

June 4, 1963

H. H. HALLAS

3,092,715

METHOD FOR MANUFACTURING FUSE LINKS

Filed May 6, 1960

4 Sheets-Sheet 1

FIG. 1

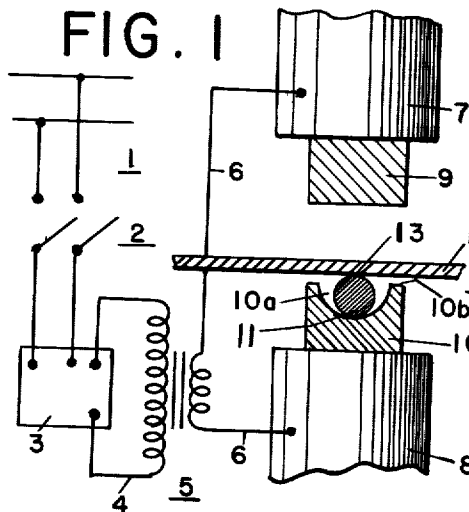


FIG. 2

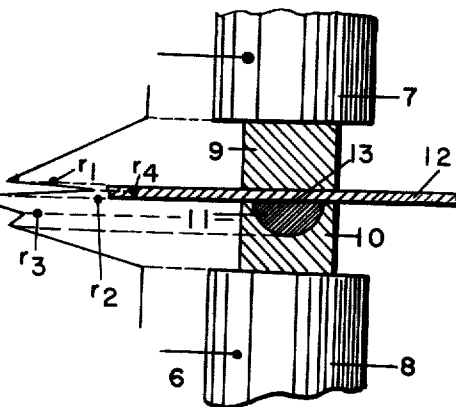


FIG. 3

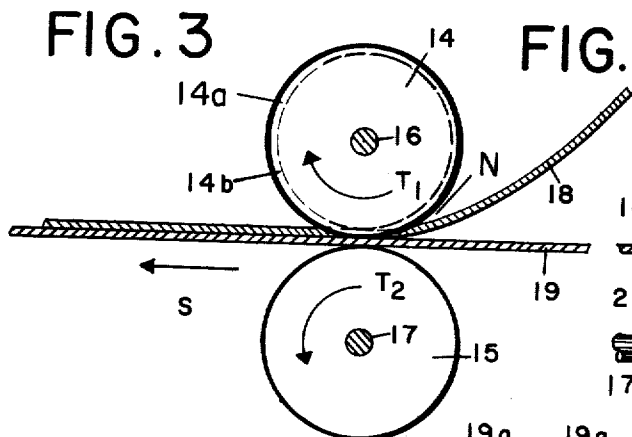


FIG. 4

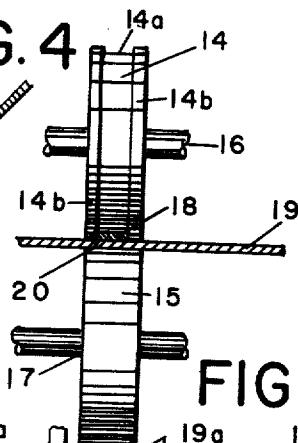


FIG. 5

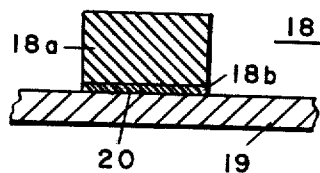
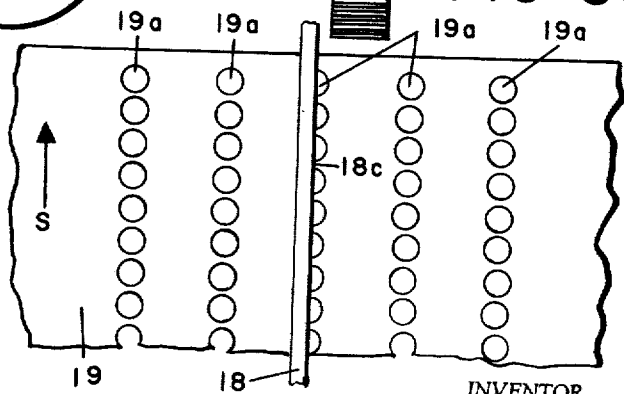


FIG. 6



INVENTOR.

Harry H. Hallas

BY

Harry H. Hallas

Atty.

