United States Patent

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[73] Assignee **General Electric Company**

[54] **FUSE ELEMENTS FOR DC INTERRUPTION**
6 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **337/159,** 337/273, 337/290
[51] **Int. Cl.** **H01h 85/10,** H01h 85/18, H01h 85/38
[50] **Field of Search** 337/273, 276, 290, 159, 160, 222, 227, 246, 278, 279, 282, 295

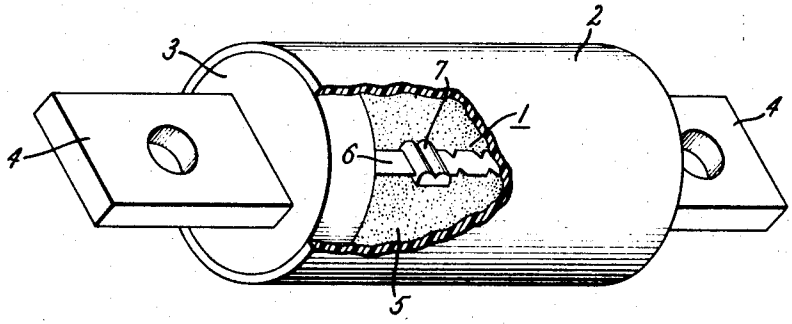
[56] **References Cited**

UNITED STATES PATENTS

3,287,524	11/1966	Huber et al.	337/159
3,009,040	11/1961	Bernstein	337/290
2,895,031	7/1959	Kozocka	337/159
2,866,038	12/1958	Kozocka	337/160
2,830,156	4/1958	Burgess, Jr.	337/246 X
1,862,317	6/1932	Ringwald	337/279 X

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ABSTRACT: A current-limiting fuse having a silicon rubber arc constricting structure encapsulating certain portions of the link having reduced cross-sectional areas. By confining and constructing the arc within the structure, the chance of creation of deleterious shunt current paths is minimized. The method disclosed encompasses flowing a still vicous room temperature vulcanized silicon rubber over a reduced portion of the fuse link to encapsulate the portion.



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Fig. 1.

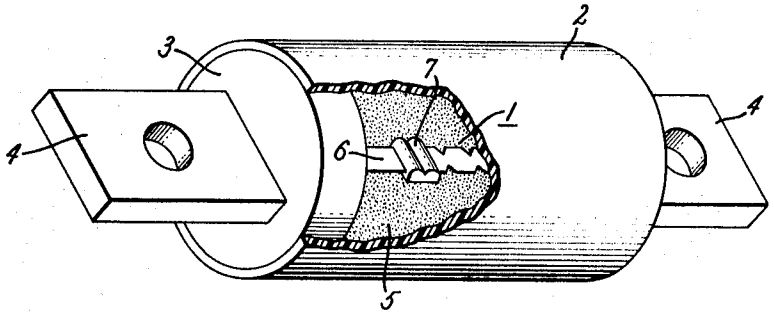


Fig. 2.

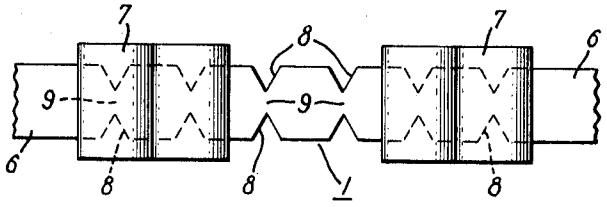


Fig. 3.

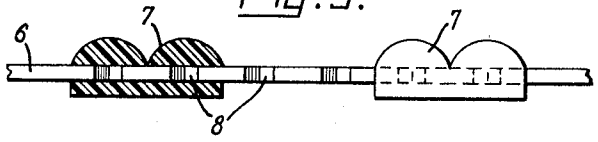


Fig. 4.

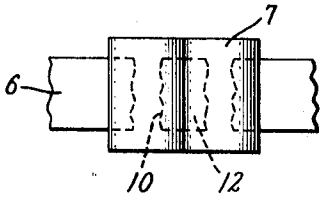
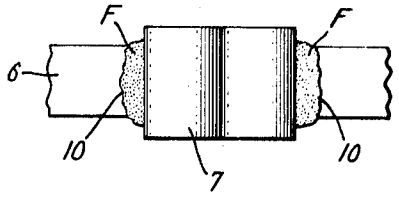


Fig. 5.



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FUSE ELEMENTS FOR DC INTERRUPTION

BACKGROUND AND OBJECTS OF THE INVENTION

This invention relates to electric fuses and in particular to a current-limiting fuse particularly well suited for application in inverter circuits or in other static power circuits where reliable direct current interruption is required.

Current-limiting fuses are quick-acting devices in that they are capable of interrupting a fault current in the circuit significantly before that fault current can reach its available peak magnitude as governed by the circuit parameters. These fuses are generally of the cartridge type having an insulative casing connecting a pair of end terminals or tangs. Inside the casing, and embedded in a pulverulent filler, there is a silver link spanning the terminals which link may have a plurality of serial-related reduced cross-sectional area portions depending upon the voltage rating of the fuse. This silver link will melt, then vaporize in response to abnormally high overloads or to short circuit (fault) currents.

The current-limiting action of these fuses occurs through the initiation of an electric arc whose voltage, acting opposite to the source voltage, acts to drive the fault current to zero. In operation the arc voltage generated should rise to a maximum rapidly and should remain at a high magnitude for sufficient time such that the fuse can properly clear and thus interrupt the circuit.

As is known, it is more difficult for a current limiting fuse to interrupt direct current than alternating current. This is due to the fact that with direct current there is no naturally falling source voltage which would increase the effectiveness of the opposing arc voltage. Consequently, in direct current circuits, the arc voltage must be high and must exceed the constant source voltage in order to drive the fault current to zero.

In alternating current circuits, the arc voltage only needs to be higher than the instantaneous AC source voltage to drive current to zero. The magnitude of arc voltage can therefore decrease with arcing time and even approach zero since source voltage reduces to zero.

In order to maintain a high arc voltage the occurrence of shunt current paths should be avoided since the effect of such paths will be to cause a decrease in arc voltage.

In the past melamine plate arc chutes have been utilized to prevent the formation of conductive fulgurite at the portions of reduced cross-sectional area of the link since the fulgurite tends to act as a shunt current path thus allowing the arc voltage to decay rapidly. Such arc chutes are shown in the following U.S. Pat. Kozacka No. 2,866,038; Kozacka No. 2,892,061; Jacobs, Jr. et al. No. 2,964,604.

It has been observed that under certain conditions commercially available fuses embodying such disclosures may not interrupt direct current as well as might be desired. We believe that the arc voltage generated using a melamine plate arc chute tends to drop off to an undesirable degree. The occurrence of such an arc voltage drop can perhaps be explained by the venting of some of the hot ionized gases created by the arc to areas laterally adjacent to the arc region. The interaction of these hot ionized gases and the hot, although unfused, sand perhaps contributes to a somewhat conductive shunt path adjacent to the lateral edges of the arc chute, thus allowing the arc voltage to drop. Further, with the prior art melamine plate arc chutes there is a possibility of molten silver venting laterally adjacent to the arcing region, thereby further contributing to a shunt current path.

Accordingly, it is an object of this invention to provide an improved current-limiting fuse so constructed that the chance of a conductive shunt current path being created is minimized or precluded.

As has been indicated, the generation of a high arc voltage is a requisite to proper circuit interruption by a current-limiting fuse. In static power circuits, owing to the use of solid-state devices, the generation of too high an arc voltage could damage such devices. The arc voltage should therefore be high but nevertheless within certain limits. Accordingly, it is another object of this invention to provide a current-limiting fuse with improved means which aids in maintaining the arc voltage within an acceptable range.

It is a further object of this invention to provide a current-limiting fuse with improved means to cushion the reduced portions of the link from the mechanical strain inherent during cyclic loads. It is still a further object of this invention to provide a method of making a current-limiting fuse element with an insulating elastomeric are constricting member surrounding at least one portion of the fuse link having a reduced cross-sectional area.

SUMMARY OF THE INVENTION

In carrying out the invention in one form, an enclosed current-limiting electric fuse having a pulverulent filler of arc-quenching material such as sand is provided with an elongated conducting link having a number of serially related portions reduced in cross-sectional area, and silicone rubber encapsulating means is disposed in substantially complete contact with all surfaces of at least one of the reduced portions of the link in order to constrict the arc and substantially preclude the formation of conductive sand or fulgurite at the arcing region. The method of encapsulating the reduced portion contemplates flowing a silicone rubber compound, while viscous, over the reduced portion of the link such that the silicone rubber is in contact with substantially all the surfaces of the reduced portion so as to isolate the portion from the sand filler.

