43 and the flange 47 of the indicator to bias the indicator 46 outwardly of the housing 42 whereupon the flange 47 engages the inside edge of aperture 45 indicating the operation of the fuse by the extension of the indicator 46 outwardly of the housing 42 into view of an inspector. Normally, the indicator 46 is held within the housing 43 against the bias of spring 48 by means of a suitable conductor 49 affixed in any suitable manner to the upper terminal 32 and extending downwardly through the central apertures 27 in all the interrupting discs 24 and longitudinally through the tubular portion of the spacers 25, through the tapered neck opening 50 of the housing 42, through an eye 51 on the inner end of indicator 46, back through the tapered opening 50 and between the shoulder 43 and bottom side of the metal plate 33. A tapered plug 52, comprised of insulating material, is tightly fitted in the tapered opening 50. Thus, wire 49 is pressed into electrically conducting relationship with the metal plate 33 when the fuse is assembled, and the plug 52 serves as an anchor for the end of link 49 to hold indicator 46 in the retracted position as shown.

In operation, when the main fuse operates, an increased current is passed through conductor 49 causing it to fuse at the loop extending into the housing 42 below the tapered plug 50 inasmuch as this portion is in air rather than in insulating material 15 as is the remainder of the link 49. This action releases the indicator 46 which extends outwardly of housing 42 under the operation of spring 48 to indicate a fusing operation has occurred.

From the foregoing, it is seen that for medium and low current interrupting abilities, the gas evolving discs or interrupter plates 24 serve as a multiple of miniature orifices surrounding the melting fuse element and provide double vented explosion pot effect for maintaining a high arc voltage, and, at the same time, generate a high pressure gas which blows the silver vapors into the surrounding medium of sand. For high current interrupting abilities, the notched fused ribbon element and the sand effectively interrupts the circuit. As an example of the effectiveness of this combination of elements for low current interruption, a fuse built with the fibre discs interrupted at full voltage a current of only 46 amperes which was only 39% of a true minimum melting current of the elements. Without the fibre discs, the same element failed to clear a minimum melting current of 120 amperes. A fuse of the foregoing type has demonstrated excellent fatigue loading characteristics and operated at all times without any undesirable expulsion of gas or vapor.

Having described preferred embodiments of the invention in accordance with the patent statutes, it is desired that the invention be not limited to these particular structures, inasmuch as it will be obvious 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. A fuse, comprising: a tubular fuse holder having a pair of spaced terminal means therein; fusible circuit interrupted means connected between said terminals and comprising a plurality of substantially parallel fusible conductors spaced from one another; interrupter means disposed intermediate the ends of said fusible means, said interrupter means including a plurality of spaced plates of a predetermined thickness of gas evolving material, said plates each having a plurality of spaced apertures each providing an arc pressure chamber within the interrupter means, said plates each encircling the fusible conductors at a plurality of different spaced points along the length of the fusible conductors so that the arc formed upon fusion of each fusible conductor within the associated aperture is subjected to a longitudinal gas blast within each aperture providing pressure within each pressure chamber to maintain the arc voltage within each aperture at a high value and to remove the conducting products of the arc to establish an insulating condition; and a granular arc-quenching material in proximity with the pressure chamber means.

2. A fuse, comprising: a tubular fuse holder having a pair of longitudinally spaced terminals therein; a plurality of fusible conductors connected between said terminals and spaced from one another; a plurality of spaced interrupter plate means in said holder, each plate comprising a disc composed of gas evolving material of a predetermined thickness having a plurality of apertures therein for receiving therethrough one fusible conductor in each aperture to provide an individual pressure chamber within each aperture when the associated fusible conductor melts and an arc is formed within the aperture to evolve gases therefrom; and a granular arc-quenching material in the holder adjacent the apertures in the interrupter plates.

