Aug. 14, 1945. C. G. SUITS ET AL 2,382,271

CURRENT LIMITING FUSE

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Fig. 1.

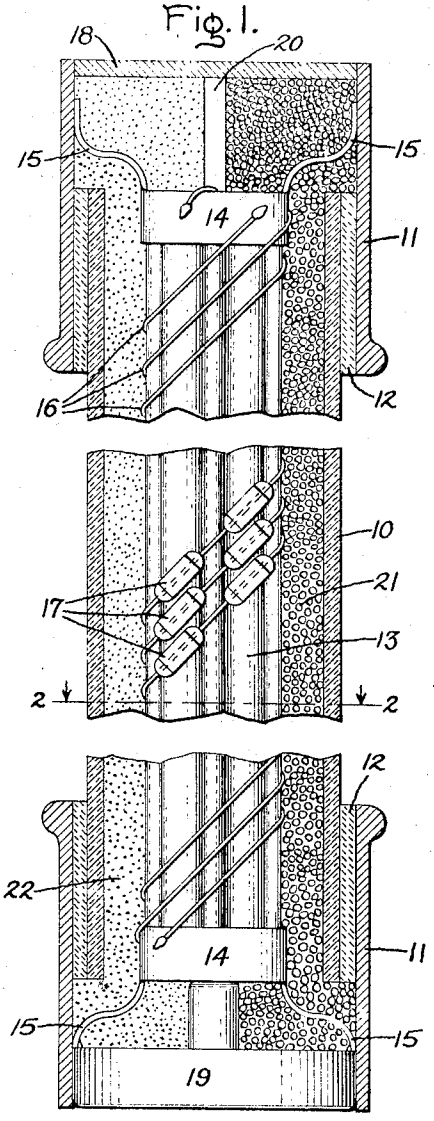


Fig. 3.

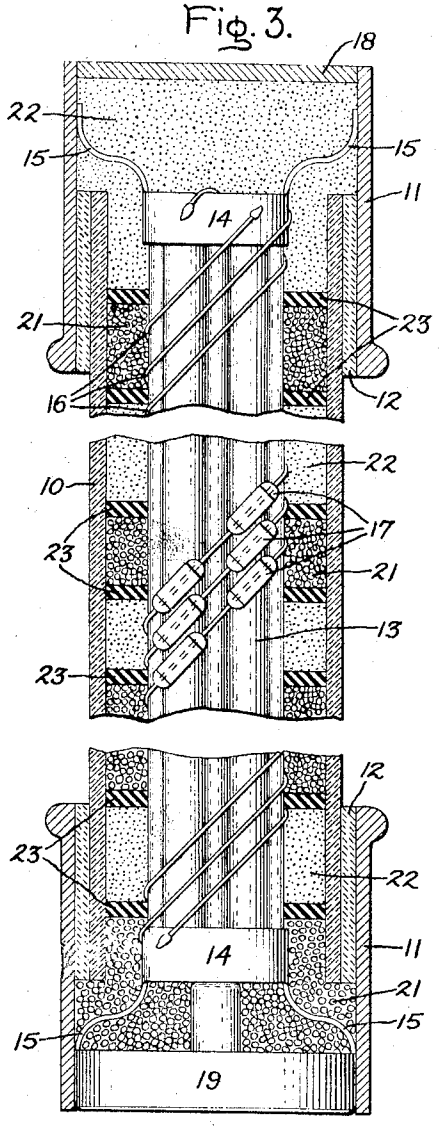
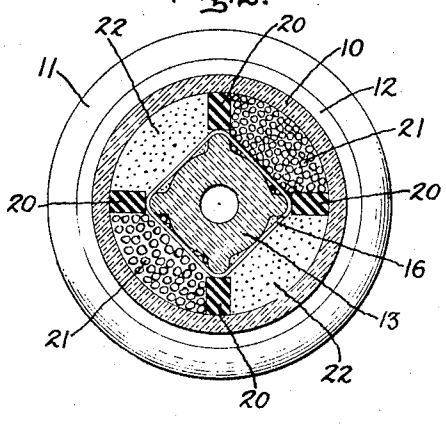


Fig. 2.



