Sept. 12, 1967 P. C. JACOBS, JR 3,341,674

ELECTRIC QUARTZ-SAND-FILLED FUSE ADAPTED TO INTERRUPT EFFECTIVELY PROTRACTED SMALL OVERLOAD CURRENTS

Filed Oct. 21, 1965 2 Sheets-Sheet 1

FIG. 1

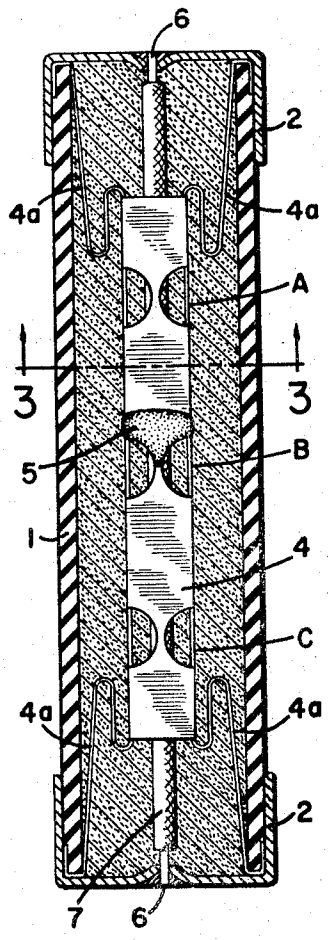


FIG. 2

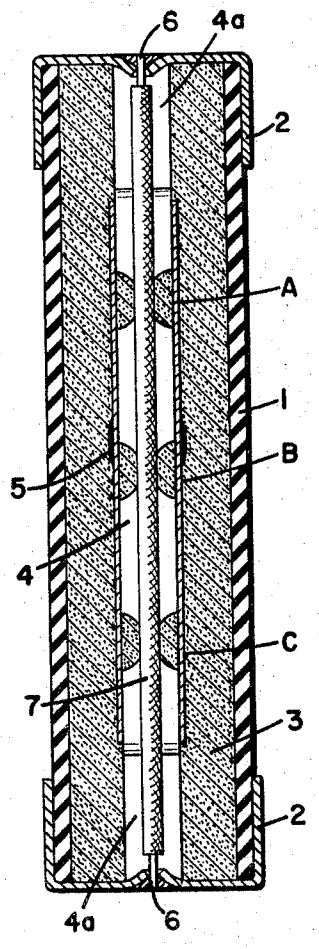
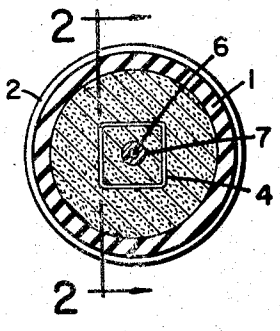


FIG. 3



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FIG. 4

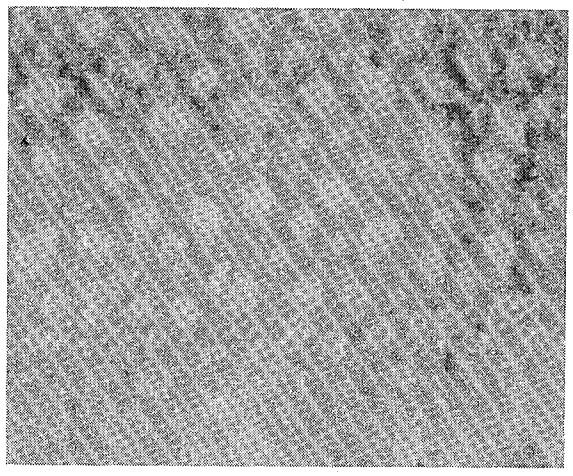
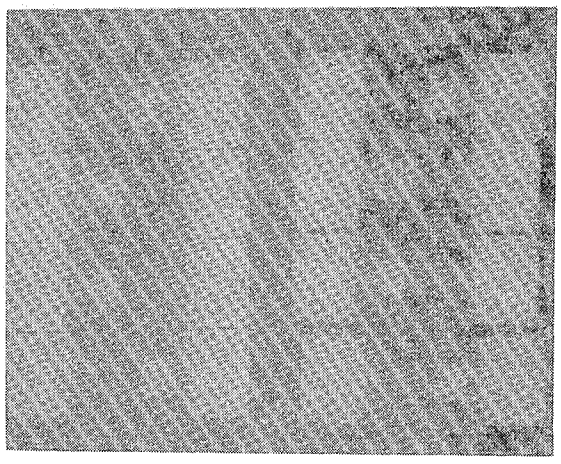


FIG. 5



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3,341,674

ELECTRIC QUARTZ-SAND-FILLED FUSE ADAPTED TO INTERRUPT EFFECTIVELY PROTRACTED SMALL OVERLOAD CURRENTS

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4 Claims. (Cl. 200—120)

This invention relates to electric fuses, and more particularly to high-interrupting capacity fuses wherein high interrupting capacity is achieved by the high heat absorbing capacity of an arc-extinguishing quartz sand filler.

