Feb. 6, 1962 F. J. KOZACKA 3,020,372

FUSE STRUCTURES

Filed Nov. 24, 1958 2 Sheets-Sheet 1

Fig. 1.

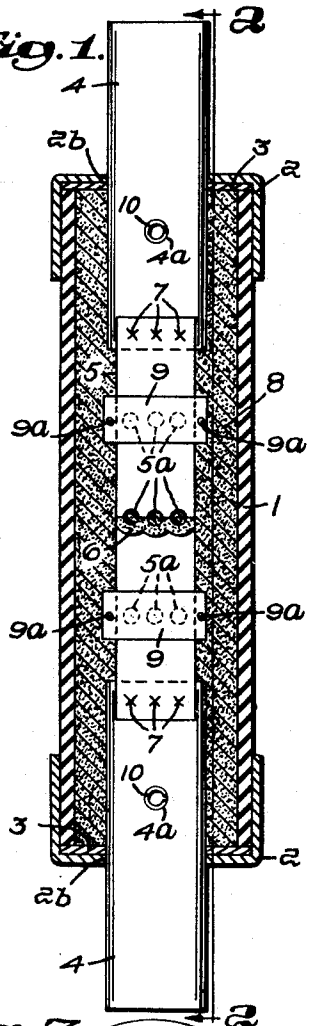


Fig. 2.

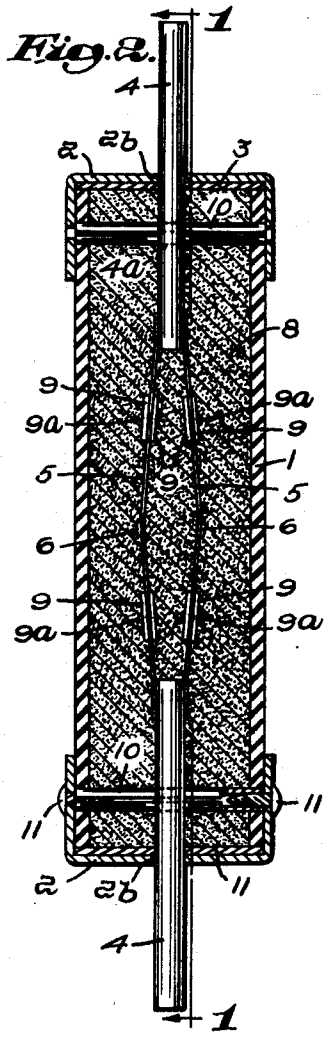
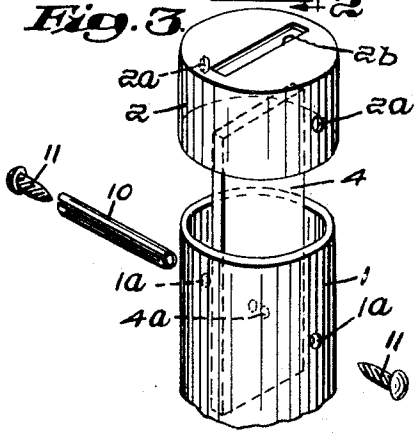


Fig. 3.



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Feb. 6, 1962 F. J. KOZACKA 3,020,372

FUSE STRUCTURES

Filed Nov. 24, 1958 2 Sheets-Sheet 2

Fig. 4a.

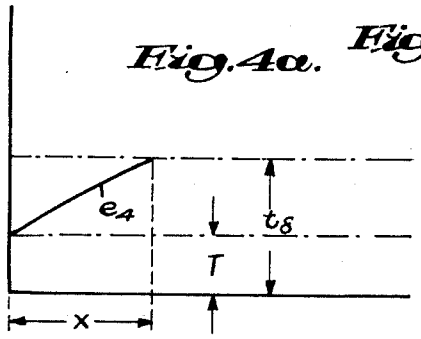


Fig. 4b.

