United States Patent [19]

Blewitt et al.

[11] **3,849,755**

[45] **Nov. 19, 1974**

[54] **CURRENT LIMITING FUSE WITH FUSE ELEMENT WITH A DIAMOND SHAPED CUTOUT**

[75] Inventors: **Donald D. Blewitt**, Pittsburgh; **Woodrow G. Shaw**, Export, both of Pa.

[73] Assignee: **Westinghouse Electric Corporation**, Pittsburgh, Pa.

[22] Filed: **Sept. 28, 1973**

[21] Appl. No.: **401,765**

[52] **U.S. Cl.** **337/295**, 337/159, 337/290

[51] **Int. Cl.** **H01h 85/04**

[58] **Field of Search** 337/159, 160, 161, 290, 337/295

[56] **References Cited**

UNITED STATES PATENTS

1,277,045	8/1918	Cole	337/295
2,734,111	2/1956	Kozacka	337/295 X
2,773,961	12/1956	Sundt	337/295 X

FOREIGN PATENTS OR APPLICATIONS

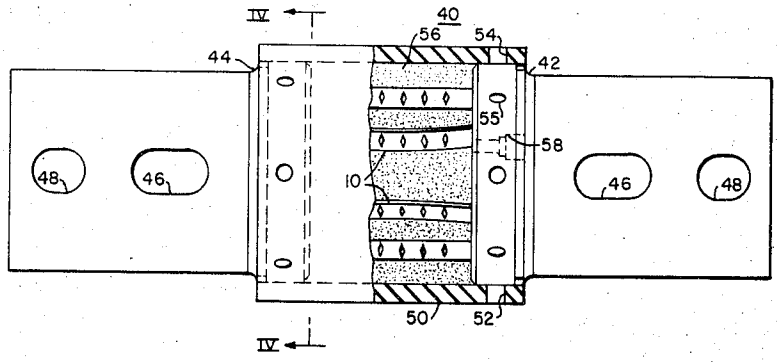
1,193,154	5/1965	Germany	337/295

Primary Examiner—J. D. Miller
Assistant Examiner—Fred E. Bell
Attorney, Agent, or Firm—M. J. Moran

[57] **ABSTRACT**

An electrical current limiting fuse of the type having fuse elements disposed in a pulverulent arc quenching material for melting after a predetermined level of current has been attained and sustained for a predetermined period of time. A fuse element of the current limiting fuse is in a form of an elongated ribbon of fuse material having a diamond shaped central opening. The diamond shaped central opening provides a pair of parallel current paths near either side of the fuse element. The diamond shaped element has two oppositely disposed angles of approximately 37 ½ degrees approximately either side edge of the fuse material.

7 Claims, 8 Drawing Figures



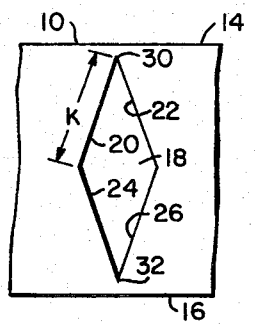


FIG. 1

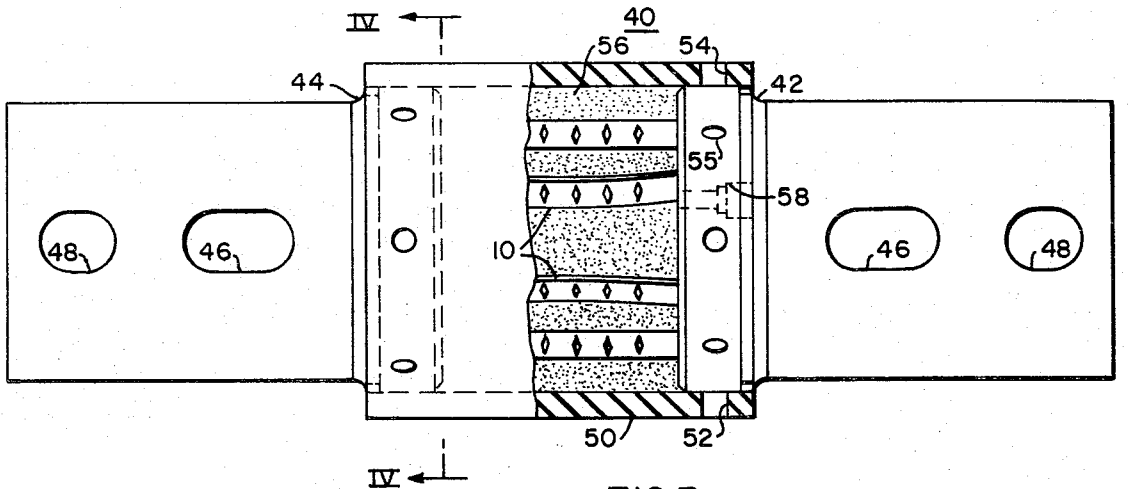


FIG. 3

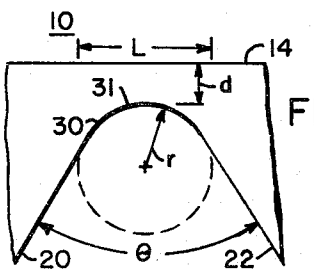


FIG. 1a

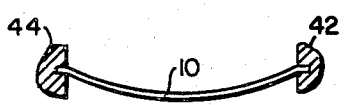


FIG. 5

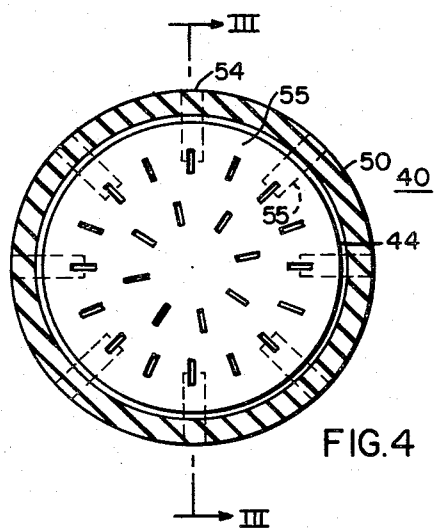


FIG. 4

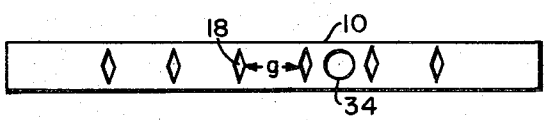


FIG. 2

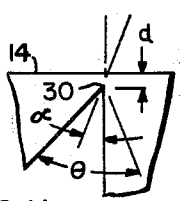


FIG. 1b

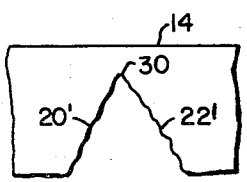


FIG. 1c

CURRENT LIMITING FUSE WITH FUSE ELEMENT WITH A DIAMOND SHAPED CUTOUT

BACKGROUND OF THE INVENTION

This invention is related to electrical current limiting fuses in general and in particular to electrical current limiting fuses having central cutouts.

It is known in the prior art that current limiting fuses having areas of reduced cross section melt at the areas of reduced cross section when overload current has flowed in the fuse element for a predetermined period of time. After melting, an electric arc is established between nonmelted portions of the fuse for a period of time. This electric arc provides a back EMF or voltage drop in the electrical circuit which is effective for limiting the letthrough current after fusing which current is related to the inductance of the network being protected among other things. Examples of United States patents showing arrangements for current limiting fuses which are notched from the outer perimeter of the fuse element inwardly are U.S. Pat. Nos. 2,781,434 issued Feb. 12, 1957 to K. W. Swain and 3,601,739 issued Aug. 24, 1971 to Donald D. Blewitt who is also the inventor in the present case. An electrical fuse having central cutouts is disclosed in U.S. Pat. No. 3,671,909 issued June 20, 1972 by S. J. Kozacka et al. An example of a fuse element having both peripheral and central cutouts is disclosed in U.S. Pat. No. 2,720,567 issued Oct. 11, 1955 to L. Detch. All of the foregoing patents make general use of the areas of reduced cross section for fusing purposes but none teach optimization of the special relationship of the cutaway portion of the fuse element. U.S. Pat. No. 2,868,040 issued Dec. 23, 1958 to W. S. Skeats teaches a fuse element having peripherally angularly notched fuse elements having inclined side walls which enclose an angle substantially within the range of 80° to 180°. This patent teaches the optimization of the angle of the peripheral notch in order to extend the timebefore-fusing characteristic of the fuse during relatively light overload conditions while insuring a relatively high rate of rise of arc voltage during fusing. In U.S. Pat. No. 3,134,874 patented May 26, 1964 by F. L. Cameron peripheral V-shaped notches having an included angle of about 36° for a current limiting fuse are taught. The oppositely disposed V-shaped notches of the latter two patents teach a fuse element with a single narrow central core or isthmus between the V notches which links relatively heavier current carrying portions on either side thereof. This unitary area of reduced cross section is subject to radial twisting which may weaken or break the fuse element at its region of reduced cross section. U.S. Pat. No. 3,138,682 shows a diamond shaped central opening in a ribbon fuse where the oppositely disposed angles nearest the side edges of the fuse ribbon are obtuse providing for areas of reduced cross section which are long compared to the minimum transverse dimension of fuse material. This configuration is chosen to cooperte with a ceramic element which may be disposed on the fuse to provide certain performance characteristics for the fuse. The elongated regions of reduced cross sections provide spans of relatively weak material which are more likely to distort or break under the influence of twisting and vibration than shorter more compact spans. Japanese Patent SHO43 (1968) 12169 entitled TUBULAR FUSE WITH INNERTUBE in the name of applicant Utsunomiya Electrical Factory

