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CURRENT-LIMITING FUSES WITH BALANCED LOW-CURRENT AND HIGH CURRENT INTERRUPTING PERFORMANCE

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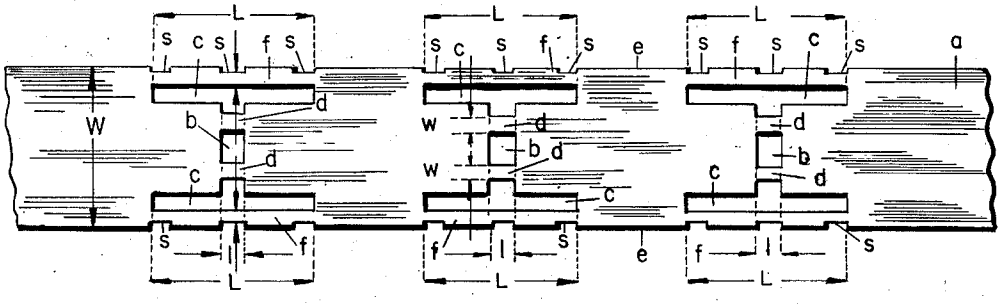


Fig. 1

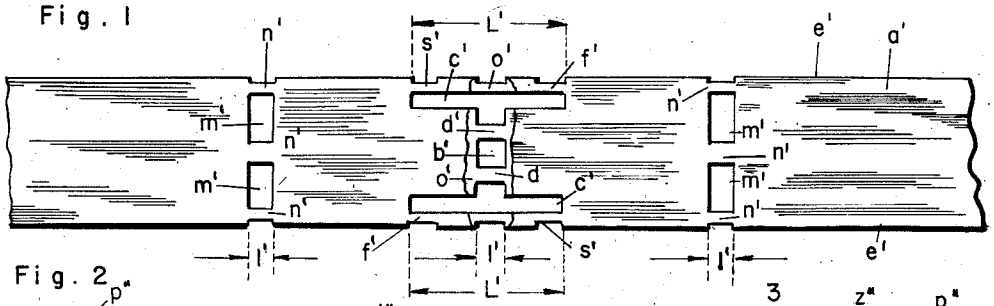


Fig. 2

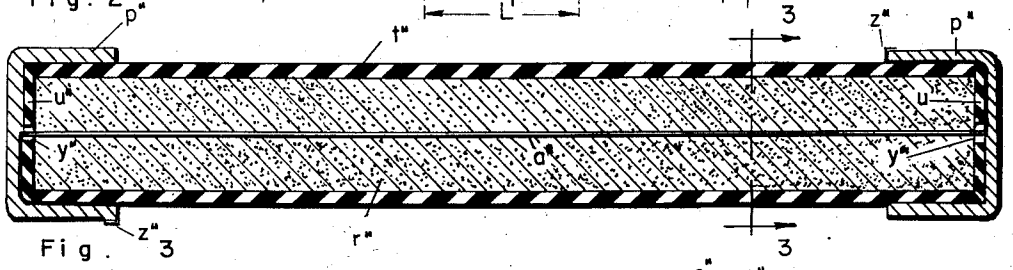


Fig. 3

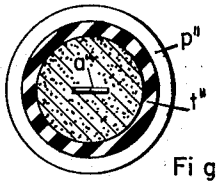


Fig. 4

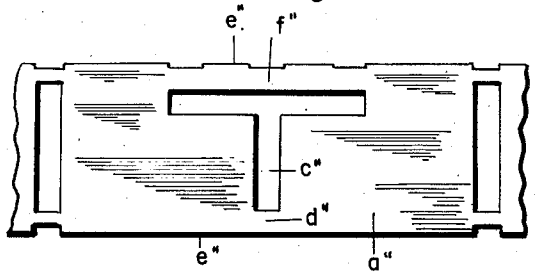


Fig. 5

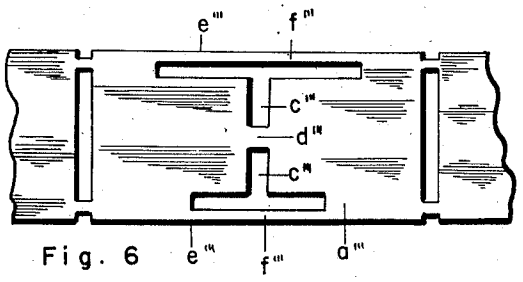


Fig. 6

Inventor:

Philip C. Jacobs, Jr.

by Irwin Kalpin

Atty.

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CURRENT-LIMITING FUSES WITH BALANCED LOW-CURRENT AND HIGH CURRENT INTERRUPTING PERFORMANCE

Philip C. Jacobs, Jr., Newtonville, Mass.

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This invention relates to current-limiting fuses, i. e. to fuses tending to limit the peaks of let-through currents well below the peaks of available fault currents.

The invention relates particularly to current-limiting fuses for elevated circuit voltages, i. e. circuit voltages of at least several kilovolts.

To achieve satisfactory current-limitation, i. e. to limit the peaks of let-through currents to relatively low values, a number of conditions must be met. The casing of the fuse must be filled with a suitable pulverulent arc-quenching filler, preferably a silicious filler such as quartz sand. For a wide range of current carrying capacity and interrupting capacity ratings the application of multiperforated ribbon-type fuse links is indicated. The fuse links ought to consist of a metal having a relatively high conductivity and a relatively low fusing energy. Silver meets these requirements best, yet in some instances copper ribbons may also be used as fuse links. When these and other conditions required for best current-limiting performance at major faults are fully met, current-limiting fuses tend to perform rather poorly on blowing at relatively small protracted overloads.

It is, therefore, one object of this invention to provide current-limiting fuses performing equally well in the entire range from the smallest protracted overload which must be interrupted to the highest available short circuit current, or the steepest rate of rise of fault current.

In the past many fuse structures have been evolved intended to achieve a reasonably rapid interruption of a circuit both in the range of relatively small excess currents and in the range of relatively high excess currents. This object could not be achieved satisfactorily except by resorting to two separate fusible interrupting devices of which one is particularly adapted to operate in the range of relatively small excess currents, and the other particularly adapted to operate in the range of relatively high excess currents.

It is, therefore, another object of this invention to provide current-limiting fuses having but one single interrupting means which effects sufficiently rapid interruption of electric circuits both in the range of relatively small excess currents and in the range of relatively large excess currents.

Other objects of the invention are to provide current-limiting fuses precluding voltage surges on blowing at high fault currents and more particularly to provide current-limiting high-voltage fuses whose ribbon-type fuse links comprise a single means for achieving relatively rapid interruptions of relatively small currents and relatively slow interruption of relatively large currents.

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 is a side elevation of a portion of a fuse link embodying the present invention;

Fig. 2 is a side elevation of a modification of the link structure shown in Fig. 1;

Fig. 3 is a longitudinal section of a current-limiting fuse comprising a fuse link as shown in Figs. 1 and 2;

Fig. 4 is a section along 4—4 of Fig. 3;

Fig. 5 is a side elevation of a portion of a simplified version of the structure shown in Fig. 2; and

Fig. 6 is a side elevation of another simplified version of the structure shown in Fig. 2.

