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F. J. KOZACKA

2,939,934

CURRENT-LIMITING LOW-VOLTAGE FUSES

Filed Aug. 18, 1958

Fig. 1.

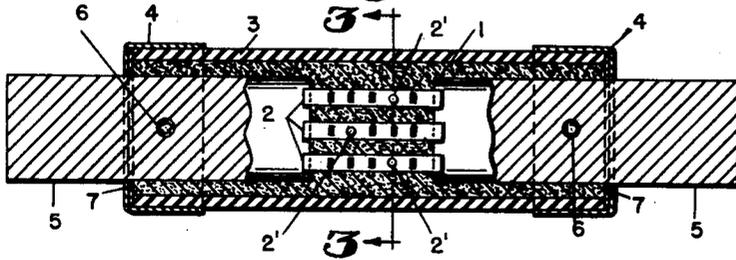


Fig. 2.

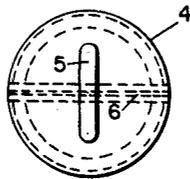
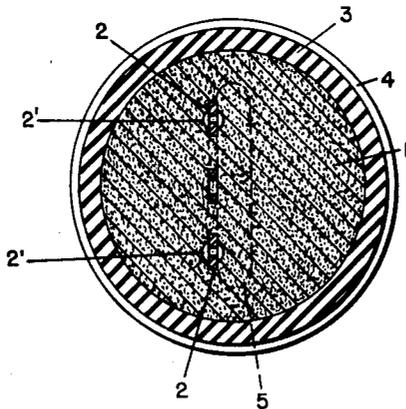


Fig. 3.



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CURRENT-LIMITING LOW-VOLTAGE FUSES

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6 Claims. (Cl. 200—131)

This invention relates to electric low-voltage fuses, and more particularly to such fuses adapted to generate arc voltages which are high in comparison to the circuit voltage.

Fuses generating arc-voltages which are high in comparison to the circuit voltage are often referred to as high-capacity fuses, which term emphasizes the ability of such fuses to interrupt very high available currents. Fuses generating high arc-voltages are often designed to interrupt high fault currents before such currents can reach their available peak values, and high-capacity fuses having this particular operating characteristic are generally referred to as current-limiting fuses.

This invention relates to high-capacity fuses, and more particularly to high-capacity fuses of the current-limiting type.

Fuses of the aforementioned character comprise a pulverulent arc quenching filler which has an intense cooling or deionizing action such as, for instance, a body of quartz sand. Such fuses further comprise a fuse link of a high conductivity low fusing energy metal (silver, copper) having a plurality of serially related points of reduced cross-sectional area. The arc-quenching action of the pulverulent filler and the geometry of the fuse link are so correlated as to result in a predetermined peak arc voltage per inch of link length upon blowing of the fuse by major fault currents. The peak arc voltage depends also upon the parameters of the circuit into which the fuse is inserted, and in fuses of the kind under consideration will be in the order of many hundreds of volts per inch of link length. It is well known in the art how to determine the geometry and the length of a fuse link required to develop the desired arc voltage when submersed in an arc-quenching filler having a predetermined arc-quenching action. The length of a fuse link for a high-capacity fuse, and more particularly for a current-limiting fuse, when determined from the viewpoint of interrupting capacity requirements (and current-carrying capacity requirements) may be much shorter than the length of a fuse link of a Standard or National Electrical Code fuse. This is due to the fact that a larger arc voltage per unit of link length may be generated in fuses of the aforementioned type than in fuses of the last mentioned type, thus calling for a much shorter active link length in one case than in the other.

If the dimensions of the fuse link and the fuse tube of a current-limiting low voltage fuse are determined in accordance with interrupting capacity requirements, and in accordance with current-carrying capacity requirements, then one may find that the outer minimum distance from the mid-point of the fuse to the nearest live part thereof tends to become too small. In the past many quite complex and expensive structures have been evolved to free ultra-short high-capacity or ultra-short current-limiting fuses from the dangers resulting from too small a minimum distance from midpoint of the fuse to the nearest live part. To date no entirely satisfactory solution to the problem in hand has been offered.

