March 1, 1955 F. J. KOZACKA 2,703,352

FUSE AND FUSE LINK OF THE TIME LAG TYPE

Filed Aug. 13, 1953

Fig. 1.

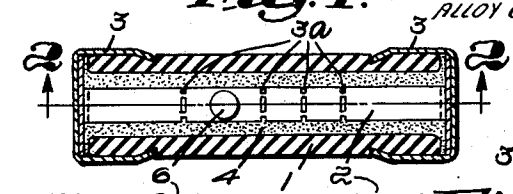



Fig. 2.

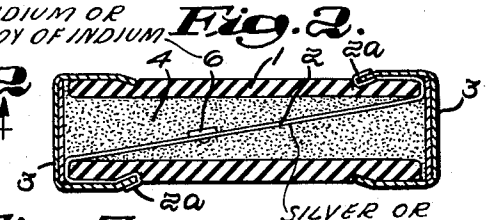



Fig. 3.

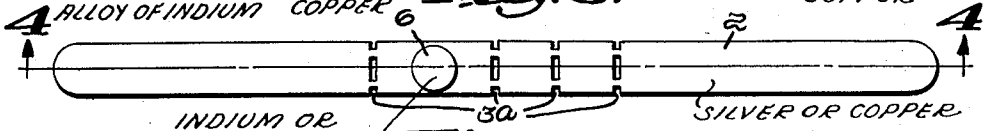



Fig. 4.

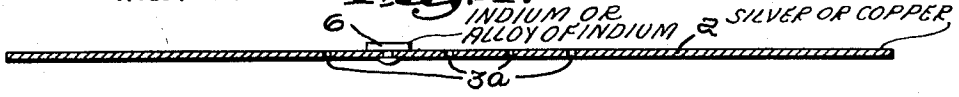
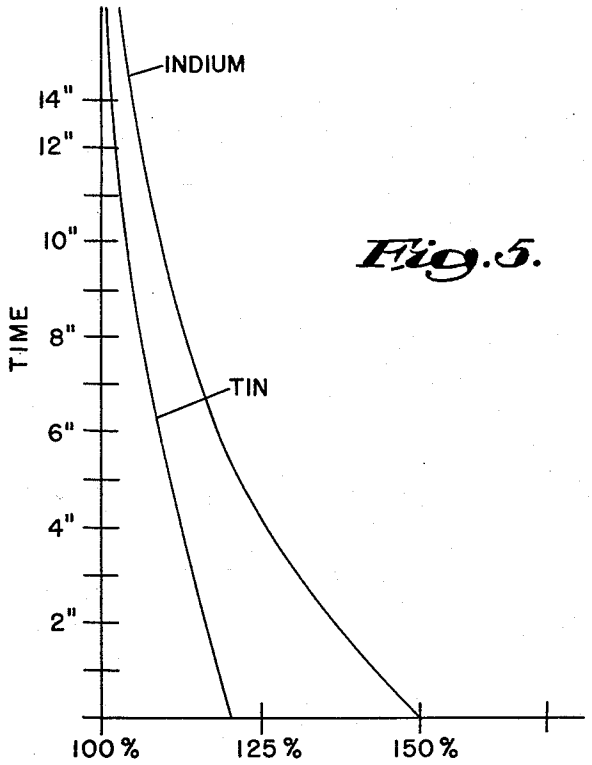



Fig. 5.




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# FUSE AND FUSE LINK OF THE TIME LAG TYPE

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19 Claims. (Cl. 200—131)

This invention relates to fuses and to fuse links, and more particularly to fuses and fuse links of the time lag type.

In some applications it is desirable to effect circuit interruption as rapidly as possible if the current in the electric circuit under consideration reaches a predetermined value, whereas it is desirable in other applications to effect circuit interruption only after predetermined excessive loads have persisted for predetermined periods of time. Fuses for the latter type applications are referred to as time lag fuses.

Some of the prior art time lag fuses are provided with a pair of cooperating contacts which are conductively interconnected by a solder joint and biased to open contact position by suitable spring means. The solder yields at a predetermined temperature resulting in separation of the pair of cooperating contacts and consequent interruption of the circuit. The mass inherent in such an arrangement is sufficiently large to obtain the long time lags required in case of fuses applied for the protection of electric motors having high inrush currents during the starting period thereof, and like applications. Drawbacks of this type of fuses include high cost of manufacture and relatively large bulk.