3. A fuse, comprising: a tubular fuse holder having a pair of spaced terminals therein; a plurality of parallel spaced fusible conductors connected between the terminals; a plurality of discs of a predetermined thickness disposed within the holder; said discs being composed of gas evolving material and spaced periodically along the fusible conductors, each disc extending transversely of the holder and all the fusible conductors and having a plurality of separate apertures therein with one fusible conductor passing through each aperture; the apertures of successive discs being substantially aligned, each of said apertures having a transverse dimension only slightly larger than the transverse dimension of the associated fusible conductor and forming an individual pressure chamber within the aperture with the associated fusible conductor when an arc is produced within the aperture and gas is evolved from the adjacent material upon fusion of the associated fusible conductor, and granular insulating material adjacent the apertures in the discs.

4. A fuse, comprising: a tubular fuse holder having a pair of spaced terminals therein near the ends of the tubular holder; a plurality of substantially fusible conductors connected between the terminals and spaced from one another; a plurality of interrupter plates formed of gas evolving material of a predetermined thickness and spaced along the fusible conductors, each of said plates extending transversely substantially across the tubular holder; a plurality of spaced apertures in each of said plates for each receiving therethrough one of the fusible conductors, each aperture comprising an arc pressure chamber within the aperture when an arc is produced in the aperture upon the fusion of the associated fusible conductor; a heat conducting cup-shaped member encompassing each interrupter plate to serve as a seat for said plate and having aperture means therein substantially coinciding with the aperture means in the plate; said heat conducting means connecting the interrupter plates to the fuse holder and serving to conduct heat from the fusible means transversely of the fuse holder, and granular insulating material in the fuse holder adjacent the apertures in the interrupter plates.

5. A fuse, comprising: a tubular fuse holder having a pair of spaced terminals therein near the ends of the holder; a plurality of spaced, parallel, fusible conductors of the flat ribbon type connected between the terminals; a plurality of interrupter plates spaced along the fusible conductors, each plate being of a predetermined thickness and extending transversely of the tubular holder and the fusible conductors, said plates being composed of gas evolving material; a plurality of spaced apertures in each plate for each receiving therethrough one of said fusible conductors, each aperture providing an arc pressure chamber within the aperture for effecting a high arc voltage when the associated fusible conductor melts within the aperture during the interruption of a relatively low overcurrent; each of said fusible conductors having prebent and notched portions periodically along its length to fatigue proof the fusible conductors and to effect a series of arcs comprising a high arc voltage upon the occurrence of high rate of rise overcurrents; and granular insulating means in the holder adjacent the apertures in the interrupter plates.

6. A fuse, comprising: a tubular fuse holder having spaced terminal means therein adjacent the ends thereof; a plurality of fusible conductors spaced from one another and connected between the terminals; a plurality of interrupter plates spaced along the fusible conductor in said holder; each plate comprissed of gas evolving material and extending transversely substantially across the holder; each plate including a plurality of apertures spaced from one another for each receiving therethrough a different one of the fusible conductors; each said aperture having a transverse dimension only slightly larger than the transverse dimension of the conductor and having a minimum thickness on the order of about one-fourth inch to provide a pressure chamber within the aperture by generating a high pressure gas within the aperture upon fusion of the associated conductor within the aperture to thus maintain a high arc voltage, and granular insulating material adjacent the apertures in the interrupter plates.

7. A fuse, comprising: a tubular fuse holder having a pair of longitudinally spaced terminals therein near the ends of the holder; a plurality of spaced fusible conductors connected between the terminals; a plurality of interrupter discs of predetermined thickness spaced along the fusible conductors, each disc extending transversely of the tubular holder and the fusible conductors and composed of gas evolving material; a plurality of apertures in each disc for each receiving therethrough one of said fusible conductors, each aperture providing an individual arc pressure chamber within said aperture for effecting a high arc voltage during the interruption of a relatively low overcurrent; each of said fusible conductors having notched portions periodically along its length to effect a series of arcs having a high arc voltage upon the occurrence of high rate of rise overcurrents; a plurality of tubular spacers disposed between successive adjacent discs to maintain longitudinal spacing between said discs, each of said spacers including a transverse opening therethrough; and granular insulating means in the holder adjacent the apertures in the interrupter discs.

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