Dec. 13, 1966 P. C. HITCHCOCK 3,291,939

FUSE STRUCTURE HAVING ARC-QUENCHING SLEEVE

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Fig. 1.

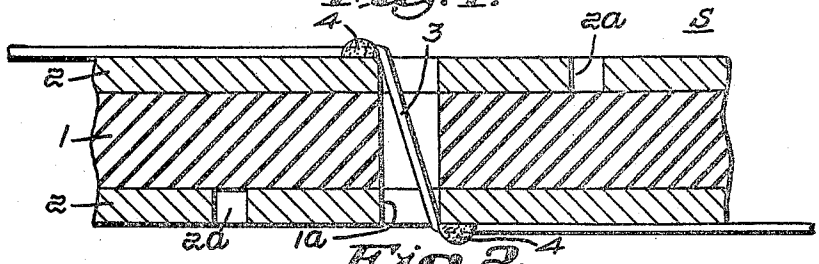


Fig. 2.

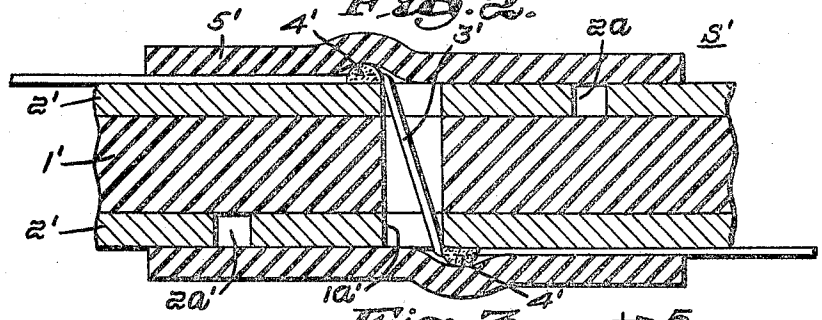


Fig. 3.

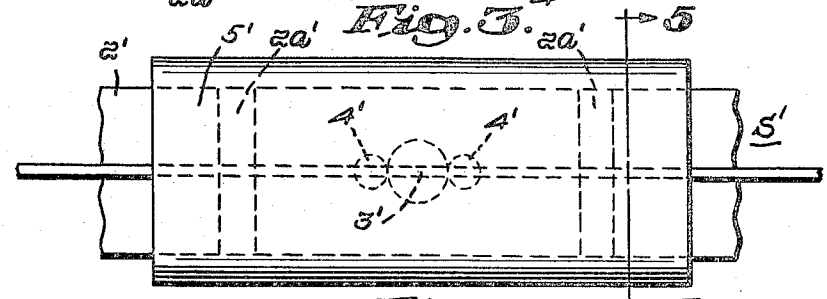


Fig. 4.

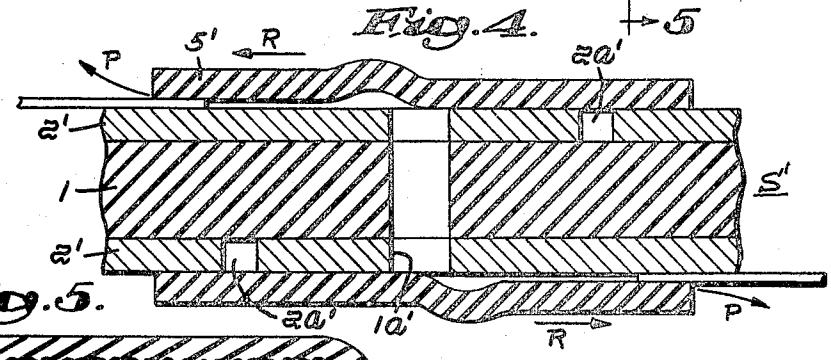
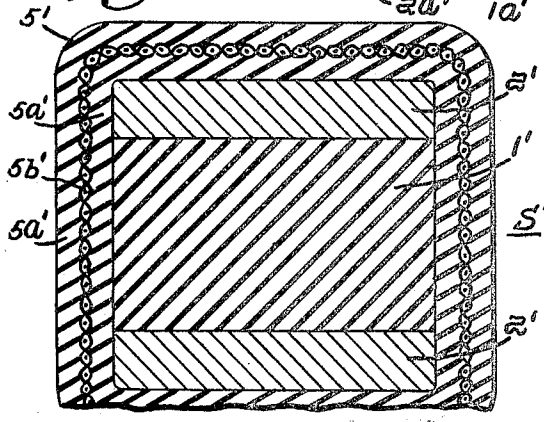