Another type of time lag fuse is predicated upon a composite link structure comprising dissimilar metals. One part of the link is made of a metal having a relatively high conductivity and a relatively high fusing point, e. g. silver or copper. Another immediately adjacent part of the link is made of a metal having a relatively low fusing point, e. g. tin. The relatively low fusing point metal is capable, upon fusion thereof, to form an alloy with the relatively higher fusing point metal. This alloy has a relatively high resistivity and causes a relatively rapid destruction of the link once the process of alloy-formation has started. Fuses of this type are relatively easy to manufacture and their bulk is relatively small, but they do not permit to achieve the long delay times necessary for many applications.

It is, therefore, one object of this invention to provide a time lag fuse which is inexpensive to manufacture and is of small bulk, yet enables to achieve considerable delay times.

Where the link of a fuse consists of one single metal having a high conductivity and a high fusing point, the amount of link metal required to carry a predetermined current is relatively small. Low fusing point metals have about ten times the resistivity of high fusing point metals and, therefore, where the link of a fuse consists of one single metal having a low fusing point and a high resistively, about ten times the quantity of metal may be required than that which would be needed if a high conductivity metal had been applied. As mentioned before, silver and copper are typical high conductivity, high fusing point metals. The former has a fusing point of 962 deg. C., and an electrical conductivity of

$$60.2\times10^4\ \frac{1}{\text{ohms/cc.}}$$

The latter has a fusing point of 1083 deg. C. and an electrical conductivity of

$$58.8\times10^4\ \frac{1}{\text{ohms/cc.}}$$



A typical low fusing point metal is tin having a fusing point of 232 deg. C. and an electrical conductivity of

$$8.8\times10^4\ \frac{1}{\text{ohms/cc.}}$$

Fuse links made solely of a high conductivity, high fusing point metal tend to operate satisfactory on short-circuit currents owing to their relatively small mass. Fuses having such links tend, however, to run too hot since on sustained overloads the link may operate for some time at a temperature relatively near to the fusing point of the metal of which the link is made.

Fuses provided with fuse links made solely of a low melting point, low conductivity metal, tend to run cool because of the relatively low temperature which the link may reach prior to blowing of the fuse, but owing to the relatively large mass of link metal involved the performance of fuses having such links is not satisfactory on occurrence of high short-circuit currents.

The composite fuse links comprising a portion of high conductivity, high fusing point metal and a portion of low fusing point, low conductivity metal which reacts metallurgically at temperatures well below the fusing point of the high conductivity, high melting point metal, are predicated to some extent upon link-destruction by alloy-formation. As mentioned before, fuses having fuse links of this type tend to have too small delay times in the low overload range, say in the range of three to five times the rated current of the fuse.

It is, therefore, another object of the invention to provide a time lag fuse having a composite fuse link adapted to alloy-formation between a high conductivity, high fusing point metal and a low fusing point, low conductivity metal wherein the time lag is considerably higher than in prior art fuses of the same type.

Still another object of this invention is to provide a time lag fuse having a composite link wherein alloy-formation takes place at lower temperature than in prior art fuses of this type, thus tending to reduce the operating temperature of the fuse.

The foregoing and other general and special objects of the invention and advantages thereof will more clearly appear from the ensuing particular description of the invention, as illustrated in the accompanying drawing wherein—

Fig. 1 is in part a longitudinal section through and in part a front elevation of a cartridge type fuse embodying the present invention;

Fig. 2 is a section along 2—2 of Fig. 1;

Fig. 3 is a front view of a fuse link embodying the present invention;

Fig. 4 is a section along 4—4 of Fig. 3, and

Fig. 5 shows two typical time-current characteristics of prior art fuses and of fuses embodying the present invention.

Referring now to Figs. 1 and 2, reference numeral **1** has been applied to a tubular casing of insulating material as, for instance, a synthetic resin laminate on a glass-cloth base. Fuse link **2** is arranged within casing **1** and interconnects conductively the two crimped terminal caps **3** used to close casing **1**, Link **2** is provided with a plurality of perforations **3***a* which are spaced substantially equidistantly along a predetermined portion of the length of link **2** arranged within casing **1**. The ends of link **2** are bent to the outside of casing **1** and clamped thereon by terminal caps **3**. The axially outer tips **2***a* of link **2** each form a small U-turn and are bent upon outer surface of caps **3** and conductively secured thereon by spot-welding.