Such fuses perform generally in a satisfactory fashion under major fault current or short-circuit current conditions. Their performance when interrupting protracted small overload currents is often not entirely satisfactory. Serious troubles are encountered in quartz-sand-filled power fuses when called to interrupt small protracted overload currents if the size of such fuses is small in relation to the current-carrying capacity thereof.

It is, therefore, one object of this invention to provide improved quartz-sand-filled fuses not subject to the above limitations, i.e. quartz-sand-filled fuses which are adapted to interrupt effectively protracted small overload currents, even if the size of the respective fuse is small in relation to the current-carrying capacity thereof.

When quartz-sand-filled fuses are subjected to small protracted overload currents the temperature of the quartz-sand-filler adjacent the point of initial break formation is relatively high, and the heat absorbing capacity of the quartz-sand-filler adjacent the point of initial break formation is correspondingly low. As a result, the dielectric recovery of a break resulting from the flow of protracted small overload currents is relatively slow, and in such instances the arcing time tends to be relatively long and the arc energy dissipated during the interrupting process relatively high.

It is, therefore, another object of this invention to provide electric quartz-sand-filled fuses wherein the dielectric recovery of a break resulting from the flow of protracted overload currents is relatively fast and wherein the arcing time at a break resulting from the flow of protracted overload currents is relatively short and the arc energy dissipated during the interrupting process is relatively small.

If a quartz-sand-filled fuse includes a first fusible element having a relatively large current-carrying capacity and a second fusible element having a relatively small current-carrying capacity shunting the first fusible element, the fusible elements form breaks in the inverse order of their respective current-carrying capacity on occurrence of small protracted overload currents, i.e. the fusible element having a relatively large current-carrying capacity forms a break first, and the fusible element having a relatively small current-carrying capacity forms a break thereafter. The first break is formed in a thoroughly pre-heated mass of quartz sand the interrupting capacity of which is seriously impaired, while the mass of quartz sand surrounding the second break is less pre-heated and, therefore, its interrupting capacity is less impaired, or better. These conditions coupled with the fact that the arc current at the second or last formed break is significantly less than that at the first formed break make it relatively easy to extinguish the arc kindled at the break which is formed last. Since the second or low current-carrying capacity fusible element limits the voltage prevailing across the break formed in the first or high current-carrying capacity fusible element as long as the second fusible element is intact, and also for the time preceding arc-extinction at the break formed at the second fusible element, the presence of the latter facilitates the dielectric recovery of the break formed in the first fusible element. For these reasons it is to be expected that arrangements of fusible elements in parallel, of which one has a relatively high current-carrying capacity, and the other a relatively small current-carrying capacity, be a useful tool in interrupting protracted small overload currents in quartz-sand-filled electric fuses.

I have conducted extensive tests at protracted small overload currents with quartz-sand-filled fuses including high current-carrying capacity fusible elements shunted by small current-carrying capacity fusible elements, and I found from these tests that such fuses do not operate satisfactorily if the size thereof is significantly reduced below existing standards in order to conform with modern requirements and current trends.

In carrying out my aforementioned tests I found that the backburn length of the second fusible element, i.e. the fusible element having the relatively small current-carrying capacity, tends to be considerable, and tends to result in the formation of a relatively long fulgurite which does not cool sufficiently fast and, therefore, is conducive to a failure of the fuse following a successful initial interruption of the protracted small overload current by it. Changing of the parameters of the second fusible element, or low current-carrying capacity fusible element, is of no avail. If its current-carrying capacity is decreased below certain limits as required to avoid formation of a dangerous fulgurite at the space previously occupied by it, its effectiveness in facilitating the dielectric recovery of the break formed in the first fusible element, or high current-carrying capacity fusible element, is decreased to such an extent as to make it virtually ineffective as a means for controlling the dielectric recovery of the main arc gap. Any decrease of the current-carrying capacity of the second fusible element, or any increase of its resistance, may be considered as a step in the direction toward the limit case of its total elimination. On the other hand, any significant increase of the current-carrying capacity of the second fusible element, or any decrease of its resistance, results in a change of the rating of the fuse structure as primarily determined by the parameters of the first fusible element or high current-carrying capacity fusible element. It results also in a significant pre-heating of the quartz sand immediately adjacent the break formed by the second or low current-carrying capacity fusible element, and a concomitant reduction of the rate of dielectric recovery of that break.