Fig. 5.



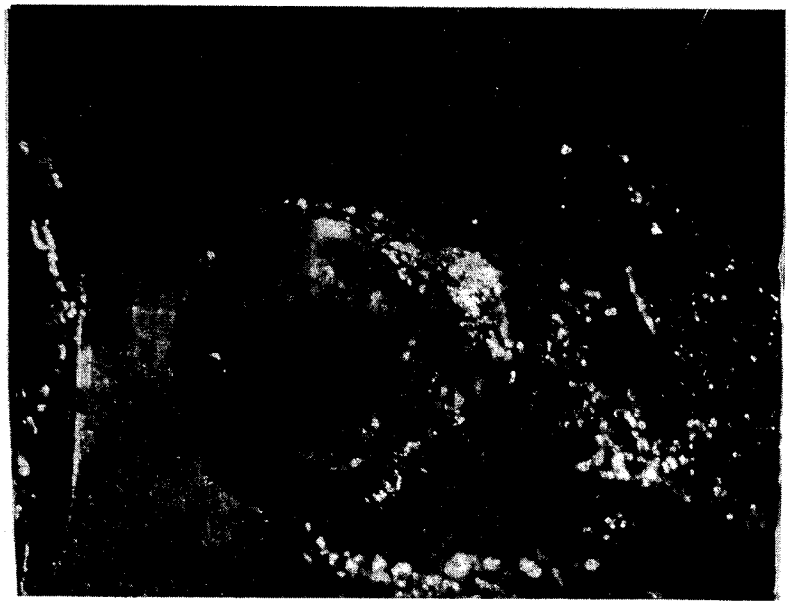
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FUSE STRUCTURE HAVING ARC-QUENCHING SLEEVE

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FIG. 6



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3,291,939

FUSE STRUCTURE HAVING ARC-QUENCHING SLEEVE

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7 Claims. (Cl. 200—120)

This invention has reference to electric fuses.

It is one object of this invention to provide electric fuses having novel and improved arc-quenching means.

It is another object of this invention to provide electric fuses having point-heat-source type fusible wires with novel and effective arc-elongating means resulting in a degree of arc elongation by far exceeding the available extremely short backburn length of such wires.

It is another object of this invention to provide electric fuses wherein a substantial degree of arc elongation is achieved by means of arc-runners and gas blast means for propelling the terminals of electric arcs along the arc-runners.

Another object of this invention is to provide an improved version of the kind of fuses disclosed and claimed in United States Patent 2,856,488 to Frederick J. Kozacka, Oct. 14, 1958, Current-Limiting Fuses for Small Current Intensities, assigned to the same assignee as the present invention.

Another object of this invention is to provide electric fuses similar to those disclosed and claimed in United States Patent 2,895,031 to Frederick J. Kozacka,(July 14, 1959, Fusible Protective Devices, assigned to the same assignee as the present invention, but having performance characteristics which are even better than the performance characteristics of electric fuses manufactured in accordance with the teachings of the aforementioned patent.

Still another object of this invention is to provide fuses performing similar to the fuses disclosed and claimed in United States Patent 2,895,031 but being less expensive to manufacture.

