Jan. 26, 1954 H. H. FAHNOE ET AL 2,667,549

ELECTRIC FUSE CONSTRUCTION

Filed May 29, 1952

Fig. 1.

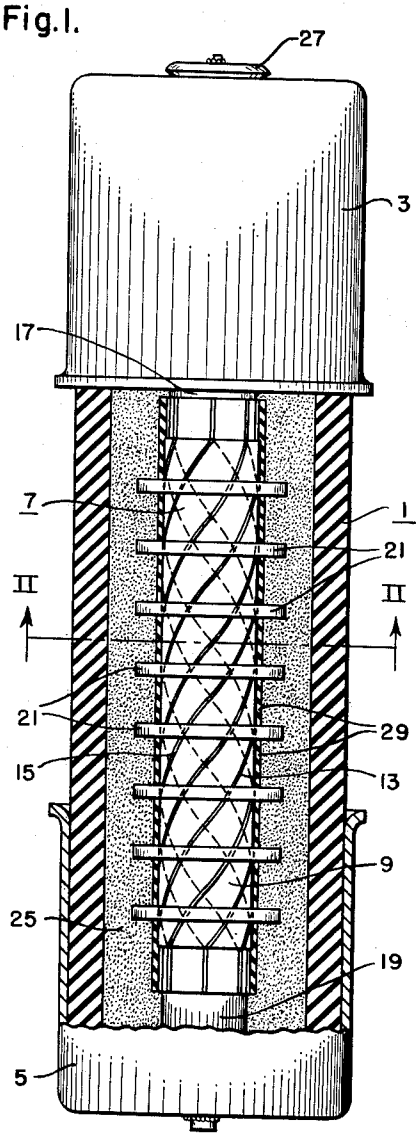


Fig. 2.

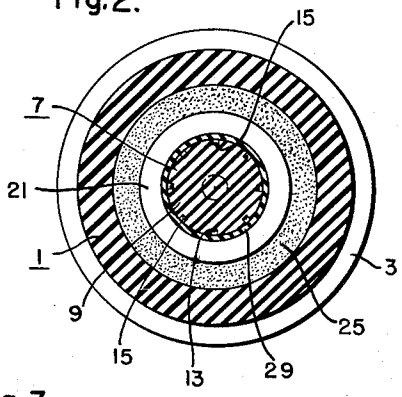


Fig. 3.

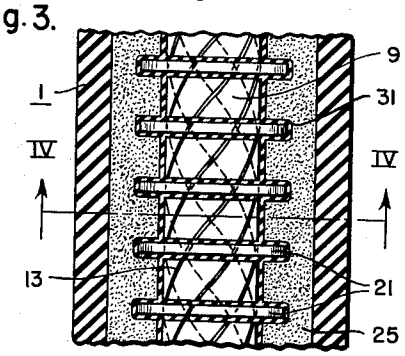


Fig. 4.

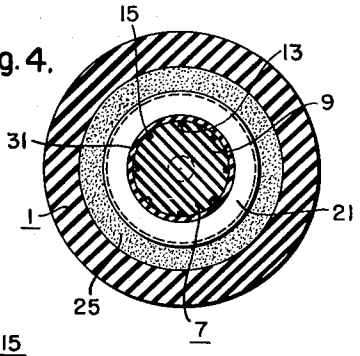


Fig. 5.

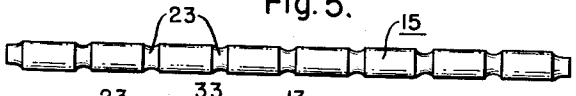
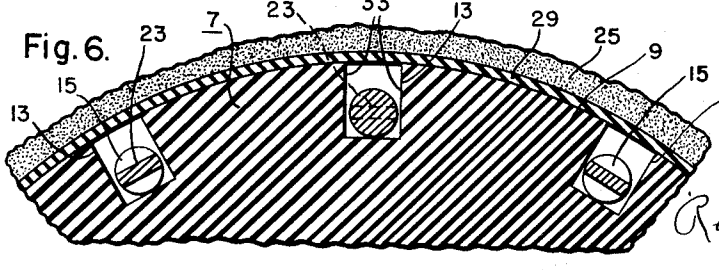


Fig. 6.



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UNITED STATES PATENT OFFICE

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ELECTRIC FUSE CONSTRUCTION

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14 Claims. (Cl. 200—120)

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This invention relates to electric circuit interrupting devices in general, and, more particularly, to electric fuse constructions.

In U. S. Patent 2,502,992, issued April 4, 1950, to Herbert L. Rawlins and Harold H. Fahnoe, and in U. S. Patent 2,496,704, issued February 7, 1950, to Harold H. Fahnoe, both patents being assigned to the assignee of the instant application, there is set forth, and claimed, a particular type of fuse, known as a current-limiting fuse. This type of fuse consists of a plurality of fusible fuse wires connected in electrical parallel and disposed in a plurality of slots or grooves provided on the outside surface of an insulating rod. The rod extends axially of the fuse with the fuse wires being disposed within the longitudinally-extending slots on the surface of the rod. The ends of the fuse wires are electrically connected to terminal disks, the latter being in turn connected to the terminal caps of the fuse, usually by means of some indicating structure, which will indicate when the fuse has blown.

To absorb the energy created during blowing of the fuse, an inert mass of finely divided material, such as sand, was disposed in proximity to the fuse wires. When such fuses were applied to circuits which were repeatedly switched on and off, as in motor-starting service, difficulty was encountered by reason of breakage of the fuse wires. We have found that the repeated heating and cooling of the wires, causing them to expand and contract in the grooves, agitated the particles of sand so that it worked in behind the fuse wires and into the lower ends of the slots provided on the surface of the rod. When the sand reached the lower end of the slot behind the fuse wire, it would prevent the fuse wire from expanding and contracting uniformly and caused its breakage.

An object of the present invention is to improve and to prolong the life of a fuse when used on repeated motor-starting service. More specifically, this is accomplished by preventing access of the small particles of sand into the bottom of the fuse-wire grooves.

Another object is to provide a suitable thin insulating covering, or easily rupturable sheet separator, to protect the fuse wires within the grooves from the sand, or other finely divided inert insulating material, and yet to allow sufficient lateral movement of the fuse wires within the grooves to enable them to expand and contract freely during the repeated switching on of heavy currents, as in motor-starting operations.

Still a further object of the invention is to improve fuse constructions by providing a thin insulating covering protecting the fuse wires within the grooves from the sand, which covering is of such a nature that upon blowing of the fuse it will disintegrate and thereby permit the sand to come into intimate contact with the fuse

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wires to absorb the energy created during fuse rupture.

Further objects and advantages will readily become apparent upon reading the following specification, taken in connection with the drawing, in which:

Figure 1 is a side elevational view, partially in vertical longitudinal section, of a fuse incorporating the principles of our invention, shown in the unblown condition, and with the thickness of the covering 29 exaggerated for clarity;

Fig. 2 is a transverse sectional view taken along the line II—II of Fig. 1, again with the thickness of the covering 29 exaggerated;

Fig. 3 is a vertical longitudinal sectional view taken through a modified type of fuse construction, which is subjected to a dipping or spraying operation with the thickness of the coating 31 exaggerated for clarity;

Fig. 4 is a transverse sectional view taken through the modified type of fuse construction shown in Fig. 3;

Fig. 5 is a side elevational view, greatly enlarged, of a portion of one of the fusible wires, and;

Fig. 6 is a greatly magnified sectional portion of the insulating rod utilized in the construction of Figs. 1 and 2, showing the free movement possible of the fuse wires within the grooves, and yet utilizing a thin covering preventing the sand getting into the grooves.

Referring to the drawing, and more particularly to Figs. 1, 2, 5 and 6 thereof, the reference numeral 1 designates a tubular fuse holder of insulating material, such as fibre or a synthetic resin. The tubular fuse holder 1 is provided with terminal caps 3 and 5 adapted to be secured over the opposite ends of the tubular holder 1. Terminal caps 3 and 5 may be of any desired conducting material, such, for example, as copper or the like, and they are preferably secured in position by a pressed fit on the ends of the fuse holder 1.

The fuse construction shown in Figs. 1, 2, 5 and 6 is similar to the fuse constructions set forth in the foregoing patents and has desirable current-limiting functions. The fuse comprises a fuse unit 7 including a rod 9 of an insulating material, which is capable of evolving an arc-extinguishing gas when in proximity to an electric arc, such, for example, as fibre or a synthetic resin. The rod 9 has a plurality of helically-extending, or spiral slots or grooves 13 disposed on its outside surface, and more clearly shown, in magnified fashion, in Fig. 6 of the drawing.

The longitudinally-extending slots or grooves 13 are cut in the periphery of the rod 9 for the reception of one or more parallel fuse wires 15. Fig. 6 more clearly shows the disposition of the fuse wires 15 within the slots 13 provided on the external surface of the insulating rod 9.

The parallel-disposed fuse wires 15 are adapted to be electrically connected at their ends with terminal disks 17 and 19 in any desired manner, such as by soldering or the like. Rod 9 has a plurality of spaced washer-shaped insulating barrier disks 21 provided thereon, for a purpose to be described, and the entire unit 7 is supported within fuse holder 1 in spaced relation to tube 1 and to the end terminals 3 and 5.

As set forth in Patent 2,496,704, the opposite ends of insulating rod 9 are provided with bores for receiving reduced extensions on the terminal disks 17 and 19. Electrically interconnecting the terminal disks 17 with the terminal cap 3 is a serially-connected indicating means, which forms no part of our invention and, consequently, is not described. Reference may be had to Patent 2,496,704 for features of this indicating means. It may be stated that upon rupture, or blowing, of the fuse assembly, the indicating means is actuated to permit the extension of an indicator disk 27, shown in Fig. 1.

The lower terminal disk 19 is directly electrically connected to the lower terminal cap 5. Disposed within the fuse holder 1 and about the fuse unit 7 is a mass of finely divided inert insulating material 25, such, for example, as sand. As mentioned previously, the sand serves to absorb the energy created during rupture of the fuse unit 7.

As previously stated, the fuse unit 7, thus far described, is similar to the current-limiting structure described in the foregoing patents. Current limitation is accomplished in this structure by reason of the following factors. The fuse wire 15 is of special construction, and may be of silver, or other material having a high temperature coefficient of resistance, and is initially chosen to be of substantially the same size of that required to carry the rated current without undue heating, and yet melt on currents above the rated current. Such a wire 15 is then provided with a plurality of reduced sections 23, more clearly shown in Fig. 5 of the drawing.

It has been found that in such a wire the fusion time is speeded up to correspond to that of a wire of substantially the same diameter as the reduced sections, at least for high values of current. This speeding up effect has been found to be roughly proportional to the ratio between the area of the large portions of the fuse wire 15 and reduced portions 23. As a practical matter, this ratio may be made as high as possible, being limited only by mechanical strength considerations. Such a fuse wire retains all the normal time-current characteristic desired in a fuse for time values in excess of approximately two cycles without appreciable reduction in current-carrying ability. Reduction in current-carrying ability varies roughly directly in proportion to the length of sections 23, so that it is desirable that these sections be made as short as possible. For short times of less than one-fourth cycle, fuse wire 15 has an exceptionally fast melting time.