June 4, 1963

H. H. HALLAS

3,092,715

METHOD FOR MANUFACTURING FUSE LINKS

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4 Sheets-Sheet 2

FIG. 7

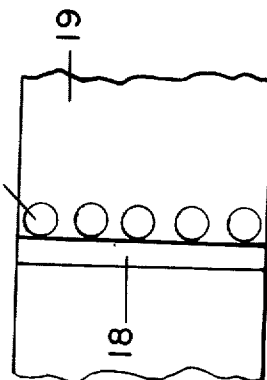
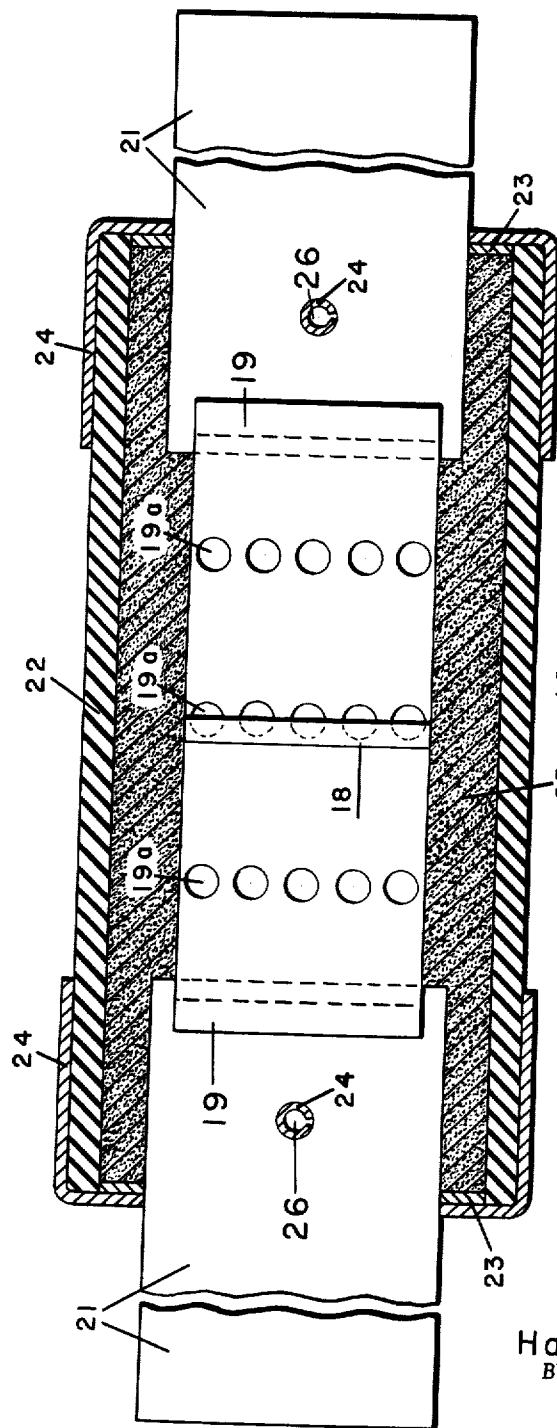


FIG. 7a

INVENTOR.
Harry H. Hallas
BY *Wm. H. Sawyer*
Atty.

June 4, 1963

H. H. HALLAS

3,092,715

METHOD FOR MANUFACTURING FUSE LINKS

Filed May 6, 1960

4 Sheets-Sheet 3

FIG. 8



FIG. 9



INVENTOR.

Harry H. Hallas

BY

Harry H. Hallas

June 4, 1963

H. H. HALLAS

3,092,715

METHOD FOR MANUFACTURING FUSE LINKS

Filed May 6, 1960

4 Sheets-Sheet 4

FIG. 10

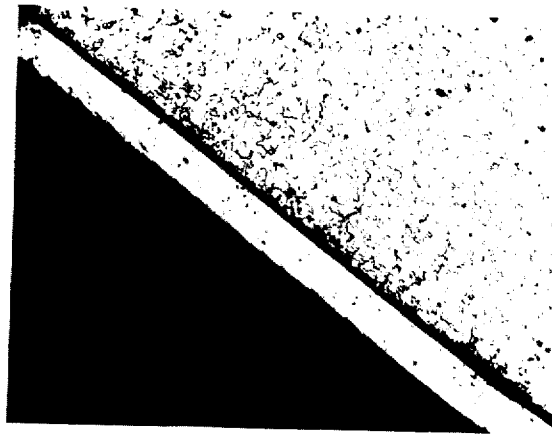


FIG. 11



INVENTOR.

