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K. A. LOHAUSEN
CURRENT LIMITING FUSE
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Fig. 1.

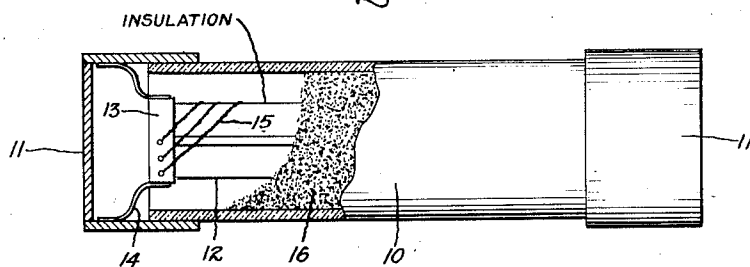


Fig. 2.

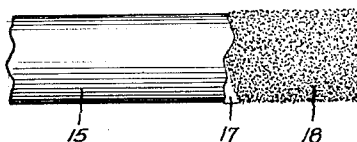
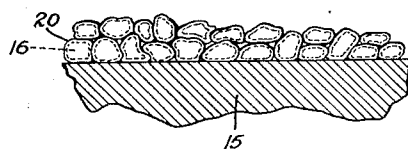


Fig. 3.



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UNITED STATES PATENT OFFICE

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CURRENT LIMITING FUSE

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20 Claims. (Cl. 200—120)

The present invention relates to fuses and has for a principal object the provision of improvements in the construction of 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 resistant ceramic material. To these parts are added an enclosing housing and terminals for the conductors.

Upon subsection 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 and the relatively cool granules causes an exceedingly rapid transfer of heat from the arc to the granules, and most of the arc energy is dissipated in this heat transfer with practically negligible pressure within the fuse enclosure. Also, it is believed that during the arcing period the portion of the filler material in immediate contiguity with the fusible element fuses so that it loses some of its resistance value and becomes a partial conductor, and that at least a portion, if not all, of the arc current transfers to this immediately surrounding fused shell of filler material. Then, upon extinction of the arc, the fused shell cools off and solidifies in the form of a hollow shell, which may be termed a "fusion shell" or "fulgurite", so that the material finally regains the properties of an insulator and inserts an extremely high resistance into 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 a high resistance 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 tends to increase rapidly, with

consequent rapid current decay and subsequent interruption of the current flow with negligible disturbance, there being no gassing or discharge of vapors or particles and practically no noise.

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. I have found that this result may be accomplished in a very effective manner by securing a less rapid insertion of resistance into the current path upon vaporization of the fusible element.

It is therefore an object of my present invention to provide means for effectively retarding insertion of resistance into the current path without detracting from the final current interrupting action of the fuse. In general, I accomplish this result in accordance with the present invention by placing around the fusible element and in immediate contiguity therewith a substance or material different in characteristics from the principal filler material, such as sand or granular quartz, in such manner that the fused shell initially formed upon vaporization of the fusible element has relatively less resistance than would be the case if the fusible element were embedded only in the principal filler material in pure form. As a result of this expedient, the voltage at the instant of fuse operation, which depends upon the resistance initially inserted and the magnitude of current flow at the instant of vaporization of the fusible element, is limited in magnitude. However, the added material is of such nature and so arranged that, as the interrupting process proceeds and the fused shell increases in cross section, the degree of concentration of the added material decreases so that the overall resistance of the fused shell increases finally to interrupt the current. This subsequent increase in resistance is not effective to produce undesirable magnitudes of voltage surge since in the meantime the current is decreasing.

My invention will be more clearly understood from the following description of exemplary practical arrangements for accomplishing the desired objectives, taken in conjunction with the accompanying drawing in which Fig. 1 illustrates an exemplary form of current limiting fuse employing an additional filler material in accordance with the invention; Fig. 2 is an enlarged view showing diagrammatically details of the arrangement and manner of application of the additional

filler material in the fuse of Fig. 1, and Fig. 3 is an enlarged detail view showing diagrammatically an alternative arrangement and manner of application of the additional filler material.

5 The fuse of Fig. 1 has an enclosing tubular casing 10 of suitable insulation material, such as fibre or glass, upon the opposite ends of which are mounted terminals 11. Within the casing is a star-shaped core 12 of high temperature resist-
10 ing ceramic material which has terminal collars 13, one of which is shown in the drawing, supported on opposite ends thereof and respectively connected with the casing terminals 11 by means of electrically conductive strips 14. A plurality of
15 fusible conductors 15 are wound spirally on the core and connected in parallel between terminal collars 13. Disposed within the interior of the casing and embedding the core and conductors is a body of granular inert or refractory arc-
20 quenching material 16 of high dielectric strength such as, for example, sand or relatively finely divided quartz.

In the embodiment of Fig. 1, the conductors are provided with a coating 17 which may be ap-
25 plied thereto in any suitable manner, such as by dipping or spraying, and which consists of a suitable tacky material such as sodium silicate, or water glass solution, capable of retaining a finely divided material 18, as diagrammatically illus-
30 trated in Fig. 2. Material 18 in the illustrated embodiment consists of sand ground to a finer grain size than that of the main filler 16 and dusted or otherwise applied to the coating 17. The intermediate layer comprising the combina-
35 tion of very fine sand and sodium silicate coating has in itself a greater conductivity at high temperatures than that of the main filler. The conductivity of this intermediate layer may be increased further by treating the same with iron
40 sulphate solution since even a low content of iron increases the electric conductivity of sand or similar filling material at high temperatures. Alternatively, the material 18 of the layer may
45 consist of aluminum oxide or a mixture of aluminum oxide and silicon dioxide.

With the above described arrangement, upon subjection of the conductors to short-circuit current, the relatively conducting layers immediately
50 surrounding the conductors, and comprising coating 17 and material 18, tend to take over the current flow during the initial stages of the interruption process so that initially the resistance inserted in the current path is not as
55 great as would be the case if the material, such as sand or granular quartz, of the main filler were employed alone. As the interruption process proceeds and the portion of the main filler material adjacent the fusible conductors attains
60 fusing temperature, the material of the innermost layers, comprised of coating 17 and material 18, combines with the main filler material. As a result of this the degree of concentration of the material of the innermost layers decreases
65 with increasing thickness of the fused shells around the conductors, with the result that the resistance of the fused shells increases, as is desired. This resistance finally attains sufficient
70 magnitude to interrupt the current flow and the fused shells cool and solidify into "fusion shells" or "fulgurites" in the manner previously pointed out. Thus, there is inserted into the current
75 path an initial resistance which is relatively low, so as not to produce voltage surges of undesirable magnitude, but which is sufficiently high to initiate decay of the current, while subsequently

this resistance increases to a value which finally is capable of completely interrupting the current flow.

The added filler material may be applied
5 around the conductors in the form of several layers having different compositions and thicknesses and so arranged that the layers which are successively closer to the conductors have successively lower resistances at high temperatures
10 as compared with the resistance of the material of the principal filler which is disposed outermost. By this arrangement, the materials of the inner layers in effect constitute impurities for the successively outer layers and a progressive
15 insertion of resistance into the current path thereby may be secured.

The added filler material may be applied also directly to the main filler material 16, as indicated in Fig. 3, by treatment of the main filler
20 material in any suitable manner, as by dipping or spraying, with a suitable substance such as a potassium silicate or iron sulphate solution, to form on the individual grains of the main filler a coating 20 capable initially of increasing the
25 surface and grain-to-grain conductivity over that which would be obtained if the main filler were employed alone in a pure and untreated form. During initial stages of interruption of high current under these conditions, the current tends to
30 flow over the surfaces of the individual grains and through the points of contact between the grains until such time has elapsed for sufficient heat to enter the grains to cause fusion thereof. Then, as the grains themselves fuse, the degree
35 of concentration of the impurity, in the form of the added substance, is reduced with consequent increase in resistance as the cross section of the fused shell increases. Finally, the degree of concentration of the impurity decreases to such an
40 extent that the overall resistance of the fused shell becomes substantially that of the material of which the grains of the main filler are comprised, which resistance is of sufficiently high
45 magnitude to interrupt the current flow.

Similar operation can be secured by mixing
45 with the main filler an added filler of the same composition but greatly reduced grain size, or by mixing with the main filler a substance of different composition, such as aluminum oxide, in
50 relatively finely divided form.

It is contemplated that with the benefit of the teachings hereinbefore set forth, there will suggest themselves to one skilled in the art various
55 other added materials and arrangements thereof for securing initially a fuse resistance which is relatively lower than that which otherwise would be secured if a principal filler of a material
60 such as sand or pulverized quartz were employed alone, and which fuse resistance subsequently increases to a magnitude sufficient for current interruption. It is intended therefore that the appended claims shall cover such modifications
65 as do not depart from the true spirit and scope of the present invention.

What I 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 an elongated fusible element and a body
70 of inert granular refractory arc-quenching material of high dielectric strength embedding said fusible element; a substance, of different characteristics from said first material, disposed in contiguity with said fusible element throughout at
75 least the major portion of the length of said element in said first material, which said substance

is of such composition and amount that the fused shell produced in said body of material adjacent the arc path initially upon fusion of said element is of substantially lower resistance than that of a fused shell which would be produced initially in said first material if the latter were employed without said substance, the composition and amount of said substance also being such that the substance allows relatively free diffusion of arc vapors into said first material during the current interrupting process, and that the condition of said substance changes during the interrupting process in a manner to cause increase in the resistance of the fused shell adjacent the arc path.

2. In a fuse of the current limiting type, including an elongated fusible element and a body of inert granular refractory arc-quenching material of high dielectric strength embedding said fusible element; a substance, of different characteristics from said first material and having greater electric conductivity at arc temperatures than said first-mentioned material, disposed in contiguity with said fusible element throughout at least the major portion of the length of said element in said first material; the composition and amount of said substance being such that it allows relatively free diffusion of arc vapors into said first-mentioned material during the current interrupting process and that the concentration of said substance decreases during the progress of the interrupting process so that there takes place an increase in the overall resistance of the fused shell formed adjacent the arc path.

3. In a fuse of the current limiting type including a body of inert granular refractory arc-quenching material of high dielectric strength and an elongated fusible element embedded in said body of material; a substance, of different characteristics from said first material, disposed in a relatively thin layer contiguously surrounding said element throughout at least the major portion of the length of said element in said first mentioned material and having a relatively greater electric conductivity at arc temperatures than said first mentioned material, said substance being of such character that it allows relatively free diffusion of arc vapors into said first-mentioned material during the current interrupting process.

4. In a fuse of the current limiting type including a body of inert granular refractory arc-quenching material of high dielectric strength and an elongated fusible element embedded in said body of material; a substance, of different characteristics from said first material, applied in the form of a coating directly on the surface of said element throughout at least the major portion of the length of said element in said first mentioned material and having a relatively greater electric conductivity at arc temperatures than said first mentioned material, said substance being of such character that it allows relatively free diffusion of arc vapors into said first material during the current interrupting process.

5. In a fuse of the current limiting type including a body of inert granular refractory arc-quenching material of high dielectric strength and an elongated fusible element embedded in said body of material; an adhesive coating on the surface of said element throughout at least the major portion of the length of said element in said body of material, and an additional material applied to said coating which said additional material

is of such composition as to afford in combination with said coating a relatively greater conductivity at arc temperatures than said first mentioned material, said coating being of such character that it allows relatively free diffusion of arc vapors into said first material during the current interrupting process.

6. In a fuse of the current limiting type including a body of sand and an elongated fusible element embedded in said body of sand; an adhesive coating applied to the surface of said element in said body of sand and finely ground sand applied to said coating, which said finely ground sand has substantially smaller grain size than said first-mentioned sand.

7. In a fuse of the current limiting type including a body of sand and an elongated fusible element embedded in said body of sand; an adhesive coating applied to the surface of said element in said body of sand, and finely ground sand applied to said coating, said last sand having substantially smaller grain size than said first sand and the layer comprised of said coating and finely ground sand being treated with a substance for increasing the electric conductivity of said layer at arc temperatures.

8. In a fuse of the current limiting type including a body of sand and an elongated fusible element embedded in said body of sand; a coating of water glass applied to the surface of said element in said body of sand and finely ground sand applied to said coating, said second sand being of substantially smaller grain size than said first sand and the layer comprised of said coating and finely ground sand being treated with an iron containing substance for increasing the electric conductivity of said layer at arc temperatures.

9. In a fuse of the current limiting type, a body of inert granular refractory arc-quenching material having a high dielectric strength, an elongated fusible element embedded in said body of material, and an additional substance, of different characteristics from said first material, surrounding the individual grains of at least that portion of said first mentioned material which is in contiguity with said element throughout at least the major portion of the length of said element, said additional substance being of such composition as to afford, during the initial stages of interruption of an excess current of large magnitude, a transition resistance from grain-to-grain which is relatively lower than the resistance of the material of which the grains themselves are composed.

10. In a fuse of the current limiting type, a body of inert granular refractory arc-quenching material having a high dielectric strength and an elongated fusible element embedded in said body of material, at least that portion of said body of material located in contiguity with said element throughout at least the major portion of the length of said element being treated with an additional substance forming on the individual grains of said material a coating having at arc temperatures a relatively lower resistance than the material of which the grains themselves are composed.

11. A fuse of the current limiting type, comprising a casing having spaced terminals; an elongated fusible element extending in said casing and connected between said terminals; a principal arc-quenching filler embedding said element and comprised of high dielectric strength refractory material having granular form such as to permit relatively free diffusion of arc vapors

- between the granules and which material is inert so as to be substantially non-gas-producing at arc temperatures; the character and arrangement of said fusible element and filler material being such that said material, if employed alone as the filler, would be capable of effecting sudden insertion into the current path, immediately upon fusion of said fusible element by large magnitude excess current, of a high resistance operative to limit the current flow to a fraction of that producible by the circuit in which the fuse is connected; and a substance, having different characteristics from said principal filler material, disposed in the principal filler in contiguity with said fusible element throughout at least the major portion of the length of said element for retarding the action of said principal filler material during the initial stage of the current interrupting process immediately following fusion of the fusible element; the composition and amount of which substance is such that it allows relatively free penetration of arc vapors into the principal filler during subsequent stages of the interrupting process and that the effect of the substance decreases during the subsequent stages of the interrupting process so that the resistance between said terminals increases due to the action of the principal filler material.
12. A current limiting fuse as defined in claim 11, further characterized in that the said substance is concentrated in a relatively thin layer closely surrounding the said fusible element.
13. A current limiting fuse as defined in claim 11, further characterized in that the said substance is embodied in a relatively thin coating applied directly on the surface of the said fusible element.
14. A current limiting fuse as defined in claim 11, further characterized in that the said principal arc-quenching filler is comprised of sand.
15. A current limiting fuse as defined in claim 11, further characterized in that said principal arc-quenching filler is comprised of relatively finely divided quartz.
16. In a fuse of the current limiting type, including spaced terminals having an elongated fusible element connected therebetween and a principal arc-quenching filler material comprised of sand embedding said fusible element; a substance disposed in said principal filler in con-

tiguity with said fusible element throughout at least a major portion of the length of the fusible element, which said substance includes finely ground sand having a grain size considerably smaller than that of said principal sand filler.

17. In a fuse of the current limiting type, including spaced terminals having an elongated fusible element connected therebetween and a principal arc-quenching filler material comprised of relatively finely divided quartz embedding said fusible element; a substance disposed in said principal filler in contiguity with said fusible element throughout at least a major portion of the length of the fusible element, which said substance includes pulverized quartz having a grain size considerably smaller than that of said principal quartz filler.

18. In a fuse of the current limiting type, including spaced terminals having an elongated fusible element connected therebetween and a principal arc-quenching filler material comprised of sand embedding said fusible element; a substance disposed in said principal filler in contiguity with said fusible element throughout at least a major portion of the length of the fusible element, which said substance includes aluminum oxide in finely divided form.

19. In a fuse of the current limiting type, including spaced terminals having an elongated fusible element connected therebetween and a principal arc-quenching filler material comprised of sand embedding said fusible element; a coating applied directly on the surface of said fusible element throughout at least a major portion of the length of the fusible element embedded in said principal filler, which said coating includes finely ground sand having a grain size considerably smaller than that of said principal sand filler.

20. In a fuse of the current limiting type, including spaced terminals having an elongated fusible element connected therebetween and a principal arc-quenching filler material comprised of sand embedding said fusible element; a coating applied directly on the surface of said fusible element throughout at least a major portion of the length of the fusible element in said principal filler, which said coating includes aluminum oxide in finely divided form.

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