Thus trying to modify the parameters of the device seems to be moving along a vicious circle and, therefore, the effectiveness of the above dual fusible element fuse structure as a means for interrupting protracted small overload currents seems to be relatively limited.

I have, however, discovered how to remove the apparent limitations imposed upon dual fusible element fuse structure of the aforementioned kind. This discovery resulted from experiments with woven sleeves of fiber glass as disclosed, for instance, in U.S. Patent 2,832,868 to Frederick J. Kozacka, issued Apr. 29, 1958, for Fillerless One-Time National Electric Code Fuses. Woven sleeves of fiber glass have a certain arc-energy-absorbing capacity and are useful arc-quenchers as long as their critical arc-energy-absorbing capacity is not exceeded. When a critical amount of arc energy is dissipated in a fuse, the entire woven sleeve of fiber glass enveloping its fusible element melts and is converted into a fulgurite, i.e. a sleeve of liquid or solid glass surrounding the arc path. The behavior of a woven sleeve of fiber glass enveloping a fusible element is, however, entirely different

if the arc energy can be limited below a certain maximum. In that case the metal vapors resulting from vaporization of the fuse link tend to condense in discrete or separate droplets on the inner surface of the woven fiber glass sleeve enveloping the fusible element. These droplets, and the solidified equivalents thereof, are more or less separated by non-conductive interstices. Some of the metal vapors diffuse through a woven sleeve of fiber glass to the outside thereof. If there is a filler of quartz sand on the outside of the woven sleeve of fiber glass, the quartz sand operates as an aftercooler, but is not converted into a relatively dense fulgurite highly conductive at elevated temperatures.

These discoveries make it possible to find a complete solution of the problem of providing compact quartz-sand-filled high interrupting-capacity fuses capable of effectively interrupting protracted small overload currents.

This will be more apparent from the following description of the invention when considered in conjunction with the following drawings, photograph and X-rays wherein

FIG. 1 is a longitudinal section of a fuse embodying the present invention;

FIG. 2 is a section along 2—2 of FIG. 3;

FIG. 3 is a section along 3—3 of FIG. 1;

FIG. 4 is a photomacrograph of coper vapors condensed on the inner surface of a woven sleeve of fiber glass which had enveloped a fusible shunt wire in a structure of the type shown in FIG. 1; and

FIG. 5 shows an X-ray of fuse structures substantially as illustrated in FIGS. 1–3 upon successful interruption of protracted small overland currents.

Referring now to the drawings, and more particularly to FIGS. 1 to 3 thereof, reference character **1** has been applied to designate a tubular casing of insulating material closed on both ends by a pair of terminal elements **2** in the form of metal caps or ferrules.

Casing **1** is filled with a body **3** of arc-quenching quartz sand. Reference numeral **4** has been applied to indicate a first fusible element having a relatively high current-carrying capacity, or a relatively small resistance, arranged inside casing **1** conductively interconnecting terminal elements **2**. Fusible element **4** is made of sheet copper, or sheet silver, and is in the form of a prism or tube having tabs **4***a* at the end thereof. Tabs **4***a* perform a dual function, i.e. they connect electrically the center portion of fusible element **4** to terminal elements **2** and they insulate the central portion of fusible element **4** thermally from casing **1** and terminal elements **2**. The center portion of fusible element **4** is provided with transverse lines of perforations defining points of reduced cross-section where breaks are formed on occurrence of major fault currents, or short-circuit currents. The center portion of fusible element **4** supports an overlay **5** of a low fusing point link-severing metal as, for instance, tin, indium, cadmium, or appropriate alloys of these metals. Terminal caps **2** are further conductively interconnected by a second fusible element **6** having a relatively small current-carrying capacity, shunting the first fusible element **4**. The second fusible element **6** is preferably in the form of a wire having a considerably higher resistance than fusible element **4**. The resistance of fusible element **6** is so high in comparison to the resistance of fusible element **4** that the current carried by the former is a negligible portion of the current carried by the latter. A woven sleeve **7** of fiber glass is mounted on fusible element **6** and envelops the latter and separates the latter from the surrounding body **3** of quartz sand. The inner diameter of sleeve **7** is considerably larger than the outer diameter of wire **6**, thus establishing a relatively large cool and porous surface for the condensation of metal vapors which may result from the vaporization of fusible element **6**. The inner surface of sleeve **7** is in physical engagement with wire **6** at some random points, but such engagement is limited to a number of discrete points, and there is at many points of wire **6** a small clearance

of varying size between wire **6** and the inner surface of sleeve **7**. This clearance is conductive to a diffusion or dilution of metal vapors resulting from vaporization of wire **6** before condensation thereof on the inner surface of sleeve **7**. The ends of sleeve **7** are spaced from caps **2** to interpose layers of quartz sand between caps **2** and the jets of hot products of arcing which may be emitted from the open ends of sleeve **7**.