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CURRENT LIMITING FUSE

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7 Claims. (Cl. 200—120)

Our invention relates to fuses and more particularly to fuses of the current limiting type.

Current limiting fuses consist in the main of a fusible element in the form of one or more conductors of suitable metal, such as silver or zinc, embedded in a granular inert or refractory arc-extinguishing material of high dielectric strength, such as sand or relatively finely divided quartz, the conductor or conductors in some instances being wound on a supporting core of high temperature resistance ceramic material. To these parts are added an enclosing housing and terminals for the conductors.

Upon subjection of such fuse to currents of large magnitude, such as upon short circuit, the fusible element attains fusing temperature and vaporizes, whereupon arcing occurs and the metal vapors rapidly expand to many times the volume originally occupied by the fusible element itself. The force of this expansion throws the metal vapors out of the arc path and into the spaces between the granules of inert filler material. These vapors condense upon the surfaces of the relatively cool granules and no longer are available for current conduction so that arcing is confined to the small space previously occupied by the fusible element. The intimate physical contact between the hot arc column and the relatively cool granules causes an exceedingly rapid transfer of heat from the arc to the granules resulting in a high voltage drop per unit length of arc column. The arc energy is dissipated in this heat transfer with practically negligible net pressure within the fuse enclosure. During the arcing period, the granules in the vicinity of the arc melt and upon cooling form a hollow shell or fulgurite consisting of fused quartz, if the arc extinguishing material is granular quartz, and a small percentage of the metal from which the fusible conductor is made. This fused shell has the properties of an insulator and in the normal operation of the fuse does not constitute a current conducting element in the current path.

As a result of the actions referred to in the preceding paragraph, there is in effect suddenly inserted into the path of the current at the instant of melting of the fusible element the high resistance formed by the arc column which initially limits the current to a magnitude which is only a small fraction of that which the system is capable of producing. The inserted resistance causes rapid current decay and subsequent interruption of the current flow with negligible mechanical disturbance, there being no gassing or discharge of vapors or particles and practically no noise.

As noted above in highly inductive circuits, the sudden insertion of resistance and rapid decay of current results in voltage surges which under some conditions may attain magnitudes sufficiently high to damage other apparatus in the system. It is both desirable and necessary to limit these voltage surges to safe magnitudes.

It is an object of our invention to provide a new and improved means for limiting the surge voltages which occur upon operation of a current limiting fuse.

It is another object of our invention to provide new and improved means for effectively retarding the insertion of resistance into the current path without detracting from the final current interrupting action of a current limiting fuse.

Further objects and advantages of our invention will become apparent as the following description proceeds and the features of novelty which characterize our invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Referring now to the drawing, Fig. 1 is a cross-sectional view of a current limiting fuse embodying our invention; Fig. 2 is a sectional view taken on line 2—2 of Fig. 1 assuming that Fig. 1 is not in section, and Fig. 3 is a cross-sectional view similar to Fig. 1 illustrating a modification of our invention.

As was mentioned above the fused shell which forms upon operation of a current limiting fuse of the type referred to above is a relatively good insulator and although it is shunted across the terminals of the circuit to be interrupted, it does not under ordinary conditions limit the interrupting ability seriously. However, near the maximum voltage condition under which the fuse will operate and when relatively minor impurities are found in the otherwise pure inert granular material such as quartz sand, the current conduction in this fused column does lead to interruption failures. We have found, however, that when a very fine grain crystalline quartz powder is used instead of quartz sand, the fulgurite formation is avoided, the fusion of the powder forming globules or beads instead of a continuously fused tube as described above.

This result increases the interrupting limit of the fuse and avoids failures to interrupt that may be caused by impurities in the filling material. Since the cooling of the arc column provided by the quartz powder is greater than that found for relatively coarse-grained sand and since this

results in an extremely rapid development of a high voltage gradient in the arc discharge column, high voltage surges may be induced in inductive circuits.