Another school of thought considered the required safe minimum distance from midpoint of fuse to nearest live part as the prime requirement around which any fuse

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whether of the Standard type, or of the high-interrupting-capacity type, or of the current-limiting type, ought to be designed. This school of thought provides any fuse, including current-limiting fuses, with a fuse tube of standard length and diameter, and provides inside of such a tube filler and fuse link means designed to generate per inch of fuse tube length substantially smaller arc voltages than those which could and would be normally generated in a current-limiting fuse of that size. Prior art fuses of this design have a fuse link which is substantially equal in length to that of the fuse tube and is designed to generate considerably smaller arc-voltages per unit of length than the arc voltages generated in compact current-limiting fuses designed on the basis of required minimum dimensions for given interrupting capacity requirements. To provide current-limiting fuses with fuse links which are longer than dictated by interrupting capacity requirements tends to result in relatively high voltage drops across the terminals of the fuse, and relatively high $i^2 \cdot r$ losses inside the fuse, which both are serious drawbacks.

It is one object of this invention to provide novel and improved high interrupting capacity fuses, particularly novel and improved current-limiting fuses which have the advantages of both of the aforementioned types of prior art fuses, and which are not subject to the limitations or disadvantages of either of these types of fuses.

Another object of the invention is to provide improved high-interrupting capacity fuses, particularly improved current-limiting fuses, which have fuse tubes of standard sizes but smaller voltage drops and $i^2 \cdot r$ losses than comparable prior art fuses.

Another object of the invention is to provide improved high-interrupting capacity fuses, particularly improved current-limiting fuses, which are designed for optimal interrupting efficiency and have the same minimum distances from mid-point to nearest live part as standard or National Electrical Code fuses.

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

Fig. 1 is a longitudinal section of a current-limiting fuse embodying the invention;

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

Fig. 3 is a cross-section along 3—3 of Fig. 1 drawn on a larger scale than Fig. 1.

The fuse according to this invention comprises a pulverulent arc-quenching filler 1 having a very high heat absorbing capacity, preferably quartz sand. Three ribbon-type fuse links 2 of a metal combining the property of high electric conductivity with that of low fusing energy are submersed in the body of quartz sand 1. Each fuse link 2 has a plurality of points of reduced cross-section established by multiperforation of the link ribbon. Casing or fuse tube 2 accommodates the body of quartz sand 1 and the fuse links 2. The three fuse links 2 have a predetermined geometry and length. Their geometry and their length and the arc-quenching action of filler 1 are so correlated as to result in a predetermined average peak arc voltage per inch of link length upon blowing of the fuse by major fault currents. Assuming that the fuse has a current rating of 200 amps. and starts to limit available currents above 3,700 R.M.S. amps. and is able to interrupt available currents up to 100,000 R.M.S. amps. All other conditions remaining the same, the peak arc voltage tends to change with the rate of rise of current. It should never exceed 2½ times the circuit voltage, and yet be sufficiently high to force the current from its let-through peak to zero before the time of the first natural current zero following fault in-

