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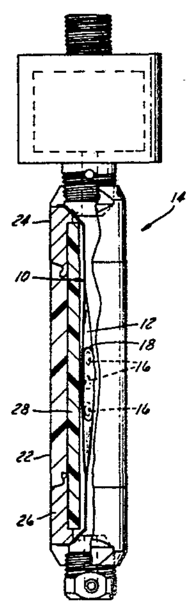
(54) **A fuse link and the combination thereof in an expulsion fuse.**

(57) A fuse link including a fuse element of known cross-sectional area having a number of holes centrally located therein to define reduced cross-sectional areas and a filler material provided in said holes, said embodiment having a short time-current melt characteristic at high overload substantially the same as the homogeneous fuse element and a long time-current melt characteristic different from the long time-current melt characteristic of the fuse element.



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TITLE: A FUSE LINK AND THE COMBINATION THEREOF IN AN EXPLUSION FUSE.

BACKGROUND OF THE INVENTION

Full range fuses, i.e., fuses of the type having short time and long time fuse characteristics are commonly used in high voltage applications. Long time characteristics have been modified by providing holes in the fuse link and by other methods which effect the long term melt characteristic without greatly changing the short term. Although these types of elements have been used extensively, accurate coordination of melt time current characteristic cannot be maintained over the full fuse range.

SUMMARY OF THE INVENTION

The fuse link of the present invention is provided with a number of predetermined sized holes centrally located in the link to define small cross sectional areas on each side of the holes. The holes are filled with a conductive material having a predetermined melt characteristic to provide a full cross section across the link for current flow. At high currents the combination of materials have substantially the same time-current melt characteristic as the fuse link. At low current overloads the fuse link will heat up and the conductive material will melt at known temperature levels wicking out of the holes thus reducing the cross sectional area of the link and producing fusing of the link at predetermined current conditions.

THE DRAWINGS

Figure 1 is an elevation view partly in section showing the fuse link according to the present invention mounted within a fuse housing.

Figure 2 is a view of the fuse link showing a number of holes located in the center thereof and filled with low temperature melt material.

Figure 3 is a view taken on Line 3-3 of Figure 2 showing a cross-section of one of the holes filled with the low temperature melt material.

Figure 4 is a time current diagram of the melt curves for various fuse links with the same .01 sec. melt time but with modifications to cause the time current characteristic to change at lower current ranges.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1 of the drawings, the fuse link 10 of the present invention is shown mounted within an expulsion fuse 14. The expulsion fuse can be of the type shown in my co-pending application, Serial No. 134,966 filed on March 28, 1980 and entitled High Current Under Oil Expulsion Fuse and generally includes a glass wound epoxy sleeve 22 having electrically conductive contacts 24 and 26 at the ends. The fuse element 12 extends through the sleeve 22 and electrically interconnects the contacts 24 and 26. A resilient pressure tube 28 is positioned within the sleeve 22 and is formed of a non-tracking, non-conducting material such as Teflon to prevent arc-over on fuse clearing. The expulsion fuse is generally mounted in the transformer and immersed in the insulating oil. The function of the expulsion fuse 14, and a more specific description of its parts and operation, is set forth in my co-pending application and is incorporated herein by reference.

The fuse link 10 includes a fuse element 12 which serves as the conductive member of the fuse

14. The time current characteristics of the element 12 is modified by combining different conductive metals in a specific configuration to achieve a variation in the slope and intersection points of the time current characteristic as seen in Figure 4 and described hereinafter.

In this regard, the element 12 is modified by providing a series of holes 16 in or near the center of the element and filling the holes with a conductive material 18 which material has a melt temperature below that of the fuse element 12. By the proper selection of the element material 12, the conductive material 18, the cross-sectional area of the element 12, and the size of the holes 16, the time current characteristic of the fuse link 10 can be adjusted to pass through several predetermined points.

The points, which may be specified, are the short time melt below .05 seconds and the long time melt 1,000 to 10,000 seconds. The size of the element 12 is calculated knowing the desired melt time for a specific high current in the 0 to .05 second melt range. The fuse link cross sectional area is calculated for a particular material, i.e. copper, using the formula $\sqrt{\frac{I^2T}{4.03 \times 10^{10}}}$ = A in inches squared. A flat ribbon of the specified material having the calculated cross sectional area is then used for the fuse element.

For fuse links made of materials other than copper such as silver, aluminum, tin or tin alloys the cross sectional area required to carry a specific current for a specific time is calculated according to the relation:

$$\text{Cross Sectional Area} = \left(\frac{I^2 \times \text{Time}}{K}\right)^{1/2}$$

where K is a constant unique to each element material. For copper $K = 4.03 \times 10^{10}$ and for silver $K = 2.88 \times 10^{10}$.

Means are then provided to modify the fuse element to achieve a long time-current melt characteristic. Such means includes one or more holes 16 drilled in the element to reduce the effective cross section of the element. The holes 16 are centered on the element so that equal reduced cross sections 20 remain on either side of the hole 16. As seen in the drawings, three holes are used which are preferably spaced approximately 1/4 inch apart. This spreads out and equalizes the effect of the holes which gives more consistent results.

Means are provided to fill the holes 16 to maintain the short time-current characteristic and to provide the long time-current characteristic. Such means is in the form of the conductive material 18 which in the preferred embodiment is a eutectic solder which melts at low temperatures produced by long time overloads but in combination with the element, in the preferred embodiment, has substantially the same current characteristic as the element at high current overloads. As described hereinafter and shown in Figure 4, if the hole size is increased, the melt curve will shift to the left and if decreased, the melt curve will shift to the right. The melt temperature and resistance of the filler material 18 will determine when the filler material will start to show its effect on the long time melt of the element. A low temperature material with resistance greater than copper will have an early or reduced melt time. The eutectic solder system begins to manifest itself at melt times over .06 seconds. At high current conditions the fuse element in combination with the filler material has a melt characteristic substantially equal to the high current melt characteristic of a homogeneous element.

The fuse sequence of the modified fuse link is as follows. At high currents which produce a melt time of .05 seconds or less on the full cross section of the fuse link, the effect of the filler material in the holes is negligible. At lower currents the fuse element heats uniformally due to the current overload. The greatest temperature is achieved slightly above the element center. This is due to the fact that both end contacts on the fuse holder act to sink the heat out of the fuse link, however, the end contact at the lower end of the fuse link is cooler since it is lower in the oil and because the oil in the fuse tube is heated by the link. The oil rises by convection causing higher temperature oil at the top of the fuse. When the temperature of the fuse link center reaches the melt temperature of the filler material 18, the metal melts and runs or wicks out of the holes in the fuse link. This suddenly reduces the overall cross section of the link on each side of the hole and the unit now follows a melt sequence similar to a solid link of the smaller cross section.

By way of explanation, a time current characteristic curve is shown in Figure 4 which graphically shows the change in characteristic of the operation of the fuse link which is achieved by the present invention. In this regard, the curve denoted by letter "A" is an average melt curve for a solid copper link having a thickness of .020 inches and a width of .195 inches. This link is formed of a flat strip of copper and shows a melt time of 100 seconds at 500 amperes. A solid eutectic link having the same thickness and width as shown in Curve "A" is shown in Curve "E". This link shows a melt time of .04 seconds at 500 amps. The curve denoted by the letter "B" is a solid eutectic link having a melt time at 500 amperes of approximately .9 seconds.

By modifying the copper fuse element, as described above, to include three holes 16 having a 9/64 inch diameter and filled with eutectic solder, a curve denoted by the letter "C" in Figure 4 is achieved. This fuse element has a melt time characteristic at 500 amperes which has now been increased to approximately 10 seconds.

A fuse link having three holes of 11/64th inch diameter filled with eutectic solder, as shown in curve D, the melt time at 500 amps is approximately 3 seconds.

Conversely in assuming a 100 second time requirement, a solid eutectic link as shown in curve B would melt at 100 amps, the link with the 11/64th diameter holes in curve D would melt at 140 amps, curve C 300 amps and curve A 500 amps. It is therefore possible to select the characteristics required for a particular expulsion fuse and to modify the fuse link to achieve the desired result.

Means are provided to prevent the fuse link from laying flat against the inner surface of the fuse tube. This is accomplished by twisting the fuse link from 180 to 360° over its length. If the fuse link were to lay flat against the inner surface of the fuse tube, the filler material 16 could pool in the area and the small cross section would not be achieved.

CLAIMS

1. A fuse link for a fuse comprising a fuse element made of a material having a known time current characteristic, a number of holes in said fuse element and a filler material in each of said holes the combination having a short time current characteristic similar to the fuse element and a long time current characteristic different from the fuse element whereby the long time melt characteristic of the fuse element can be selectively varied to a known requirement.

2. A fuse link as claimed in Claim 1 wherein said fuse element is formed of copper.

3. A fuse link as claimed in Claim 1 wherein said fuse element is formed of a conductive material selected from a group consisting of silver, copper, aluminum, tin and tin alloys.

4. A fuse link as claimed in either Claim 2 or Claim 3, wherein said fuse element has a cross sectional area calculated to carry a specific current for a specific time according to the relation Cross Sectional Area = $\left(\frac{I^2 \times \text{Time}}{K}\right)^{1/2}$

where "K" is a constant unique to each element material.

5. A fuse link as claimed in any one of Claims 1 to 4, wherein the filler material is a eutectic solder.

6. A fuse link as claimed in any one of Claims 1 to 4, wherein the filler material is a conductive material with a melt temperature below that of the link material.

7. A fuse link as claimed in any one of Claims 1 to 6, wherein said holes are of equal diameter and are equally spaced from the edges of the element.

8. A fuse link as claimed in any one of Claims 1 to 6, wherein said holes are of a shape which will allow the filler material to flow or wick out of the hole when it melts.

9. A fuse link as claimed in any one of Claims 1 to 8, wherein said holes are located on the link to create the desired localized heating in the reduced cross sectional areas.

10. A fuse link as claimed in any one of Claims 1 to 9, wherein the combination of said filler material in the holes of the fuse element causes the element to have a melt characteristic at high current conditions substantially equal to the high current melt characteristic of a homogeneous element.

11. In combination an expulsion fuse including a tubular housing having an electrical contact at each end and a fuse link as claimed in any one of Claims 1 to 11 within said housing connected to the conductive members, wherein the fuse link includes a ribbon of material having a known time current characteristic and a number of openings centrally located in the fuse element.

12. A combination as claimed in Claim 11 wherein said element is twisted at least 180° throughout its length.

13. A fuse link for an electric fuse comprising a fuse element having a predetermined cross-sectional area in the fusing portion of the length of the element which will cause fusing at a desired short time high current condition, said element having a hole or number of holes in or near the centre thereof.

14. A fuse link as claimed in Claim 13, wherein the combination of said filler means in the holes of the fuse element causes the element to have a melt characteristic at high current conditons substantially equal to the high current melt characteristic of a homogeneous element.

15. A fuse link as claimed in Claim 13, wherein said fuse element with the filler material combines to have a melt characteristic at low current conditions substantially different from the low current melt characteristic of the homogeneous fuse element.

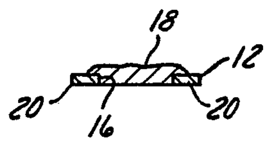


FIG. 3

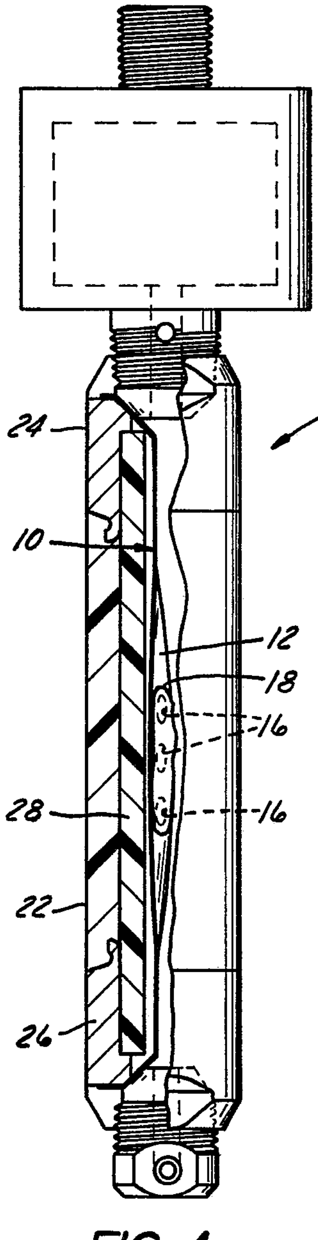


FIG. 1

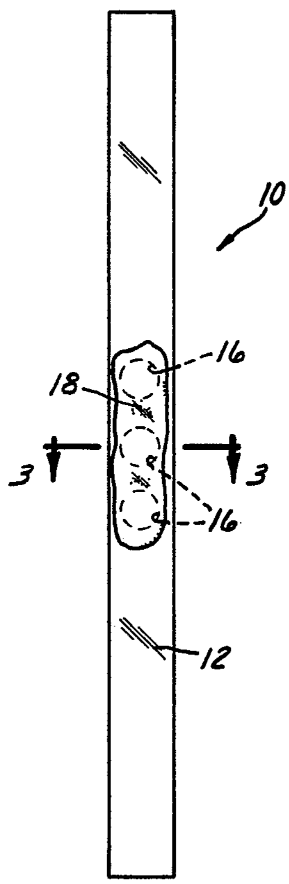
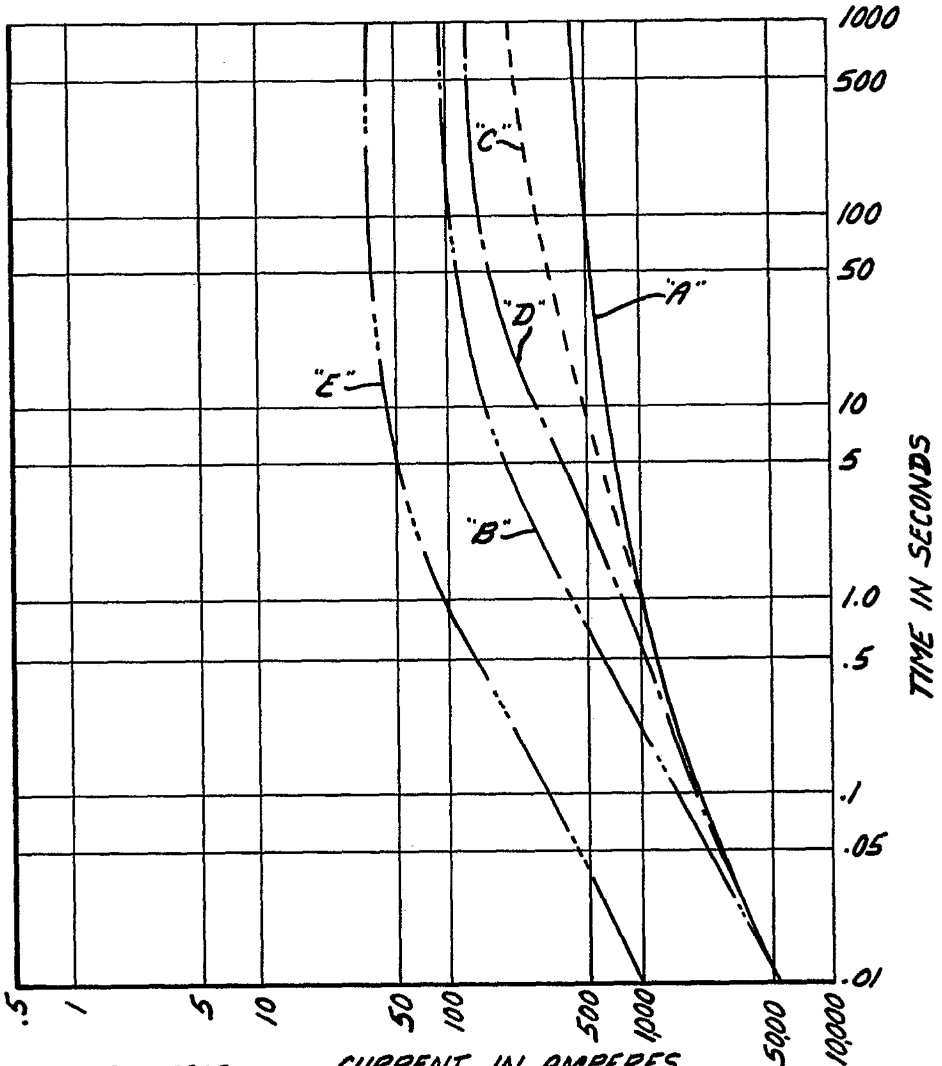


FIG. 2

MELT CURVES



—— SOLID .020 X .195 COPPER

- - - .020 X .195 COPPER WITH 3 9/64 DIA. HOLES – FILLED

—·— .020 X .195 COPPER WITH 3 11/64 DIA. HOLES – FILLED

—··— SOLID EUTECTIC FUSE LINK (6000 AMPS @ .01 Sec.)

—---— SOLID .020 X .195 EUTECTIC FUSE LINK

FIG. 4