Harry H. Hallas
BY

William Salzer

1

3,092,715

METHOD FOR MANUFACTURING FUSE LINKS
 Harry H. Hallas, Newton, Mass., assignor to The Chase-Shawmut Company, Newburyport, Mass.
 Filed May 6, 1960, Ser. No. 27,430
 13 Claims. (Cl. 219-117)

This invention has reference to time-lag fuses, and more particularly to time-lag fuses wherein time-lag is achieved by providing an alloy-forming overlay of a metal having a relatively low fusing point, e.g. tin, on a base metal having a relatively high fusing point and relatively high conductivity, e.g. silver or copper.

It is one object of this invention to provide improved time-lag fuses of the above description.

Such fuses are predicated upon metal diffusion governed by certain differential equations.

The application of metal diffusion for the purpose of achieving time-lag in electric fuses has been described in a paper by A. W. Metcalf "A New Fuse Phenomenon," BEAMA Journal (British) Pt. 1, April 1939, pp. 109-112; Pt. 2, May 1939, pp. 151-152. The time-current characteristics of this type of fuse shown in the above paper, and those of like time-lag fuses based on work done along the same lines as Metcalf, subsequent to Metcalf, evidence a relatively wide spread from average values. In other words, the time-current characteristic of this type of fuse is not a line but a relatively wide band. While the blowing-currents and blowing-times of any particular fuse design are defined by and lie within that band, the exact time actually required by a given specimen to blow when carrying a given current cannot be predicted.

It is, therefore, one object of this invention to provide means for narrowing the band width of the time-current characteristic or, in other words, to provide means which are conducive to a higher degree of uniformity of performance than in prior art time-lag fuses predicated on the formation of alloys between metals having dissimilar fusing points.

In prior art fuses of the above description, the time-current characteristic is not only a relatively wide band, but a band which tends to widen during the useful life of the fuse. This phenomenon is frequently referred to as ageing.

It is, therefore, another object of the invention to provide means which result in both narrowing of the band width of the time-current characteristic and precluding spreading of its width during the lives of the fuses.

The total time involved in interrupting a circuit by a time-lag fuse which is based on metal diffusion comprises three distinct periods, namely (1) the period required for fusion of the low fusing point metal, (2) the period from fusion of the low fusing point metal to kindling of an arc, and (3) the period from kindling of an arc to achieving arc extinction.

The first mentioned and second mentioned periods of time vary depending upon alloy-formation which has taken place before occurrence of the excess current which causes the fuse to blow, i.e. during the manufacturing process of the fuse, and during the useful life of the fuse.

It is a further object of this invention to provide processes for manufacturing fuse links making it possible to minimize alloy-formation during manufacturing, and making it possible to rigidly standardize whatever minimal alloy-formation takes place during manufacturing.

The larger the mass of low fusing point metal, the longer the times involved for a given current to heat that mass to its fusing point. It follows therefrom that fuse links required to have substantial lag times, call for relatively large masses of overlay metal.

2

It is, therefore, another object of this invention to provide processes for manufacturing fuse links making it possible to bond relatively large masses of low fusing point metals to high fusing point metals, which processes also minimize alloy-formation incident to the bonding operation, and which processes make it also possible to rigidly standardize and control minimized alloy-formation.

It is well known from the theory of electric resistance of metals and alloys that in a perfectly periodic lattice a beam of electrons moving in a given direction continues to move in that direction indefinitely. In other words, a perfect lattice has no resistance whatever. If the lattice is not perfectly periodic electrons moving through the lattice structure will be scattered, from which scattering resistance results. The periodicity of a lattice is impaired by the presence of foreign atoms in solid solution. Even if the amounts of impurities are small the relative increase in resistance may be very large.

As a general rule, when considering the manufacture and operation of fuse links with overlays of a metal having a relatively low fusing point placed on a base metal having a relatively high fusing point, consideration is given but to the diffusion of the high fusing point metal into the low fusing point metal. However, the diffusion of the low fusing point metal into the high fusing point metal is also important in regard to operation as well as in regard to manufacture of the fuse.

Overlays of a relatively low fusing point metal may be made by placing some low fusing point overlay metal on one side of the high fusing point base metal, and then heating the side of the base metal opposite to that on which the overlay metal has been placed. Under such conditions the base metal may reach temperatures way above the fusing point of the overlay metal, and then a significant and highly detrimental diffusion of overlay metal into the base metal may occur.

It is, therefore, another object of this invention to provide heating means for bonding a low fusing point overlay metal to a high fusing point base metal which are not conducive to that kind of heat distribution which favors a migration of the low fusing point overlay metal into the high fusing point base metal.