For a better understanding of the present invention reference may be had to the accompanying drawings in which:

FIG. 1 is a longitudinal section of a portion of a prior art structure forming the point of departure of the present invention;

FIG. 2 is a longitudinal section similar to that of FIG. 1 showing a portion of a structure embodying the present invention;

FIG. 3 is a top-plan view of the structure of FIG. 2;

FIG. 4 is a longitudinal section of the structure of FIG. 2 in the process of performing a very severe interrupting duty;

FIG. 5 is a section on a larger scale taken along 5—5 of FIG. 3; and

FIG. 6 is a photomacrograph of the structure of FIGS. 2 to 5, inclusive, upon the performance of a severe interrupting duty close to the limit of the interrupting capacity thereof.

Referring now to the drawings, and more particularly to FIG. 1 thereof, reference character S has been applied to generally indicate a length of copper-clad organic insulating material of the kind widely applied in making so-called printed circuits. Strip S is a laminate including the inner layer 1 of organic insulating material which is sandwiched between the two outer layers 2 of metal, preferably copper. Strip S is provided with a narrow circular bore or passage 1*a* extending transversely across layer 1 and layers 2. A wire 3, preferably of silver, is threaded through bore or passage 1*a*. The outer ends of wire 3 are conductively connected to layers 2. Reference numeral 4 has been applied to indicate solder joints

conductively connecting the ends of wire 3 outside of bore or passage 1*a* to copper layers 2. Transverse grooves 2*a* extend all the way across copper layers 2, thus interrupting the current path formed by upper copper layer 2 as well as interrupting the current path formed by the lower copper layer 2. The structure of FIG. 1 thus establishes the following current path: left portion of upper copper layer 2, upper solder joint 4, portion of wire 3 in bore or passage 1*a*, lower solder joint 4, right portion of lower copper layer 2.

FIG. 1 has been drawn on a very large scale. Actually the current-carrying length of wire 3 is sufficiently short to fairly approximate a point-heat-source. In other words, the current-carrying length of wire 3 hardly exceeds the thickness of a sheet of copper-clad laminate of the kind used in printed circuitry. Because of the shortness of the current-carrying length of wire 3 and because of the smallness of the cross-section thereof, the $\int i^2 \cdot dt$ values required for fusing and vaporizing the current-carrying length of wire 3 are very small. Thus an electric conductor including points of reduced cross-section formed by one or more serially connected portions of wire inside of one or more passages formed in a copper-clad laminate lends itself particularly well, when used as a fusible protective device, to minimize the required fusing $\int i^2 \cdot dt$ values. Because the burnback length of wire 3 is very short, i.e. because the current-carrying length of wire 3 situated between solder joints 4 and inside of bore or passage 1*a* is very short, a single break formed by fusion of the wire 3 shown in FIG 1 generates but a relatively small arc voltage. If the circuit voltage is relatively high, many units of the kind shown in FIG. 1 must be arranged in series—as shown in FIGS. 2–4 of the above referred-to United States Patent and described in connection therewith—to achieve the required increase of the arc voltage.

A further improvement of the arc voltage may be obtained by filling an appropriate synthetic resin into bore or passage 1*a*, thus plugging the latter. While this increases to some extent the arc voltage per point of break, it has no significant bearing on the available burnback-length which is substantially equal to the distance between the aforementioned solder joints 4.

The hottest point of fusible wire 3 is midway between solder joints 4. The portions of wire 3 which are situated outside of bore or passage 1*a* are shunted by copper layer 2 and, therefore, are virtually not carrying any current. Upon occurrence of an excessive current wire 3 melts at its hottest point midway between solder joints 4 and burns back toward solder joints 4. If the circuit is interrupted before, or at the time, the terminals of the arc reach solder joints 4, the performance of the structure of FIG. 1 is satisfactory. If the arcing persists after the arc terminals have reached solder joints 4, the arc terminals burn deep into solder joints 4 and metal layers 2, resulting in evolution of metal vapors adverse to successful interruption of the faulted circuit.