The favorable result of the fuse action described is to limit the maximum current during interruption to a small fraction of that which the system is capable of producing. To attain the desirable end of a more gradual insertion of resistance into the circuit whereby the voltage surges produced are minimized, we have found it desirable to subdivide the total length of the fusible element or elements in such a manner that these elements are alternately surrounded by the fine-grained and coarse-grained sand. Those sections of the fusible element which are embedded in the fine-grained sand function as described above to produce a high voltage gradient, but no continuous fused element in the discharge path. Conversely, those portions of the fusible element which are surrounded by coarse-grained sand produce relatively small voltage gradients but have the property of forming a continuous fused tube along the discharge path. By alternating the fine-grained and coarse-grained sand, the desirable objective is achieved of having no continuous fused path between the terminals of the fuse and having a high voltage gradient—and hence a high interrupting ability—which is, however, developed in a step-wise manner so that abnormal voltage surges are not produced in inductive circuits.

The current limiting fuse of Fig. 1 is illustrated as comprising an enclosing tubular casing 10 of insulating material such as fiber or glass upon the opposite ends of which are mounted terminals 11 as by a suitable seal 12. If casing 10 is constructed of glass then 12 is a suitable glass-to-metal seal. Within the casing is a star-shaped core 13 of high temperature resisting ceramic material which has terminal collars 14 supported on opposite ends thereof and respectively connected to the casing terminals 11 by means of electrically conductive strips 15.

A plurality of fusible conductors 16 are spirally wound on supporting core 13 which electrically interconnect terminal collars 14 of the star-shaped core 13. Small sections of the conductors 16 intermediate their ends are enclosed in beads 17 of ceramic material which provide thermal chambers and serve to isolate the enclosed sections of the conductors from the inert arc-extinguishing medium in which the conductors are embedded and which will be described in greater detail hereinafter. Thus heat radiation from the enclosed sections of the conductors is retarded as compared with the heat radiation from those portions of the conductors which are in contact with the interrupting media so that fusion of the conductors at the enclosed sections is insured under low current conditions.

The upper end of the current limiting fuse having a tubular casing 10 is closed by a suitable end closure member such as 18. A suitable indicator 19 such as is disclosed and claimed in United States Letters Patent 2,188,816—Rankin, granted January 30, 1940 and assigned to the same assignee as the present application, is provided in order to indicate whether the fuse has operated.

In order to limit the surge voltage which would occur upon the operation of the current limiting fuse described thus far without any additional means, our invention is specifically concerned with embedding portions of the fusible member 16 in inert granular arc-extinguishing material of varied grain size. This arc-extinguishing material may comprise sand, finely divided quartz, or like material, which is inert or non-gas-producing at the arc temperatures likely to be encountered upon fuse operation. As is best shown in Fig. 2, tubular casing 10 is longitudinally divided as by spacer members 20, into a plurality of compartments. Alternate compartments are filled as indicated with inert granular material of relatively large grain size 21, while the remaining compartments are filled with an arc-extinguishing material 22 having a very fine grain size. With this arrangement the fusible conductors 16, spiralled about ceramic core 13 have succesive portions along the length thereof embedded in layers of finely divided granular material and layers of coarsely divided granular material. Due to the different cooling features of these materials, a progressive or step-by-step development of voltage gradient in the discharge column is secured so as to greatly limit the surge voltage.

It should be understood by those skilled in the art that in certain cases it might be desirable to dispense with the supporting core 13.

It will be obvious from the description included above that instead of providing longitudinal spacer members 20 to produce separate compartments for the inert-arc-extinguishing material in casing 10, that a plurality of separate tubes might be provided in casing 10. Such a multi-tube construction is disclosed in United States Letters Patent 2,143,038—Smith. These separate tubes would be filled with granular material having different grain sizes.

In Fig. 3 we have illustrated a modification of our invention and the corresponding parts in Fig. 3 are designated by the same reference numerals as in Fig. 1. Instead of longitudinally dividing tubular casing 10 by means of spacer members 20 as indicated in Figs. 1 and 2, the casing 10 is divided into a plurality of compartments axially spaced from one another by means of separators 23, which may be equally spaced from one another or which may have a varied spacing as indicated in Fig. 3. Alternate compartments are filled with coarse grain arc-extinguishing material 21 while the remaining compartments are filled with material 22 having a very fine grain size. As in the case of Fig. 1 the fusible conductors 16 have successive portions thereof embedded in fine and coarse grain inert arc-extinguishing material by means of which progressive or step-by-step dissipation of the fusible element or conductors is secured with the consequent limitation of the surge voltage which might otherwise result.

While we have disclosed certain particular embodiments of our invention, it will be apparent to those skilled in the art that our invention is not limited to the particular construction shown, but that changes and modifications may be made without departing from the spirit and scope of our invention and we aim in the appended claims to cover all such changes and modifications.

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

1. In a fuse of the current limiting type including spaced terminals having an elongated fusible element designed to dissipate throughout substantially the whole of its length interconnecting said terminals, an arc-quenching material surrounding said fusible element, said arc-quenching material comprising alternate layers of large grain size and small grain size inert nonconduct-

ing material so that successive portions of said fusible element are embedded in material of different grain size to limit the surge voltage on an associated system due to the current limiting action of said fuse.

2. In a fuse of the current limiting type comprising a casing, an inert arc-quenching material filling said casing, a pair of spaced terminals mounted on the said casing and a fusible element designed to dissipate throughout substantially the whole of its length embedded in said arc-quenching material interconnecting said terminals, said arc-quenching material comprising a layer of fine grain inert nonconducting material and a layer of coarse grain inert nonconducting material so that said fusible element is embedded in both said fine grain and coarse grain material to limit the surge voltage on an associated system due to the current limiting action of said fuse.

3. An enclosed high voltage fuse of the type having a fusible conductor designed to dissipate throughout substantially the whole of its length embedded in an inert arc-extinguishing medium, said fuse being provided with means for precluding the occurrence of overvoltages during circuit interruption characterized by the fact that in order to reduce the overvoltages successive portions of the fusible conductor are embedded in inert nonconducting arc-extinguishing mediums of the same material but of considerably different grain size.

4. A high voltage circuit-interrupting device including an insulating casing, an insulating support arranged in said casing, a circuit interrupting element having a long fusible section designed to dissipate ultimately throughout substantially the whole of its length, means for dividing said casing into a plurality of compartments, an inert nonconducting finely divided arc-extinguishing material in certain of said compartments, and a coarse granular inert nonconducting arc-extinguishing material in other of said compartments, whereby effective limitation of the surge voltage encountered upon operation of the circuit-interrupting device is provided.

5. A high voltage circuit-interrupting device including an insulating casing, an insulating support arranged in said casing, a circuit interrupting element having a long fusible section designed to dissipate ultimately throughout substantially the whole of its length, means for longitudinally dividing said casing into a plurality of compartments, an inert nonconducting finely divided arc-extinguishing material in certain of said compartments, and a coarse granular inert nonconducting arc-extinguishing material in other of said compartments, whereby effective limitation of the surge voltage encountered upon operation of the circuit-interrupting device is provided.

6. A high voltage circuit-interrupting device including a tubular insulating casing, an insulating support arranged in said casing, a circuit interrupting element having a long fusible section designed to dissipate ultimately throughout substantially the whole of its length, means for dividing said casing into a plurality of compartments longitudinally spaced from one another along the axis of said tubular casing, an inert nonconducting finely divided arc-extinguishing material in certain of said compartments, and a coarse granular inert nonconducting arc-extinguishing material in other of said compartments whereby effective limitation of the surge voltage encountered upon operation of the circuit-interrupting device is provided.

7. An enclosed high voltage fuse of the type having a fusible conductor designed to dissipate throughout substantially the whole of its length embedded in an inert arc-extinguishing medium, said fuse being provided with means for precluding the occurrence of overvoltages during circuit interruption characterized by the fact that in order to reduce the overvoltages successive portions of the fusible conductor are embedded in inert nonconducting granular arc-extinguishing mediums having a considerably different grain size.

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