The fuse structure illustrated in FIGS. 1–3 is a time-lag fuse. In such fuses it is desirable to limit heat exchange between the fusible element or fuse link and ambient space. This requirement is met by keeping the tubular center portion of fusible element **4** as short as compatible with the requirement of generation of a relatively high arc voltage, and by the presence of tabs **4***a* having a smaller aggregate cross-section than that of the tubular center portion of fusible element **4**. The length of fusible element **6** and that of sleeve **7** is as long as possible, in order to generate as high an arc voltage as possible, and the length of sleeve **7** is only limited by the need of protecting the terminal elements **2** against the action of hot products of arcing issuing from the axially outer ends of sleeve **7**.

The overlay **5** on fusible element **4** is conventional in time lag fuses. In the structure of FIGS. 1–3 overlay **5** limits the temperature in the center region of fusible element **4** and, therefore, limits the temperature of the quartz sand which cools the hot products of arcing resulting from vaporization of fusible element **6** that are not condensed on the inner surface of sleeve **7**, but flow radially outward through the pores of sleeve **7**.

FIG. 3 shows the way in which relatively diluted metal vapors are condensed on the inner surface of sleeve **7**, i.e. in discrete droplets with intervening spaces rather than in the form of a continuous conductor of current. The metal vapors diffusing through the pores in sleeve **7** into the radially outer body **3** of quartz sand are not sufficiently hot to fuse the quartz sand into a solid fulgurite. They fuse but surface elements of particles of quartz sand without fusing the particles of quartz sand through and through. In part the metal vapors condense in discrete or separate droplets on particles of quartz in a fashion similar to that shown in FIG. 3.

This particular non-fulgurite-forming performance of fusible element **6** and sleeve **7** is predicated on a limitation of arc energy, and does not occur if this condition is not met. The required limitation of arc-energy can, however, be achieved without difficulty and is compatible with an improved recovery of the break formed by overlay **5** in fuse link **4** at the occurrence of protracted small overload currents. It will be understood that on occurrence of such currents the current path through fusible element **4** is severed by the action of overlay **5**, whereupon fusible element **6** fuses forming a second break terminating the interrupting process initiated by formation of a break in fusible element **4**.

Major fault currents, or short-circuit currents, result in the formation of series breaks in fusible element **4**, followed by fusion of fusible element **6**.

FIG. 4 shows that in a fuse structure embodying this invention the degree of back-burn and metal vaporization is relatively small when interrupting protracted small overloads.

FIG. 5 shows a dramatic increase in the degree of back-burn and metal vaporization under similar conditions in a fuse not embodying the present invention.

It will be apparent to those skilled in the art that various changes and modifications may be made in the fuse structure illustrated and described without departing from the spirit and scope of the invention, as set forth in the appended claims.

I claim as my invention:

1. An electric fuse comprising in combination:

(a) a tubular casing of insulating material;

(b) a pair of terminal elements closing the ends of said casing;

(c) an arc-quenching quartz-sand-filler inside said casing;

(d) a first fusible element having a relatively large current-carrying capacity inside said casing, conductively interconnecting said pair of terminal elements and submersed in said quartz-sand filler;

(e) a second fusible element having a relatively small current-carrying capacity shunting said first fusible element; and

(f) a woven sleeve of glass fibers enveloping said second fusible element and separating said second fusible element from said quartz-sand-filler.

2. An electric fuse as specified in claim 1 wherein said first fusible element comprises a center portion having a predetermined length less than the length of said casing and formed by a metal ribbon having serially related points of reduced cross-section and bent to define a tubular structure and wherein said second fusible element and said woven sleeve are arranged inside of said tubular structure and exceed in length said predetermined length.

3. An electric fuse as specified in claim 1 wherein said sleeve has open ends situated adjacent to said pair of terminal elements but separated from said pair of terminal elements by layers of said quartz-sand-filler.

4. An electric fuse as specified in claim 2 wherein said first fusible element supports a mass of a metal having a lower fusing point than the metal of which said first fusible element is made.

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H. B. GILSON, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,341,674 September 12, 1967

Philip C. Jacobs, Jr.

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

Column 4, line 2, for "conductive" read -- conducive --; line 59, for "4" read -- 5 --; same column 4, lines 63 to 65, strike out "FIG. 5 shows a dramatic increase in the degree of back-burn and metal vaporization under similar conditions in a fuse not embodying the present invention.".

Signed and sealed this 20th day of August 1968.

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents