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Kozacka

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[54] **RIBBON-TYPE FUSIBLE ELEMENT FOR HIGH-VOLTAGE FUSES AND FUSE INCLUDING THE ELEMENT**

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

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

[58] **Field of Search** 337/159, 290, 295, 337/186, 273, 274, 280; 338/62, 298, 299, 319, 320

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Assistant Examiner—F. E. Bell
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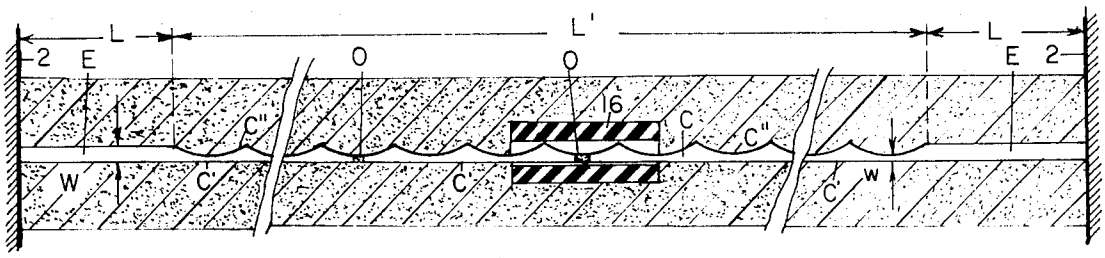
[57] **ABSTRACT**

A fusible element for a full range clearing ability fuse for elevated circuit voltages such as, for instance, 5 to 15 kV. The fusible element has a configuration adapted to result in a wirelike time-current curve when forming part of a fuse. The fusible element has a center portion which is undulating on one side thereof and has end portions which are not undulating. The fusible element is wound helically and supported in a tubular casing in coaxial relation to the latter without resort to a supporting mandrel thereof. The fuse may be provided with several helically wound fusible elements supported by the pulverulent arc-quenching filler inside the casing and by means of special beads and in the absence of any mandrel support.

16 Claims, 10 Drawing Figures



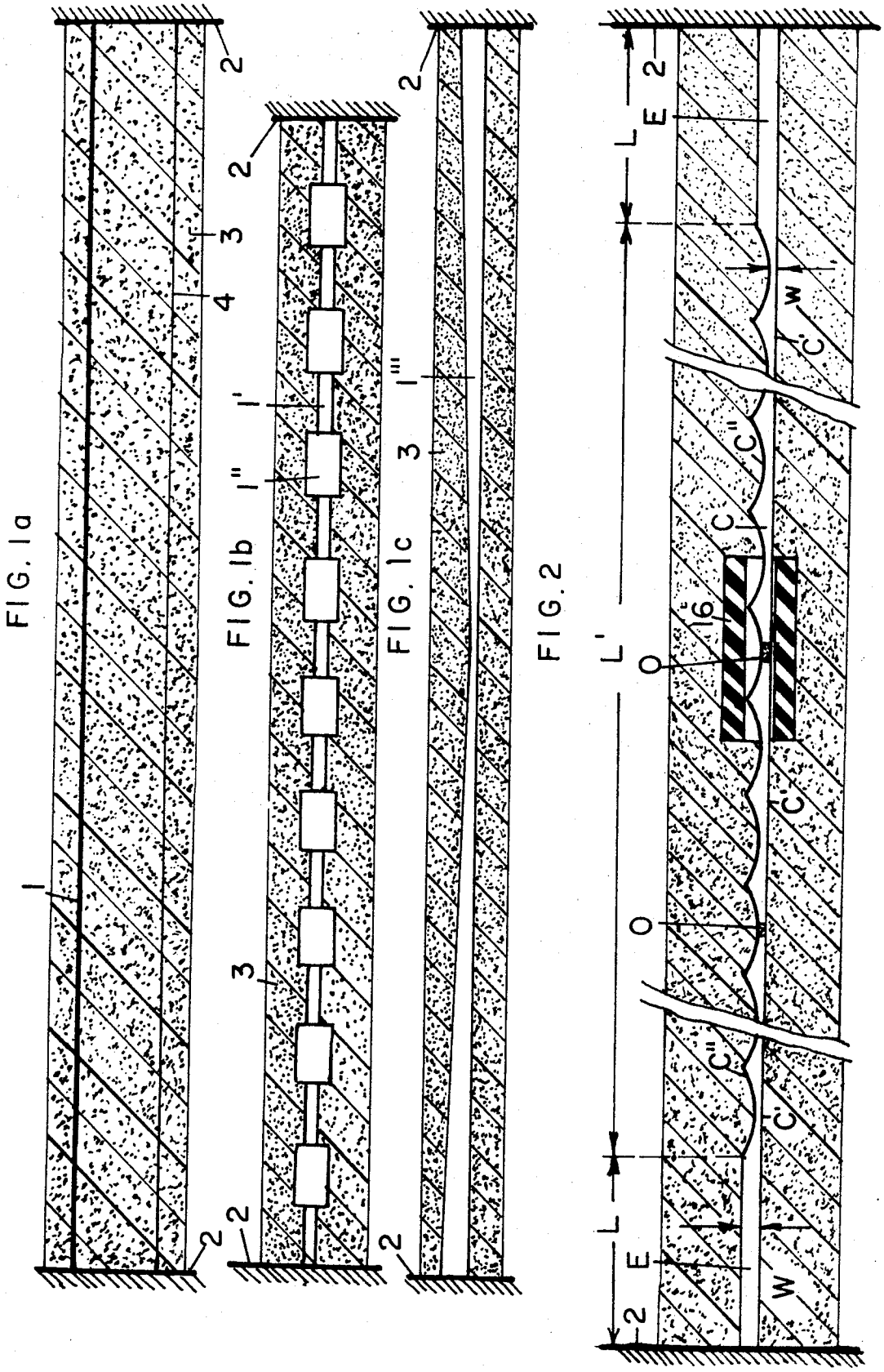
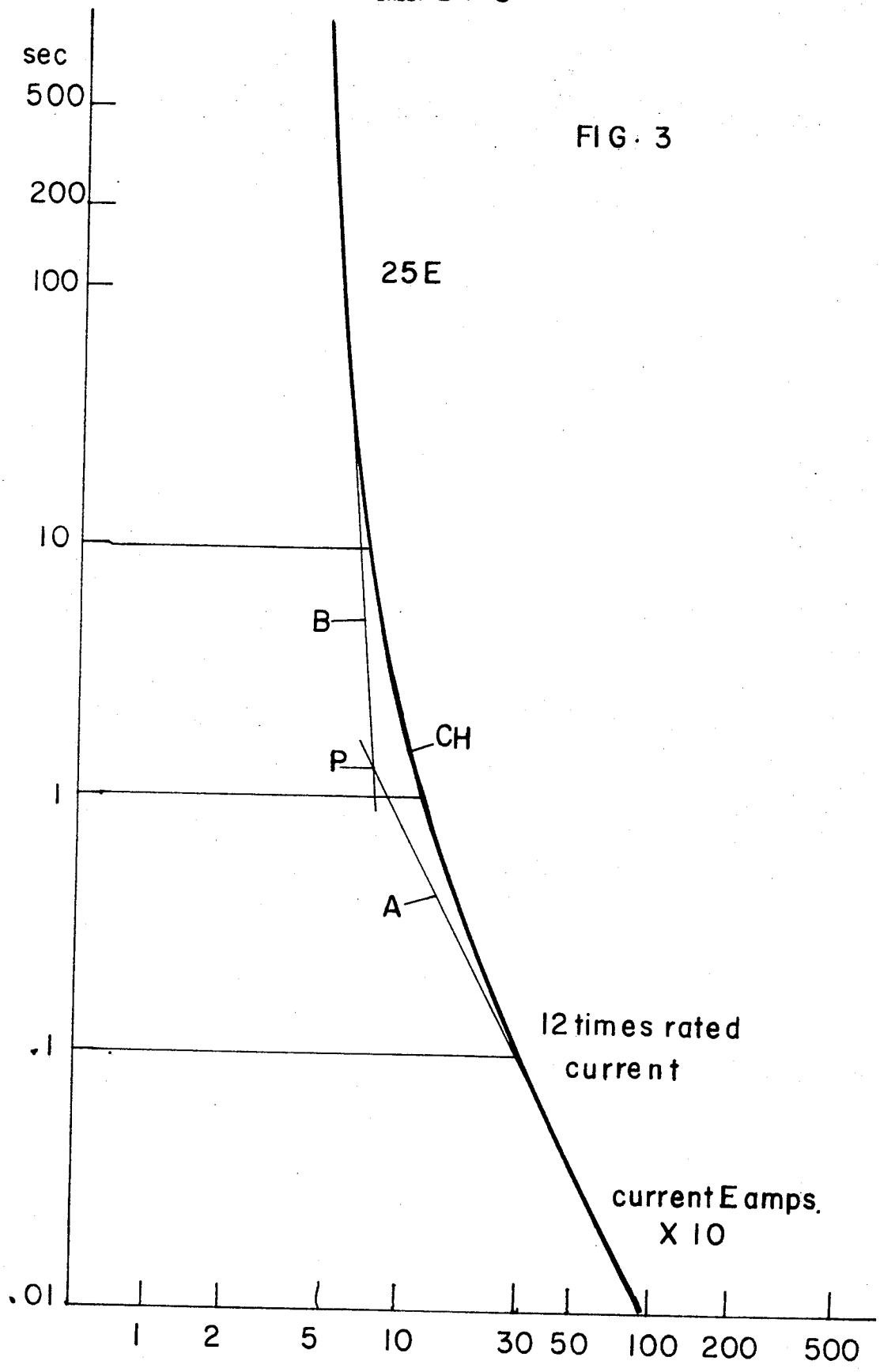


FIG. 1a
FIG. 1b
FIG. 1c
FIG. 2
1
2
3
4
1'
1''
1'''
L
E
W
C'
C''
16
0
L'

FIG. 3


sec
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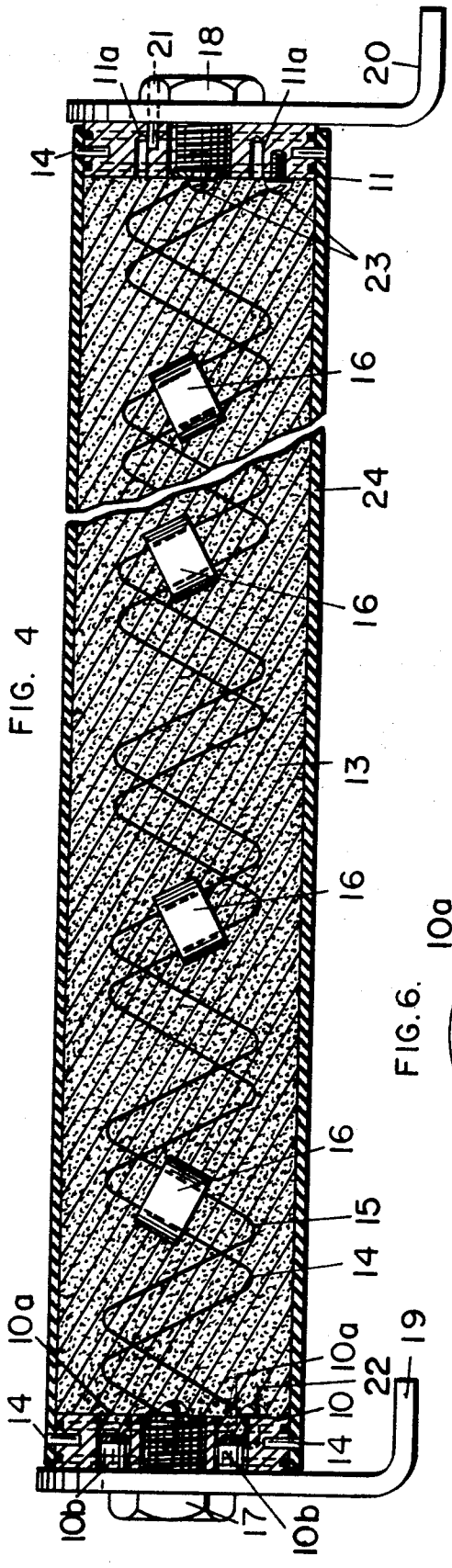

FIG. 4

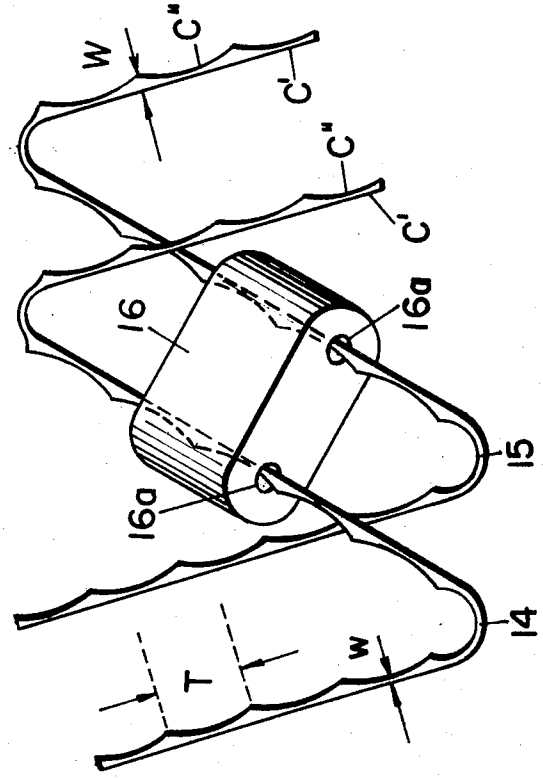

FIG. 8

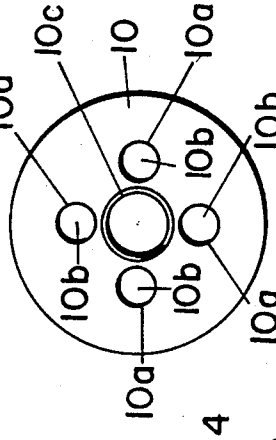

FIG. 6.

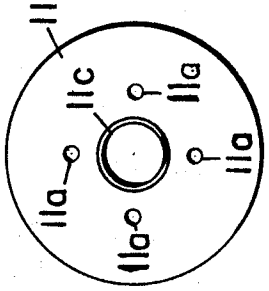

FIG. 7

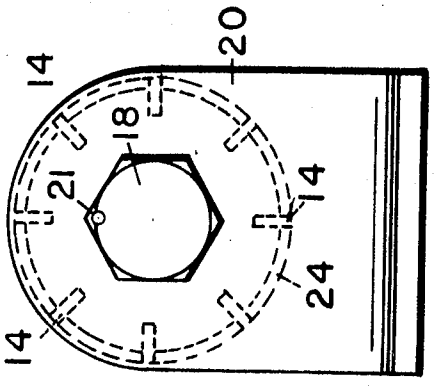

FIG. 5

RIBBON-TYPE FUSIBLE ELEMENT FOR HIGH-VOLTAGE FUSES AND FUSE INCLUDING THE ELEMENT

BACKGROUND OF THE INVENTION

In the past current-limiting fuses for elevated circuit voltages, say 5 to 15 kV and above, were used predominantly for back-up purposes and had predominantly a ribbon-type melting characteristic, as distinguished from a wire-type melting characteristic.

In more recent time it was required that current-limiting fuses for elevated circuit voltages be capable of interrupting not only major fault currents but also overload currents. This type of fuses is referred-to as "wide range fuses" or "general purpose fuses". Such fuses are capable of interrupting small overload currents, but not capable of interrupting all overload currents which may occur. Fuses capable of interrupting all inadmissible currents which may occur including major fault currents are referred to as full range clearing ability type fuses. Full range clearing ability type fuses must be capable of interrupting overload currents so small that it may take at least 1 hour, or even several hours, on account of the smallness of the overload current to cause blowing of the fuse.

The present invention refers to a full range clearing ability fuse within the above meaning intended for elevated circuit voltages, particularly intended for application in transformer circuits. This and similar applications require a fusing characteristic, or time-current curve, which is that of a long wire, or similar to that, or substantially the same as that, of a long wire.

This invention relates to full range clearing ability type fuses having wire-like time-current curves. The term wire-like time-current curve which is frequently used calls for some comment.

The time-current curve of a fuse having a fusible element in form of a fusible wire depends on conditions of heat transmission. Heat transmission, in turn, depends upon the arrangement of the fusible element inside the fuse tube, the thermal conductivity of the arc-quenching filler and that of the fuse tube, etc. Hence the conditions of heat transmission in a fuse are so complex that a general mathematical definition of the time-current characteristic of wires of circular cross-section has not been found as yet. Many mathematical definitions of the fusing characteristic of a fuse have been evolved under simplifying assumptions as, e.g. the presence of a single fusible element. The present invention is not limited to cases where these assumptions apply, and in particular not limited to fuses having a single fusible element. For practical purposes several definitions of a fuse having a wire-type time-current characteristic may be given. The time-current characteristic of a fusible wire has a low current portion which is substantially straight, a high current portion which is substantially straight, and an intermediate portion which is curved. The tangent to the low current portion of the time-current characteristic and the tangent to the high current portion of the time-current characteristic intersect at a characteristic point. For fuses whose fusible elements are round wires (or functional equivalents of round wires), and are sufficiently long so that the temperature in the center portions of the fuses is not significantly affected by heat exchange occurring at terminals thereof the aforementioned characteristic point of intersection lies between 1 sec. and 10 sec.