The general structure of the fuse shown in Figs. 1 and 2 is more fully disclosed in a patent application filed by Paul C. Hitchcock, Electric Fuse, Ser. No. 240,553, filed August 6, 1951, now United States Patent No. 2,680,173 dated June 1, 1954, and assigned to the same assignee as the present invention.

Link **2** is surrounded by a pulverulent arc-quenching filler, preferably chemically pure quartz sand, and is provided with an overlay **6** made of indium, or of a low fusing point alloy of indium, e. g. an indium-rich tin-indium alloy. Indium is a metal having a relatively low fusing point, i. e. its fusing point is 154 deg. C. When the indium overlay reaches the critical alloying temperature

thereof due to a relatively small but protracted overload, the metal of which link **2** consists, e. g. silver, rapidly dissolves in the indium resulting in a silver-indium alloy having characteristics entirely different from those of silver and indium. As a result of this process of dissolution of silver in indium, the fuse link **2** is rapidly destroyed and the current path through the fuse interrupted. As long as the indium, or indium alloy, overlay is below the critical alloying temperature, no appreciable dissolution of silver into the overlay takes place. When the indium, or the indium alloy, reach their critical alloying temperature the silver of which link **2** is made rapidly dissolves in it, the rate of penetration and diffusion of the silver into the indium alloy, and vice versa, the rate of penetration and diffusion of the indium, or indium alloy, into the silver increasing in proporton to the rise in temperature.

Comparative tests have been made with multiperforated identical ribbon type fuse links of silver of which one had an overlay of tin and the other an overlay of silver. Both overlays were substantially identical with regard to the amount of overlay metal involved. The silver ribbons which have been used in conducting these tests were .0065 in. × .086 in. in cross-section. The results of the tests are tabulated below.

*Link with tin overlay*

| Current | Time |
|---|---|
| 25 amps | indefinite without fusing. |
| 27 amps | Do. |
| 30 amps | Do. |
| 33 amps | Do. |
| 34 amps | fused within 12 minutes. |
| 40 amps | fused within 31 seconds. |

*Link with indium overlay*

| Current | Time |
|---|---|
| 25 amps | indefinite without fusing. |
| 28 amps | Do. |
| 30 amps | fused within 12 minutes, 25 seconds. |
| 33 amps | fused within 8 minutes. |
| 34 amps | fused within 4 minutes, 45 seconds. |
| 40 amps | fused within 28 seconds. |

The minimum fusing current of the link having an overlay of tin was about 33.5 amps., whereas the minimum fusing current of the link having an overlay of indium was about 29.0 amps. Fig. 5 shows the fusing time of the link with the overlay of tin and of the link with the overlay of indium plotted against current in terms of per cent at the minimum fusing current. It is immediately apparent from Fig. 5 that the fuse link having an overlay of indium has longer time lags for identical overloads in terms of percent of the minimum fusing current.

Generally the characteristics of time lag fuses are described in terms of rated current rather than in terms of minimum fusing current. The fuse standards require that a fuse must blow within one hour at 135% of the rated current. This definition leaves a wide latitude with regard to the rating of fuses. For the purpose of obtaining a precise common denominator for the comparison of prior art time lag fuses and of time lag fuses with an overlay of indium, or indium alloy, the rated current may be defined as the current at 135% of which the fuse blows within one hour. If two generally identical fuses, e. g. fuses of the type shown in Figs. 1 and 2, are made up to have identical current ratings within the above definition of current rating, one fuse having an overlay of tin and the other fuse having an overlay of indium, or a low fusing point indium alloy, the time-current characteristics of the two fuses show that the latter has longer delay times in the range of about three times the rated current than the former.

A fuse with a given fuse link of silver having an overlay of tin was normally rated at 30 amps. When an identical structure was made up except for a substitution of the overlay of tin by an overlay of indium, the fuse had to be derated to 25 amps.

In the manufacture of alloy-forming link overlays it is generally preferable to use low fusing point alloys of indium rather than pure indium. Tin-indium alloys are very satisfactory. As an example the eutectic alloy of tin and indium may be used for the purposes of this invention. Such an alloy has an eutectic temperature of 117 deg. C. and comprises 48 at. per cent of tin.

The fusing point of indium being 315° F. and the fusing point of tin being 449° F., it is apparent that fuses with links having overlays of indium tend to run cooler than fuses with links having overlays of tin.