Referring now to Fig. 1 of the drawing, reference character *a* has been applied to indicate a ribbon of a metal having a relatively high conductivity and a relatively low fusing energy. Ribbon *a* is preferably made of silver, though it might be made of copper for some applications. Ribbon-type fuse link *a* is provided with a plurality of necks, i. e. points of reduced cross-sectional area where there is a tendency toward relatively high current-density, toward heat generation at a relatively rapid rate, and toward initial fusion and arc initiation. Reference numerals *b* and *c* have been applied to indicate punched out portions, or perforations. Perforations *b* have a substantially rectangular outline, and perforations *c* are substantially T-shaped. The necks *d* formed between perforations *b* and *c* are relatively short and their ohmic resistance is relatively small. Reference letter *l* has been applied to indicate the relatively short length of necks *d*. T-shaped perforations *c* and the edges *e* of link *a* jointly define relatively long necks *f* having a relatively high ohmic resistance. Reference letter L has been applied to indicate the relatively long length of necks *f*. The width *w* of necks *d* is small in comparison to the total width W of link *a*, e. g. the ratio of *w/W* may be in the order of 1:20.

Each neck *f* is provided with three serially related restricted cross-section portions, or sub-necks *s*. When any excess current causes fusion of neck *f*, sub-necks *s* tend to form series breaks.

Referring now to Fig. 2, numeral *a'* indicates a portion of a ribbon-type fuse link, preferably made of silver. The outline of the link is substantialy rectangular, the link being bounded laterally by a pair of parallel edges *e'*. The middle or center region of link *a'* is provided with a square perforation *b'* and a pair of T-shaped perforations *c'*. Short necks *d'* having a relatively small ohmic resistance are formed between perforations *b'* and *c'*. Long necks *f'* having a relatively high ohmic resistance are formed between the edges *e'* and perforations *c'*. Reference letter *l'* has been applied to indicate the length of necks *d'*, and reference letter L' has been applied to indicate the length of necks *f'*. The region of link *a'* immediately adjacent necks *d'* and *f'* is covered by an overlay *o'* made of a metal having a fusing point lower than silver, capable of forming with silver alloys having a higher resistivity than silver. Overlay *o'* consists preferably of tin, or indium, or suitable alloys of tin or indium. Link *a'* is also provided with rectangular perforations *m'* forming necks *n'* whose length has been indicated by reference character *l'*. The length of necks *d'* and the length of necks *n'* is equal and the total width of cross-sectional area of the two necks *d'* is substantially equal to the total width or cross-sectional area of each group of three necks *n'*. As a result of this geometrical configuration, fusion will occur substantially simultaneously at necks *d'* and *n'* when the rate of rise of current is so rapid as to permit heat exchange phenomena to be neglected. Each neck *f'* is provided with three serially related cross-section portions, or sub-necks *s'*, tending to form series breaks upon blowing of the fuse.

Referring now to Figs. 3 and 4, reference numeral *a''* has been applied to indicate a ribbon-type fuse link identical to fuse links *a* and *a'*, illustrated in Figs. 1 and 2,

the latter figures being drawn on a considerably larger scale. Fuse link a'' is arranged in a tubular casing t'' which may consist of glass, a ceramic material, or a synthetic-resin-glass-cloth laminate. The ends of casing t'' are closed by a pair of suitable terminal elements such as a pair of metal caps p''. Casing t'' is filled with a pulverulent silicious arc-quenching filler r'', preferably chemically pure quartz sand. Metal washers U'' clamped by caps p'' against casing t'' close the ends of the latter and are each provided with a rectangular perforation y'' for the passage of link a''. The ends of link a'' are firmly clamped in position between casing t'' and caps p''. Reference characters z'' have been applied to indicate two points where the ends of links a'' are turned outwardly, out of the narrow gaps formed between casing t'' and caps p'', and spot-welded to caps p''.