Further objects and advantages of this invention will become apparent as the following description proceeds, and the features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to, and forming part of, this specification.

For a better understanding of the invention reference may be had to the accompanying drawings illustrating the invention wherein:

FIG. 1 shows, diagrammatically, an arrangement of parts for carrying this invention into effect and a fuse link in an initial stage of the manufacturing process thereof;

FIG. 2 shows substantially the same parts as FIG. 1 in another position thereof, illustrating the final stage of the process indicated in FIG. 1;

FIG. 3 shows, in side elevation, another arrangement of parts for carrying the invention into effect;

FIG. 4 is a front view of the arrangement of parts shown in FIG. 3;

FIG. 5 is a cross-section, on a larger scale, of the product manufactured by means of the arrangement shown in FIGS. 3 and 4;

FIG. 6 is a top-plan view of a fuse link material manufactured by means of the arrangement shown in FIGS. 3 and 4;

FIG. 7 is a longitudinal section of a time-lag fuse comprising a fuse link embodying the present invention;

FIG. 7a shows a modification of a detail of FIG. 7;

FIG. 8 is a photomicrograph at a magnification of

3

50× of a cross-section of a prior art fuse link of copper having an overlay of tin;

FIG. 9 is a photomicrograph at a magnification of 500× of the same cross-section as shown in FIG. 8;

FIG. 10 is a photomicrograph at a magnification of 50× of a cross-section of a fuse of copper having an overlay of tin manufactured according to the present invention; and

FIG. 11 is a photomicrograph at a magnification of 500× of the same cross-section as shown in FIG. 10.

Referring now to the drawings, and more particularly to FIGS. 1 and 2 thereof, numeral 1 has been applied to generally indicate a source of electric current connected to an electric timer by the intermediary of electric switch 2. Timer 3 controls the primary circuit 4 of a transformer 5 whose secondary circuit 6 comprises electrodes 7 and 8. Electrodes 7 and 8 are provided with inserts 9 and 10, preferably made of carbon steel. Insert 10 defines a cavity 10a into which a pre-measured pellet 11 has been placed. Pellet 11 consists of a metal in the nature of soft, low fusing point solder, i.e. a metal having a relatively low melting point and a relatively low conductivity. Pellet 11 may consist of tin, tin-lead alloys, indium if the base metal of the link is silver, etc. Numeral 12 indicates a relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity, e.g. silver or copper.

The process according to this invention is initiated by adjusting timer 3 for a given closing time and lowering electrode 7 and insert 9 so as to engage sheet 12. At this time switch 2 is being closed and parts 7, 9 are further lowered exerting pressure upon pellet 11. When insert 9 engages sheet 12, a current path is established through sheet 12 and pellet 11. The current then flowing through the secondary circuit 6 of transformer 5 is relatively small on account of the relatively high ohmic resistance of pellet 11. The compression of pellet 11 then progressively taking place between insert 10 and sheet 12 is largely due to so-called cold flow, which is more or less enhanced by virtue of the fact that pellet 11 is being heated by the passage of an electric current through it. The moment sheet 12 engages the upper surface 10b of insert 10 a current path is established through sheet 12 immediately adjacent to the surface 13 between pellet 11 and sheet 12, shunting the flow of current through pellet 11 and having a considerably smaller electric resistance than pellet 11. As a result, the magnitude of the current in circuit 6 increases and this causes a relatively intense heating of interface 13, while all other parts of the arrangement remain relatively cool. Pellet 11 fuses at the interface 13 on account of the heating of interface 13 and can precisely be controlled by timer 3, fusion of pellet 11 can be limited to an extremely thin layer of pellet 11. This layer establishes a fusion bond with sheet 12 without causing any significant diffusion of the base metal of which sheet 12 is made into the material of which pellet 11 is made. The temperature at the interface 13 can be rigidly controlled to stay below temperatures at which a significant diffusion of the low fusing point metal of which pellet 11 is made into the high fusing point metal of which sheet 12 is made will occur.