BRIEF DESCRIPTION OF THE DRAWING

This invention will be better understood and its various objects and advantages will be more fully appreciated from the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a perspective view of a current-limiting fuse embodying our invention, with a portion of the fuse casing being broken away;

FIG. 2 is an enlarged plan view of the fuse element shown in FIG. 1;

FIG. 3 is an elevation view partially in section of the fuse element shown in FIG. 2;

FIG. 4 is a plan view of a portion of the fuse element shown in FIG. 2 showing discontinuities formed as a result of the occurrence of a typical fault current; and

FIG. 5 is a view similar to FIG. 4 showing the discontinuities formed as a result of the occurrence of a more severe fault current.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1–3, the illustrated fuse comprises a tubular insulative casing 2 whose opposite ends are closed by disc-shaped conductive terminals 3 having tangs 4 projecting axially therefrom. The casing 2 is filled with a pulverulent arc-quenching material 5, which may be quartz sand to support the fuse element and to aid in arc extinction. Spanning the terminals 3 inside the casing 2 and embedded in the filler 5 there is a fuse element 1 which is made up of an elongated, ribbon-like silver link 6 and an elastomeric arc-constricting structure 7. Of course other conductive materials may be used in lieu of silver, and other types of fuse links, for example a wirelike link, may be used in lieu of the ribbonlike link within the scope of this invention. As is best seen in FIG. 2, link 6 has a plurality of serially related, longitudinally spaced pairs of laterally opposing notches 8, the number of notch pairs determining the voltage rating of the fuse. The juncture of a pair of notches 8 creates a portion 9 of the link having a reduced cross-sectional area. It is of course contemplated that the points of reduced cross-sectional area can be created by use of configurations other than notches; for example, the link can be perforated to form parallel, narrow necks therein. While only a single link 6 has been illustrated for the sake of drawing simplicity, it is customary in the art to utilize a plurality of such links in parallel in a high-current fuse of this type.

Encapsulating and surrounding selected portions 9 of reduced cross-sectional area is an insulating elastomeric arc-constricting body 7. This body is made up of a silicone rubber and is in immediate contact with substantially all of the surfaces of the associated reduced portion 9 of the link so that there are no voids or communicative passages to the filler 5. Arc constricting body 7, by completely isolating the reduced portion 9 from the filler, precludes the gases generated during arcing from venting laterally into the surrounding filler 5. Thus the creation of conductive fulgurite at this region is precluded, and the availability of a shunt current path is minimized.

Further, the elastomeric nature of the arc-constricting body 7 tends to confine and constrict the arc which results in a high arc current density and improved arc voltage characteristics. This elastomeric nature also serves an important mechanical function as well, since it aids in decreasing the strain on the encapsulated reduced portion 9 of link 6. This strain is the inherent effect of a cyclic load.

Another feature of the elastomeric are constrictor 7 is that, being made of silicone rubber, it can withstand higher steady-state temperatures than can prior art melamine plate arc chutes.

As can be seen in FIGS. 2 and 3 there are six serially related portions 9. A first pair of three reduced portions 9, located near one end of the link 6, is under a pair of arc-constricting bodies 7, a second or central pair of reduced portions 9 is in direct communication with the sand, and the third pair of reduced portions 9, at the opposite end of the link, is under another pair of arc-constricting bodies 7. The central two portions 9 are left in open communication with the sand because during steady-state operation the mid portion of link 6 tends to reach higher temperatures than the end portions of the link. This uneven heating occurs because the terminals 3 and tangs 4, being massive as compared to the link 6, act as heat sinks for the ends of link 6. Accordingly, we prefer to leave the reduced portions 9 which are in the middle portion of the link in direct communication with the sand.

In operation the fuse embodying our invention is intended to be connected between a source of DC electric power and an external load-circuit which may include a solid-state (semiconductor) device. Upon the occurrence of a fault in the protected circuit, the reduced portions of the link are heated by the increasing current and begin to melt and vaporize. After melting and vaporization is accomplished, arcs are generated across the resulting gaps. Each arc at those portions of the link covered by our arc constrictor 7 is initially constricted thus aiding rapid buildup of the arc voltage. Arc constrictor 7, being elastomeric, also tends to confine the arc and its hot ionized arc products to within the constrictor. As such, the chance of creating deleterious shunt current paths is minimized. By minimizing shunt current paths the generated arc voltage is able to remain high. This voltage, acting opposite to the source voltage, drives the fault current to zero, whereupon the dielectric strength of the fuse is sufficient to prelude further flow of current, and interruption is complete.