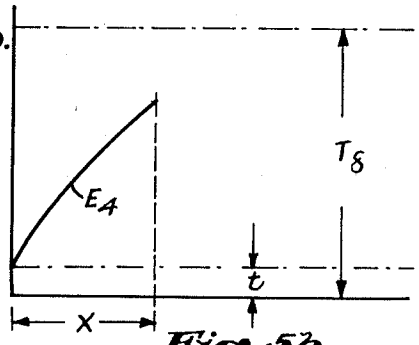


Fig. 5a.

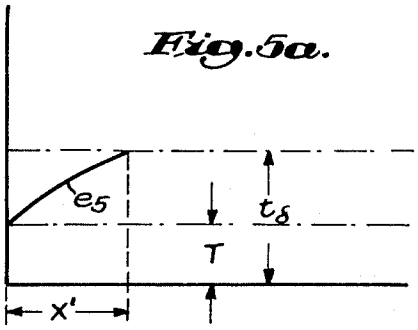


Fig. 5b.

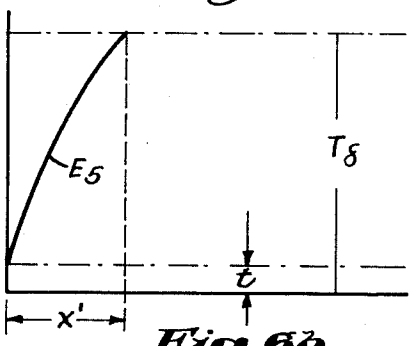


Fig. 6a.

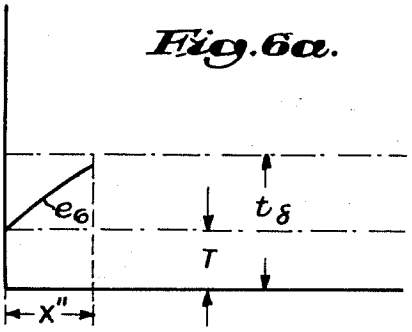


Fig. 6b.

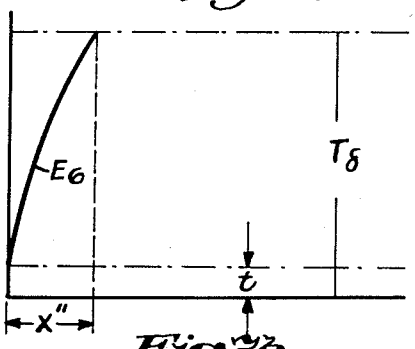


Fig. 7a.

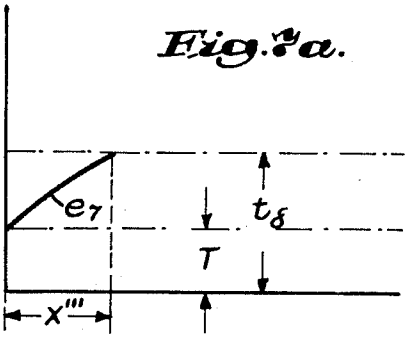
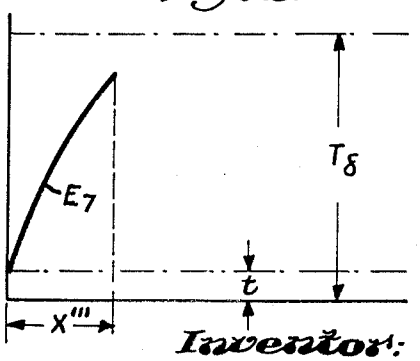


Fig. 7b.



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3,020,372

FUSE STRUCTURES

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Filed Nov. 24, 1958, Ser. No. 775,881
10 Claims. (Cl. 200—131)

This is a continuation in part of my copending patent applications Ser. No. 658,162, filed May 9, 1957 for Current-Limiting Fuses With Increased Interrupting Capacity, now United States Patent 2,866,038 and Ser. No. 764,293, filed September 30, 1958 for Time Lag Fuses, now United States Patent 2,988,620.