Corporation discloses a fuse element having a central cutout therein but where the vertices of angles of the cutout near the edges of the fuse element are rounded with a relatively large radius of curvature compared with the length of a side of the angle. This gives elonaged areas of reduced cross section between larger adjacent areas in the fuse. It would be advantageous to provide a fuse element with a central cutout which provides two spans or regions of reduced cross sections between relatively larger sections of current conducting material in a fuse element to thereby increase the structural strength of the fuse element. It would also be advantageous to provide a fuse element with a central cutout or opening which is of a shape to optimize the trade-off between the pre-melting current carrying characteristic of the fuse element (to thereby maximize its effective rated current) and post-melting arc sustaining characteristic (to maximize its current limiting characteristics).

SUMMARY OF THE INVENTION

In accordance with this invention an electrical current limiting fuse is provided having one or more parallel fuse elements disposed therein between space terminals. A non-electrically conducting, tubular member is disposed between the space terminals to enclose the fuse elements. A pulverulent arc quenching material is added to enhance the current limiting action of the fuse. The fuse elements have spaced regions of reduced cross section which melt according to well-known fusing characteristics, e.g. the $i^2t = k$ characteristic. The angles nearest the sides of the ribbon-like fuse material of the diamond shaped cutout are preferably 37½° plus or minus 30 minutes, but may range between 30° and 45° for satisfactory operation. The angle of 37½° is chosen because it provides a trade off between the optimum pre-melting characteristic of the fuse and the optimum fusing characteristic of the fuse. In a fuse element the area or areas of reduced cross section are those areas which melt first during overload conditions because electrical current density in these areas is highest and melting temperature is attained sooner here than in any other portion of the fuse. This is because the areas of reduced cross section represent the areas of highest resistance in the fuse element. If the areas of reduced cross section are elongated the net pre-fusing effect is to provide a very high resistance link between two areas of relatively low resistance. Generally speaking the longer the length of the area of reduced cross section the higher the electrical resistance of the entire fuse link. The higher the electrical resistance is the more heat is generated therein by any given amount of electrical current flowing therethrough. Since fusing or fuse blowing is a function of fuse element heating or temperature it can be seen that fuse elements with higher electrical resistance at the areas of reduced cross section are more likely to blow or melt before fuse elements having lower electrical resistance at the areas of reduced cross section. Said in another way this means that the fuses with less electrical resistance at the regions of reduced cross section have higher current ratings. If a diamond shape cutout is used in the fuse ribbon it is important for the vertex of the angles formed near the sides of the ribbon to be as sharp as possible. Said in another way it is important for the radius of curvature of the vertex to be very small compared with the length of the peripheral lines forming