During the interruption of a typical fault condition, the burnback of the silver link 6 will not extend longitudinally beyond the arc-constricting body 7. This is illustrated in FIG. 4 where the burnback point 10 is shown under the constrictor 7. Accordingly, there will be silicone rubber insulating each unburned longitudinal link section 12 from the next. Further, since no venting occurs there will be no conductive fulgurite in the area adjacent the arc constrictor 7 to act as a shunt current path.

After a more severe fault condition, as shown in FIG. 5, the link 6 may be burned back to a point 10, outside the arc constrictor 7, indicating that the arc directly communicated with the filler 5 and formed a fulgurite F at that point. Nevertheless, no lateral venting of the hot ionized gases occurs during arcing in the arc constrictor 7, and the formation of a conductive shunt current path between fulgurites F at adjacent points 10 is therefore minimized. The constrictor 7 effectively confines the arc to a relatively harmless region of the fuse.

It thus becomes apparent that with the use of the instant arc constrictor 7 the arc voltage can be maintained at a high level for a sufficient time for the fuse to properly clear any fault current within its rating.

While the preceding discussion involves direct current interruption it is of course contemplated that fuses embodying our invention may also be utilized in alternating current circuits and accordingly could have a dual rating, DC and AC.

One method of making the improved element 1 encompasses flowing a still viscous room temperature vulcanized silicone rubber completely around the desired reduced portion 9 of the link 6 such that the rubber directly contacts substantially all of the surfaces of that portion 9 and then allowing the rubber structure 7 to cure.

Alternately, a strip of cured silicone rubber is placed under one flat side of the reduced portion 9 and in contact with it. A still viscous room temperature vulcanized silicone rubber is then poured onto the other side of that portion 9 and the strip so as to immediately contact substantially all of the surfaces of that portion 9. The encapsulating body 7 is then cured. This alternative method has practical manufacturing advantages in that it allows for ease of application of the silicone rubber.

The step of encapsulating in either embodiment can be done either manually or through the use of automatic means.

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that various changes and modifications may be without departing from the invention in its broader aspects. We therefore intend herein to cover all such changes and modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electric fuse of the current-limiting type which during interruption generates a high arc voltage thus minimizing the effects of fault currents comprising:
   a. a tubular insulating casing;
   b. a pulverulent filler inside said casing;
   c. an elongated fuse link in said casing, said link having first, second and third longitudinally spaced portions of reduced cross-sectional area, the second portion being directly exposed to said filler, and
   d. insulating encapsulating means completely surrounding and in immediate contact with said first and third reduced portions of said link and isolating said first and third portions of said link from said filler thereby substantially precluding the formation of conductive fulgurite in the region of said first and third reduced portions of said link during interruption.

2. A current-limiting fuse of the type specified in claim 1 wherein said insulating encapsulating means comprises silicone rubber.

3. A current-limiting fuse of the type specified in claim 2 wherein said silicone rubber is of the room temperature vulcanized class.

4. The method of making an improved current-limiting fuse comprising the steps of:
   a. providing an electrically conductive link having at least one portion reduced in cross-sectional area;
   b. completely encapsulating said reduced portion in an insulating material such that said material is in an immediate contacting relationship with substantially all surfaces of said reduced portion of said link,
      said encapsulation being accomplished by the steps of:
      1. placing a base of elastomeric insulating material under said reduced portion of said link and
      2. pouring further elastomeric insulating material, while viscous, over said reduced portion of said link and said base so that said elastomeric material surrounds and contacts substantially all surfaces of said reduced portion of said link, and
   c. disposing said link in a casing between a pair of conductive terminals and in a pulverulent filler.

5. The method of making an improved current-limiting fuse element as specified in claim 4 wherein said elastomeric insulating material comprises silicone rubber.

6. The method of making an improved current-limiting fuse element as specified in claim 5 wherein said viscous elastomeric insulating material comprises room temperature vulcanized silicone rubber.