It is one object of the present invention to further develop and to improve the fusible protective devices disclosed in the above identified patent applications.

Prior art electric fuses are specially designed either for A.-C. applications or for D.-C. applications. Where an electric fuse structure designed for A.-C. applications and tested in an A.-C. test circuit is used in a D.-C. installation, the fuse has to be drastically derated.

It is, therefore, another object of this invention to provide universal fuses which lend themselves well to application in both A.-C. circuits and D.-C. circuits.

Another object of the invention is to provide universal fuses equally well applicable in A.-C. circuits and D.-C. circuits to which fuses a high unitary rating for both kinds of applications may be assigned.

Another object of this invention is to provide fuses having increased time-lags in the range of relatively large overcurrents.

Another object of the invention is to provide fuses including a common means for achieving time lag in the high overload range and for inhibiting or suppressing follow currents.

Still another object of the invention is to provide electric fuses comprising improved means for securing the blade contacts and the ferrules to the casing of the fuses.

The foregoing and other general and special objects of the invention and advantages thereof will appear more clearly from the ensuing particular description of the invention as illustrated in the accompanying drawings, wherein:

FIG. 1 shows a fuse structure embodying the invention taken along 1—1 of FIG. 2;

FIG. 2 shows the same structure as FIG. 1 and is a section taken along 2—2 of FIG. 1;

FIG. 3 is an isometric exploded view of the upper end of the casing of the structure of FIGS. 1 and 2 and of the parts associated with it; and

FIGS. 4*a*, 4*b*, 5*a*, 5*b*, 6*a*, 6*b*, 7*a* and 7*b* are exponential curves diagrammatically illustrating temperature rises at different points of fuse structures under different operating conditions.

Referring now to the drawing and more particularly FIGS. 1 to 3 thereof, numeral 1 has been applied to indicate a tubular insulating casing, preferably made of a suitable synthetic-resin-glass-cloth laminate. The ends of casing 1 are closed by terminal caps or ferrules 2 of sheet metal which are mounted on the casing, each having a rectangular opening 2*b* on the axially outer surface thereof. Caps or ferrules 2 have also lateral holes 2*a* arranged in registry with holes 4*a* in knife blade contacts 4. Resilient washers 3 are clamped between caps 2 and casing 1. Blade contacts 4 project through the rectangular openings 2*b* in caps 2 and through registering rectangular openings in washers 3 into the inside of casing 1. Pins 10, preferably in the form of hollow, laterally slotted, end-chamfered spring pins, which are highly resilient, project through the lateral holes 1*a* in casing 1 and holes 4*a* in blade contacts 4. Drive screws 11 are driven into the outer ends of spring pins 10 through registering holes

2*a* in caps 2. Screws 11 radially expand spring pins 10 and the heads of screws 11 abut against ferrules 2. Thus blade contacts 4 are firmly and yet simply attached to casing 1.

Casing 1 houses a pair of fusible elements 5 in form of wide ribbons made of a metal having a high fusing point—such as silver or copper. The width of elements 5 is but slightly less than that of knife blade contacts 4. Fusible elements or ribbons 5 are arranged on opposite sides of blade contacts 4 sandwiching the axially inner ends thereof. They are attached to, as well as conductively connected with, blade contacts 4 by spot-welds 7. Each fusible element or fuse link 5 is provided with three transverse lines of perforations 5*a* forming regions or points of reduced cross-sectional area. The center line of perforations 5*a* of each fuse link 5 is associated with an overlay 6 of a low fusing point metal such as tin capable, when melted, to corrode the base metal and to thus sever links 5 at the center region or center point of reduced cross-sectional area. The characteristic features of overlay 6 have been more fully disclosed in my copending patent application Ser. No. 764,293, filed September 30, 1958 for Time Lag Fuses, now United States Patent 2,988,620, and reference may be had to that patent for details regarding this overlay. Overlay 6 extends to, but not beyond, the transverse line of symmetry of the center perforations 5*a* and its width is equal to that of each fusible element 5. Each of the axially outer lines of perforations 5*a* is covered by a pair of plates 9 of an organic insulating material which is fairly heat resistant and includes preferably an insert of glass-fiber-cloth. The constituent plates 9 of each pair of plates are joined together by rivets 9*a* arranged along the transverse line of symmetry of the axially outer lines of perforations 5*a*. Links 5 and the axially inner ends of knife blade contacts 4 are submersed in a fulgurite-forming arc-quenching filler, preferably chemically reasonably pure quartz sand.

