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HIGH VOLTAGE FUSES

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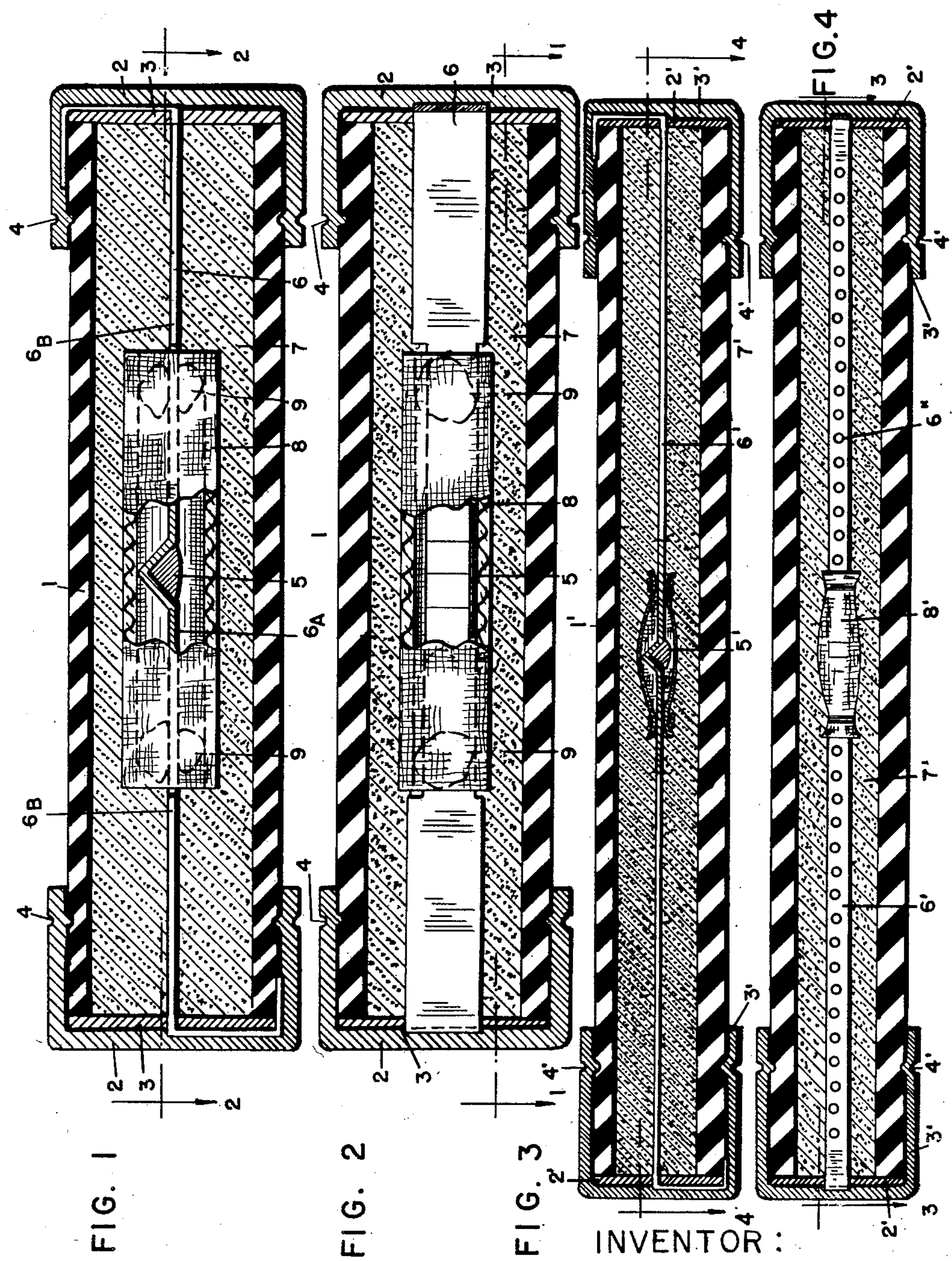

INVENTOR:

PHILIP C. JACOBS, JR.

BY Irwin Salzer his ATTY.

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HIGH VOLTAGE FUSES

Philip C. Jacobs, Jr., Newtonville, Mass., assignor to The Chase-Shawmut Company, Newburyport, Mass.