Another advantage of the application of indium as a time lag producing agent is the fact that indium does not oxydize at normal temperatures as tin does.

Among the low melting point alloys of indium that can be applied for the purposes of this invention mention may be made of the alloys of indium with lead, cadmium and bismuth. Indium-tin alloys are generally preferable.

Fuse link overlays of indium and low melting point alloys thereof can be produced in different fashion and by different means. Indium is a very soft metal and can be directly wiped on a fuse link of silver. Another practical way of producing overlays of indium is by indium plating.

Fig. 4 shows a fuse link having necks or portions of restricted cross-sectional area **3***a*. The width and the length of necks **3***a* are both very short, resulting in relatively small $i^2 \cdot r$ losses at the neck area. A rivet **6** made of an indium-rich indium-tin-alloy is arranged immediately adjacent and between two of necks **3***a*. Necks **3***a* fuse and vaporize instantly at the occurrence of major fault currents and the resulting arc causes vaporization of rivet **6**. Because of the smallness of rivet **6** the arc gap will not be seriously contaminated by the tin and indium vapors resulting from the vaporization thereof. At the occurrence of sustained overloads the indium of which rivet **6** is made diffuses into the solid silver of the link, and vice versa silver diffuses into the rivet. As a result, the current path of the link is rapidly destroyed. Relatively little heat is required to achieve this result since rivet **6** is very small and has a relatively low alloying temperature and since the mass of the link which must be converted into a silver indium alloy to effect destruction of the link is quite small.

Overlays of indium, or of low fusing point alloys of indium, can be applied to fuse links of uniform cross-section, i. e. having no restricted cross-section portions or necks, to fuse links having but one single restricted cross-section portion or neck, and to fuse links having a plurality of restricted cross-section portions or necks.

Consider a fuse having a fuse link with one single indium-alloy forming element arranged at a predetermined point of the link. Subjecting said link to different continuous load currents beginning with the minimum fusing current up to currents of 500–600% of the minimum fusing current, the following behavior may be observed. Up to a critical current of say 300 to 400% of the minimum fusing current, the fuse will blow with predeterminable time delays, interruption of the circuit being initiated by a desintegration of the fuse link at the point where the alloying element of indium, or of an indium-alloy, is located. At increasing loads the time delay occurring at this point is so long that the fuse link will reach at some other point thereof the fusing temperature of the high fusing point metal before the indium element, or indium-alloy element, reaches the relatively low temperature required for initiating the metallurgical reaction of alloy-formation between the high-melting point metal and the indium, or indium-alloy element. In other words, at relatively high overloads the link may reach at some point thereof the fusing point of silver, or copper, respectively, but at such high overloads the fuse blows after a relatively short time, sufficiently short to preclude undue heating of the fuse structure by $i^2 \cdot r$ losses occurring in the fuse link.

Having disclosed preferred embodiments of my invention it is desired that the same be not limited to any particular structures disclosed. It will be obvious to any person skilled in the art that many modifications and changes may be made without departing from the broad spirit and scope of my invention. Therefore it is desired that the invention be interpreted as broadly as possible and that it be limited only as required by the prior state of the art.

I claim as my invention:

1. In a lag-type fuse means defining a link-receiving chamber and a fuse link arranged within said chamber, said fuse link having a first portion consisting of a metal having a relatively high fusing point and a second portion consisting of a metal having a relatively low fusing point, said second portion being operatively related to said first portion to cause alloy-formation between said first

portion and said second portion at a predetermined temperature of said second portion, and said second portion comprising indium.

2. In a lag-type fuse means defining a link-receiving chamber and a fuse link arranged within said chamber, said fuse link having a first portion consisting of a metal having a relatively high fusing point and a second portion consisting of a metal having a relatively low fusing point, said second portion being operatively related to said first portion to cause alloy-formation between said first portion and said second portion at a predetermined temperature of said second portion, and said second portion comprising an alloy of indium.

3. A lag-type fuse according to claim 2 wherein said second portion comprises an alloy of tin and indium,

4. In a lag-type fuse means defining a link-receiving chamber and a fuse link arranged within said chamber, said fuse link having a first portion consisting of a metal having a relatively high fusing point and a second portion consisting of a metal having a relatively low fusing point, said second portion being operatively related to said first portion to cause alloy-formation between said first portion and said second portion at a predetermined temperature of said second portion, and said second portion consisting of indium.