Such a time-current characteristic may be achieved either with fusible elements in the form of round wires, or with sheet metal strips or extremely narrow ribbons which are square or rectangular in cross-section.

Fuses having fusible elements in the form of wires, or equivalents of wires, have a tendency to generate dangerous voltage surges incident to blowing thereof on major fault currents. The conventional or generally accepted method of precluding generation of such voltages surges in the use of stepped wires or, in other words, wires having sections whose cross-sectional areas differ significantly from each other, thus having different fusing $i^2 \cdot t$ values and hence fusing sequentially. Wires of this description are difficult to manufacture, and the manufacture thereof requires relatively expensive equipment. It is, therefore, a further object of this invention to provide full range clearing ability type fuses having time-current curves of the same nature as fuses having fusible wires varying in diameter to avoid dangerous voltage surges incident to blowing thereof on major fault currents, but achieving this result by means of a narrow ribbon which is easier to manufacture than wires of varying diameter known as stepped or graded wires.

Most electric fuses, and more particularly fuses having relatively long fusible elements, are subject to a phenomenon sometimes referred-to as that of current transfer. When a fuse is subjected to progressively increasing overload currents the point or arc initiation tends to shift from a point close to the center between the terminal elements of the fuse to a point or points relatively close to terminal elements of the fuse. The phenomenon of transfer of the point of arc initiation at a critical overload current is well known in the fuse art. It has been explained in part, but not yet been fully analyzed. Fusible elements are often provided with a low melting point overlay intended to melt before the fusible element reaches its melting temperature and then to sever the fusible element by a metallurgical reaction in the nature of metal interdiffusion. This metallurgical reaction involves time which time may exceed the time required for points of the fusible element not covered by the overlay to form a break. This formation of a break remote from the point covered by a low fusing point metal-severing overlay may be attributed to fusion at that remote point within a shorter time than that required to form a break at the point where the metal-severing overlay is located. However time-lag is but one of the factors involved in the phenomenon of the shift or transfer of the point of arc initiation from a point close to the transverse median plane of the fuse where the aforementioned overlay is normally located to another point remote from that point and relatively close to one of the terminals of the fuse. In fuses for elevated circuit voltages having relatively long fusible elements, the transfer at a critical current of the point of arc initiation from the center region of the fusible elements in axially outwardly direction to a point close to the terminal elements seems to be due to the formation at critical currents of large stresses at particular points relatively close to the terminals of the fuse. This tendency has been explored and proved by numerous tests and is particularly significant and important in fuses whose fusible elements are round wires or behave thermally similar to such wires. In such instances the center portion of the fusible elements are relatively free to expand and to contract in a direction longitudinally of the fuse

tube or casing, and thus thermal stresses at these portions are relatively limited. On the other hand, the axially outer portions of the fusible elements have a relatively limited freedom of expansion and contraction in a direction longitudinally of the fuse tube, and thus thermal stresses at these portions tend to be relatively large. If the point of initial break formation has a specific spacing from a terminal element, and if the critical transfer current requires for its interruption a backburn length exceeding that specific spacing, the fuse is bound to fail. It is, therefore, of great importance to control the magnitude of the transfer current and to provide means making it possible to interrupt the same when the point of initial break formation shifts from the transverse median plane or center of fuse structure toward a terminal element thereof. All other conditions remaining unchanged, the rate of the growth or elongation of an arc gap is proportional to the current density in the electrodes between which the arc is formed. Hence the danger of failure of a fuse can be greatly reduced or eliminated by imparting such a geometry to the fusible element that the backburn velocity in axially outward direction from a point of arc initiation close to a terminal element is less than the backburn velocity from that point in axially inward direction.

In many cases fuses for elevated circuit voltages must be provided with fusible elements which are wound more or less helically between the ends thereof. This is often achieved by winding the fusible elements around a supporting mandrel or supporting center post of electric insulating material. The presence of such a support means for the fusible elements is particularly indicated where the fusible elements are formed by relatively thin wires, or fragile wire-like ribbons. In full range clearing ability fuses the mandrel supporting the fusible elements is an extremely critical part because it may be subjected to prolonged pre-heating and be at a relatively high temperature at the time a break is formed and a low current arc is ultimately kindled in the fuse. Under such conditions the insulating material of which the mandrel for supporting the fusible element is made is in a thermal state highly adverse to successful extinction of the low current arc. If a mandrel for supporting fusible elements is pre-heated over a long period of time to a relatively high temperature it must be made of a relatively expensive ceramic insulating material greatly increasing the cost of manufacture. The present invention relates to a fuse, and more particularly a full range clearing ability fuse, with a fragile wire-like helically wound fusible element wherein a supporting mandrel or supporting spider for the fusible element is dispensed with, thus avoiding the serious problems likely to arise from the presence of such a part.

SUMMARY OF THE INVENTION

Electric fuses embodying this invention include a tubular casing of electric insulating material and a pair of terminal elements arranged adjacent the ends of and closing said casing. The casing houses an arc-quenching filler of quartz sand. Fusible element means conductively interconnecting said pair of terminal elements are submersed in said arc-quenching filler. Said fusible element means are formed by a narrow strip of sheet silver having a relatively long center portion and end portions each having a length substantially less than the length of said center portion. Said center portion has a straight edge on one side thereof and an undulating edge at the opposite side thereof varying periodically in width from a predetermined minimum to a predetermined maximum width. Each of said end portions has straight parallel edges spaced substantially equal to said predetermined width of said center portion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1*a*–1*c* are diagrammatic representations of prior art fuses;

FIG. 2 is a diagrammatic representation of a fuse embodying this invention;

FIG. 3 is a time current curve of a fuse embodying the present invention;

FIG. 4 is substantially a longitudinal section of a fuse embodying the present invention;

FIG. 5 is an end view of the structure of FIG. 3;

FIG. 6 is an end view of one of the terminal plugs of the structure of FIG. 3;

FIG. 7 is an end view of the other terminal plug of the structure of FIG. 3; and

FIG. 8 is an isometric view of a modified portion of the structure of FIG. 3.

BRIEF REVIEW OF THE PRIOR ART

FIG. 1*a* shows diagrammatically an early current-limiting fuse having a fusible element 1 formed by a silver wire conductively interconnecting terminal elements 2 and embedded in a body 3 of quartz sand. Silver wire 1 is shunted by a tungsten wire 4 also conductively interconnecting terminal elements 2. The casing enclosing the fusible elements 1,4 and the body 3 of quartz sand has been deleted in FIGS. 1*a*–1*c* and in FIG. 2. The tungsten shunt wire 4 was added to the silver wire 1 to limit the surge voltage incident to blowing of the fuse.

FIG. 1b shows diagrammatically an improved version of the fuse of FIG. 1a. The fusible element extending between terminal elements 2 is made up of cylindrical sections 1',1'' having different diameters and fusing sequentially. This results in two sequential voltage surges whose magnitude may, however, exceed permissible limits.

FIG. 1*c* shows diagrammatically a fuse having a fusible element 1''' extending between terminal elements 2. The cross-section of fusible element 1''' changes progressively throughout its length, i.e. it increases progressively axially outwardly from its center. This improves surge voltage control, but for lack of multibreaks the initial arc voltage may be too small. The time-current characteristic of the fuse of FIG. 1*c* is nearer that of a fuse having a ribbon fuse link than to that of a fuse having a wire-like fusible element. These limitations of the fusible element 1''' may, however, be reduced by provision of fusible elements including a relatively large number of relatively short serially arranged sections of which each has substantially the geometry of the fusible element 1''' of FIG. 1*c*, i.e. whose cross-section changes progressively from points of minimum cross-sectional area to points of maximum cross-sectional area. Such a modification of the structure of FIG. 1*c* is however not yet capable of interrupting successfully extremely small overload currents, and does not perform as a full range clearing ability fuse must perform.

FIG. 2 is a diagrammatic representation of a fuse embodying this invention, the left portion of FIG. 2 show-

ing one end, and the right portions of FIG. 2 showing the other end, of the fuse and the center region of FIG. 2 showing a broken away part of the center portion of the fuse. The fusible element of FIG. 2 interconnecting terminal elements 2 is intended for fuses having a voltage rating in excess of 5 kV. It is formed by a relatively narrow strip of sheet silver having a relatively long center portion C. Center portion C has a straight edge on one side C′ thereof and an undulating edge C″ on the opposite side thereof and varies periodically from a minimum width w to a maximum width W. The fusible element further includes end portions E each having a length L substantially less than the length L′ of the center portion C. Each of the end portions E has straight parallel edges having a spacing substantially equal to said maximum width W of said center portion. The ratio of said minimum width w of said center portion to said maximum width W of said center portion should be in the order of 1:2. The undulating edge of the center portion C is formed by a series of circular elements each having a radius of curvature which is a large multiple of the maximum width W of the center portion C. W may be in the order of 0.06 inches and the above referred-to radius of curvature may be in the order of nine-sixteenth inch. The link may be provided at one point thereof, or at several spaced points thereof, with a low fusing point linksevering overlay O of tin or an equivalent silver-severing metal. This will be described below more in detail.

FIG. 3 is a time-current curve of a fuse having a wire-like fusible element, or fuse link, as shown in FIG.2. The fuse has an E rating of 25 within the meaning of the American National Standard specifications for power fuses 46-3; 46-7.2. The high current range of the time-current characteristic CH is almost straight. At about 12 times the rated current the time-current characteristic CH begins to deviate significantly from a straight line. The fuse blows within about 0.1 sec. when subjected to currents about 12 times its E rating. Reference character A has been applied to indicate the tangent to the time-current curve at the 12 times E point thereof which, for all practical purposes, is an extension of the high current portion of the time-current curve CH. Reference character B has been applied to indicate the tangent to the low current portion of the time-current characteristic CH. Lines A and B intersect at the point P. One way of defining a wire-type time-current curve is to state that its A and B lines intersect in the 1 to 10 sec. range thereof, or to state that the point P where lines A and B intersect is situated in the 1 to 10 sec. range. This definition includes fuses having fusible elements formed by relatively long wires of circular cross-section but is not limited to fuses having such fusible elements. It includes fuses having fusible elements made of narrow strips of sheet silver as shown in FIG. 2 and described in the context thereof.

Referring now to FIGS. 4–7, numeral 24 has been applied to indicate a tubular casing of electric insulating material, e.g. a melamine-glass-cloth laminate. Terminal elements 10,11 are arranged adjacent the ends of casing 24 and close the latter. Numeral 13 has been applied to indicate an arc-quenching filler of quartz sand inside of casing 1. The terminal elements 10,11 are in the form of plugs press-fitted into casing 24 and pinned to casing 24 by steel pins 14. Fusible element means 14,15 are submersed in arc-quenching filler 13, and interconnect conductively terminal plugs 10,11. Fusible element means 14,15 may be formed by wires having a circular cross-section, or by narrow ribbons having a wirelike time-current curve. To be more specific, fusible element means 14,15 may be formed by ribbons as shown in FIG.2, and described in connection with this figure which are wound helically as indicated in FIG. 8. Each fusible element 14,15 may thus be formed by a narrow strip of sheet silver having a relatively long center portion C and end portions E each having a length substantially less than the length of the center portion C (FIG. 2). The center portion C has a straight edge C′ on one side thereof, an undulating edge C″ at the opposite side thereof, varying periodically in width from a minimum width w to a maximum width W. The end portions of fusible elements 14,15 have straight parallel edges having a spacing substantially equal to said maximum width W of said center portion (FIG.2). The ratio of the aforementioned minimum width w to the aforementioned maximum width W is in the order of 1:2. This ratio is required to achieve a time-current characteristic like that of a wire. Reference numeral 16 has been applied to indicate a plurality of beads of electric insulating material. Each bead 16 has a plurality of substantially parallel bores 16a. FIG. 8 shows on a larger scale than FIG.4 one such bead having a pair of parallel bores 16a. Each of fusible elements 14,15 is threaded through one of bores 16a in each bead 16 to maintain a substantially fixed axial spacing between fusible elements 14 and 15 in the absence of a mandrel structure around which fusible elements 14,15 are wound and which supports fusible elements 14,15. Beads 16 consist preferably of an epoxy resin having an inorganic non-tracking filler material. Such a material has a very small thermal conductivity and, therefore tends to form zones of elevated temperature at a plurality of points along fusible elements 14,15. Fusible elements 14,15 may be provided at some or at all points which are covered by beads 16 with a metal-severing low fusing point overlay O(FIG.2), e.g. an overlay of tin. The aforementioned bead and overlay arrangement tends to establish series multibreaks in each fusible element 14,15 on occurrence of small overload currents. In FIG. 8 reference character T has been applied to indicate the length of one of the undulations forming one of the edges C″ of fusible elements 14,15. T is the spacing between a pair of contiguous points of maximum width of the center portions C of the fusible element 14, 15. The length of the bores 16a in beads 16 should exceed the length T of the andulations of fusible elements 14,15. To be more specific, the length of each bore 16a in each bead 16 should preferably be about twice the length T of an undulation. If fusible elements are provided with metal-severing low fusing point overlays O these should be provided at points of narrowest width of fusible elements 14,15(FIG.2) and arranged approximately in the center of bores 16a. Thus beads 16 extend to both sides of the metal-severing overlays O in their center a length equal to about the length T of the undulations of the fusible elements 14,15. FIG.8 shows only sections of the undulated center portions C of fusible elements 14, 15, but not the non-undulated end portions E thereof (FIG.2). The length of each of non-undulated or straight edge end portions E of fusible elements 14,15 is about 7 to 10 percent of the length of their undulated center portion C. These are rough empirical data which are in fairly good agreement with the following equation

$$L=\tfrac{1}{2}[2.30 \times 10^{-3} \times 1/6j\ ]$$

wherein L is the length of each of the end portions E of fusible elements **14,15** in centimeters and j is the current density in said end portions in amps/cm^2 at about 12 times the E rating of the fuse.

It has been found that in a fuse of the kind under consideration the point of arc initiation shifts at currents of about 12 times the E rating toward a point of the fusible elements **14,15** situated near one of the terminal elements **10,11** or to a point of reduced cross-sectional area of fusible elements **14,15** closest to one of terminal elements **10,11.** The points of arc initiation at **12** times the E rating must be spaced sufficiently far from terminal elements **10,11** to preclude back-burn into the latter allowing a maximum arcing time of about 10 cycles or one-sixth sec. In the above equation $2{\cdot}3 \times 10^{-3}$ is a constant which depends upon the nature of the metal and that of the arc-quenching filler and assumes approximately the above value (± 20 percent) considering a thin wire like silver ribbon embedded in quartz sand. The dimension of this constant is cm^3/amp.sec.

The fuse structure illustrated in FIGS. 4–8 is intended to be assembled according to the teachings disclosed in the co-pending patent application of Erwin Salzer, filed 7-9-71, Ser. No. 161,084 for METHOD OF ASSEMBLING ELECTRIC HIGH VOLTAGE FUSES AND SUBASSEMBLY THEREFOR, assigned to the same assignee as the present patent application. To this end the axially inner end surfaces of terminal plug **10** are provided with four bores **10***a* having a relatively large diameter and the axially inner end surface of terminal plug **11** is provided with four recesses **11**a having a relatively small diameter. Bores **10***a* extend all the way through terminal plug **10,** but the length of recesses **11***a* is shorter than the thickness of plug **11** so that bores **11***a* are closed at the axially outer ends thereof. When the fuse is entirely assembled bores **10***a* are closed by plug inserts **10***b*. Both terminal plugs **10,11** are provided with centrally arranged, internally screw-threaded passageways **10***c* and **11***c*, respectively, closed by hex screws **17** and **18,** when the fuse is entirely assembled. Screw **18** clamps angular terminal element **19** against the axially outer end surface of terminal plug **10,** and screw **18** clamps angular terminal element **20** against the axially outer end surface of terminal plug **11.** Pin **21** projects through the head of screw **18** into plug **11** to prevent it from becoming loose unintentionally when the fuse is subjected to vibrations while in service. Screw **17** may be provided with a like pin (not shown), if desired.

Preparatory to assembly of the fuse structure of FIGS. 4–8 a bushing (not shown) is inserted into each passageway or bore **10***a* of terminal plug **10.** These bushings have an outer diameter equal to that of bores **10***a*, and these bushings have an inner diameter equal to that of recesses **11***a* and thus serve the purpose of reducing the diameter of bores **10***a* to that of recesses **11***a*. Then four rods circular in cross-section are inserted into the aforementioned bushings in plug **10** and the ends of the rods are inserted into recesses **11***a* in plug **11,** thus forming a squirrel-cage-like structure including the aforementioned rods and the terminal plugs **10,11.** Recesses **11***a* may be internally screw-threaded and the ends of the rods engaging recesses **11**a may have an appropriate external screwthread. To increase the dimensional stability of the aforementioned squirrel-cage-like structure terminal plugs **10,11** may be tied together by a center post (not shown) having screw-threaded portions engaging the screw-threads in bores **10***c*,**11***c* of terminal plugs **10,11.** Thereafter fusible elements **14,15** are wound helically around the aforementioned rods. The ends of fusible elements **14,15** adjacent plug **10** are screwed by means of screws **22** against the axially inner end surface of plug **10** and the ends of fusible elements **14,15** adjacent plug **11** are screwed by means of screws **23** against the axially inner end surface of plug **11.** These mechanical joints between fusible elements **14,15** and plugs **10,11** are preferably supplemented by solder joints as set forth in detail in U.S. Pat. No. 3,571,775 to Frederick J.Kozacka et al., Mar. 23, 1971 for HIGH-VOLTAGE FUSE HAVING A PLURALITY OF HELICALLY WOUND RIBBON FUSE LINKS. The squirrel-cage-like subassembly including plugs **10,11,** fusible elements **14,15** with beads **16** thereon wound around the aforementioned rods and the aforementioned center post is then inserted (or press-fitted) into casing or fuse tube **24** and attached to the latter by steel pins **14.** Thereupon the aforementioned center post is screwed out of screwthreaded bores **10***c*,**11***c*. This can now safely be done since at this point of the assembling process the dimensionally stable tubular casing or fuse tube **24** firmly positions terminal plugs **10,11.** Upon removal of the center post both bores **10***c*,**11***c* are open. Bore **11***c* is thereafter closed by insertion of screw **18** into it at the same time affixing angular terminal element **20** to plug **11.** Then casing or fuse tube **24** is filled with quartz sand through screw-threaded bore **10***c* in plug **10.** The rods supporting fusible elements **14,15** have ends projecting beyond the axially outer end surface of plug **10** for subsequent convenient removal thereof from casing **24.** The aforementioned rods do not only form a temporary support for fusible elements **14,15,** but also form abutments positioning beads **16.** When casing **24** is filled with the pulverulent arc-quenching filler **13,** beads **16** as well as fusible elements **14,15** are positioned and supported by the latter. This allows removal of the supporting rods from casing **24.** That is a very critical operation if fusible elements **14,15** are fragile, and particularly if they are formed by narrow strips of sheet silver as shown in FIGS. **2** and **8.** There must be some friction between fusible elements **14,15** and the supporting rods thereof in order to preclude an involuntary displacement of fusible elements **14,15** relative to the supporting rods during the assembly steps preceding filling of casing **24** with filler **13.** This necessary friction results in a tendency of displacing helically wound fuse links **14,15** in axial direction incident to removal of their supporting rods. The structure of FIGS. **4–8** reduces this tendency to the point of its elimination. This is achieved by means of the aforementioned bushings inserted into bores **10***a* of plug **10.** These bushings are removed preparatory to removal of the rods supporting fusible elements **14,15.** As a result of removal of these bushings a certain clearance is established between the supporting rods for fusible elements **14,15** and the surface of bores **10***a*. The removal of the rods supporting fusible elements **14,15** is then effected in three consecutive steps without axial displacement of helically wound fusible elements **14,15.** The first step consists in a movement of the supporting rods in a direction longitudinally thereof a distance substantially equal to the depth of bores **11***a* so as to establish a small clearance be-

tween the ends of the rods adjacent plug **11** and plug **11**. The next step consists in moving the ends of the rods adjacent plug **10** radially inwardly as far as the clearance between the rods and bores **10***a* allows. As a result of this movement the rods are disengaged from fusible elements **14,15**, and cannot exert an axial pull upon fusible elements **14,15** when removed from fuse tube **24**. The final step in the removal of the temporary supporting rods for fusible elements **14,15** consists in their withdrawal from tube **24** through bores **10**a in plug **10**. During this removal process the rods are slanting relative to the axis of fuse tube **24** and out of engagement with fusible windings **14,15**. The assembly is completed by plugging holes **10***a* by plugs **10***b*, plugging hole **10***c* by screw **17**, at the same time affixing terminal element **19** to terminal plug **10**.

The large beads **16** not only form effective spacers between contiguous turns of fusible elements **14,15**, but form also very effective supports for the latter in the absence of a link-supporting mandrel. This supporting action of beads **16** results from the large interface between beads **16** and surrounding pulverulent filler **13**. If the fusible elements **14,15** are provided with a low fusing point metal-severing overlay, e.g. tin, at the points thereof situated inside of beads **16**, this establishes a tendency of formation of multibreaks when interrupting overload currents such as, e.g. overload currents equal to, or less than, 12 times the E rating of the particular fuse.

If beads **16** are made of a mixture of a melamine resin and a suitable inorganic filler, the beads will evolve gases under the action of electric arcs kindled therein, producing arc-quenching blasts of gas directed in opposite directions. As explained more in detail in my copending patent application filed May 4, 1972, Ser. No. 250,175 for HIGH VOLTAGE FUSE HAVING FULL RANGE CLEARING ABILITY the beads **16** should be of a material having a thermal conductivity of much less than that of quartz filler **13**, and preferably less than 0.05 Btu/hr/sq ft/°F/ft. This is true of mixtures of a melamine resin and oxides of aluminum.

The undulated center portions C of fusible elements **14,15** form a plurality of points of reduced cross-sectional area establishing series breaks and series arclets at the occurrence of major fault currents. The axially outer non-undulated ends E of fusible elements **14,15** are adapted to result in a smaller backburn velocity in axially outward direction than the backburn velocity in axially inward direction incident to formation of a break adjacent a point of transition from the center portion C to the axially outer end portions E of fusible element means **14,15**. This feature clearly shown in FIG.2 is of particular importance when the point of arc initiation transfers from the point where a silver-severing low fusing point overlay is supported by the center portion of the fusible element toward the aforementioned point of transition between the center portion C and the end portions E of a fusible element.

I claim as my invention:

1. A fusible element for electric fuses having a voltage rating in excess of 5 kV formed by a narrow strip of sheet silver including a relatively long center portion and end portions each having a length substantially less than the length of said center portion, said center portion having a straight edge on one side thereof and an undulating edge on the opposite side thereof and varying periodically in width from a minimum width to a maximum width, and each of said end portions having straight parallel edges having a spacing substantially equal to said maximum width of said center portion.

2. A fusible element as specified in claim **1** wherein the ratio of said minimum width of said center portion to said maximum width of said center portion is in the order of 1:2.

3. A fusible element as specified in claim **1** wherein said undulating edge is formed by a series of circular elements each having a radius of curvature being a large multiple of said maximum width of said center portion.

4. An electric fuse for circuits having an elevated circuit voltage including

a. a tubular casing of electric insulating material;

b. a pair of terminal elements arranged adjacent the ends of and closing said casing;

c. an arc-quenching filler of quartz sand inside said casing; and

d. fusible element means inside said casing submersed in said arc-quenching filler and conductively interconnecting said pair of terminal elements, said fusible element means being formed by a narrow strip of sheet silver having a relatively long center portion and end portions each having a length substantially less than the length of said center portion, said center portion having a straight edge on one side thereof and an undulating edge at the opposite side thereof and varying periodically in width from a predetermined minimum width to a predetermined maximum width, and each of said end portions having straight parallel edges spaced substantially equal to said predetermined maximum width of said center portion.

5. An electric fuse as specified in claim **4** wherein said pair of terminal elements is conductively interconnected by a plurality of substantially helically wound fusible element means, the ratio of said predetermined minimum width of said center portion to said predetermined maximum width of said center portion of said plurality of fusible element means being in the order of 1:2, and a plurality of beads of an electric insulating material each having a plurality of substantially parallel bores, each of said plurality of fusible elements being threaded through one of said plurality of bores in each of said plurality of beads to maintain a substantially fixed axial spacing between said plurality of fusible element means in the absence of a mandrel structure for supporting said plurality of fusible elements.

6. An electric fuse as specified in claim **6** wherein said plurality of beads consist of an epoxy resin having an inorganic non-tracking filler material.

7. An electric fuse as specified in claim **4** wherein the ratio of said predetermined minimum width of said center portion to said predetermined maximum width of said center portion is in the order of 1:2.

8. An electric fuse as specified in claim **4** wherein the length of each of said end portions is in the order of L cm as determined by the equation

$$L = \tfrac{1}{2}[2.30 \times 10^{-3} \times 1/6j],$$

wherein j is the current density in amp/cm^2 prevailing in said end portions of said fusible element means at about **12** times the E rating of the fuse.

9. An electric fuse as specified in claim **4** wherein the length of each of said end portions is about 7 to 10 percent of the length of said center portion.

10. An electric fuse including
a. a tubular casing of electric insulating material;
b. a pair of terminal elements arranged adjacent the ends of and closing said casing;
c. a pulverulent arc-quenching filler inside said casing;
d. a plurality of substantially wire-like substantially helically wound fusible element means inside said casing submersed in said arc-quenching filler and conductively interconnecting said pair of terminal elements; and
e. a plurality of beads of an electric insulating material each having a plurality of substantially parallel bores, each of said plurality of fusible elements means being threaded through one of said plurality of bores in one of said plurality of beads to maintain a substantially fixed spacing between contiguous turns of said plurality of fusible element means in the absence of a mandrel structure for supporting said plurality of fusible element means.

11. An electric fuse as specified in claim 10 wherein said plurality of beads consist of a gas-evolving insulating material having a thermal conductivity of less than 0.50 Btu/hr/sq ft/°F/ft.

12. An electric fuse as specified in claim 10 wherein said plurality of wire-like fusible element means consist of silver wires of circular cross-section.

13. An electric fuse as specified in claim 10 wherein said plurality of wire-like fusible element means consist of narrow strips of sheet silver having a straight edge on one side thereof and a substantially undulating edge on the opposite side thereof.

14. An electric fuse as specified in claim 11 wherein said plurality of wire-like fusible element means consist of conductors of silver having a length and a cross-section adapted to result in a time-current curve whose low current tangent and whose high current tangent intersect in the range of 1 second to 10 seconds.

15. An electric fuse including
a. a tubular casing of electric insulating material;
b. A pair of terminal plugs arranged adjacent the ends of and closing said casing, one of said pair of terminal plugs having a plurality of eccentric recesses in the axially inner end surface thereof and the other of said pair of terminal plugs having eccentric bores in registry with said eccentric recesses and plugged by bore-plugging means;
c. a pulverulent arc-quenching filler inside said casing;
d. a helically wound fusible element means of silver inside said casing submersed in said arc-quenching filler conductively interconnecting said pair of terminal plugs, said fusible element means being supported by said arc-quenching filler in the absence of a supporting mandrel therefor, the length and the cross-section of said fusible element means being adapted to establish in a time-current curve whose low current tangent and whose high current tangent intersect in the range of 1 second to 10 seconds, said fusible element means having a center portion provided with a plurality of spaced points of reduced cross-sectional area forming series arclets at the occurrence of major fault currents, and said fusible element means having axially outer end portions adapted to result in a smaller backburn velocity in axially outward direction than the backburn velocity in axially inward direction incident to formation of a break adjacent a point of transition from said center portion to said axially outer end portions of said fusible element means; and
e. an overlay of a silver-severing low fusing point metal supported by said center portion of said fusible element means.

16. An electric fuse including
a. a tubular casing of electric insulating material;
b. a pair of terminal plugs arranged inside said casing adjacent the ends thereof closing said casing;
c. a filler of quartz sand inside said casing;
d. a helically wound fusible element of silver inside said casing submersed in said filler and conductively interconnecting said pair of terminal plugs, said fusible element being formed by a narrow strip of sheet silver having a relatively long center portion and end portions each having a length substantially less than the length of said center portion, said center portion having a straight edge on one side thereof and an undulating edge at the opposite side thereof and varying periodically in width from a predetermined minimum width to a predetermined maximum width, and each of said end portions having straight parallel edges having a spacing substantially equal to said predetermined maximum width of said center portion;
e. a plurality of overlays of a low fusing point silver-severing metal arranged in spaced relation along said fusible element; and
f. a plurality of beads of a material having a lower thermal conductivity than said filler of quartz sand mounted on said fusible element, each of said plurality of beads covering one of said plurality of silver-severing overlays, and the length of each of said plurality of beads exceeding the spacing between a contiguous pair of points of said predetermined maximum width of said fusible element.

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