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This invention relates to fuses, and more particularly to current-limiting fuses. Current-limiting fuses blow at the occurrence of large fault currents in less than a quarter of a cycle of a current wave of 60 C. P. S. after fault inception, i. e. before the fault current can reach the peak intensity which the electric system into which the fuse is inserted is capable of supplying. In such fuses arc voltage is being built-up at such a rapid rate that the fault current decays from its limited peak to zero prior to the first natural current zero of the fault current.

Fuses of the aforementioned type tend to operate unsatisfactorily at the occurrence of overloads of inadmissible duration, as distinguished from major fault currents or short-circuit currents, and this tendency is particularly noticeable with current-limiting fuses having relatively high voltage ratings, say 3 kv. to 30 kv.

It is, therefore, one object of this invention to provide current-limiting fuses which operate satisfactorily both on the occurrence of fault currents of inadmissible duration, and on the occurrence of major fault currents or short-circuit currents, and which fuses lend themselves well to operating voltages in excess of 600 volts, up to many kilovolts.

Another object of the invention is to provide current-limiting fuses wherein the build-up of arc voltage on the occurrence of overloads of inadmissible duration is relatively rapid, resulting in a limitation of arc energy and arcing time, and wherein the voltage surge incident to blowing on occurrence of major fault currents or short-circuit currents is relatively moderate, so as not to endanger the insulation of the electric system into which the fuse is inserted.

Another object of the invention is to provide a current-limiting fuse comprising means effective upon blowing of the fuse at overload currents of inadmissible duration for more rapidly increasing the temperature of the portions of the fuse link situated immediately adjacent to the point of initial break and for increasing the contamination of the arc gap to effect back-burning and growth of the arc gap at an increased rate.

Still another object of the invention is to provide current-limiting fuses having means permitting to apportion at will the amount of axial venting and the amount of radial venting of the arc gap formed upon blowing of the fuse at overloads of inadmissible duration.

A further object of the invention is to provide current-limiting fuses having semi-porous means at the hot spot region thereof tending to inhibit at small current intensities radial venting of the products of arcing into the pulverulent arc quenching filler but tending to permit such venting at high current intensities resulting from major faults.

Other objects of the invention and advantages thereof will, in part, be obvious and in part appear hereinafter.

For a fuller understanding of the invention reference should be had to the following detailed description and drawing, wherein:

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Fig. 1 is in part a longitudinal sectional view taken along 1—1 of Fig. 2 and in part a side elevation of a fuse embodying my invention, some of the parts thereof being shown as being broken away;

Fig. 2 is in part a longitudinal sectional view taken along 2—2 of Fig. 1 and in part a front view of the fuse structure shown in Fig. 1;

Fig. 3 is in part a longitudinal sectional view of another fuse embodying my invention taken along 3—3 of Fig. 4 and in part a side elevation of said fuse; and

Fig. 4 is in part a longitudinal sectional view taken along 4—4 of Fig. 3 and in part a front view of the fuse structure shown in Fig. 3.

Referring now to Figs. 1 and 2, the fuse structure shown therein comprises a ribbon-type fuse link of a metal having a relatively small resistivity, a relatively low specific heat and a relatively high fusing point. The metal best complying with these requirements is silver. Silver has a resistivity of 1.64×10^{-6} ohm-centimeters at 20 deg. C., a resistivity when solid at the melting point of 8.4×10^{-6} ohm-centimeters, a resistivity of 16.6×10^{-6} ohm-centimeters when liquid at the melting point, a specific heat of 2.60 watt-sec./deg. C.-cm.^{3}, and a fusing point of 940 deg. C. As an alternative to silver, though not as desirable as silver, copper may be used in some instances. Copper has a resistivity of 1.72×10^{-6} ohm-centimeters at 20 deg. C., a resistivity when solid at the melting point of 10.2×10^{-6} ohm-centimeters, a resistivity of 21.3×10^{-6} ohm-centimeters when liquid at the melting point, a specific heat of 3.76 watt-sec./deg. C.-cm.^{3}, and a fusing point of 1063 deg. C. The corresponding values for other metals are of quite a different order. The aforementioned constants are conducive to a relatively high current-limiting action, as is well known in the art, and therefore does not need to be shown.