the angle. If the radius of curvature is relatively large, by the foregoing standard, the vertex itself provides a region of elongated resistance. Consequently in the present invention the lengths of the areas of reduced cross section are reduced insofar as they are effected by the radii of curvature of the vertices of the oppositely disposed angles of the diamond shaped cutout. It can also be seen that if the foregoing angles are made relatively small the amount of fusible material adjacent thereto increases and therefore the fuse resistance near the areas of reduced cross section decreases and the full load current rating of the fuse is thereby upgraded or raised. After fusing or melting at the area of reduced cross section, it is desirous to provide a sustained arc between unmelted portions of the fuse element to generate a back EMF which acts to limit peak-let-through current during the fusing process. The lower the peak-let-through current the better because the let-through-current if not retarded is available to cause damage in the network which is being protected by the fuse. It has been found that a sustained arc of relatively high voltage is best produced by elongated areas of reduced cross section or said in another way the arc is more easily maintained for current limiting purposes if the angles of the diamond shaped cutout nearest the sides of the fuse element are made large. Consequently it can be seen that those physical characteristics of a fuse which provide optimum fuse operation before fusing tend to cause degraded fuse operation during the fusing or melting operation and vice versa. Consequently it is desirable to provide an effective trade-off between prefusing and fusing fuse characteristics. It has been found that a diamond shaped fuse element having sharp vertices at the angles nearest the outer edges of the fuse ribbon which angles are approximately 37½° provides an effective trade-off between fuse operating characteristics before fusing and during fusing. In addition it has been found that the mechanical and electrical properties of two parallel regions of electrically conducting material of reduced cross section between fuse sections of relatively larger cross section more than equals the electrical characteristics and mechanical characteristics of a fuse element of the same general size having opposed V-shaped notched portions taken out of the periphery thereof which provides only one region of electrically conducting material shape cutout which provides two parallel electrically conducting paths of a given cross sectional area has better electrical characteristics and mechanical characteristics than a fuse element with one path in the middle of the fuse element having a cross section area of twice the size. Two relatively short interlinking paths provide enhanced structural strength. The exposure of more surface area to arc quenching material provides better arc limiting characteristics and heat dissipation characteristics.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention reference may be had to the preferred embodiments exemplary of the invention shown in the accompanying drawings in which:

FIG. **1** is a broken away side elevation of a fuse element having a diamond shaped opening in the central portion thereof;

FIG. **1***a* is an enlarged view of the vertex of the angle **30** of FIG. **1**;

FIG. **1***b* shows another embodiment of a portion of the fuse element of FIG. **1** at the vertex **30**;

FIG. **1***c* shows another embodiment of the fuse element;

FIG. **2** shows an elongated fuse element in side elevation;

FIG. **3** shows a side elevation partially broken away of a current limiting fuse structure;

FIG. **4** shows a cross section of the fuse structure shown in FIG. **3** along the line III—III and,

FIG. **5** shows the disposition of a fuse element between portions of oppositely disposed terminals such as shown in FIG. **3.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and FIG. **1** in particular there is shown a broken away portion of an electrical fuse element **10.** Fuse element **10** in this embodiment of the invention comprises a fuse element for an electrical current limiting fuse. Fuse element **10** comprises electrically conductive material which is suitable for interrupting electrical current flowing therethrough when the current is at a predetermined value, as an example the fuse element **10** may be comprised of an alloy of silver or tin. Fuse element **10** comprises an upper edge or surface **14** and a lower edge or surface **16.** In this embodiment of the invention fuse element **10** is shown as a relatively flat ribbon-like strip where edges **14** and **16** represent the relatively thin elongated side surfaces of the ribbon. Fuse element **10** has disposed therein a central opening **18.** In this embodiment of the invention central opening **18** comprising a parallelogram or diamond shape. The diamond sbaped opening **18** has four linear sides **20, 22, 24** and **26.** Sides **20** and **26** are parallel and sides **22** and **24** are parallel. In addition in this embodiment of the invention sides **20, 22, 24** and **26** which together form the periphery of the central opening **18** are of equal length. The peripheral sides **20** and **22** meet at a common point or apex **30** forming therebetween an angle. As will be described hereinafter with respect to FIG. **1**a, the radius of curvature of the apex **30** is relatively small. Consequently the apex may generally be referred to as sharp. Apex **30** is spaced from surface **14.** The fuse material between the edge or surface **14** and the apex **30** constitutes an electrically resistive region of reduced cross section compared with the size of the cross section of other portions of the fuse link as shown FIG. **1.** Peripheral sides **24** and **26** of opening **18** are joined or meet at apex **32** forming an angle. It will be noted that apex **32** is spaced from edge or elongated surface **16** in a manner similar to the spacing of apex **30** and edge **14.** Electrical current may flow through fuse element **10** from right to left or left to right. In either case the electrical current must divide and flow generally in equal paths around the apexes **30** and **32** through the restricted regions between the edges **14** and **16** respectively.

Referring now to FIG. **1**a an enlarged portion of the fuse element **10** in the vicinity of apex **30** of FIG. **1** is shown. Apex **30** comprises an arcuate portion **31** having a generally fixed radius of curvature r. Portions of the sidewalls **20** and **22** are shown intersecting the arcuate portion **31** tangentially. The angle theta (θ) formed between the side portions **20** and **22** in the preferred embodiment of the invention is substantially

within a range from 30° to 45°. The preferred angle theta (θ) is 37½°. The tip of the apex **30** is spaced or separated from the outer surface or edge **14** of the fuse element **10** by a distance *d*. Although the spatial relationships have been distorted for purposes of illustration it is to be understood that the radius of curvature *r* is to be significantly smaller than the distance *d*. In the preferred embodiment of the invention the radius of curvature *r* is one-fifth or 20 percent of the distance *d*. Ideally apex **30** should have a radius of curvature of zero. However it is recognized that fabricating techniques limit the actual size of the radius of curvature r to a practical lower limit. In the preferred embodiment of the invention the radius *r* is approximately 0.002 inches, the distance *d* is 0.01 inches plus or minus 0.0002 inches, the thickness of the fuse material (not depicted here) is approximately 0.02 inches, the distance from apex **30** to apex **32** is approximately 0.18 inches shown in FIG. **1**. It is desirous to make the radius of curvature r as small as possible so that the distance L depicted in FIG. **1***a* is minimized. The distance L measures an elongated path of relatively high electrial resistance for the pre-melting electrical current in the fuse element **10**. The longer the path L is the higher the resistance of the fuse element, consequently the more heat which is generated during normal pre-fusing operating conditions. It would be very desirable to make L as small as possible because this would enhance the operation of the fuse during non-fusing conditions. This would have the advantage of increasing the current rating of the fuse element. However, it is desirous to have a fuse element which operates efficiently not only during pre-fusing operation but during the fusing operation as well. In the preferred embodiment of the invention fuse element **10** is utilized as an electrical current limiting fuse element which blows or fuses after an overload of electrical current and which generates an arc voltage thereafter which limits the further increase of electrical current which may occur due to electrical inductance in the various electrical circuits connected to the fuse element. The narrow region of the material between the arcuate portion **31** and the surface **14** of the fuse element **10** in Fig. represents the area of highest resistance in the fuse element and consequently is heated to a higher temperature by electrical current flowing therethrough and more rapidly than any other portion of the fuse element except another constricted region such as in the vicinity of apex **32** as shown in FIG. **1**. Such being the case fuse element **10** blows, melts or fuses in the region or neck between the arcuate portion **31** and the surface **14**. When this happens the electrical current is maintained through the hot plasma or arc which exist between the remaining portions of the fuse element on adjacent sides of the recently melted region of reduced cross section. The arc generates a voltage which acts to retard or limit further current flow. The voltage is generally related to the length of the arc and generally increases therewith. It is desirous to provide a high voltage arc relatively quickly to thereby quickly begin to limit current which may be flowing in the plasma or arc and to also provide an arc voltage which is sustained for a relatively long period of time. Usually the arc will be completely extinguished and current will cease to flow before the current goes through a current zero. The diamond shaped opening characteristically shown in FIGS. **1** and **1a** provides the arc voltage amplitude and time characteristics described. The arc is prevented from rapidly expanding through the material around the region of arcuate portion **31** because in each succeeding increment of time the amount of material to be burned away or consumed by the arc increases. As can be seen this retards the relatively rapid propagation of the arc into the regions on either side of the arcuate portion **31**. This has the desirable characteristic effect of maintaining relatively high arc voltage for a sustained period of time. The arc can be maintained for an acceptable period of time if the length K of the sidewalls **20** and **22** as shown in FIG. **1** is relatively long compared to the dimension *d* of the region of reduced cross section. This provides a greater amount of material to be consumed by the arc than if the dimension K was relatively smaller. In the preferred embodiment K is equal to or greater than 10 times *d*. It has also been found that the size of the angle theta (θ) is preferably different for maximized prefusing operation of the fuse and maximize fusing operation of the fuse element. For example before fusing it is desirous to make the distance L as small as possible and to have as much fuse material available for current conduction as possible. This means that the angle theta (θ) should be relatively small. However during a fusing operation it is desirous to increase the size of the angle theta (θ) over the size that is best for pre-fusing operations. The reason for this is as follows: if the angle theta (θ) is made extremely large, approximately 180°, the portion of the fuse between arcuate portion **31** and surface **14** approaches the shape of a rectangular strip of material which provides a high arc voltage upon blowing or fusing but which is extinguished almost immediately because of the limited volume of material to be consumed by the arc. On the other hand if the angle theta (θ) is very small, approximately 0°, the arc voltage is sustained for a relatively long period of time because the amount of material to be consumed is very large. However the arc voltage is initially small because the arc cannot elongate at a rapid pace. Consequently it is desirous to have an angle of theta (θ) during the fusing process which is sufficiently large to cause a relatively high arc voltage in a relatively short period of time but which is not so large as to cause the arc voltage to collapse before the current to be limited thereby has completely been interrupted. The maximum angle for this purpose has been found to be significantly smaller than the previously described maximum angle for desirable steady state non-fusing operation. It is desirous therefore to provide a trade off between the angle theta (θ) which is best for a non-fusing operation in the fuse element **10** and the angle theta (θ) which is best for the fusing operation in the fuse element **10**. It had been found experimentally that an angle theta in a range between 30° and 45° best accomplishes this purpose. It has further been found that an angle of 37½° is the preferred angle for providing the trade-off previously discussed. It may be noted that the diamond shaped element of FIG. **1** resembles in some senses a fuse element section having **2** oppositely disposed V-shaped notches in the peripheral surfaces thereof which are spaced near the apexes thereof. It has been found in experimentations concerning the diamond shaped element that, all other factors being equal, an improvement is provided by the diamond shaped element if the following criteria are met:

(1) $d << K$; and

(2) $30° < \theta < 45°$.

The improvement takes two forms, first the diamond cutout element is stronger structurally than the V-notched element because there are two regions of support rather than one. This is true even though each region of support in the diamond shaped notched element is one-half or less the size of the single region in the V-shaped notched element. Also upon fusing rather than one relatively large arc being generated carrying all the current during the fusing operation two arcs of approximately the same voltage are formed having smaller cross sectional areas. It has been found that the cooling of the two arcs is easier than the cooling of the single arc. Since the voltage of the arc is related to how cool it is kept it can be seen that each of the plural arcs provides a higher current limiting voltage. Consequently the peak-let-through-current during fusing can be reduced for equal cross sectional areas of reduced cross section. The diamond shaped element may have the same resistance as the V-shaped notched element. However it has been found that the peak-let-through-current for the V notched elements is 15 to 20 percent greater than that of the diamond shaped elements of the present invention for equal cross sectional areas and source voltage. Consequently a diamond shaped cutout in a fuse element can only be equaled in peak-let-through-current reduction characteristic by a V-notched element having 23 to 31 percent more cross sectional area. A reason for the improvement lies in the fact that the arcing path is separated into two parallel parts which enhance the ability of the surrounding material (which in the preferred embodiment of the invention may be a pulverulent arc quenching material such as sand) to absorb the energy and quench the arc.

FIG. 1C shows an embodiment of the invention where the side walls **20'** and **22'** undulate for better heat removal.

Referring now to FIG. **2** a whole fuse element **10** is shown. Fuse element **10** includes a number of diamond shaped cutouts **18** each of which are separated by a distance g. Fuse element **10** may also include a portion of tin or silver alloy material **34** which is provided to burn out or fuse first thus causing the necked or reduced portions of the fuse element to quickly burn out to meet thereafter. Fuse element **10** upon fusing will provide a series of two parallel arcs for each of the diamond shaped elements **18.** The combined series arc voltage acts to limit electrical current flowing through fuse element **10.**

Referring now to FIG. **3** there is shown a cartridge type fuse **40** which employs the fuse element **10** as a constituent part thereof. Cartridge fuse **40** includes spaced electrical terminals **42** and **44** which have holes or openings **46** and **48** therein which are adapted for bolting the terminals to complementary electrical conductors or bus bars. An electrically insulating tubular casing **50** is provided for enclosing the fuse elements **10** and for spacing the terminals **42** and **44.** In a preferred embodiment of the invention the insulating casing **50** is cylindrical, tubular and the terminals **42** and **44** are snugly fit to either end thereof. In a preferred embodiment of the invention drilled holes such as **52** and **54** are provided in the outer casing **50** through which a pin or similar anchoring means may be inserted to engage similar holes **55** in the terminals **42** and **44** to lock the terminals to the insulating casing **50.** The insulating casing **50** may be constructed of glass melamine or similar electrically insulating material. In terminal **42** is provided a fill hole **58** through which pulverulent arc quenching material **56** such as quartz sand may be provided to surround the fuse elements **10** so that upon fusing a fulgarite may be formed which absorbs heat during the fusing operation and thereafter acts as a dielectric insulator between the terminals **42** and **44.** In the preferred embodiment of the invention the fuse **40** specifically satisfies the requirements imposed by NEMA FU 1-1966 for a class L fuse. In the preferred embodiment of the invention the fuse **40** is a 600 volt curent limiting fuse for conducting current between 601 and 6000 amperes and which has a maximum interruption rating of 200,000 amperes RMS symmetrical.

It will be noted in this fuse construction multiple fuse elements **10** are arranged in parallel between the terminals **42** and **44.** This provides more current carrying capacity during operating conditions and also provides a desirable fusing characteristic. It is generally known in the fuse art that the more parallel arclets that can be established between terminals the better the fusing action. Consequently multiple fuse elements **10** are provided in fuse **40.** For the same reason the generation of two multiple arcs in the fuse element, such as shown in FIG. **1,** provides for a better fusing characteristic. This is related to the phenonomena of current commutation where a fuse element blows initially causing the other parallel fuse elements to be quickly overloaded and thus causing them to blow almost immediately thereafter. The first blown fuse element will conduct current and support an arc until the electrical resistance thereof is so high that the overload current seeks paths of lower resistance. This may cause the arc to be extinguished for a very short period of time in the recently blown fuse element while causing the non-blown low resistance fuse elements to fuse or blow thus generating their own arcs which in turn burn back causing the arc current to seek once again lower paths of resistance. Eventually the previously blown fuse element which is no longer conducting represents the lowest path of resistance and an arc is restruck thereacross. This effect is known as commutation or said in another way the jumping of an arc alternately between parallel fuse elements, during a fusing operation, as the resistance in each parallel changes in proportion to the amount of the fuse element burned back by the preceding arc is commutation.

Referring now to FIG. **5,** a portion of the fuse **40** is depicted as a fuse element **10** between portions of the two terminals or electrodes **42** and **44.** Fuse element **10** is shown in a bowed configuration. The bowed configuration is utilized for many reasons, however, one of the most important reason is to allow for the contraction and expansion of the fuse element drawing normal non-fusing operating conditions when the electrical current flowing therethrough changes causing the heat generated therein to change correspondingly. It is well known that metallic fuse elements contract and expand in relationship to the heat generated therein.

Referring now to FIG. **4,** a cross section of fuse element **40** cutaway along lines IV—IV shown in FIG. **3** is depicted. The electrically insulating cylindrical tubular glass melamine outer shell **50** is shown in the cross section view. Behind it is shown a view of terminal **44** having fuse elements **10** which are radially arranged around the inside surface thereof. The aligned holes or

openings **54** and **55** are shown disposed radially around the outer perimeter of fuse terminal **44.**

It is to be understood that fuse element **10** may in some embodiments of the invention be adapted for use in fuses other than current limiting fuses. It is also to be understood that the fuse element **10** when used in a current limiting arrangement is useful over a wide range of fuse ratings in terms of power, voltage and current. It is also to be understood that the particular configuration of the terminals **44** and **42** as well as the structural characteristics of the tubular member **50** are not limiting nor is the chemical composition of the arc quenching material **56** limiting. It is also to be understood that the characteristic parallelogram or diamond shaped central opening shown in the drawings may in other embodiments of the invention be different. As an example the central opening may comprise only one angle and have another characteristic shape in the periphery thereof for other electrical properties. It is also to be understood that the fuses of FIGS. **3, 4** and **5** are not limited to the fuse elements shown in FIGS. **1, 1**a and **2** but merely show a preferred embodiment for utilizing the fuse elements of FIGS. **1, 1***a* and **2.**

The apparatus embodying the teaching of this invention have several advantages. By utilizing the optimized diamond shape central opening of the invention structural fuse strength is increased over peripherally V-notched fuses. Another advantage lies in the smaller distance *g* which can be maintained or provided between adjacent central opening because of the relatively small angle of the diamond shaped opening near the outer peripheries of the fuse element. This means that the merger of the arcs in both a parallel and series sense can be delayed. Another advantage lies in the general proposition that the more parallel electrical arcs in a fuse or fuse element during fusing the better the operating characteristics of the fuse element during fusing. Another advantage is the ability of a fuse element having a diamond shaped central opening to maintain relatively high arc voltages for a relatively long period of time, without introducing extremely large initial arc voltages which might be destructive in themselves to the apparatus protected by the fuse element. Another advantage of the present invention is the improved cooling characteristics of the fuse element both during pre-fusing operation and during the fusing operation. Another advantage lies in the fact that the relative resistance of the fuse element to electrical current flow during pre-fusing or non-fusing operation is relatively low compared with a fuse having an angular notched or diamond shaped portion therein which has a relatively large radius of curvature at the apex thereof because the smaller the apex the smaller the region of reduced cross section as measured in a longitudinal sense and consequently the smaller the linear or longitudinal resistance thereof. Another advantage lies in the fact that a fuse element having a diamond shaped central opening and having peripheral angles of relatively small radius of curvature can be stamped from fuse material having a thickness which is slightly larger than the distance between the apex and one edge of the fuse element. Another advantage lies in the fact that the let-through-energy of a V-notched element ranges from 26 to 43 percent more than for an element with a diamond shaped central opening with all other factors being the same.

What we claim as our invention is:

1. An electrical fuse, comprising:

a. a tubular casing of electrical insulating material;

b. spaced terminals disposed adjacent portions of said casing; and

c. a fuse element of electrically conductive material disposed within said casing and electrically connected to said spaced terminals for interrupting electrical current flowing through said fuse when said current is of a predetermined value, said electrically conductive material having a central opening therein, said central opening enclosing as one part of the periphery thereof an angle substantially in the range of 30° to 45°, said angle having an apex which is spaced from one surface of said electrically conductive material by a predetermined distance to thereby provide an electrically resistive region of reduced cross section, the bisector of said angle being perpendicular to said one surface within a predetermined range, the radius of curvature of said apex of said angle being smaller than said distance between said apex and said one surface by a predetermined amount to thereby reduce the electrical resistance of said conductive material adjacent said region of reduced cross section, the length of at least one peripheral side of said angle being larger by a predetermined amount than said predetermined distance between said apex and said one side.

2. An electrical current limiting fuse, comprising:

a. a tubular casing of electrical insulating material;

b. spaced terminals disposed adjacent portions of said casing;

c. pulverulent arc quenching material disposed within said tubular casing; and

d. a fuse element of electrically conductive material disposed within said casing and electrically connected to said spaced terminals for interrupting electrical current flowing through said fuse when said current is of a predetermined value, said electrically conductive material having a central opening therein, said central opening enclosing as one part of the periphery thereof an angle substantially in the range of 30° to 45°, said angle having an apex which is spaced from one surface of said electrically conductive material by a predetermined distance to thereby provide an electrically resistive region of reduced cross section which melts in the presence of said predetermined value of electrical current, the bisector of said angle being perpendicular to said one surface within a predetermined range, an electrical arc being produced for limiting said current, said arc quenching material assisting in quenching said arc, the radius of curvature of said apex of said angle being smaller than said distance between said apex and said one surface by a predetermined amount to thereby reduce the electrical resistance of said conductive material adjacent said region of reduced cross section, the length of at least one peripheral side of said angle being larger by a predetermined amount than said predetermined distance between said apex and said one side.

3. The combination as claimed in claim **2** wherein said central opening is substantially in the shape of a parallelogram.

4. The combination as claimed in claim **2** wherein said angle is substantially 37.5°.

5. The combination as claimed in claim 2 wherein said predetermined distance is equal to or larger than approximately 5 times the radius of curvature of said apex.

6. The combination as claimed in claim 2 wherein said bisector of said angle is perpendicular to said one surface within 4°.

7. The combination as claimed in claim 2 wherein the length of said at least one peripheral side of said angle is equal to or larger than approximately 9.5 times the distance between said apex and said one surface.

* * * * *