To achieve successful interruption of a faulted circuit increase of the number of breaks is not always a good answer to generation of insufficient arc voltages. Increasing of the number of breaks increases the initial arc voltage. Continued arc elongation increases the arc voltage in the more advanced stages of the interrupting process, rather than initially at the time of kindling of one or several arcs. Therefore increasing of the number of breaks and increasing of the length of backburn are not equivalents by any means.

The structure of FIGS. 2–4 is substantially the same as that shown in FIG. 1, but includes additional means allowing a larger degree of arc elongation than the structure of FIG. 1 and being more readily applicable and less expensive to apply than the synthetic resin filler of United States Patent 2,895,031.

In FIGS. 2–4 the same reference characters as in FIG. 1 with a prime sign added have been applied to indicate like parts. Thus S' is a strip of copper-clad organic insulating material comprising the inner insulating layer 1' sandwiched between outer copper layers 2'. The latter are provided with transverse grooves 2*a*' severing layers 2'. Wire 3' preferably of silver is threaded through bore or passage 1*a*' and conductively connected at 4' by solder joints to copper layers 2'. Sleeve 5' of a heat-shrinkable organic insulating material surrounds copper-clad strip or support S'. Sleeve 5' tightly seals both ends of bore or passage 1*a*' and fits tightly the portions of copper layers 2' adjacent passage 1*a*'. Sleeve 5' is preferably made of a modified polyolefin whose molecules have been cross-linked by high-energy electron beam radiation. Thus a compound is formed which does not melt or flow at any normal operating temperature to which sleeve 5' is subjected.

As shown in FIG. 5 sleeve 5' comprises an inner layer 5*a*' of irradiation cross-linked polyolefin tightly fitting strip S', an intermediate layer 5*b*' of glass-cloth and an outer layer 5*a*' of irradiation cross-linked polyolefin laminated together to form an integral sleeve structure. To achieve best performance sleeve 5' ought to be a laminated structure as indicated above, rather than to consist only of a heat-shrinkable substance such as irradiation cross-linked polyolefin. The intermediate glass cloth layer 5*b*' operates as an effective heat absorber after fusion of wire 3' and kindling of an arc at the point of wire 3', and it increases, in addition thereto, the mechanical strength of the composite sleeve 5'.

When an arc is kindled by fusion of wire 3' midway between solder joints 4', the structure performs initially in the same way as the structure of FIG. 1, i.e. the heat of the arc evolves jets of relatively cool gas from the organic insulating layer 1'. These jets of relatively cool gas penetrate, or diffuse, into the arc path and tend to accelerate the dielectric recovery thereof.

Assuming the rate of dielectric recovery to be insufficient, i.e. assuming that the length of wire 3' between solder joints 4' is completely consumed or vaporized, and that the arc terminals therefor arrive at solder joints 4' and at the portion of sleeve 4' immediately adjacent thereto. This results in generation of high gas pressures inside of passage 3 caused by the evolution of gas from sleeve 5' tending to drive, or propel, the arc terminals along copper layers 2' in opposite directions longitudinally of strip S'. This results in a significant elongation of the arc and a significant increase of the arc voltage at a period of time following arc initiation rather than at the time of arc initiation.

It will be understood that the arc which is kindled upon fusion of wire 3' midway between points 4' is subjected to various actions. The relatively cool gases evolved from the lateral walls of bore or passage 1*a*' mix turbulently with the hot gases at the immediate arcing zone and tend to decrease the ionization of the latter. There is an electromagnetic or electrodynamic loop action tending to project the portion of the arc immediately adjacent copper layers 2' against the inner surface of sleeve 5'. The sleeve 5' reacts to the movement of the arc toward it by ejecting jets of relatively cool gas toward the portions of the arc moving toward it. The pressure inside bore or passage 1*a*' tends to drive the arc terminals axially outwardly away from bore or passage 1*a*'. When the arc terminals have moved to points 4' where a conductive connection is established between copper layers 2' and wire 3', the arc terminals are virtually in physical engagement with sleeve 5', resulting in intense evolution of gases therefrom right into the terminals of the arc then. The terminals of the arc move, or are propelled, under the action of these various effects axially outwardly as indicated by arrows R in FIG. 4. The terminals of the arc may cause some burning of copper layers 2', but the degree of burning is not so severe as to immobilize the arc terminals by formation of deep electron-emitting craters. Thus copper layers 2' form a kind of arc runner, i.e. a means along which the arc terminals are moved or propelled and kept in motion. This is clearly apparent from the photomacrograph of FIG. 6. FIG. 6 shows the arc path along one of layers 2'. The arc path is a severe burning of layers 2' resulting from a very onerous test close to the limit of the interrupting capacity of the device. Consequently the arc path is conspicuous and comprises numerous beads of melted metal. Yet, nevertheless, as is clearly apparent from FIG. 6, the arc terminals have been kept in motion axially outwardly resulting in progressive elongation of the arc path and in progressive addition of points of sleeve 5' as cross-gas-blast-generating means. The arc path is immobilized except that the arc terminals are allowed to travel and, therefore, the arc path cannot move away from the immediately adjacent gas-evolving increments of sleeve 5' and thus avoid the intense de-ionizing action of the latter.

The structure of FIGS. 2–5 can readily be designed in such a fashion as to avoid a motion of the terminals of the arc beyond sleeve 5', i.e. outside of the area covered by sleeve 5'. At relatively severe interruptions hot arc products will be ejected from sleeve 5', as indicated by the arrows P in FIG. 4. Hence it is necessary, or desirable, to enclose the structure of FIGS. 2–5 in a tubular casing substantially in the same fashion as illustrated in FIG. 7 of the aforementioned United State Patent 2,895,031 to Frederick J. Kozacka.

While FIGS. 2–5 show an interrupting device embodying this invention including a current path having but one single break-forming point of reduced cross-section formed by a length of wire, a plurality of such points may be arranged in series as shown in FIGS. 3 and 4 of the aforementioned United States Patent 2,856,488 to Frederick J. Kozacka.

Structures of the kind shown in FIGS. 2–5, inclusive, are made by mounting a sleeve of a heat-shrinkable material loosely upon a wired copper-clad strip as shown in FIG. 1 and thereafter heating the sleeve to cause shrinking thereof. The sleeve then shrinks under stress around the wire support S and its metal layers 2. When the shrinking process is completed the heat-shrinkable sleeve is tightly clamped against both ends of the transverse wire-receiving passage 1*a* in strip or support S, and also tightly clamped against the portions of the metal overlay 2 adjacent said passage.

It will be understood that though but one embodiment of the invention has been 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. An electric fuse comprising in combination:
   (a) a support of organic insulating material defining a transverse passage;
   (b) metallic means cladding opposite sides of said support;
   (c) a fusible element threaded through said passage having ends situated outside said passage and conductively connected to said metallic means; and
   (d) gas-evolving means responsive to fusion of said fusible element and kindling of an arc for establishing a gas-blast moving the terminals of said arc beyond the break formed upon fusion of said fusible element between said metallic cladding means along said metallic cladding means in substantially opposite directions, said gas-evolving means including a sleeve of a heat-shrinkable organic insulating material shrunk under stress around said support and around said metallic means, said sleeve being tightly clamped against both ends of said passage and being tightly clamped against the portions of said metallic means adjacent said passage.

2. An electric fuse comprising in combination:
(a) a support of organic insulating material defining a transverse passage;
(b) copper layers cladding opposite sides of said support;
(c) a fusible wire threaded through said passage having ends situated outside said passage and conductively connected to said layer; and
(d) gas-evolving means responsive to fusion of said fusible wire and kindling of an arc for establishing a gas-blast moving the terminals of said arc beyond the ends of said wire in substantially opposite directions along said copper layers, said gas-evolving means including a sleeve of a laminate having outer layers of a heat shrinkable organic insulating material and an inner layer of glass-cloth, said sleeve being shrunk under stress around said support and around said copper layers, and said sleeve being tightly clamped against both ends of said passage and being tightly clamped against the portions of said copper layers adjacent said passage.