As mentioned above, the three transverse lines of perforations 5*a* form three regions or points of reduced cross-sectional area on link 5. When arcs are being kindled at the points where the axially outer lines of perforations 5*a* are situated, plates 9 preclude formation of arc-gap-shunting fulgurites. To be more specific, when arcs are being kindled at the above mentioned points, the arcs are confined to the space between plates 9, and thus plates 9 keep the quartz sand away from the arc terminals and preclude shunting of the arc terminals by fulgurites resulting from fusion of the quartz sand 8. When an arc is kindled at the points where the axially outer lines of perforations 5*a* are situated, plates 9 are slightly separated at their wide edges by arc-generated pressure and the products of arcing are then allowed to escape preponderantly in directions longitudinally of link 5. Fulgurites are then formed where the hot products of arcing sweep over the cool quartz sand. Since these fulgurites are formed in space outside of the outline of plates 9, and since the arcs formed at the points of break are confined to the space inside the outline of plates 9, the fulgurites formed do not shunt the arc gap. Consequently the fulgurites do not maintain a flow of current parallel to the arc path after arc extinction.

The mode of operation of the structure of FIGS. 1 and 2 will be more fully understood from a consideration of FIGS. 4*a* to 7*b*. FIGS. 4*a*, 5*a*, 6*a* and 7*a* show the rise of temperature at the center zone of reduced cross-sectional area—formed by the center line of perforations 5*a*—plotted against time. FIGS. 4*b*, 5*b*, 6*b* and 7*b* show the rise of temperature at the axially outer zones of reduced cross-sectional area—formed by the axially outer lines of perforations 5*a*—plotted against time.

In drawing FIGS. 4*a*, 4*b*, 5*a*, 5*b*, 6*a*, and 6*b* it was as-

sumed that the cover plates 9 were omitted from the structure of FIGS. 1 and 2. FIGS. 7*a* and 7*b* refer to the structure of FIGS. 1 and 2 with cover plates 9 added, as shown in FIGS. 1 and 2.

The structure of FIGS. 1 and 2 has a predetermined current rating which does not vary significantly whether or not cover plates 9 are present. When the fuse carries its rated current a certain relatively high steady state temperature will prevail in the center region of the fuse link 5 where the center zone of reduced cross-sectional area is situated. This steady state temperature has been indicated by the reference character T. When the fuse carries its rated current a certain relatively low steady state temperature will prevail in the regions of the fuse link 5 where the axially outer zones of reduced cross-sectional area are situated. This steady state temperature has been indicated by reference character *t*. The horizontal line t_f indicates the relatively low temperature at which link 5 is being severed at the center thereof by the corrosive action of overlay 6. The horizontal line T_f indicates the relatively high temperature at which link 5 is being severed at the axially outer points of reduced cross-sectional area by fusion of the base metal of link 5. The base metal of link 5 being a high fusing point metal such as silver, or possibly copper, and the overlay metal being a low fusing point metal such as tin or indium, the level of line T_f is considerably higher than the level of line t_f. Considering a given relatively small overload current, say an overload current in the order of 300 percent the rated current of the fuse, the temperature at the center zone of reduced cross-section will rise from the initial steady state value T according to the exponential curve e_4 and will reach the temperature t_f at which link 5 is severed by the corrosive action of overlay 6 after an interval of time *x*. Under the given overload conditions the temperature at the axially outer zones of reduced cross-sectional area will rise from their initial steady state value *t* according to the exponential curve E_4 but will not reach the fusing temperature T_f of the base metal of link 5 because the circuit will be interrupted by corrosion of the center of link 5 before the axially outer zones of reduced cross-sectional area reach the fusing temperature T_f. It is apparent that the rise of exponential curve E_4 is much more rapid than the rise of exponential curve e_4. This is due to the fact that heat is abstracted more rapidly from the center zone of reduced cross-sectional area than from the axially outer zones of reduced cross-sectional area. This, in turn, is due to the fact that heat absorbing overlay 6 imparts to the center zone of reduced cross-sectional area a larger heat absorbing capacity than that of the axially outer zones of reduced cross-sectional area.

If the overload current is increased a critical current will be reached, say an overload current in the order of 400 percent of the rated current of the fuse, at which the center region of reduced cross-sectional area will reach the temperature t_f at the same time as the axially outer regions of reduced cross-sectional area reach the temperature T_f. This case has been illustrated in FIGS. 5*a* and 5*b*. It takes the time *x'* for the center region of reduced cross-sectional area to rise from the steady state temperature T to the link-destroying temperature t_f, and it takes the same time *x'* for the axially outer regions of reduced cross-sectional area to rise from the steady state temperature *t* to the fusing temperature T_f of the base metal. Since the overload current of FIGS. 5*a* and 5*b* is higher than the overload current of FIGS. 4*a* and 4*b*, the rise of exponential curve e_5 is steeper than the rise of exponential curve e_4 and the rise of exponential curve E_5 is steeper than the rise of exponential curve E_4. Under the conditions shown in FIGS. 5*a* and 5*b* the circuit may either be interrupted at a single break formed in the center of link 5, at two points of break formed at the axially outer regions of reduced cross-sectional area, or at three points of break, i.e. the first mentioned point of break and the two last mentioned points of break. Which of the three mentioned possibilities actually occurs depends upon small accidental manufacturing tolerances.

Assuming now that the overload current is further increased, then a situation of the kind illustrated in FIGS. 6*a* and 6*b* will occur. The temperature at the axially outer regions of reduced cross-sectional area rises from *t* to T_f within the time *x''* which is not sufficient to raise the temperature at the center of the link from T to t_f. Consequently the current path through the fuse structure is only interrupted at the axially outer regions of reduced cross-sectional area and remains intact at the center region of reduced cross-sectional area. More generally speaking, there is a critical overload current which may be designated as the transfer current which, when exceeded, causes a shift of the point of break from the center of the link to its axially outer ends. The larger the current carried by the fuse, the shorter the time required by the fuse to blow, i.e.

$$x > x' > x''$$

and the closer the overload current interrupted at the center of link 5 to the transfer current, the smaller the time lag.

Many applications require a substantial time-lag above and beyond the magnitude of a given transfer current of a given structure expressed in terms of percent of its rated current. It may, for instance, be possible to achieve a given time-delay for a given current which is so many percent of the given rate by providing a corrosive low fusing point overlay at a given point of the fuse link, whereas a particular application may require that the given time delay obtain for a higher percentage of the rated current. This can be achieved, according to this invention, by associating each of the axially outer points of reduced cross-sectional area with a heat absorbing body or mass which delays the rise of temperature at that point.

FIGS. 7*a* and 7*b* refer to the structure of FIGS. 1 and 2 with the heat absorbing link-sandwiching plates 9 added to it. The structure is subjected to the same overload current as in the case of FIGS. 6*a* and 6*b*. The addition of plates 9 results in a slower rise of temperature at the axially outer points of reduced cross-sectional area which is expressed by the fact that the exponential curve E_7 is not as steep as the exponential curve E_6. The interval of time *x''* is not sufficient to bring the axially outer points of reduced cross-sectional area to the fusing point T_f of the base metal but the interval of time *x'''* is sufficient to raise the temperature at the center of the fuse link to the corrosion destruction temperature t_f. It will be apparent that

$$x''' > x''$$

or, in other words, the addition of heat absorbing plates 9 results in longer time delays in the current range above the original transfer current of the structure, i.e. the transfer current obtaining in the absence of plates 9. The addition of plates 9 increases the critical current or transfer current at which the point of initial fusion and arc formation is transferred from the center of the link to the axially outer points or regions of reduced cross-section area thereof. The exponential curves e_6 and e_7 describe the rise in temperature at the center of fuse link 5 under identical conditions, including equality of the overload currents and are, therefore, identical curves, except that curve e_6 does not rise to the corrosion level t_f whereas curve e_7 reaches the corrosion level t_f.

As indicated above, plates 9 have two functions of which one is to increase the delay times of the fuse and of which the other is to inhibit formation of arc-gap-shunting fulgurites. The latter results in a drastic reduction both as to time and magnitude of the follow current or leakage current which flows through the fuse after extinction of the arcs formed therein incident to blowing thereof. Both purposes of plate 9 call for materials having a high heat absorbing or abstracting capacity.

The more heat is being absorbed by plates 9 prior to blowing of the fuse, the slower the rise of temperature at the axially outer points or regions of reduced cross-sectional area of link 5, the longer the time-lags which are being achieved. The more heat is being abstracted from the arcs taking the place of the axially outer points of reduced cross-sectional area of link 5 upon fusion at these points, the larger the arc voltage and the shorter the arcing time. The non-vaporized portions of links 5 form after coolers for the products of arcing which escape from the axially outer arcing zones in directions preponderantly longitudinally of links 5. Snythetic-resin-fiber-glass-cloth laminates are particularly useful for fashioning the time-lag and shunt-fulgurite-inhibiting arc-chute-forming plates 9.

The invention is not limited to fuses having fuse links comprising a center point of break where time-delay is achieved by means of a low fusing point overlay and two axially outer points of break provided with dual function arc-chute-forming plates 9. It would be perfectly feasible to use links comprising but two points of reduced cross-sectional area of which one is associated with a low fusing overlay and the other with a heat absorbing shunt-fulgurite-inhibiting arc-chute-forming plate structure 9. The structure shown in FIGS. 1 and 2 comprising three serially related points of reduced cross-sectional area is intended for circuits having a circuit voltage up to 600 volts and for circuits having such a high voltage provision of a minimum of three points of reduced cross-sectional area has been found to be necessary or desirable.

The considerations set forth in connection with FIGS. 4*a* to 7*b* are valid for fusing times longer than 1 cycle of a current wave of 60 cycles per second, or for fusing times longer than 1/60 of a second. For shorter fusing times the phenomena governing the behavior of the structure of FIGS. 1 and 2 is of an entirely different nature. For very short fusing times the heat flow away from the axially outer points of reduced cross-sectional area to plates 9 is insignificant, and therefore, under such conditions, the presence of plates 9 may be neglected as a first approximation to actually prevailing conditions. For very short fusing times the heat flow away from the center region or point of reduced cross-sectional area to overlay 6 is also insignificant, and therefore, under such conditions, the presence of overlay 6 may also be neglected. The transverse perforations in the center of links 5 and the axially outer transverse perforations are supposed to be identical. Because of this and since heat flow can be neglected if only very high currents and very short fusing times are being considered, the $\int i^2 \cdot dt$ values required to produce a break at any of the three regions or points of reduced cross-sectional area substantially equal constants, or may be considered to be such constants as a close approximation to actually prevailing conditions. Therefore, if the fault currents are high, breaks are formed at all three points *fo* reduced cross-sectional area of links 5 either simultaneously or in such rapid sequence as to form three serially related arcs. As a result, the fuse structure of FIGS. 1 and 2 produces particularly high arc voltages if the fault currents under interruption are very high.

The above has been vertified by careful tests which proved that three series breaks are always formed when the fault current under interruption exceeds a certain magnitude.

It will be understood that although but one embodiment of the invention has been illustrated and described in detail, the invention is not limited thereto. It will also be understood that the structure illustrated may be modified without departing from the spirit and scope of the invention as set forth in the accompanying claims.

I claim as my invention:

1. A fusible protective device comprising an insulating casing, a pulverulent arc-quenching fulgurite-forming filler inside said casing, a fusible element in ribbon-form submersed in said filler, said element having a first zone of reduced cross-sectional area situated between the ends thereof, low fusing point metal overlay means on said element adjacent, said first zone of reduced cross-sectional area, said element having additional zones of reduced cross-sectional area situated between said first zone and said ends of said element forming arc gaps upon fusion thereof, and said additional zones of reduced cross-sectional area being provided with insulating means adapted to preclude upon formation of said arc gaps formation of arc-gap-shunting fulgurites by said filler.

2. A fusible protective device comprising an insulating casing, a filler of quartz sand inside said casing, a fusible element in ribbon form submersed in said filler, said element having a first line of perforations situated between the ends thereof and extending transversely across said element, low fusing point metal overlay means on said element extending transversely across said element adajcent said first line of perforations, said element having additional lines of perforations situated between said ends thereof and said first line of perforations, said additional lines of perforations extending transversely across said element and defining zones of reduced cross-sectional area forming arc gaps upon fusion thereof, and each of said additional lines of perforations being sandwiched between a pair of plates of a synthetic-resin-glass-cloth laminate adapted to inhibit upon formation of said arc gaps formation of arc-gap-shunting fulgurites by said quartz sand.

3. A fusible protective device comprising a tubular insulating casing, a pair of blade contacts projecting from the outside of said casing into the inside thereof, a filler of quartz sand in said casing, a pair of ferrules mounted on said casing for retaining said filler in said casing, a pair of spaced ribbon-shaped fusible elements of a metal having a relatively high fusing point inside said casing submersed in said filler, said pair of elements sandwiching the inner ends of said pair of blade contacts and being conductively connected thereto, each of said pair of elements having a first line of transverse perforations situated between the ends thereof, a pair of overlays of a metal having a relatively low fusing point each on one of said pair of elements and each arranged adjacent said first line of perforations thereof, each of said pair of elements having two additional lines of transverse perforations situated between the ends thereof and said first line of perforations, said additional lines of perforations defining on each of said pair of elements two zones of restricted cross-sectional area forming arc gaps upon fusion thereof, and four pairs of plates of a synthetic-resin-glass-cloth laminate, each of said pairs of plates sandwiching therebetween one of said additional lines of perforations.

4. A fusible protective device comprising an insulating casing, a pulverulent arc-quenching filler inside said casing, a fusible element of a high fusing point metal in ribbon-form submersed in said filler, said fusible element having a center zone of reduced cross-sectional area, an overlay of a low fusing point metal associated with said center zone and corroding said element when melted, said element further having at least one axially outer zone of reduced cross-sectional area where initial fusion and initial arc formation occur when an excess current carried by said element exceeds a predetermined limit, and a heat absorbing mass of insulating material on said element immediately adjacent said axially outer zone increasing said predetermined limit to a higher value than that which would obtain in the absence of said mass.

5. A fusible protective device comprising a tubular insulating casing, a filler of quartz sand inside said casing, a ribbon of a high fusing point metal submersed in said filler, said ribbon having a center zone of reduced cross-sectional area, an overlay of a metal having a lower fusing point than the fusing point of the metal of which said ribbon is made associated with said center zone, said

ribbon further having a pair of axially outer zones of reduced cross-sectional area where initial fusion and initial arc formation occur when an excess current carried by said ribbon exceeds a predetermined limit, and two pairs of plates of a synthetic-resin-glass-cloth laminate mounted on said ribbon each sandwiching therebetween one of said pair of axially outer zones to increase said predetermined limit to a higher value than that which would obtain in the absence of said two pairs of plates.

