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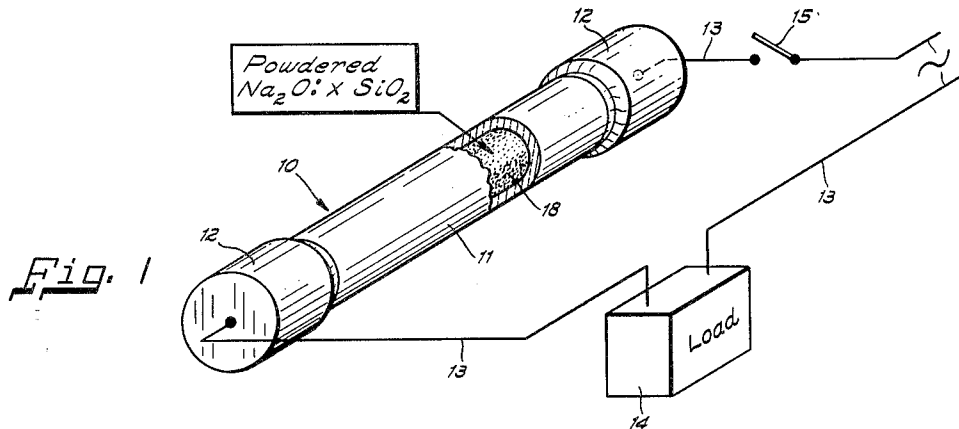
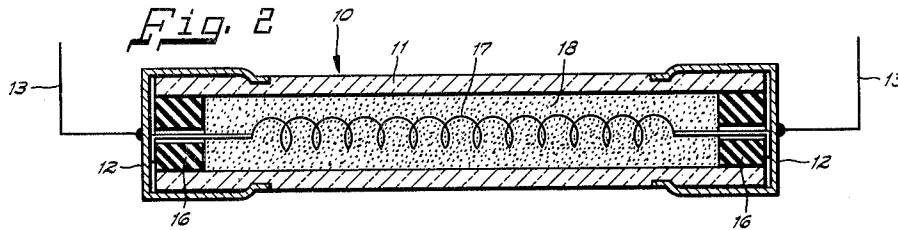
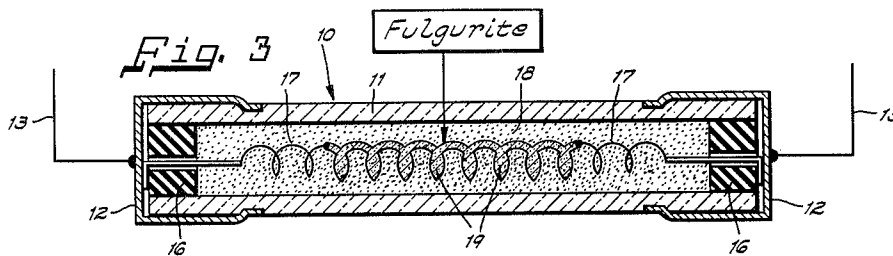
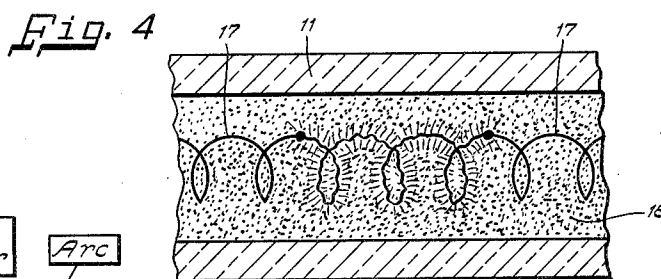
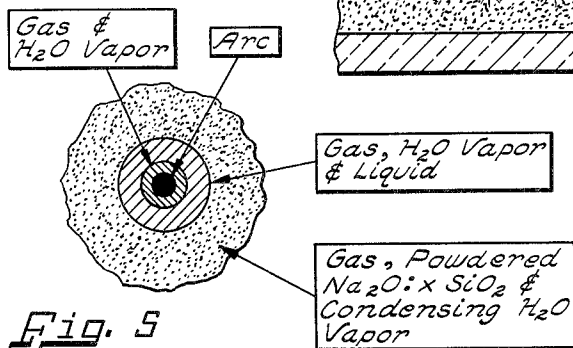
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FUSE WITH HYDRATED ARC EXTINGUISHING MATERIAL

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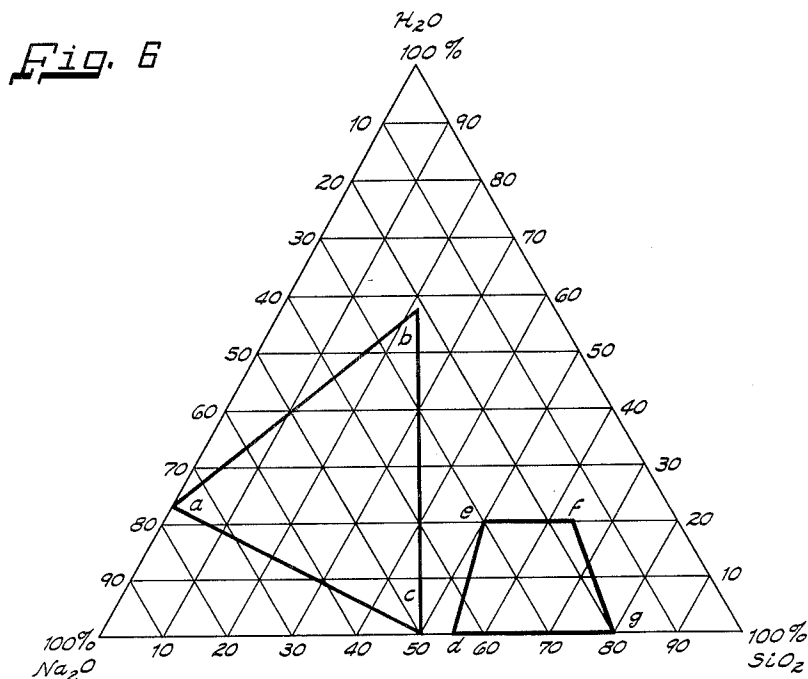
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2 Sheets-Sheet 2



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1

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FUSE WITH HYDRATED ARC EXTINGUISHING MATERIAL

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3 Claims. (Cl. 200-120)

The invention relates to circuit interrupters and more particularly to current interrupters of the fusible type having means for limiting the magnitude and duration of the current during current interruption.

A fuse is the simplest device used for interrupting an electric circuit under short-circuit and excessive overload current magnitudes. Several types of fuses are commercially available which utilize a suitable dielectric in surrounding relation to a fusible element to aid in extinguishing the arc formed when the fusible element melts.

In one type of fuse when fusible element is enclosed in an insulating tube filled with a suitable arc quenching liquid such as carbon tetrachloride, oil, or pyrene. The container for the liquid must be hermetically sealed to prevent the liquid from leaking or evaporating. Such liquid-filled fuses often give off toxic gases in manufacture and use. Further, the fusible elements of liquid-filled fuses are sometimes corroded by the arc extinguishing liquid unless the chemical components are of the highest purity. A further disadvantage inherent in a liquid-filled fuse is that due to cost and maintenance. A fuse of this type necessarily must be returned to the manufacturer for renewal, and an additional supply of fuses must be kept on hand to replace those being renewed. As the initial cost of installation is high, it follows that the maintenance cost may prove burdensome.

For certain protective applications enclosed fuses have been employed in the past incorporating a gas-producing solid filler material such as boric acid in surrounding relation to the fusible element. Such fuses generate large quantities of gas which are expelled from the fuse tube in interrupting the arc. Consequently, such expulsion type fuses cannot be utilized in many locations. Fuses employing solely a gas-producing material often fail entirely to interrupt extremely high short circuit currents, and further they do not open the circuit with sufficient rapidity so that the fuse arc resistance is introduced during the first half cycle of the short circuit current, i.e., they are not current-limiting.

Current limiting fuses, often referred to as "sand fuses," employ a finely divided inert filling material such as sand or pulverized quartz in surrounding relation to the fusible element. Current limiting fuses do not expel gases, and they introduce the fuse arc resistance during the first half cycle of the short-circuit current. However, because of the arc extinguishing characteristics of the sand, such fuses must be exceptionally long in order to provide the desired arc interrupting ability. Further, heating often becomes a problem in a sand fuse because of the long fusible section. Sand fuses suddenly insert a high resistance into the path of the current with the result that undesirable magnitudes of voltage surge occur in the circuit being interrupted.

2

It is an object of the invention to provide a compact fuse which need not be hermetically sealed; does not expel gases in extinguishing the arc; is non-toxic in manufacture and when clearing the arc; is inexpensive and simple to manufacture; utilizes components that do not corrode the fusible element and need not be chemically pure; which has excellent arc extinguishing characteristics; and which is current-limiting but does not insert the fuse arc resistance into the circuit with such rapidity that undesirable magnitudes of surge voltage result in the circuit being interrupted.

These and other objects and advantages of the invention will be readily apparent from the following detailed description when taken in conjunction with the accompanying drawing wherein:

FIG. 1 is a diagrammatic perspective view showing the preferred embodiment of the fuse of the invention connected in an electrical circuit;

FIG. 2 is a vertical sectional view through the fuse illustrated in FIG. 1;

FIG. 3 is a view similar to FIG. 2 after the arc has been cleared;

FIG. 4 is a partial view similar to FIG. 2 schematically representing the condition of the fuse after a portion of the fusible element has been melted by fault current;

FIG. 5 is an enlarged, fragmentary, cross-section schematic view through the fusible element of the fuse shown in FIG. 1 while conducting fault current; and

FIG. 6 is a triaxial diagram showing the relative percentages of the components of the arc extinguishing material of the preferred embodiment of the invention.

Referring to the drawing, the preferred embodiment of the invention comprises a fuse 10 having an enclosing tubular casing 11 of suitable insulating material such as fibre, cardboard, or glass provided with conductive caps, or terminals 12 closing the open ends of casing 11 and swaged into indentations in the exterior surface of casing 11. Fuse 10 is connected by conductors 13 in an electrical circuit energized from a source of alternating current and including a load 14 and a disconnect switch 15.

Plugs 16 telescoped with a snug fit into the tubular casing 11 adjacent the end caps 12 seal the ends of the tubular casing 11. A fusible element 17 of a suitable conductive material such as silver or a tin-lead alloy without casing 11 and preferably being of helical configuration is attached by suitable means such as soldering or spot welding to the end caps 12. Axial bores are provided in the plugs 16 to receive the ends of fusible element 17.

The helical fusible element 17 is contiguous to and embedded within a suitable hydrated alkali metal silicate 18, preferably in powder form, filling the casing 11. The alkali metal may be selected from the group consisting of sodium, lithium, potassium, rubidium or cesium, although in the preferred embodiment hydrated sodium silicate powder fills casing 11. In alternative embodiments of the invention a combination of these alkali metal silicates may be utilized for the arc extinguishing material. Hydrated sodium silicate powder in either amorphous or crystalline form provides excellent arc extinguishing characteristics and is effective in cooling the arc and preventing re-ignition after the alternating current has

passed through zero. The formula of a suitable sodium silicate powder is $\text{Na}_2\text{O}:3.3 \text{ SiO}_2$ with approximately 17 percent water. The percentages by weight of Na_2O , SiO_2 , and H_2O which will provide the improved results of the invention for the preferred embodiment are shown in the triaxial diagram of FIG. 6 and lie within the area defined approximately by the lines *ab*, *bc*, and *ca*, which includes the crystalline powder, and the area defined approximately by the lines *de*, *ef*, *fg*, and *gd* which includes the amorphous form of sodium silicate. The respective sides of the triaxial diagram of FIG. 6 indicate the percentage by weight of Na_2O , SiO_2 , and H_2O . As is well known, the percentages of the three variables represented by any point on the diagram are determined by projections to the corresponding percentage scales parallel to the sides of the triangle. For example, point *b* represents an embodiment having approximately 58 percent by weight of water (determined by projecting parallel to the triangle base to the 0–100% H_2O scale); approximately 21 percent by weight of Na_2O (determined by a projection parallel to the right side of the triangle to the 0–100% Na_2O scale); and approximately 21 percent by weight of SiO_2 (determined by projecting parallel to the left side of the triangle to the 0–100% SiO_2 scale). Similarly, point *e* represents an embodiment having 20 percent H_2O , 30 percent Na_2O and 50 percent SiO_2 .

FIGS. 3–5 schematically represent our theory of the changes which occur within the fuse during interruption of the arc. FIG. 4 illustrates schematically the conditions immediately after fault current has caused the fusible element 17 to attain fusing temperature and vaporize and depicts that the initial melting is adjacent the middle portion of the fusible element 17. The melting of a small section of the fusible element 17 results in the formation of an arc in this region which conducts the fault current. As the fault current continues, the arc increases in length and follows the helical configuration of the fusible element 17 while simultaneously the heating and rapid buildup of pressure by the arc progresses outwardly.

It is believed the water released by the hydrated alkali silicate 18, when heated by the high temperature of the arc, cools the arc and facilitates extinguishment thereof. As illustrated in FIG. 5, which schematically represents a cross section through the fuse while it is conducting fault current, the arc is surrounded by an annular region comprising water vapor and gases, including the silicate in the vapor phase, which are migrating outwardly from the arc. A second annular region surrounding the inner ring comprises the silicate in the liquid phase, water vapor, and gases generated by the arc which are migrating outwardly. An outer region surrounding the concentric inner areas comprises condensing water vapor, gases, and the solid silicate 18 which absorbs and condenses some of the gases generated by the arc and also condenses the water vapor. It is believed the arc is extinguished at least partially by cooling resulting from water vapor released from the silicate incident to the heat of the arc and at least partially by the physical contact between the arc and the relatively cool silicate granules, by lengthening of the arc, and by pressure. The powdered alkali metal silicate under the heat and pressure of the arc undergoes a change of state to the liquid phase and also releases water vapor, both of which help to cool and extinguish the arc and prevent re-ignition, after the alternating current has passed through zero, without a sufficient buildup of pressure to rupture casing 11. The water released by the alkali metal silicate includes both those molecules of water which are combined chemically and the water absorbed physically by the powder silicate 18.

After interrupting of the arc, a fulgurite 19 remains in the configuration of the fusible element 17 before melting. The diameter of the fulgurite 19 is dependent upon the fault current interrupted by the fuse, and a small hollow may exist at the center of the fulgurite. It is believed that during arcing the silicate 18 changes to the

liquid and vapor state so that it is at least a partial conductor and carries part of the arc current and prevents immediate insertion of high resistance into the current path. Upon arc extinction, the silicate 18 cools off and solidifies in the form of a fulgurite so that the material regains the properties of an insulator and inserts high resistance into the current path.

The degree of current limiting by the fuse is dependent upon the size of the particles of the hydrated alkali metal silicate powder 18 and the pressure with which they are compacted within the enclosing casing 11. Satisfactory results were obtained with particles in the range of from 65 mesh to 400 mesh. An increase in particle size of the sodium silicate powder 18 decreases the current limiting ability of the fuse. Satisfactory results were also obtained when the arc extinguishing material contained a variety of particle sizes. An increase in the pressure with which the sodium silicate powder particles are packed increases the current limiting ability of the fuse.

The hydrated alkali metal powder 18 of the preferred embodiment does not require hermetic sealing of the enclosing casing 11, it does not corrode the fusible element and need not be chemically pure, and it is non-toxic in manufacture and in clearing the fault. The disclosed fuse is inexpensive and simple to manufacture; it does not expel gases in clearing the arc; and it has excellent arc interrupting characteristics. The disclosed fuse construction is current limiting but it does not insert the fuse arc resistance with such rapidity into the current path that undesirably high surge voltages are generated in the circuit being interrupted. Further, the degree of current limiting can be controlled by varying the size of the particles of the metal alkali silicate powder and the pressure with which they are packed.

While only a few embodiments of the invention have been illustrated and described, many modifications and variations thereof will be apparent to those skilled in the art, and consequently it is intended in the appended claims to cover all such modifications and variations which fall within the true spirit and scope of the invention.

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

1. In a current limiting fuse including spaced terminals having a fusible element connected therebetween adapted to vaporize when fusing temperature is attained, whereby arcing occurs; hydrated sodium silicate in powder form having the formula $\text{Na}_2\text{O}:3 \text{ SiO}_2$ with approximately 17 percent water in contiguity with and surrounding said fusible element throughout a major portion of the length of said fusible element, said silicate expelling said water and being changed to the vapor and liquid state as a result of the heat of the arc formed upon vaporization of said fusible element and resulting in rapid transfer of heat from the arc and rapid dissipation of the arc energy.

2. In a current limiting fuse including spaced terminals having a fusible element connected therebetween, hydrated sodium silicate arc extinguishing material in powder form in intimate contact with and embedding said fusible element throughout the major portion of the length of said fusible element, said material containing Na_2O and SiO_2 and H_2O in the relative percentages lying within the areas defined approximately in the accompanying diagram by the lines *ab*, *bc*, and *ac* and by the lines *de*, *ef*, *fg* and *gd*.

3. In a current limiting fuse, a tubular enclosing casing, conductive caps on the ends of the casing, a fusible element within said casing connected at its ends to said end caps, and hydrated alkali metal silicate powder within said casing in contiguity with and embedding said fusible element throughout a major portion of the length of said fusible element, said alkali metal being selected from a group consisting of potassium and sodium, the water contained in said silicate powder being expelled and said silicate powder contiguous said element being changed

5

from the solid to a different physical state by the heat of the arc formed as a result of vaporization of said fusible element, the heat of vaporization of said water aiding in cooling and removing energy from said arc and said silicate in different physical state aiding in cooling said arc and also being partially conductive and controlling the rate of insertion of resistance into the current path and limiting the rate of rise of the voltage in the circuit being interrupted by said fuse.

5

6

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