ception. The geometry or geometrical configuration links 2 and the arc-quenching capacity of filler 1 are such as to result in dangerously high arc voltage peaks if links 2, and more particularly the perforated portion thereof, and filler 1 extend substantially throughout the entire length of fuse tube or casing 3. Filler 1 extends actually throughout the entire length of the fuse tube 3, but the length of fuse links 2 is substantially less than the length of fuse tube 3. The relative shortness of the links 2 minimizes the voltage drop across the fuse and I^2R losses and heat generation in the fuse when carrying its rated current and relatively small overload currents. The links 2, in spite of their shortness, are able to effect a current-limiting interruption of the faulted circuit on major faults. This is due to the multibreak feature of links 2 resulting from being multiperforated, combined with the nature of the pulverulent arc-quenching filler 1 with which links 2 are associated. Both ends of the relatively long fuse tube 3 are closed by closing elements in the form of caps 4, permanently secured to fuse tube 3 by pins 6, or by conventional means not shown such as, for instance, crimping or riveting. The relatively great length of the fuse tube 3 compared to that of the fuse links 2 provides a safe minimum distance between the midpoint of the fuse tube 3 and the nearest live part, namely caps or ferrules 4. The fact that the entire length of the casing or fuse tube 3 is filled with a potent deionizer such as quartz sand makes it possible to dispense with expensive pressure-resistant terminal elements such as, for instance, copper plugs, for closing the fuse tube and to resort to simple inexpensive closing or terminal elements in the form of sheet metal caps 4. The fuse further comprises a pair of knife-blade contacts 5, or equivalent connectors, each projecting across one of caps 4 and secured to casing 3 by the pin 6 holding caps 4 in position. Each blade contact or connector 5 has one end projecting axially outwardly beyond fuse tube 3 and each blade contact or connector has another end projecting axially inwardly into the body of quartz sand 1. Gaskets or seals 7 are interposed between the axially outer ends of fuse tube 3 and caps 4. The fuse further comprises appropriate means providing permanent conductive fused connections between the axially outer ends of fuse links 2 and the axially inner end of knife-blade contacts or connectors 5. Fuse links 2 may either be spot-welded to knife-blade contacts 5, or conductively connected thereto by soft solder joints.

Fuse links 2 are preferably made of silver, but could also be made of copper, if desired. Other metals having a substantially different conductivity and a substantially different fusing energy from silver and copper will not do. The distance between the perforations in fuse links 2 is such as to preclude merger by backburning of the series arclets incident to the occurrence of major fault currents. This design of fuse links has been described more in detail in United States Patent 2,592,399 to William S. Edsall et al., April 8, 1952, Current-Limiting Fuse, and reference may be had to this patent for further details thereof. As also shown in the above Edsall et al. patent fuse links 2 are provided with means for causing interruption of the circuit on the occurrence of protracted overloads of relatively small intensity. To this end each fuse link 2 is provided with a rivet 2' of tin, or a suitable alloy of tin adapted to destroy or interrupt links 2 by corrosion occurring above the fusing point of tin. When rivets 2' melt, the silver of links 2 adjacent to rivets 2' dissolves in the melted rivet metal and diffuses into the same, thus forming tin-silver alloys of relatively high resistivity, and reducing the cross-sectional areas of links 2, until the same are eventually entirely severed.

The operation of the fuse structure shown is in essence the same as that of the structure disclosed in the above Edsall et al. patent. There are, however, some important distinctions. The current-limiting fuses dis-

closed in this patent are intended to be constructed as compact as possible. Due to the increase of the ratio of the volume of the body of quartz sand to the interrupting capacity (which may be in the order of 100,000 amps.) inherent in the present structure, the transient pressure incident to blowing is greatly reduced, and this enables to use simple sheet metal caps rather than massive copper plugs to close the ends of the casing 3. The heat transfer from the link zone, or the arcing zone, respectively, through the arc-quenching filler to the internal surface of casing 3 is so intense that casing 3 must be made of a synthetic resin-glass-cloth laminate, i.e. it cannot be made of organic insulating materials of the kind used in standard fuses, such as vulcanized fiber, or the like organic insulating materials.

It will be understood that fuses having different current and voltage ratings call for fuse tubes of different lengths as provided by the Underwriter Standards, and the table below indicates how the standard length varies with the current and voltage rating.