Fuse link **6** is arranged in a casing **1** of insulating material, preferably a synthetic-resin-glass-cloth laminate. Both ends of casing **1** are closed by metal washers **3** of which each is provided with a slot for the passage of fuse link **6**. The axially outer ends of fuse link **6** are bent in such a way that a portion of the link on each end thereof is situated on, and in physical engagement with, the outer surface of casing **1**. The portions of fuse link **6** which are situated on the outer surface of casing **1** are firmly clamped to it by terminal elements **2** in the form of metal caps. Casing **1** is provided with circular grooves, and the portions of caps **2** juxtaposed to these grooves are rolled into these grooves as shown at **4**, thus preventing caps **2** from being blown off casing **1** by virtue of the high pressures which may occur therein during circuit interruptions involving large amounts of arc energy. The axially outer bent ends of link **6** are preferably tin coated and soldered to the inner surfaces of caps **2**. This can be achieved by inductive heating of the fuse after complete assembly thereof. Fuse link **6** comprises an axially inner portion $\mathbf{6}_A$ and axially outer portions $\mathbf{6}_B$. The width and cross-sectional area of the former portion is smaller than the width and cross-sectional area of the latter portions. Shoulders are formed where the axially inner fuse link portion $\mathbf{6}_A$ meets the axially outer fuse link portions $\mathbf{6}_B$. The axially inner portion $\mathbf{6}_A$ is bent in such a way as to form an angular cavity, which cavity is coextensive with the hot spot of the fuse structure. A body **5** of relatively low fusing point metal is accommodated in the angular cavity defined by link **6**. That metal is adapted to form alloys with the metal-silver or copper—of which fuse link **6** is made which alloys have a relatively high resistivity. Such alloy-formation or metallurgical reaction takes place at the occurrence of overloads of inadmissible duration causing fusion of metal body **5**. The low fusing point metal body **5** inside the angular cavity formed by fuse link 6 may be tin, or a suitable alloy of tin. Indium or alloys of indium may likewise be used, as shown in United States Patent 2,703,352 to Frederick J. Kozacka, Fuse and Fuse Link of the Time Lag Type, issued March 1, 1955. A mass of a pulverulent arc-quenching medium 7, preferably quartz sand which is chemically reasonably pure, is accommodated within casing 1 and the axially outer portions 6_B of fuse link 6 are directly submersed in the sand. A sleeve 8 of an inorganic heat resistant insulating material, preferably of woven glass fibers, covers the axially inner portion 6_A of link 6. Sleeve 8 covers only the axially inner portion 6_A of link 6 but exposes the axially outer portions 6_B of the link to the immediate arc-quenching action of the pulverulent silicious filler 7. The shoulders formed between link portions 6_A and 6_B tend to form abutments limiting or precluding axial displacement of sleeve 8 along link 6. This tendency is particularly effective if the fit of sleeve 8 on link 6 is relatively tight and if the weave of sleeve 8 is relatively resilient. The axially outer ends of sleeve 8 may be closed by plugs 9 of glass wool, as shown. Plugs 9 tend also to hold sleeve 8 in its position. As an alternative, the ends of woven glass fiber sleeve 8 may be closed sufficiently by attaching the inner surfaces of sleeve 8 to the surface of link 6, as by means of a suitable heat resistant adhesive, for instance, water glass.

The operation of the fuse structure shown in Figs. 1 and 2 is as follows:

Assuming occurrence of a major fault, then the portions 6_A and 6_B of fuse link 6 will fuse and vaporize in rapid sequence. However, the difference in time between their respective fusion and vaporization tends to limit the rate of change of current and, therefore, the resulting surge voltage, below a dangerous level. While sleeve 8 operates as a gas barrier, or impediment to the outward flow of gas, as long as the gas pressure therein is relatively low, if made of an appropriate glass cloth sleeve 8 permits substantial radial venting at high internal pressures. It may be said that sleeve 8 operates at major fault currents and concomitant high internal pressures as if it were not present and the space occupied by the sleeve 8 were occupied by the silicious arc quenching medium 7. This statement is correct inasmuch as at high pressures the pores in sleeve 8 permit the radial escape of products of arcing in the same way as the interstices between the grains of the quartz filler and inasmuch as the sleeve 8 is being converted, or fused by the heat of the arc, into glass-like metal silicates in the same way as quartz sand is.

Considering now occurrence of an overload of excessive duration, under such circumstances the silver of which link 6 is made will diffuse into the metal body 5 upon fusion of the latter, forming various brittle alloys which have a relatively high resistivity. Metallurgical erosion of link 6 results ultimately in the formation of a small break in link 6 and kindling of a low current arc. Such arcs have the tendency to hang on for a long time, to generate large amounts of heat by virtue of their duration ultimately resulting in thermal destruction and failure of the fuse. This is being precluded in the structure shown by the coaction of the vapors resulting from vaporization of the low fusing point metal body 5 under the heat of the arc and the sleeve 8. These vapors tend to contaminate the arc gap since their escape is greatly impeded by the action of sleeve 8. Some of these vapors condense on sleeve 8, but they are not sufficiently hot to cause fusion of the latter. Such condensation tends to further impede venting of the vapors of the low fusing point metal radially through sleeve 8. These vapors are, therefore, compelled to flow axially along link 6, thus pre-heating the severed terminals of the link between which arc initiation had occurred. This, in turn, is conducive to more rapid growth of the arc gap, more rapid increase of arc voltage and, therefore, more rapid arc extinction. Where the growth of an arc

gap is relatively slow, the increase of arc voltage resulting from gap growth and arc elongation is again lost, in part, by virtue of a decay of the arc voltage in the center region of the arc, i. e. at the point where the arc had been originally kindled. This decay of arc voltage is due to excessive heat generation at this point, resulting from excessive arc duration. Heating of the portions of the fuse link immediately adjacent to the arc gap by an abundance of hot arc products combined with a thorough contamination of the arc gap by an abundance of metal vapors having a very low ionization potential is equivalent to more rapid back-burning of the fuse link by an arc whose current intensity is relatively higher. In other words, the critical low current arcs are caused to behave as less critical arcs involving relatively higher arc currents would behave. This includes a build-up of arc voltage at a more rapid rate than normally encountered in fuses at low overload currents.

If the body 5 of low fusing point metal were omitted from the link 6, fusion would ultimately take place at about the same point of the link, this being the hottest spot of the fuse structure. Since the fusing temperature of silver is considerably higher than that of tin or the like low fusing point metals, the vapors of silver flowing along the link might be expected to have an even more intense heating effect upon the link than those of the low fusing point metal and result in an even more rapid back-burning of the arc gap. This is, however, not the case. The difference in behavior, i. e. the greatly accelerated interruption of the circuit, may be explained by the contamination of the arc gap by an abundance of superheated highly conductive metal vapors, whereas silver vapors have a high resistivity at the vaporization temperature of silver.

It is possible to substitute a sleeve of another material for the sleeve 8 of woven fiber glass, e. g. a sleeve of a ceramic material. Such substitution entails, however, some disadvantages which may even be fatal in some instances. The sleeve of woven fiber glass enables to control the ratio of radial and axial venting, which ratio could not be controlled if the sleeve were made of a ceramic material whose porosity is insignificant and does not enable radial venting. A sleeve of woven fiber glass or glass cloth may safely extend along a substantial portion of the entire length of the link without impairing the short-circuit current interrupting ability of the fuse, the sleeve-covered portion still remaining an effective short-circuit current interrupter, the glass-cloth sleeve 8 operating in substantially the same fashion as the pulverulent arc-quenching medium 7 itself, and being backed up in depth by the pulverulent arc-quenching medium 7. Any increment of link length covered by a sleeve having not substantially the same properties as glass cloth sleeve 8 would more or less be lost as a means for the interruption of short-circuit currents and similar major fault currents, i. e. it would be appropriated for interruption of currents of minor magnitude, as overload currents of inadmissible duration.

In Figs. 3 and 4 like parts as in Figs. 1 and 2 have been indicated by the same reference numerals with a prime added. It is, therefore, not necessary to describe in detail the structure shown in Figs. 3 and 4 inasmuch as it does not differ from that shown in Figs. 1 and 2.

The structure shown in Figs. 3 and 4 comprises a fuse link 6′ having a plurality of circular perforations 6″ which are equidistantly arranged along substantially the entire length of the link. The center portion of the link is not perforated and provided with a bent defining an angular cavity receiving a wedge-shaped mass 5′ of tin. The tin is applied in hot condition to link 6′, and is therefore in intimate contact with the surface of the link. Sleeve 8′ of porous fiber glass cloth covers the tin body 5′ and the immediately adjacent portions of link 6′. The axially outer ends of sleeve or cover 8′ are closed, as by threads of fiber glass wound around them.

The operation of the structure shown in Figs. 3 and 4 closely resembles that of the structure shown in Figs. 1 and 2. The former is designed for relatively high currents and relatively low voltages and the latter for relatively high voltages and relatively low currents. The multiperforated fuse link structure of Figs. 3 and 4 is not conducive to excessive surge voltages on blowing of the fuse on major fault currents.

Where higher current intensities are to be carried than those for which the structures shown in Figs. 1 to 4 are intended, a plurality of fuse links may be arranged between the terminal elements of the fuse, each supporting a body of link-destroying and arc gap contaminating low fusing point metal and each such body being covered by a sleeve, preferably made of resilient porous glass cloth.

It will be understood that it is necessary, for best results, to select glass cloth woven from glass fibers having a chemical purity comparable to that of the pulverulent arc-quenching filler inside of the casing. The purity of the glass fibers is a matter of particular importance where the sleeve extends along a substantial portion of the total length of the link.

Having disclosed preferred embodiments of my invention, it is desired that the same not be limited to any particular structure disclosed. It will be obvious to persons skilled in the art that many modifications and changes may be made without departing from the broad spirit and scope of my invention. Therefore it is desired that the invention be interpreted as broadly as possible and that it be limited only as required by the prior state of the art.

I claim as my invention:

1. A current-limiting fuse comprising a casing of insulating material, terminal elements on the outer ends of said casing, a ribbon-type fuse link of a metal having a relatively low resistivity and a relatively low specific heat conductively interconnecting said terminal elements, a body of a metal on said fuse link having a lower fusing point than the fusing point of the metal of said fuse link adapted to destroy said fuse link by a metallurgical reaction taking place at a temperature below the fusing point of said metal of said fuse link, and a sleeve of heat resistant inorganic insulating material tending to guide the vapors of said lower fusing metal resulting from destruction of said fuse link by said metallurgical reaction and consequent arcing in a direction substantially longitudinally of said fuse link.

2. A current-limiting fuse comprising a casing of insulating material, terminal elements on the outer ends of said casing, a ribbon-type fuse link of a metal having a relatively small resistivity, a relatively low specific heat and a relatively high fusing point conductively interconnecting said terminal elements, a body of a relatively low fusing point metal on said fuse link adapted to form with the metal of said fuse link alloys having a relatively high resistivity, a mass of a pulverulent silicious arc-quenching substance inside of said casing in physical contact with a portion of said fuse link, and a sleeve of a heat resistant inorganic insulating material mounted on said fuse link, covering said body of relatively low fusing point metal and restraining the vapors thereof resulting from arcing from freely flowing into said mass of arc-quenching substance.

3. A current-limiting fuse comprising a casing of insulating material, terminal elements on the outer ends of said casing, a ribbon-type fuse link of a metal having a relatively low resistivity, a relatively low specific heat and a relatively high fusing point conductively interconnecting said terminal elements, a body of a relatively low fusing point metal on said fuse link adapted to form with the metal of said fuse link alloys having a relatively high resistivity, a mass of quartz sand inside of said casing surrounding said fuse link, and a cover of woven glass fibers mounted on said fuse link at the point thereof where said body of relatively low fusing point metal is located, the weave of said fibers being sufficiently loose to apportion the vapors of said low fusing point metal generated upon blowing of said fuse into a transverse flow component across said cover and a longitudinal flow component inside said cover.

4. A current-limiting fuse comprising a casing of synthetic-resin-glass-cloth laminate, terminal elements on the outer ends of said casing, a multiperforated ribbon-type fuse link of silver conductively interconnecting said terminal elements, a link-destroying element comprising tin supported by said fuse link, a mass of quartz sand inside of said casing surrounding said fuse link, and a sleeve of heat resistant inorganic insulating material covering said link-destroying element.

5. A current-limiting fuse as specified in claim 4 wherein said sleeve consists of glass fiber cloth and is substantially sealed on the axially outer ends thereof to impede the out-flow of products of arcing in a direction longitudinally of said sleeve.

6. A current-limiting fuse comprising a casing of insulating material, terminal elements on the outer ends of said casing, a ribbon-type fuse link of a metal having a relatively low resistivity, a relatively low specific heat and a relatively high fusing point conductively interconnecting said terminal elements, said fuse link comprising an axially inner portion having a relatively small width and axially outer portions having a relatively large width and having shoulders formed between said inner portion and said outer portions, a body of a relatively low fusing point metal on said fuse link adapted to form with the metal of said fuse link alloys having a relatively high resistivity, a mass of quartz sand inside of said casing surrounding said fuse link, and a sleeve of woven glass fibers covering said inner portion of said fuse link but exposing said outer portions thereof to the immediate arc-quenching action of said quartz sand.

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