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March 29, 1966 H. W. MIKULECKY 3,243,552

CURRENT LIMITING FUSE

Filed Sept. 8, 1964 2 Sheets-Sheet 1

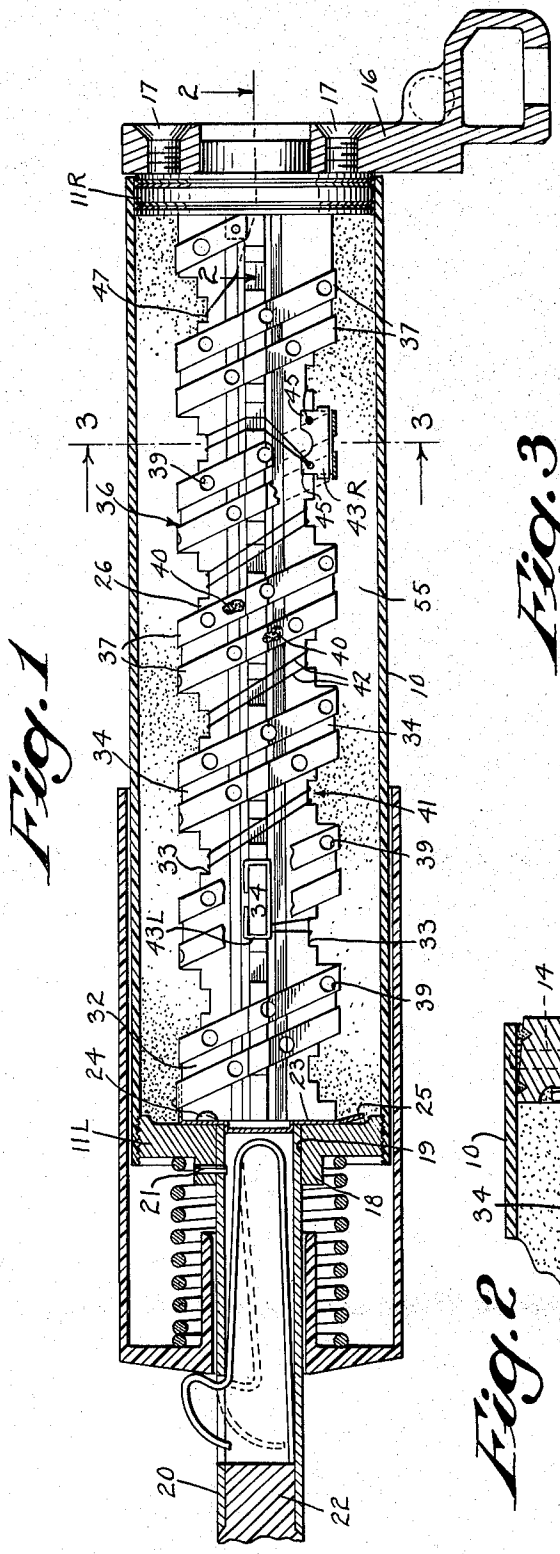


Fig. 1

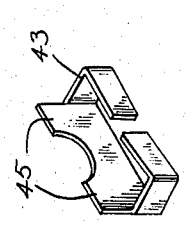


Fig. 7

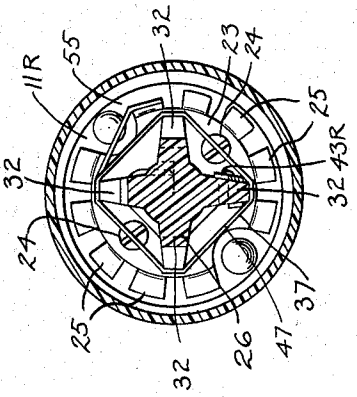


Fig. 3

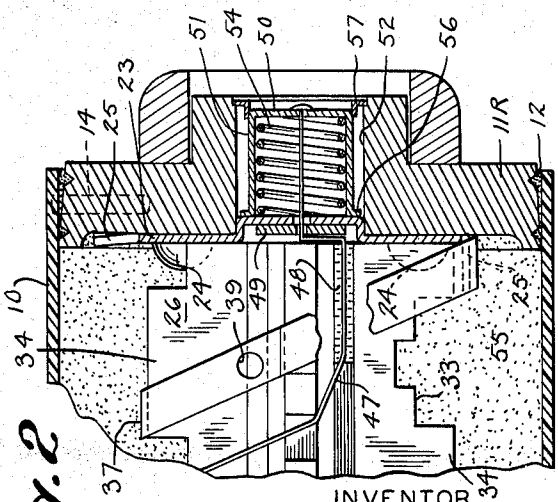


Fig. 2

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CURRENT LIMITING FUSE

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Fig. 4a

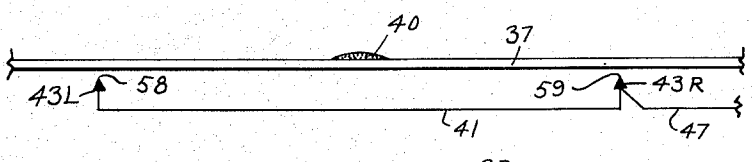


Fig. 4b

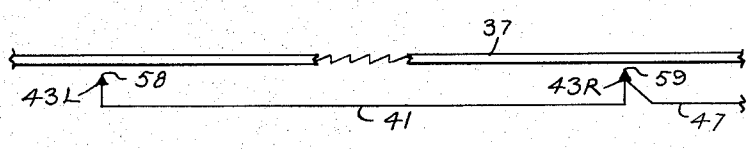


Fig. 4c

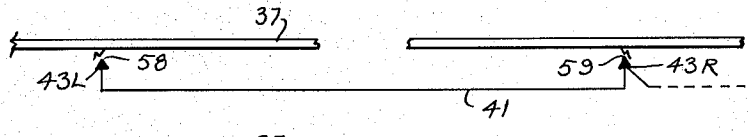


Fig. 4d

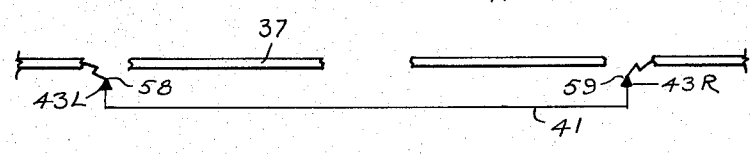


Fig. 4e

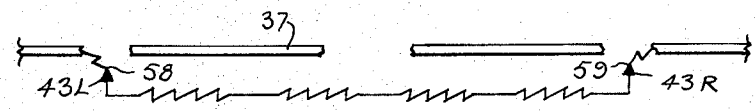


Fig. 4f



Fig. 5

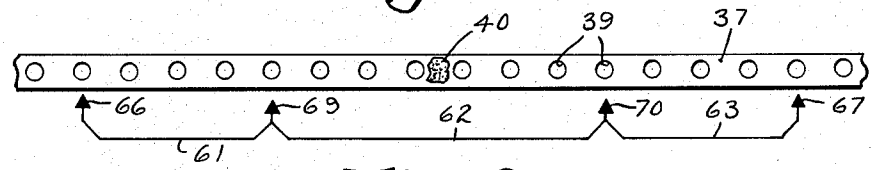
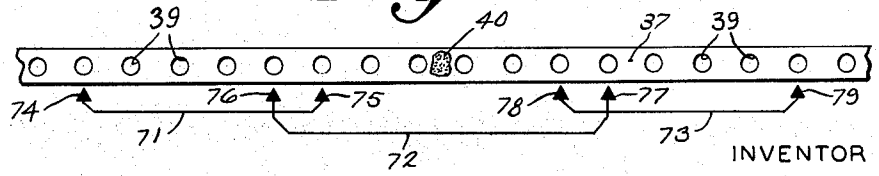


Fig. 6



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United States Patent Office 3,243,552 Patented Mar. 29, 1966

3,243,552

CURRENT LIMITING FUSE

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Filed Sept. 8, 1964, Ser. No. 394,957
13 Claims. (Cl. 200—120)

This invention relates to fuses and, more particularly, to fuses of the current limiting type which limit the flow of current in an electrical circuit under short circuit conditions to a substantially smaller value than the available short circuit current of the circuit.

Current limiting fuses conventionally comprise a fusible element embedded in a granular inert material of high dielectric strength such as sand or finely divided quartz. Usually the fusible element is in the form of one or more thin conductors of silver wound on a supporting core, or spider, of high temperature resistant ceramic material. When subjected to current of fault magnitude, the fusible element attains fusing temperature and vaporizes, whereby arcing occurs and the metal vapors rapidly expand to many times the volume originally occupied by the fusible element and are thrown into the spaces between the granules of inert filler material where they condense and are no longer available for current conduction. The current limiting effect results from the interaction of the metal vapors and the inert granular material surrounding the fusible element. The physical contact between the hot arc and the relatively cool granules causes a rapid transfer of heat from the arc to the granules, thereby dissipating most of the arc energy with very little pressure buildup within the fuse enclosure. The vapors of silver have relatively low conductivity unless their temperature is particularly high, and the temperature of the silver vapors is rapidly reduced by the quartz sand filler until the vapors will not support a flow of current. Consequently, a high resistance is, in effect, inserted into the path of the current and initially limits the current to a magnitude which is only a small fraction of that available in the circuit.