Electrical Rating	Length of Fuse Tube, inches	
	Volts	Amps.
250	0-30	2 ± 1/32
		3 ± 1/32
		3 7/8 ± 1/16
		4 3/8 ± 1/16
300	0-30	2 1/2 ± 1/32
		3 1/8 ± 1/32
		3 7/8 ± 1/16
		4 3/8 ± 1/16
600	0-30	5 ± 1/32
		5 1/2 ± 1/32
		6 1/8 ± 1/16
		6 7/8 ± 1/16
750	0-30	7 1/2 ± 1/32
		8 1/8 ± 1/32
		8 7/8 ± 1/16
		9 3/8 ± 1/16

Because fuses embodying the present invention generate much higher arc voltages than standard fuses the length of their links must be substantially less than the standard casing length for the particular current rating, but since the required arc voltage is achieved without resorting to high internal pressures inside of fuse tube or casing 3, the entire construction of the fuse structure requires relatively little ruggedness or mechanical strength.

The fuse structure shown in the drawing has been tested, and found to operate satisfactory both in the low-current interrupting range and in the high-current interrupting range as long as applied to the protection of A.-C. circuits. The very same structure lends itself also to the protection of D.-C. circuits having high available fault currents if links 2 are provided with plate structures or arc chutes of the kind disclosed in my copending patent application Ser. No. 658,162, filed May 9, 1957 for Current-Limiting Fuses With Increased Interrupting Capacity, now United States Patent 2,866,038, issued December 23, 1958.

It will be understood that though 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. In an electric current-limiting low-voltage fuse the combination of a body of quartz sand; a ribbon fuse link of a metal combining the property of relatively high conductivity with that of relatively low fusing energy, said fuse link forming a plurality of serially related points of reduced cross-section and being submersed in said body of quartz sand, the number of said points of reduced cross-section being so high as to limit the length of said link to a substantially shorter distance than twice the safe minimum distance from midpoint of the fuse to nearest live part; a fuse tube of a synthetic-resin-glass-cloth laminate accommodating said body of quartz sand and said fuse link, the length of said fuse tube considerably ex-

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ceeding said length of said fuse link and being at least twice said safe minimum distance from midpoint of the fuse to nearest life part; a pair of sheet metal caps closing both ends of said fuse tube; and a pair of knife-blade contacts arranged in substantially the same plane as said fuse link each projecting transversely across one of said pair of caps, each of said pair of knife-blade contacts having one end projecting axially outwardly beyond said fuse tube and each of said pair of knife-blade contacts having another end projecting axially inwardly into said body of quartz sand; and means providing conductive connections between the axially outer ends of said fuse link and the axially inner ends of said knife-blade contacts.

2. An electric fuse as specified in claim 1 wherein said fuse link is of silver and is spot-welded to said pair of knife-blade contacts.

3. In an electric current-limiting low-voltage fuse the combination of a pulverulent arc-quenching quartz filler; a multi-perforated ribbon-fuse link made of a relatively high conductivity relatively low fusing energy metal and having a predetermined length submersed in said filler; the arc-quenching action of said filler and the geometry of said fuse link being so correlated as to result in a predetermined average peak arc-voltage per inch of link length upon blowing of said fuse by major fault currents; a fuse tube of a synthetic-resin-glass-cloth laminate accommodating said filler and said fuse link, the length of said fuse tube being such as to result in dangerously high arc-voltage peaks if said filler and the perforated portions of said link were extending substantially throughout the entire length of said fuse tube, said filler extending substantially throughout the entire length of said fuse tube and the length of said fuse link being substantially less than the length of said fuse tube; a pair of closing elements permanently secured to said fuse tube at the axially outer ends thereof; a pair of connectors each projecting transversely across one of said pair of closing elements, each of said pair of connectors having one end projecting axially outwardly beyond said fuse tube and each of said pair of connectors having another end projecting axially inwardly into said arc-quenching filler; and fused means providing permanent conductive connections between the axially outer ends of said fuse link and the axially inner ends of said pair of connectors.