6. A fusible protective device comprising a tubular insulating casing, a filler of quartz sand inside said casing, a ribbon of a high fusing point metal submersed in said filler, said ribbon having a transverse center line of perforations forming a center zone of reduced cross-sectional area, a transverse overlay of a metal having a lower fusing point than the fusing point of the metal of which said ribbon is made provided on said ribbon adjacent said center zone thereof, said ribbon further having a pair of transverse axially outer lines of perforations forming a pair of axially outer zones of reduced cross-sectional area where initial fusion and arc formation occur when an excess current carried by said ribbon exceeds a predetermined limit, and insulating means having a relatively high specific heat mounted on said ribbon covering said axially outer lines of perforations and separating said axially outer lines of perforations from said filler to delay fusion of said ribbon at said axially outer zones and to inhibit said filler from freely reaching arcs formed upon fusion of said ribbon at said pair of axially outer zones.

7. A fusible protective device comprising a tubular insulating casing, a filler of quartz sand inside said casing, a silver ribbon in said casing submersed in said filler, said ribbon having a first zone of reduced cross-sectional area situated between the ends thereof, an overlay of a metal having a lower fusing point than silver supported by said ribbon and adapted to interrupt said ribbon at said first zone by corrosion on occurrence of relatively small overloads, said ribbon having additional zones of reduced cross-sectional area situated between said first zone and said ends of said ribbon, said additional zones forming ribbon-interrupting arc gaps on occurrence of relatively large overloads, and bodies of heat resistant insulating material having a relatively large heat absorbing capacity mounted on said ribbon in close heat-exchanging relation to said additional zones, and said bodies being adapted to inhibit formation of fulgurites by said filler shunting said arc gaps.

8. A fusible protective device comprising an insulating casing, a pulverulent arc-quenching filler in said casing, a high fusing point metal ribbon in said casing submersed in said filler, said ribbon having a first transverse line of perforations situated between the ends thereof, a transverse low fusing point metal overlay on said ribbon adjacent said first line of perforations adapted to corrode said ribbon on occurrence of relatively small overloads, said ribbon having additional transverse lines of perforations situated between said ends thereof and said first line defining points of reduced cross-sectional area adapted to fuse on occurrence of relatively large overloads, and bodies of heat-resistant insulating material mounted on said ribbon over said additional lines of perforations, said bodies being formed by arc chute structures adapted to permit the escape of products of arcing substantially only in directions longitudinally of said ribbon.

9. A fusible protective device comprising a tubular insulating casing, a fusible element of a metal having a relatively high fusing point arranged in said casing, said element having a plurality of points of reduced cross-sectional area all having substantially the same fusing $\int i^2 \cdot dt$ at currents sufficiently high to cause fusion of said plurality of points in less than $\frac{1}{100}$ sec., one of said plurality of points being associated with an overlay of a metal having a relatively low fusing point and when melted corroding said metal having a relatively high fusing point, and another of said plurality of points being enveloped by and in intimate heat-exchanging relation with a heat absorbent insulating plate structure.

10. A fusible protective device comprising a tubular insulating casing, a ribbon of a metal having a relatively high fusing point arranged in said casing, said ribbon having a plurality of identical transverse lines of perforations forming a plurality of points of reduced cross-sectional area all having substantially the same fusing $\int i^2 \cdot dt$ at currents sufficiently high to cause fusion of said plurality of points in less than $\frac{1}{100}$ sec., one of said plurality of lines of perforations being associated with an overlay of a metal having a relatively low fusing point and when melted corroding said metal having a relatively high fusing point, and another of said plurality of lines of perforations being sandwiched between a pair of heat absorbent insulating plates.

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