3. An electric fuse comprising in combination:
(a) a support of organic insulating material defining a transverse passage;
(b) copper layers cladding opposite sides of said support;
(c) a fusible silver wire threaded through said passage having ends situated outside said passage and conductively connected to said copper layers; and
(d) gas-evolving means responsive to fusion of said fusible wire and kindling of an arc for establishing a gas-blast moving the terminals of said arc beyond the ends of said wire in substantially opposite directions along said copper layers, said gas-evolving means including a sleeve of a laminate having outer layers of radiation cross-linked heat-shrinkable polyolefin and an inner layer of glass-cloth sandwiched between said outer layers, said sleeve surrounding said support and said copper layers, and said sleeve tightly sealing both ends of said passage and tightly fitting the portions of said copper layers adjacent said passage.

4. An electric fuse comprising in combination:
(a) a metal clad strip of organic insulating material defining a transverse passage;
(b) a length of wire threaded through said passage and having one end conductively connected to the upper metal-cladding and another end conductively connected to the lower metal-cladding of said strip; and
(c) gas-evolving means responsive to fusion of said length of wire and kindling of an arc for establishing a blast of gas moving the terminals of said arc beyond the ends of said wire in substantially opposite directions along said upper metal-cladding and along said lower metal-cladding of said strip, said gas-evolving means including a sleeve surrounding said strip at the region of said transverse passage thereof, said sleeve comprising layers of heat shrinkable organic insulating material sandwiching therebetween a layer of fiber glass material, said sleeve being shrunk under stress around said strip and being tightly clamped against both ends of said passage and being tightly clamped against said strip along the entire length thereof surrounded by said sleeve.

5. An electric fuse comprising in combination:
(a) a metal clad strip of organic insulating material defining a transverse passage;
(b) a length of wire threaded through said passage and

having one end conductively connected to the upper metal-cladding and the other end conductively connected to the lower metal-cladding of said strip; and
(c) gas-evolving means responsive to fusion of said length of wire and kindling of an arc for establishing a blast of gas moving the terminals of said arc beyond the ends of said wire in substantially opposite directions along said upper metal-cladding and along said lower metal-cladding of said strip, said gas-evolving means including a sleeve surrounding said strip at the region of said transverse passage, said sleeve comprising layers of heat shrinkable polyolefin sandwiching therebetween a layer of fiber glass material, said sleeve being shrunk under stress around said strip and being tightly clamped against both ends of said passage and being tightly clamped against said strip along the entire length thereof surrounded by said sleeve.

6. An electric fuse comprising in combination:
(a) a copper-clad strip of organic insulating material defining a transverse passage;
(b) a length of wire threaded through said passage and having one end conductively connected to the upper copper-cladding layer and the other end conductively connected to the lower copper-cladding layer of said strip; and
(c) gas-evolving means for propelling arc terminals formed on said upper copper-cladding layer and on said lower copper-cladding layer upon fusion of said wire in opposite directions longitudinally of said strip, said propelling means including a sleeve of a heat shrinkable organic insulating material shrunk under stress around said strip.

7. An electric fuse comprising in combination:
(a) a copper-clad strip of insulating material defining a transverse passage;
(b) a length of wire threaded through said passage and having one end conductively connected to the upper cladding layer and the other end conductively connected to the lower cladding layer of said strip; and
(c) gas-evolving means for propelling arc terminals formed on said upper cladding layer and on said lower cladding layer upon fusion of said wire in opposite directions longitudinally of said strip, said propelling means including a sleeve of a laminate having layers of radiation cross-linked heat-shrinkable polyolefin sandwiching therebetween a layer of glass-cloth, said sleeve being shrunk under stress around said strip and being tightly clamped against both ends of said passage.

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