The operation of the structures shown in Figs. 1–4 will now be described. Since the ohmic resistance of necks d is considerably less than the ohmic resistance of necks f, the current flowing in link a will be concentrated in necks d. In spite of the high current-densities occurring in necks d, the current carrying ability (or floating current, or minimum fusing current) of link a will be relatively high on account of the short length of necks d tending to minimize $i^2 \cdot r$ losses, and on account of the relatively great width W of link a tending to rapidly dissipate whatever heat is being generated at necks d. On occurrence of protracted overloads initial fusion will occur at necks d where the current density in link a is highest. The fact that the resistance of shunt necks f is relatively high results in a significant voltage drop at both points of initial break, resulting in turn in the formation of an arc gap of some length. As arc voltage is being built up at the points of initial arc formation, the current is being shifted away from the regions of necks d and flows through the high resistance necks f. This permits cooling and de-ionization of the initially formed arc gaps, and fusion of the relatively long necks f. Fusion will be initiated at the three points s where the width, or cross-sectional area, of necks f is fairly small and because series breaks are being formed along necks f, the arc voltage formed in the region of necks f will be appreciable, tending to drastically reduce the arcing time and the arc energy.

The process of interruption at the necks d, f situated in the center of link a may precede arc initiation at other necks d, f which are situated axially outwardly. As a general rule, the long breaks formed at the regions of necks f in the center of link a are sufficient to interrupt relatively small protracted overload currents. Hence it may not be necessary to provide additional overload current interrupting breaks on the fuse link.

Fig. 2 shows a fuse link wherein overload interrupting necks in addition to the necks d' and f' in the center region of the fuse link have been omitted. In that figure the overlay o' causes initial fusion to occur at necks d' and f' at relatively low temperatures. Final interruption of relatively low currents is effected by progressive back-burning of necks f'. Back-burning is accelerated by virtue of sub-necks s'. Necks n' are not caused to fuse at overloads; these necks form breaks on occurrence of major fault currents only.

In case of major fault currents necks d and f fuse sequentially as in case of small protracted overloads. In other words, the feature of sequential fusion of necks d and f is common to both low current and high current interruptions. Sequential fusion at two parallel neck regions tends to limit the rate of change of current

$$\frac{di}{dt}$$

and hence the excess voltage that may be generated incident to interruption of major fault currents.

As indicated above, in the structure of Fig. 2 major fault currents are being interrupted at the serially formed breaks n', d', f', n'.

The fuse links shown in Figs. 1 and 2 are preferred embodiments of the invention. The fuse links shown in Figs. 5 and 6 are based upon exactly the same principles as those shown in Figs. 1 and 2, yet are not as desirable in some instances as the latter because of a less favorable ratio of current carrying capacity to arc-quenching capacity expressed in terms of area of interaction between link and quenching medium.

Referring now to Figs. 5 and 6, reference characters c'' and c''' have been applied to indicate substantially T-shaped perforations in the silver ribbons a'' and a''', respectively.

The structure shown in Fig. 5 comprises but one single T-shaped perforation. One portion of T-shaped perforation c'' extends substantially parallel to the edges e'' of link a'' defining a relatively long neck f'' having a relatively high ohmic resistance. The other portion of perforation c'' extends transversely across link a'' defining a relatively short neck d'' having a relatively low ohmic resistance. Necks d'' and f'' fuse sequentially both on protracted overloads and on major faults.

In the structure of Fig. 6 the ribbon-type fuse link a''' is provided with two T-shaped perforations c''' of different sizes. The upper perforation c''' has a portion extending parallel to ribbon edges e''' which portion is longer than the portion of the lower T-shaped perforation c''' extending parallel to ribbon edges e'''. As a result, the upper neck f''' is longer and has a higher ohmic resistance than the lower neck f'''. Both necks f''' shunt the very short neck d''' which has a very low ohmic resistance. On occurrence of protracted overloads as well as on occurrence of major faults the interruption of the circuit is initiated by fusion of neck d'''. Thereafter the lower neck f''' fuses and finally the upper neck f''' fuses.

The term neck has been used in the foregoing in its customary or conventional meaning with reference to a relatively short portion of restricted cross-sectional area which defines the point or points of initial fusion and arc initiation along the active or fusible length of the link. In accordance with this object of a neck the length thereof is a relatively small fraction of the active or fusible length of a link.