5. A lag-type fuse comprising means defining a link-receiving chamber and a ribbon-type fuse link of a high fusing point metal arranged within said chamber, said fuse link being provided with a rivet consistng of an alloy of indium at a point of said link situated between the ends thereof.

6. A lag-type fuse according to claim 5 wherein said rivet consists of an alloy of tin and indium.

7. A lag-type fuse comprising a tubular casing, a pair of spaced terminal elements each supported by one end of said casing, a pulverulent arc-quenching filler within said casing, a ribbon type fuse link of a high fusing point metal submersed in said filler and conductively interconnecting said pair of terminal elements, and an overlay on said fuse link consisting of an alloy of indium with another low fusing point metal.

8. A lag-type fuse according to claim 7 wherein said overlay consists of an alloy of tin and indium.

9. A fuse link for time lag fuses consisting substantially of a high fusing point metal supporting between the ends thereof an alloy-forming low fusing point metal element, said low fusing point metal element comprising indium.

10. A fust link according to claim 9 wherein said low fusing point metal element consists of an alloy of indium with another low fusing point metal.

11. A fuse link for time lag fuses comprising a ribbon of silver having a point of restricted cross-sectional area defining the point of arc initiation at the occurrence of major fault currents, and a low fusing point metal element supported by said silver ribbon at a point of said silver ribbon situated immediately adjacent said point of restricted cross-sectional area thereof to cause destruction of said point of restricted cross-sectional area at a predeterminable range of overload currents by a metallurgical reaction between silver and said low fusing point metal element, said low fusing point metal element including indium.

12. A fuse link according to claim 11 wherein said low fusing point metal element consists of an alloy of indium with another low fusing point metal.

13. A lag-type fuse comprising a tubular casing, a pulverulent quartz filler within said casing, terminal elements closing said casing at the ends thereof and a



link arranged within said filler and conductively interconnecting said terminal elements, said link being made in part of a metal having a relatively high conductivity and a relatively high fusing point and in part of a low fusing point alloy of indium to cause destruction of said link by formation of an alloy between said relatively high fusing point metal and the indium phase of said alloy upon heating of said low fusing point alloy to a predetermined temperature.

14. A lag-type fuse comprising a tubular casing, a pulverulent quartz filler within said casing, terminal elements closing said casing at the ends thereof and a link arranged within said filler and conductively interconnecting said terminal elements, said link comprising a ribbon of silver and an overlay of a low fusing point alloy of indium in intimate contact with said silver ribbon.

15. A lag-type fuse comprising a tubular casing, a pulverulent arc-quenching filler within said casing, a pair of terminal elements closing said casing at the ends thereof and a link arranged within said filler and conductively interconnecting said pair of terminal elements, said link comprising a multi-perforated ribbon of a metal having a relatively high conductivity and a relatively high fusing point and an element of a low fusing point alloy of indium supported by said ribbon at a perforated point thereof to destroy said ribbon by alloy-formation at said point at the occurrence of overload currents within a predeterminable range.

16. A fuse comprising a tubular casing, a pulverulent arc-quenching filler within said casing, a pair of terminal elements at the ends of said casing, and a fuse link arranged within said filler and conductively interconnecting said pair of terminal elements, said link comprising a first portion of a metal having a relatively high conductivity and a relatively high fusing point and a second portion of a low fusing point alloy of indium supported by said first portion to cause destruction of said link by formation of an alloy between said high fusing point metal and the indium phase in said second portion upon heating of said second portion to a predeterminable temperature.

17. A fuse link for time lag fuses comprising a ribbon of copper having a point of restricted cross-sectional area defining the point of arc initiation at the occurrence of major fault currents, and a low fusing point metal element supported by said copper ribbon at a point of said copper ribbon situated immediately adjacent said point of restricted cross-sectional area thereof to cause destruction of said point of restricted cross-sectional area at a predetermined range of overload currents by a metallurgical reaction between copper and said low fusing point metal element, said low fusing point metal element including indium.

18. A fuse link according to claim 17 wherein said low fusing point metal element consists of an alloy of indium with another low fusing point metal.

19. A lag-type fuse comprising a tubular casing, a pulverulent quartz filler within said casing, terminal elements closing said casing at the ends thereof and a link arranged within said filler and conductively interconnecting said terminal elements, said link comprising a ribbon of copper and an overlay of a low fusing point alloy of indium in intimate contact with said copper ribbon.

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