4. In an electric current-limiting low-voltage fuse the combination of a body of quartz sand; a fuse link of silver having a plurality of serially related points of reduced cross-sectional area submersed in said body of quartz sand; the arc-quenching action of said body of quartz sand and the geometry of said fuse link being so correlated as to result in a predetermined average peak arc voltage per inch of link length upon blowing of said fuse under major fault conditions; a fuse tube of a synthetic-resin-glass-cloth laminate accommodating said body of quartz sand and fuse link, the length of said fuse tube being such as to result in dangerously high arc voltage peaks if said body of quartz sand and said fuse link were allowed to extend substantially throughout the entire length of said fuse tube, said filler extending substantially throughout the entire length of said fuse tube and the length of said link being substantially less than the length of said fuse tube; a pair of caps closing both ends of said fuse tube; a pair of knife-blade contacts each projecting transversely across one of said pair of caps, each of said pair of knife-blade contacts having one end projecting axially outwardly beyond said fuse tube and each of said pair of knife-blade contacts having another end projecting axially inwardly into said body of quartz sand; and means establishing fused conductive connections between the axially outer ends of said fuse link and the axially inner ends of said pair of knife-blade contacts.

5. In an electric current-limiting low-voltage fuse the combination of a pulverulent arc-quenching quartz filler; a fuse link of a high conductivity low fusing energy

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metal having a plurality of serially related points of reduced cross-sectional area submersed in said filler; a fuse tube accommodating said filler and said fuse link and being substantially equal to standard length as defined by the table below:

	Electrical Rating		Length of Fuse Tube, inches
	Volts	Amps.	
250	-----	0-30	2 ± 1/4
		31-60	3 ± 1/4
		61-100	3 3/4 ± 1/4
		101-200	4 3/8 ± 1/4
		201-400	4 7/8 ± 3/4
600	-----	401-600	5 7/8 ± 3/4
		0-30	5 ± 1/4
		31-60	5 1/2 ± 1/4
		61-100	5 7/8 ± 1/4
		101-200	6 7/8 ± 1/4
		201-400	7 7/8 ± 3/4
		401-600	8 7/8 ± 3/4

the length of said fuse link being substantially less than standard length as defined by the table above; a pair of terminal elements adapted to permanently close the ends of said fuse tube; a pair of connectors each projecting transversely across the general plane of one of said pair of terminal elements, each of said pair of connectors having one end projecting axially outwardly beyond said fuse tube and each of said pair of connectors having another end projecting axially inwardly into said arc-quenching filler inside said fuse tube; and means providing permanent conductive connections between the axially outer ends of said fuse link and the axially inner ends of said pair of connectors.

6. In an electric current-limiting low-voltage fuse the combination of a body of quartz sand; a multiperforated ribbon fuse link of silver submersed in said body of quartz sand; a fuse tube of a synthetic-resin-glass-cloth laminate accommodating said body of quartz sand and said fuse link, the length of said fuse tube being substantially equal to standard length as defined by the table below;

	Electrical Rating		Length of Fuse Tube, inches
	Volts	Amps.	
250	-----	0-30	2 ± 1/4
		31-60	3 ± 1/4
		61-100	3 3/4 ± 1/4
		101-200	4 3/8 ± 1/4
		201-400	4 7/8 ± 3/4
600	-----	401-600	5 7/8 ± 3/4
		0-30	5 ± 1/4
		31-60	5 1/2 ± 1/4
		61-100	5 7/8 ± 1/4
		101-200	6 7/8 ± 1/4
		201-400	7 7/8 ± 3/4
		401-600	8 7/8 ± 3/4

the length of said fuse link being substantially less than standard length as defined by the table above; a pair of terminal caps closing the ends of said fuse tube; a pair of knife-blade contacts each projecting transversely across one of said pair of terminal caps, each of said pair of knife-blade contacts having one end projecting axially outwardly beyond said fuse tube and each of said pair of knife-blade contacts having another end projecting axially inwardly into said body of quartz sand inside said fuse tube; and means providing fused conductive connections between the axially outer ends of said fuse link and the axially inner ends of said pair of knife-blade contacts.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,939,934

June 7, 1960

Frederick J. Kozacka

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, lines 58 and 59, for "trnsversely cross" read
-- transversely across --.

Signed and sealed this 1st day of November 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE
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