The quartz sand particles in the immediate vicinity of the arc fuse and become partial conductors at the high temperature of the arc and form a fulgurite, or semiconductor. The fulgurite resulting from fusion and sintering of the quartz sand particles is in the nature of a glass body, and as it cools it loses its conductivity and becomes an insulator.

High voltage, high amperage current limiting fuses used to control fault currents of high magnitude conventionally employ fusible elements of silver ribbon having serially related portions of relatively small cross sectional area and intermediate portions of relaitvely large cross sectional area, for example, a silver ribbon provided with a plurality of circular spaced apart perforations which determine the portions where fusion of the fusible element is initiated on currents of short circuit magnitude. The perforations form portions of reduced cross sectional area which limit the peak arc voltage and make it possible to distribute the thermal duty of the arc quenching granular material relatively evenly over the entire filler body. If such a fuse is subject to fault current of high magnitude, all of the portions of small cross sectional area fuse and vaporize almost simultaneously, resulting in the formation of arclets in series and controlling the transient voltage across the fuse. When subjected to small

protracted fault currents, the arc gap first formed is generally progressively enlarged by vaporization of the silver element until the gap is of sufficient length to effect final interruption of the circuit and consequently the fulgurite is generally continuous. When interruption of small overload currents results in arcing over a plurality of cycles, the arc energy tends to be large. The relatively large arc energy and the dissipation of additional heat resulting from I^2R losses caused by the flow of follow current through the fulgurite combine to delay the cooling of the central portion of the fulgurite which remains partially conductive, and only the end portions of the fulgurite, where the arc contacts the relatively cool filler particles, tend to interrupt the arc. Most of the voltage appears across the ends of the fulgurite, which are of higher resistance than the hot central portions thereof, and tends to flashover the hot gases, and consequently reignition of the fusible element and post interruption failure frequently occur when current limiting fuses control overload currents of small magnitude.

It is an object of the invention to provide a current limiting fuse for controlling both currents of overload proportions and of short circuit proportions which has improved means to prevent re-ignition of the arc when clearing relatively low magnitude currents.

It is a further object of the invention to provide a current limiting fuse for interrupting both large and small fault currents which has means to form a series of arc gaps or fulgurites rather than a continuous fulgurite when clearing prolonged, low magnitude overload currents.

These and other objects and advantages of the invention will be more readily apparent from the following detailed description when taken in conjunction with the accompanying drawing wherein:

FIG. 1 is a sectional view through a current limiting fuse embodying the invention;

FIG. 2 is a view taken on line 2—2 of FIG. 1;

FIG. 3 is a view taken on line 3—3 of FIG. 1;

FIGS. 4*a*–4*f* are schematic views illustrating the sequential operation of the fuse of FIG. 1 when interrupting small magnitude fault currents;

FIGS. 5 and 6 are schematic views of alternative embodiments of the invention illustrating the main and auxiliary fusible elements in linear form rather than helically wound as in the actual construction and as shown in FIG. 1; and

FIG. 7 is a perspective view of the arcing electrodes utilized in the embodiment of FIG. 1.

Referring to the drawing, a tubular enclosing casing **10** for a current limiting fuse is constructed of suitable insulating material such as glass fiber impregnated with epoxy resin, glass, or fiber. A metallic end piece **11R** is secured on the right end of casing **10** by means of any suitable seal such as epoxy cement **12** and radially extending pins **14** (see FIG. 3) protruding through the casing **10** and into holes in end piece **11R**. A metallic end piece **11L** may have external threads engaging internal threads formed near the left end of casing **10**. A metallic hinge assembly **16** may be secured to end piece **11R** shown at the right end of fuse casing **10** by screws **17** engaged within threaded apertures in the end piece **11R**. The end piece **11L** shown at the left end of fuse casing **10** has a smaller diameter portion **18** and an axial bore **19**. A tubular metallic terminal member **20** extends into axial bore **19** with a force fit and is rigidly secured to end piece **11L** by pins **21** extending radially

through tubular member **20** and smaller diameter portion **18** of end piece **11L**. Terminal member **20** may be adapted to fit within a stationary contact jaw of an electrical switch, and an insulating member **22** provided with an eye (not shown) for receiving a hookstick may be secured in the end of terminal member **20** by suitable means such as epoxy cement. End plates **23** are disposed against the internal surface of end pieces **11L** and **11R** and are secured thereto by screws **24**. Each end plate **23** has a plurality of radially extending tabs **25** adjacent its outer periphery which may be bent down and form terminals to which the fusible conductors can be connected. An elongated insulating core, or spider **26**, is axially mounted within casing **10**. The ends of spider **26** are affixed to metallic end plates **23** by suitable means such as epoxy cement.

Spider **26** is of generally star-shaped cross section having a plurality of radially protruding, peripherally spaced apart, longitudinally extending fins **32**. Each fin **32** has a plurality of depressions **33** of semi-cruciform configuration spaced apart longitudinally of spider **26** forming longitudinally spaced apart raised shoulders **34**.

The depressions **33** of peripherally successive fins **32** are progressively staggered in a direction longitudinal of the spider **26** so that the peripherally successive depressions **33** define a continuous helical path and the peripherally successive raised shoulders **34** form support means of helical configuration for a circuit interrupting main fusible element **36** which is usually of silver or copper and normally carries all of the current and as disclosed in FIGS. 1 and 2 comprises a pair of parallel ribbons **37** of suitable fusible material such as silver helically wound so as to contact only the peripherally spaced apart raised shoulders **34** of spider **26** and being electrically connected in parallel between metallic end pieces **11**. The ends of the ribbons **37** are soldered to tabs **25** on end plates **23**.

Spider **26** may be of inert ceramic material such as porcelain, but it preferably is of an electrical insulating material adapted to evolve gas in the presence of an arc, as disclosed in my copending application Serial No. 313,640 filed October 10, 1963, having sufficient mechanical strength to be self supporting, and being capable of withstanding temperatures up to 250° F. continuously without degradation and temperatures up to 500° F. for periods up to one hour without excessive degradation or decomposition. Spider **26** may be of a molded thermosetting composition comprising a water insoluble binder and an anti-tracking substance selected from the class consisting of the hydrates and oxides of aluminum and magnesium. The composition may also include other fillers such as mica, glass, fiber, asbestos, or silica, and one suitable material comprises approximately 60 percent aluminum hydrate filler, 20 percent melamine resin binder, and approximately 20 percent asbestos.

When the fuse is required to control currents of short circuit proportions, the silver ribbons **37** of the main fusible element **36** may be provided with a plurality of circular perforations, or holes, **39** spaced apart along the length thereof which determine the points where fusion of the element is initiated when the fault current and its rate of rise are high. The perforations **39** form portions of reduced cross sectional area so that each ribbon **37** has a number of serially related portions of relatively small cross sectional and intermediate areas of relatively large cross sectional area. Beads **40** of low melting temperature alloy such as tin-lead solder are in intimate contact with the main silver ribbons **37** preferably adjacent the midpoint thereof. At melting currents flowing for prolonged periods, the fusible ribbons **37** become hot enough to melt the alloy bodies **40**, and the amalgamation of the silver and alloy causes a hot spot with high enough resistance to melt the ribbon **37** at this point. This construction, known as the "M" effect, allows the fusible ribbon **37** to melt at a temperature in the 400°–600° F. range when subjected over a long period of time to low magnitude currents as compared to the 1760° F. melting temperature for pure silver. It will be appreciated that on currents of short circuit magnitude, the alloy element **40** has little or no effect and the silver elements **37** vaporize at the fusion temperature for the silver.

An auxiliary fusible element **41** is wound on spider **26** in radially inward spaced relation from the main element **36** and in the helical path defined by the depressions **33**. Auxiliary element **41** may be a copper or a silver ribbon, a copper or a silver wire, a plurality of silver wires **42**, as shown in the drawing, or a resistance wire, and is electrically connected at its ends by suitable means such as solder to metallic clip, arc gap electrodes **43** each of which fits over one of the raised shoulders **34** of spider **26**. The ends of clip electrodes **43** are resiliently urged against the raised shoulder **34** to prevent movement of the electrode **43** relative to spider **26**. The arc gap electrodes **43** are located at points approximately midway between the low melting temperature alloy bead **40** and the ends of the main fusible ribbons **37**, and the arc gap electrodes **43** are spaced radially inward from the main ribbon **37** so that an air gap of approximately $\frac{1}{64}$ inch to $\frac{1}{32}$ inch exists between the electrodes **43** and the main ribbons **37**. The arc gap electrodes **43** have sufficient mass to withstand arcing without deformation or melting over prolonged periods until the auxiliary element **41** clears the fault. Depending tab portions **45** extending in a direction away from the main ribbons **37** are provided on the arc gap electrodes **43** to which the ends of the auxiliary element **41** are attached by suitable means such as solder so that the arc cannot easily contact the auxiliary element **41** and cause premature melting thereof.

Auxiliary fusible element **41** is selected so that the ratio of the average 100 second melting current of the main element **36** to the average 100 second melting current for the auxiliary element **41** is in the range of 2 to 6, and preferably this ratio is approximately four. Stated in another manner, auxiliary fusible element **41** is selected to have a minimum melting current sufficiently less than that of the main element **36** so that, when the minimum melt current is reached for the main element **36**, good low current clearing characteristics exist for the auxiliary element **41**.

An indicator wire **47** of suitable material having higher resistance than silver such as tungsten or Nichrome is connected at one end to the arc gap electrode **43R** adjacent hinge assembly **16** at the right end of the fuse as shown in the drawing. The indicator wire **47** is wound in the helical path defined by the depressions **33** and extends through an opening **48** in the right end of spider **26**, through axial opening in an insulating disc **49**, the end plate **23**, and the end piece **11R**, and is secured by suitable means such as solder to the bottom wall **50** of a cup shaped indicator **51**. Cup shaped indicator **51** is normally disposed within an axial bore **52** in end piece **11R** and is urged outward therefrom to a visible position by a compression spring **54**. Indicator wire **47** normally holds indicator **51** in the inward position wherein spring **54** is compressed between the bottom wall **50** of indicator **51** and the end plate **23**. Indicator **51** has a circumferential flange **56** adjacent its open end, and an eyelet **57** secured by suitable means such as staking to the end piece **11R** adjacent the margin defining axial bore **52** interferes with flange **56** and prevents indicator **51** from being removed from end piece **11R**.

Disposed within the interior of casing **10** and embedding the spider **26**, the main ribbons **37**, the auxiliary element **41** and the indicator wire **47** is a body of granular inert or refractory material **55** of high dielectric strength such as sand or finely divided quartz.

Under currents of short circuit magnitude, the main element **36** and the indicator wire **47** vaporize almost

instantaneously, thereby permitting spring **54** to urge indicator **51** to a visible position as an indication that the fuse has operated. The disclosed fuse is particularly adapted to clear relatively small magnitude currents of overload proportions, and FIGS. *4a–4f* schematically show the sequence of operation under these conditions and illustrate the main and auxiliary elements as a single ribbon **37** and as single wire **41** respectively to facilitate the understanding of the invention. Under relatively small but prolonged overloads, the main ribbon **37** melts first at the low melting temperature alloy bead **40** near the center of the ribbon, and the main ribbon **37** begins to burn back under the initial arc formed at this point as shown schematically in FIG. *4b*. As discussed hereinbefore, even when the main ribbon **37** has perforations **39** forming portions of reduced cross sectional area, the arc gap first formed at the center of the ribbon is being progressively enlarged by the vaporization of the ribbon rather than forming arclets in series. The full line potential appears across the glass-like fulgurite resulting from the fusion of the quartz filler **55** immediately adjacent the initial arc, and the relatively large arc energy, the excessive duration of arcing, and the I^2R losses due to flow of follow current when clearing prolonged low magnitude current delay the cooling of the central portion of the fulgurite so that it remains semiconducting. Consequently, only the two end portions of the fulgurite where the arc contacts the relatively cool quartz sand tend to extinguish the arc.

As soon as the voltage rises sufficiently across the arc formed at bead **40** adjacent the center of the main element ribbon **37**, the air gap **58** between the clip electrode **43L** shown at the left of the drawing and the main ribbon **37** sparks over, thereby causing current flow through the indicator wire **47**. Since the portion of indicator wire **47** within casing **10** and embedded in the quartz sand filler **55** has better heat dissipation characteristics than the portion of indicator wire surrounded by air within axial bore **52** in end cap **11R**, the latter portion surrounded by air will melt first under low fault conditions and assure movement of indicator **51** to visible position.

Since the indicator wire **47** is of relatively high resistance, it will melt almost immediately at a number of points and impose the arc voltage across the air gaps **58** and **59** in series and flashover air gap **59** as shown in FIG. *4c* and thus connect auxiliary element **41** in parallel with main ribbon **37**. The intense heat of the arcing to the main element **37** at the air gaps **58** and **59** quickly burns open sections of the main ribbon **37** adjacent the clip electrodes **43L** and **43R** as shown in FIG. *4d*. Auxiliary element **41** has been selected so that its minimum melt current is approximately one-fourth that of the main fusible element **37**, and consequently several half cycles will be required to vaporize the auxiliary element **41** on the relatively low fault current. During the time required to melt the auxiliary element **41**, arcing will continue at the air gaps **58** and **59** between the arc gap electrodes **43** and the main element ribbons **37** and will destroy a small section of each main ribbon **37** adjacent each of the air gaps. During the plurality of cycles the auxiliary element **41** is melting, the fulgurite at the center of the main ribbon **37** has had time to cool and lose its conductivity. Interruption of the fault current by the auxiliary element **41** as schematically illustrated in FIG. *4f* is particularly easy when the spider **24** is of gas evolving material which cools the inert granules **55** and helps prevent reignition of the arc as disclosed in my aforementioned application S.N. 313,640. However, if insufficient length of the main silver ribbon **37** has been consumed, re-ignition of the main element **37** may occur. As illustrated in FIG. *4f*, the main ribbon **37** will now be burning back at the fulgurite at the center of the ribbon and also at the fulgurites adjacent the air gaps **58** and **59**. Since arcing is occurring at three regions rather than at a single fulgurite, the burning back of the main ribbon **37** will occur at a much faster rate and the arc energy is dissipated in three regions rather than at a single fulgurite, thereby permitting the central portion of the fulgurites to cool and become a nonconductor. Further, the fuse will thus have the two end portions with good arc extinguishing characteristics at each of the three fulgurites, and consequently the disclosed fuse rapidly clears small overload currents.

If the cross section of auxiliary element **41** is too large as compared to main ribbon **37**, the arc at the air gaps **58** and **59** may exist for a sufficient length of time to damage that section of the fuse. If, on the other hand, the cross sectional area of auxiliary element **41** is insufficient, the time of arcing at the air gaps may be too short to completely burn the main ribbon **37** open at this point and consequently only one opening will be provided in the main ribbon if re-ignition occurs.

FIGS. 5 and 6 illustrate embodiments wherein the main fusible element is caused to burn back at a still greater number of points when subjected to small prolonged overload currents. The main and auxiliary fusible elements of the embodiments of FIGS. 5 and 6 are preferably wound helically on a support spider and embedded within a granular inert filler in the same manner as in the preferred embodiment, but in order to simplify the description and facilitate the understanding of the invention, the main and auxiliary elements are shown in linear form in the drawing and the arc gap electrodes are designated as arrowheads. The main fusible element of the embodiment of FIG. 5 is a silver ribbon **37** connected between the fuse end pieces (not shown) and having a plurality of spaced apart circular perforations **39** and a bead **40** of low melting temperature alloy adjacent its center. The serial arrangement of three silver wire auxiliary elements **61**, **62**, **63** is parallel to but electrically isolated from the main ribbon element **37**. The outer auxiliary elements **61** and **63** may be of the same wire size and are of smaller wire size than the central auxiliary element **62**. Electrodes **66** and **67** at the outer ends of auxiliary elements **61** and **63** (which may be similar to clip electrodes **43** of the preferred embodiment) form air gaps with the main electrode **37** which are smaller than the air gaps formed between main ribbon **37** and electrodes **69** and **70** connected respectively at the junctions of auxiliary elements **61** and **62** and of auxiliary elements **62** and **63**. On small overload currents, the main ribbon **37** will first melt at the bead **40** at the center of the ribbon **37** and the ribbon will burn back from this point. After the arc voltage across the fulgurite at the center of ribbon **37** rises to a sufficiently high magnitude, the air gaps between ribbon **37** and electrodes **66** and **67** flashover and continue to burn back the ribbon **37** at these points during the period required to melt the auxiliary elements **61** and **63** and thus clear the overload current. If the main ribbon **37** is re-ignited, the voltage across the arc at the fulgurite adjacent the center of the main element **37** will rise sufficiently to flashover the air gaps between the main ribbon **37** and the electrodes **69** and **70**, and the arcing at these air gaps during the period required to melt the auxiliary element **62** will destroy sections of the main ribbon **37** adjacent the electrodes **69** and **70**. If the main ribbon element **37** is now re-ignited, five arcs are connected in series throughout the length of main element **37**, and the main element will be burning back at ten different places, thereby providing ten fulgurite end portions with good arc extinguishing characteristics which rapidly clear the overload current.

In the embodiment of FIG. 6, three auxiliary silver wire elements **71**, **72** and **73** are disposed parallel to main ribbon **37** but isolated therefrom by air gaps formed between main element **37** and electrodes **74** and **75** connected to the ends of auxiliary element **71**, electrodes **76** and **77** connected to the ends of auxiliary element **72**, and electrodes **78** and **79** connected to the ends of auxiliary

element 73. The center auxiliary element 72 is not joined to the outer auxiliary elements 71 and 73 as in the embodiment of FIG. 5, and the center auxiliary element 72 crosses the outer auxiliary elements 71 and 73 so that electrodes 76 and 77 are closer to the ends of main ribbon 37 than electrodes 75 and 78. When the main element 37 melts adjacent bead 40 on a small fault current, the arc voltage appears across only electrodes 76 and 77, thereby causing the air gaps between these electrodes and the ribbon 37 to flashover. The arcing at the air gaps causes the main ribbon to melt adjacent electrodes 76 and 77 during the interval required to melt the center auxiliary element 72. If current flow should re-ignite the main element 37 which has been burned open at three places, a portion of the arc voltage will now appear across electrodes 74 and 75 and a portion of the arc voltage will also appear across electrodes 78 and 79, thereby causing the air gaps between these electrodes and the main fusible element 37 to flashover. The subsequent arcing at these gaps causes the main ribbon 37 to melt adjacent arc gap electrodes 74, 75, 78 and 79 during the interval required to melt the auxiliary elements 71 and 73. If current now re-ignites the main element 37, seven arcs will be connected in series throughout the length of main element 37, and fourteen fulgurite end portions having good arc extinguishing characteristics tend to interrupt the overload current.

While only a few embodiments of the invention have been illustrated and described, many modifications and variations thereof will be readily apparent to those skilled in the art, and consequently it is intended in the appended claims to cover all such modifications and variations which fall within the true spirit and scope of the invention.

I claim:

1. In a high voltage fuse of the current limiting type, a tubular insulating casing, metallic terminals on the ends of said casing, a main fusible element within said casing interconnecting said metallic terminals, a body of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing having its ends spaced slightly from portions of said main element on opposite sides of said body of alloy and forming air gaps with said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range of from 2 to 6, and granular inert refractory arc quenching material within said casing embedding said main and auxiliary elements, whereby flashover of said air gaps connects said auxiliary element in parallel with said main element and burns away portions of said main element adjacent said air gaps while said auxiliary element is melting and provides a plurality of arcing points in series along the length of said main element.

2. In an electric circuit interrupter capable of substantially limiting the magnitude of fault current flowing therethrough including a fusible main element having a body of low melting temperature alloy in intimate contact therewith, means for causing said main element to burn back in a plurality of serially related points when interrupting low magnitude fault current including an auxiliary fusible element spaced apart at its ends by air gaps from portions of said main element on opposite sides of said body of alloy, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from 2 to 6, and granular inert arc quenching material embedding said main and auxiliary fusible elements.

3. In an electric circuit interrupter capable of substantially limiting the magnitude of fault current flowing therethrough including a fusible main element having a low melting temperature alloy element in intimate contact therewith, means for causing said main element to burn back in a plurality of serially related points when interrupting low magnitude fault current including an auxiliary fusible element spaced apart at its ends by air gaps from portions of said main element on opposite sides of said alloy element, means disposed adjacent each said air gap and responsive to arcing in said gap for burning completely through a portion of said main element adjacent said gap, and granular arc quenching material embedding said main and auxiliary fusible elements and said last-named means.

4. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a main fusible element within said casing interconnecting said terminals and having a maximum long time melting temperature of approximately 600° F. when subjected to prolonged fault currents of relatively small magnitude, an auxiliary fusible element within said casing having its ends spaced slightly by air gaps from longitudinally spaced apart portions of said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from 2 to 6, and granular inert refractory arc quenching material within said casing embedding said main and auxiliary elements, whereby flashover of said air gaps connects said auxiliary element in parallel with said main element and burns away portions of said main element adjacent said air gaps, while said auxiliary element is melting, and provides a plurality of arcing points in series along the length of said main element.

5. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a main fusible element within said casing interconnecting said terminals, a body of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing having its ends spaced slightly from portions of said main element on opposite sides of said body of alloy forming air gaps with said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from 2 to 6, insulating support means within said casing for said main and fusible elements and being in contact with said fusible elements at only spaced apart points along the length of said main and auxiliary elements and being adapted to evolve gas in the presence of an arc, and granular inert refractory arc quenching material within said casing embedding said support means and said main and auxiliary elements.

6. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casings, a spider extending parallel to the axis of said casing and having peripherally spaced apart, radially protruding fins generally longitudinal thereof, a main fusible element within said casing interconnecting said terminals and being wound helically on said spider so that it touches only said fins, a body of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing wound helically on said spider so that it touches only said fins and having its ends spaced slightly from portions of said main element on opposite sides of said body of alloy and forming air gaps with said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from 2 to 6, the portions of said fins in contact with said main and auxiliary elements being of an insulating material adapted to evolve gas in the presence of an arc, and granular inert refractory arc quenching material within said casing embedding said spider and said main and auxiliary elements.

7. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a spider of star shaped cross section having radially protruding fins extending longitudinally thereof disposed within said casing parallel to the axis thereof, a main fusible element within said casing interconnecting said terminals and being helically wound on said spider and touching only spaced apart portions of the periphery of

said spider along said fins, a body of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing wound helically on said spider and touching only spaced apart portions of the periphery of said spider along said fins and having its ends spaced slightly from portions of said main element on opposite sides of said body of alloy and forming air gaps with said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range of two to six, granular inert refractory material of high dielectric strength within said casing embedding said spider and said main and auxiliary elements, said spider being of a molded, thermosetting, electrical insulating composition, including a water insoluble binder and an anti-tracking material adapted to evolve gas when heated by an arc selected from a class consisting of the hydrates and oxides of magnesium and aluminum.

8. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a spider of heat resistant insulating material extending parallel to the axis of said casing having peripherally spaced apart, radially protruding fins generally longitudinal thereof, said fins having depressions spaced apart longitudinally thereof forming raised portions between said depressions and the depressions of peripherally successive fins advancing longitudinally of said spider and defining a generally helical path and said raised portions of peripherally successive fins forming generally helical support means radially outward from said helical path, a main fusible element within said casing interconnecting said terminals and being wound on said helical support means defined by said raised portions, a bead of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing disposed in the helical path defined by said depressions and having its ends spaced slightly from portions of said main element on opposite sides of said bead forming air gaps with said main element, the ratio of 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from two to six, and granular inert refractory arc quenching material within said casing embedding said spider and said main and auxiliary elements.

9. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a spider of heat resistant insulating material adapted to evolve gas in the presence of an arc extending parallel to the axis of said casing and having first and second concentric spaced apart, generally helical paths in the exterior periphery thereof, a main fusible element within said casing disposed in said first helical path and interconnecting said terminals, a body of low melting temperature alloy in intimate contact with said main fusible element, an auxiliary fusible element within said casing disposed in said second helical path and having its ends spaced slightly from portions of said main element on opposite sides of said alloy body and forming air gaps with said main element, the ratio of the 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range of from two to six, said spider contacting only portions of said main and auxiliary elements spaced apart longitudinally of said elements, and granular inert refractory arc quenching within said casing embedding said spider and said main and auxiliary elements.

10. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a spider of heat resistant insulating material adapted to evolve gas in the presence of an arc extending parallel to the axis of said casing having peripherally spaced apart, radially protruding fins generally longitudinal thereof, said fins having depression spaced apart longitudinally thereof forming raised portions between said depressions and the depressions of peripherally successive fins advancing longitudinally of said spider and defining a genrally helical path and said raised portions of peripherally successive fins forming generally helical support means radially outward from said helical path, a main fusible element within said casing interconnecting said terminals and being wound on said helical support means defined by said raised portions, a bead of low melting temperature alloy in intimate contact with said main element, arc gap electrodes affixed to individual raised portions of said spider on opposite sides of said bead and being spaced slightly inward radially from said main elements and defining air gaps therewith, an auxiliary fusible element within said casing disposed in the helical path defined by said depressions and being affixed at its ends to said arc gap electrodes, the ratio of 100 second melting current of said main element to the 100 second melting current of said auxiliary element being in the range from two to six, and granular inert refractory arc quenching material within said casing embedding said spider and said main and auxiliary elements and said arc gap electrodes.

11. In an electric circuit having current limiting fuse means for substantially limiting the magnitude of fault current flowing through said circuit including a fusible main element having a body of low melting temperature alloy in intimate contact therewith and granular inert arc quenching material embedding said main element, means for causing said main element to burn back in a plurality of serially related points when interrupting low magnitude fault current including an auxiliary element embedded in said arc quenching material and extending parallel to said main element and spaced apart at its ends by first and second air gaps from portions of said main element on opposite sides of said body of alloy, and a second auxiliary element embedded in said arc quenching material and extending parallel to said main element and having its ends spaced slightly from portions of said main element on opposite sides of said first air gap and forming third and fourth air gaps with said main element, whereby the arc voltage developed across the portion of said main element burned away by arcing at said first air gap will flashover said third and fourth air gaps.

12. In combination with an electric circuit having current limiting fuse means for substantially limiting the magnitude of fault current flowing through said circuit including a fusible main element having a low melting temperature alloy element in intimate contact therewith, means for causing said main element to burn back in a plurality of serially related points when interrupting low magnitude fault current including three serially connected auxiliary fusible elements extending parallel to said main element, the middle auxiliary element having a higher minimum melting current than the outer auxiliary elements, the junctions of said three auxiliary elements being spaced apart by first and second air gaps from portions of said main element on opposite sides of said alloy element and the outer ends of said outer auxiliary elements being spaced from said main element by third and fourth air gaps spaced further from said alloy element than said first and said second air gaps and having lower flashover voltages than said first and second air gaps, and granular inert arc quenching material embedding said main and said auxiliary fusible elements.

13. In a high voltage fuse of the current limiting type, a tubular insulating casing, terminals on the ends of said casing, a main fusible element within said casing interconnecting said terminals, a body of low melting temperature alloy in intimate contact with said main element, an auxiliary fusible element within said casing having its ends spaced slightly from portions of said main element on opposite sides of said body of alloy and forming air gaps with said main element, means dis-

posed adjacent each said air gap and responsive to arcing in said air gap for burning through a portion of said main element adjacent said air gap, and inert granular refractory arc quenching material within said casing embedding said main and auxiliary elements and said last-named means, whereby the arc voltage across the portion of said main element at said body of alloy

when interrupting low magnitude fault current will flashover said air gaps and burn back said main element adjacent each said air gap.

No references cited.

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