It will be understood that the sequence in which the three necks d''' and f''' fuse at major fault currents is much more rapid than the sequence of fusion at relatively low currents; yet the sequence fusion feature is sufficiently effective at high currents to limit the rate of change of current to values tending to preclude damage by voltage surges to the insulation of the system.

It will be understood that by illustrating herein several forms of fuse links, I do not intend to limit my invention thereto. It will be further understood that the invention may take forms other than the structures described and illustrated herein. It will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent arc-quenching filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of a relatively high conductivity relatively low fusing energy metal immersed in said filler conductively interconnecting said pair of terminal elements, said link comprising a relatively short neck portion and said link further comprising a relatively long neck portion having an ohmic resistance considerably higher than said relatively short neck portion, and said relatively long neck portion being adapted to shunt said relatively short neck portion.

2. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent silicious arc-quench-

ing filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of silver conductively interconnecting said pair of terminal elements, said link comprising a pair of relatively long neck means forming edges of said link and said link further comprising relatively short neck means having a substantially lower ohmic resistance than said relatively long neck means situated in the space between said relatively long neck means and shunted by said relatively long neck means.

3. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent arc-quenching filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link having a substantially rectangular outline made of a relatively high conductivity relatively low fusing energy metal immersed in said filler conductively interconnecting said pair of terminal elements, said link being provided with at least one substantially T-shaped perforation, one portion of said perforation extending substantially parallel to the edges of said link and defining a relatively long neck having a relatively high ohmic resistance and the other portion of said perforation extending substantially transversely across said link and defining a relatively short neck having a relatively low ohmic resistance.

4. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent silicious arc-quenching filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of silver immersed in said filler conductively interconnecting said pair of terminal elements, said link being provided with a pair of substantially T-shaped perforations, each of said pair of perforations having a portion extending substantially parallel to the edges of said link and defining a relatively long neck having a relatively high ohmic resistance, and each of said pair of perforations having a portion extending transversely across said link at right angles to the edges thereof forming therebetween a relatively short neck having a relatively low ohmic resistance.

5. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent arc-quenching filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of a relatively high conductivity relatively low fusing energy metal immersed in said filler conductively interconnecting said pair of terminal elements, said link being shaped to provide a pair of parallel current path, one of said pair of current path being relatively short and having a relatively low ohmic resistance and the other of said pair of current path being relatively long and having a relatively high ohmic resistance, said relatively long current path having a plurality of serially related points of reduced cross-sectional area tending to form series breaks upon fusion of said relatively long current path.

6. A current-limiting fuse comprising a tubular casing of insulating material, a quartz sand filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of silver conductively interconnecting said pair of terminal elements, said link comprising a relatively short neck portion and said link further comprising a relatively long neck portion having an ohmic resistance considerably higher than said relatively short neck portion, said relatively long neck portion being adapted to shunt said relatively short neck portion, an overlay on said link comprising a metal having a fusing point lower than silver capable of forming with silver alloys having a higher resistivity than silver, and said overlay being arranged on said link immediately adjacent to said relatively short neck portion and immediately adjacent to said relatively long neck portion thereof.

7. A fuse link for current-limiting fuses comprising a silver ribbon having a pair of substantially T-shaped perforations, each of said pair of perforations having a portion extending substantially parallel to the edges of said link and defining a relatively long neck portion having a relatively high ohmic resistance, and each of said perforations having a portion extending transversely across said link forming therebetween a relatively short neck portion having a relatively low ohmic resistance.

8. A current-limiting fuse comprising a tubular casing of insulating material, a pulverulent arc-quenching filler inside said casing, a pair of terminal elements closing the ends of said casing, a ribbon-type fuse link of a relatively high conductivity relatively low fusing energy metal having a predetermined active length immersed in said filler and conductively interconnecting said pair of terminal elements, said link defining a plurality of current paths of different length, and the length of each of said plurality of current paths being but a relatively small fraction of said predetermined active length.

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