Thus, with a fuse wire having a diameter of .036 inch and reduced portions of .0145 inch it has been found that the time current characteristic on low currents up to about 400 amperes is substantially the same as those of a fuse wire of uniform diameter equal to the large diameter portion of wire 15. However, on currents above 400 amperes, fuse wire 15 is much faster with its characteristics on these higher currents being substantially coincident with the characteristics of a fuse wire of uniform diameter which is substantially the same as the diameter of reduced

sections 23. This means that fuse wire 15 has its continuous current carrying ability substantially unimpaired, by provision of reduced section 23, and even its time current characteristic on light overloads will be substantially unchanged. However, on heavy overloads, where it is desired to limit the current, fuse wire 15 operates much faster than it would without the reduced sections 23, which means that it is possible to initiate the current limiting action at a very early point in the first half cycle of fault current.

Actual current limitation is effective by providing a high arc voltage upon fusion of fuse wires 15, which arc voltage is built up substantially instantaneously, to thereby exert a limiting or choking effect on the current and prevent its rise beyond a predetermined value. The particular structure disclosed provides a high arc voltage per unit length of unit 7, which means that the overall length of the fuse is small. One way of providing such a high arc voltage per unit of arc length is to provide a relatively large number of reduced sections 23 in fuse wire 15 so that when these reduced sections melt, a plurality of serially related arcs will be found and the summation of the arc voltages of these series arcs will then be greater than the arc voltage across a single arc. Generally speaking, the arc voltage per unit of length is directly proportional to the number of series arcs or restrictions 23 per unit of length. This suggests that maximum arc voltage per unit length may be obtained by providing as many restrictions 23 per unit of length as is physically possible. However, as the number of restrictions 23 per unit of length is increased, a point is eventually reached where a further increase results in a decrease in current carrying ability. It has been found that at least for voltages above 600 volts, at least two restrictions 23 per inch of fuse wire 15, or a total of ten should be provided to obtain an effective rise in arc voltage with a fuse wire which is not of excess length. This corresponds approximately to a spacing of restrictions 23 not to exceed about 15 times the large diameter of the fuse wire. It is desirable, however, to use the maximum number of restrictions possible without substantially impairing the current carrying ability. The most desirable number of restrictions is dependent on the size of the fuse wire, and appears to correspond roughly to a spacing of about 3½ times the largest diameter of the wire. This is an optimum spacing, since spacings as low as about twice the largest diameter of the fuse wire may be employed with good results.

Because fuse wires 15 are in close proximity to the walls of slots 13, it will be apparent that the arc formed upon interruption will cause the evolution of arc-extinguishing gas from the walls of the slot, and this gas will blast laterally through the arc to perform three functions, all of which act to increase the arc voltage and to extinguish the arc. First, the blast of arc-extinguishing gas acts to sweep metal vapor out of the arc stream and out of slots 13 into the material 25 in which the metal vapor becomes dispersed and condenses into separated particles insulated from each other so that a high resistance path is maintained outside the slots. Secondly, the blast of arc-extinguishing gas also acts to supply un-ionized gas to the arc path to further increase the resistance of the arc path and to extinguish the arc at current zero. A third function of the transverse gas blast is to cause the series arcs to be looped outwardly toward filling

material 25, thereby lengthening the arc path and, consequently, increasing the resistance thereof and the voltage drop across it. One function of washers 21 on supporting rod 9 will now be apparent, as preventing escape of the arcs from slot 13 and, consequently, from proximity with the gas-evolving material and from the restricting action from the narrow slot, and thus preventing the series arcs from restriking as a single arc outside the slots.

From the foregoing, it is apparent that efficient current limitation of the first half cycle of the arcing current may be obtained with the structures disclosed, because (1) the fusible wires themselves are capable of melting to establish an arc at least on such high currents which it is desired to limit, in a very short time, that is in a very small fraction of a half cycle, (2) as soon as the arc is established it is subjected to all of the factors enumerated above to create an arc voltage high enough to prevent any further rise of a fault current.

When a fuse structure, such as that set out above, is applied on repeated motor-starting operations it is necessary for the fuse wires 15 to be able to expand and contract freely within the slots 13, since they are heated by the high motor in-rush current each time the motor is started. To prolong the life of the fuse on repeated motor-starting, the notched-silver wires 15 were placed in the spiral grooves 13, which permitted the wire to expand uniformly without buckling. This improved the performance of the fuse but it was found that the small particles of sand which surround the interrupter were getting into the grooves. Also these small particles of sand were getting behind the wire 15 when it expanded and prevented the wire from returning to its original position upon cooling, thus causing the wire to break. Sifting the sand to remove the small particles improved the performance to the extent that 200 or 300 motor starts could be obtained before failure. This was not sufficient improvement, and the performance depended upon the amount of fine sand remaining after sifting and also upon the amount of fine sand produced by the sand breaking into small particles.

We have discovered a method of eliminating the breakage of the fusible elements 15 under normal motor starting conditions regardless of the particle size of the sand. A thin barrier or frangible covering 29 of material possessing considerable strength is placed over the grooves to keep the sand out of the grooves 13 in which the notched wires 15 are located. This permits the wire 15 to expand and contract freely. During the interruption of short circuits the arc disintegrates the barrier, and the sand is immediately in contact with the arc to absorb the energy.

In the construction set out in Figs. 1, 2, 5 and 6, one layer 29 of .00176 thick resin tape, such as a regenerated cellulose, or cellophane tape, was used around the fibre rod 9 between each pair of fibre washers 21. Fuses assembled with the cellophane tape 29 around the interrupter were tested with simulated motor starting conditions and were not damaged after 2,000 motor starts. Interrupting tests were then taken, and the interrupting ability was in no way impaired.

Another method of producing the thin barrier or covering is shown in Figs. 3 and 4 of the drawing. Here the thin barrier or covering 31 is sprayed on the unit 7, or the unit 7 is dipped in a plastic material which will completely cover the top of the grooves without interfering with

the free movement of the fusible elements 15. Preferably the material 31 must not flow down on the fibre walls 33 (Fig. 6) of the slots 13 or the interrupting characteristic of the fuse is changed. Such flowing down would not only interfere with the free movement of the fuse wire 15 within the slot 13, but also the gas-evolving characteristic of the wall 33 would be changed by the presence of the foreign material, namely the plastic.

We have discovered a suitable material providing a web finish is a plasticized vinyl resin dissolved in a ketone solvent. The material is such that it may be easily stripped off of the unit 7 and is similar to that which the United States Government utilized in encasing military equipment for storage.

From the foregoing description it will be apparent that we have prevented the finely divided material, such as sand, from entering into the bottoms of the slots 13 in back of the wire 15, either by taping between the washers 21, or by dipping or spraying the entire unit 7 with a suitable thin covering 31. The result has been to prolong the operational life of the fuse and yet not to interfere with the efficient operating characteristics of the fuse.

The films 29, 31 used in the practice of the invention may comprise resinous film forming polymers. Examples thereof are vinyl polymers, such as polyvinyl acetate, polyvinyl butyrate and polyvinyl chloride, polyvinylidene chloride, cellulose, cellulose esters and ethers, such as cellulose acetate, cellulose butyrate and ethyl cellulose, polystyrene, and synthetic elastomers. The films 29, 31 may be applied from solutions or dispersions of the polymers or as preformed film or sheets. As an example we have sprayed and dipped a solution of a copolymer of vinyl acetate-vinyl chloride plasticized with dibutyl phthalate in a ketone solvent. Preformed films of regenerated cellulose such as cellophane and cellulose acetate may be wrapped on the fuse.

Even different forms of paper may be used with suitable adhesives, the only prerequisite being that the sand, or finely divided inert material, is kept out of the grooves, and the arc may rupture the covering to contact the inert material to facilitate arc extinction.

Although we have shown and described specific structures, it is to be clearly understood that the same were merely for the purpose of illustration and that changes and modifications may readily be made therein, by those skilled in the art, without departing from the spirit and scope of the invention.

We claim as our invention:

1. A fuse including a fuse holder of insulating material having spaced terminals thereon, current-limiting circuit-interrupting means connected between said terminals including one or more fusible conductors, a rod of insulating material having one or more grooves provided therein, the one or more fusible conductors being disposed within the one or more grooves, a thin rupturable covering over the open side of the groove so as to enclose the fusible conductor within the groove, and an inert insulating material outside of the covering to assist in arc extinction.

2. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is dis-

posed, a thin rupturable insulating covering for the slot, and an inert insulating material outside of the covering to assist in arc extinction.

3. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, an insulating rod forming a groove, one of the fusible conductors being disposed within the groove, a thin frangible insulating covering for the groove, and finely divided inert insulating material about the covering to assist in arc extinction.

4. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, an insulating gas-evolving rod forming a groove, one of the fusible conductors being disposed within the groove, a thin frangible insulating covering for the groove, and finely divided inert insulating material about the covering to assist in arc extinction.

5. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating gas-evolving means forming a slot, within which one of the fusible conductors is disposed, a thin rupturable insulating covering for the slot, and an inert insulating material outside of the covering to assist in arc extinction.

6. A fuse including a fuse holder of insulating material having spaced terminals thereon, current-limiting circuit-interrupting means connected between said terminals including one or more fusible conductors, a rod of insulating gas-evolving material having one or more grooves provided therein, the one or more fusible conductors being disposed within the one or more grooves, a thin frangible covering over the open side of the groove so as to enclose the fusible conductor within the groove, and an inert insulating material outside of the covering to assist in arc extinction.

7. A fuse including a fuse holder of insulating material having spaced terminals thereon, current-limiting circuit-interrupting means connected between said terminals including one or more fusible conductors, a rod of insulating material having one or more grooves provided therein, the one or more fusible conductors being disposed within the one or more grooves, a thin rupturable covering over the open side of the groove so as to enclose the fusible conductor within the groove, an inert insulating material outside of the covering to assist in arc extinction, and a plurality of spaced insulating transversely-extending barriers disposed about the rod in said inert insulating material to prevent the formation by the heat of an arc of any continuous conductor or semi-conductor in said inert material.

8. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is disposed, a thin frangible insulating covering for the slot, an inert insulating material outside of the covering to assist in arc extinction, and a plurality of spaced insulating transversely-extending barriers disposed about the insulating means in said inert insulating material to prevent the formation by the heat of an arc of any continuous conductor or semi-conductor in said inert material.

9. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, an insulating rod forming a groove, one of the fusible conductors being disposed within the groove, a thin insulating covering for the groove, finely divided inert insulating material about the covering to assist in arc extinction, and a plurality of spaced insulating transversely-extending barriers disposed about the rod in said inert insulating material to prevent the formation by the heat of an arc of any continuous conductor or semi-conductor in said inert material.

10. The combination in a fuse structure of means for extinguishing an arc therein including a rod of insulating material, one or more slots disposed substantially longitudinally of the rod, at least one fusible conductor disposed within a slot, finely divided insulating material disposed about the rod of insulating material, and thin rupturable covering means of insulating material over the slot to prevent the entrance of said finely divided insulating material into the slot.

11. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is disposed, a thin frangible film of insulating resinous material over the slot, and an inert insulating material outside of the thin film to assist in arc extinction.

12. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is disposed, a thin film of insulating material over the slot, and an inert insulating material outside of the thin film to assist in arc extinction, wherein the thin film of insulating material comprises a vinyl polymer.

13. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is disposed, a thin film of insulating material over the slot, and an inert insulating material outside of the thin film to assist in arc extinction, wherein the thin film of insulating material is selected from the group consisting of cellulose, cellulose esters and cellulose ethers.

14. A fuse including a pair of spaced terminals, conducting means electrically connecting the spaced terminals including one or more fusible conductors, insulating means forming a slot, within which one of the fusible conductors is disposed, a thin film of insulating material over the slot, and an inert insulating material outside of the thin film to assist in arc extinction, wherein the thin film of insulating material is selected from the group consisting of cellulose, cellulose esters and cellulose ethers, wherein the thin film comprises regenerated cellulose.

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WILLIAM A. GASKILL.

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