FIG. 2 shows all the parts illustrated in FIG. 1 after compression of pellet 11 into a semi-spherical overlay on sheet 12. The circuitry shown in FIG. 1 has been omitted in FIG. 2. FIG. 2 illustrates, diagrammatically, the resistance R inside of the gap formed between electrodes 7 and 8. It will be understood that the curve representing the resistance changes throughout the entire bonding process, and that the curve of FIG. 2 refers to an arbitrary selected point of time. The contact resistance r_1 between insert 9 and sheet 12 is lower than the contact resistance r_2 between insert 10 and pellet 11. The contact resistance r_2 is maximum at the initial stage of

4

the process illustrated in FIG. 1, and decreases progressively as pellet 11 is being compressed and the area of engagement between pellet 11 and insert 10 increased. The magnitude of r_2 depends upon the metals of which parts 11 and 12 are made, the geometry of pellet 11 and of cavity 10a, surface conditions of parts 11 and 12, the size and contour of face 10b, and the force by which electrodes 7 and 8 are acted upon. The time of current flow and the intensity of the current are adjusted in such manner that the surface of pellet 11 remote from sheet 12 and the surface of sheet 12 engaged by insert 9 never reach the fusing point of the respective metal. It has not been found necessary to water-cool electrodes 7 and 8 in order to achieve this end; but under certain circumstances water-cooling of electrodes 7 and 8 may be desirable, or necessary. Reference characters r_3 and r_4 have been applied to indicate the total resistance of pellet 11, and base of metal 12, respectively. It is apparent that the former is considerably higher than the latter. The interface 13 is the point of highest resistance, and greatest heat generation. It is the only point where fusion occurs.

The area of engagement between insert 9 and sheet 12 is much larger than the area of engagement between sheet 12 and pellet 11 and the area of engagement between sheet 12 and insert 10. Therefore the current density at the upper surface of sheet 12 will be considerably less than the current density at the lower surface of sheet 12. Hence heating will primarily occur at the lower surface of sheet 12 and bring the lower surface of sheet 12 to the fusing point of the metal of which pellet 11 is made without need of heating portions of sheet 12 remote from pellet 11 to a temperature above the fusing temperature of the metal of which pellet 11 is made.

Referring now to FIGS. 3 and 4, numerals 14 and 15 have been applied to indicate a pair of rolls supported by shafts 16 and 17, respectively. Rolls 14, 15 are electrodes and are connected to the same circuitry as shown at the left of FIG. 1, i.e. they form part of a secondary circuit of a transformer. Rolls 14, 15 are preferably made of carbon steel. The upper roll 14 is provided with a peripheral groove 14a which is rectangular in cross-section and adapted to receive a relatively thick and narrow wire or strip 18 of a metal in the nature of soft, low fusing point solder, e.g. tin, or an alloy of tin. Strip 18 is taken from a rotatable supply reel (not shown). A relatively thin and relatively wide sheet 19 of a metal having a relatively high conductivity and a relatively high fusing point, e.g. copper, is fed to the nip N formed between rolls 14 and 15. Sheet 19 is moved from right to left, as indicated by the arrow S. This may be achieved by suitable transport rolls not shown in the drawing. Strip 18 is inserted into, and guided by circular groove 14a in roll 14. Rolls 14 and 15 may either be power driven or rotated as indicated by arrows T_1 and T_2 by frictionally engaging strip 18 and sheet 19. An electric current is caused to flow from roll 14 through strip 18, sheet 19 and roll 15. The portion of that current flowing through strip 18 is relatively small since the specific resistance of the metal of which strip 18 is made is relatively high and since strip 18 is relatively thick. The current flowing through strip 18 is not sufficient to cause fusion of strip 18 at any point thereof. The preponderant portion of the current flowing from roll 14 to roll 15 flows through the two flanges 14b, 14b of roll 14 laterally bounding groove 14a and strip 18. The current density will be highest at the points where sheet 19 is engaged by flanges 14b, 14b of rolls 14 and lowest where the lower surface of sheet 19 is engaged by the relatively wide surface of roll 15. Hence heat generation will be concentrated on the upper surface of sheet 19 and will be limited to two marginal zones immediately adjacent the interface 20 formed between strip 18 and sheet 19.

By proper selection of all the parameters affecting the process, and in particular the intensity of the current flow-

5

ing between rolls 14, 15 and the duration each increment of strip 18 and sheet 19 is heated by that current, depending in turn on the velocity at which materials 18, 19 are moved in the direction of arrow S, fusion of strip 18 can be limited to a narrow zone immediately adjacent to sheet 19. This has been indicated in FIG. 5 wherein reference character 18a has been applied to that portion of the prefabricated strip 18 whose microstructure has remained unchanged during the bonding process and wherein reference character 18b has been applied to indicate a narrow zone immediately adjacent interface 20 that was fused during the bonding process and whose original microstructure changed thereby.

Referring now to FIG. 6, the sheet 19 shown therein which may be a thin and wide copper sheet is provided with a plurality of spaced parallel lines 19a each formed by a plurality of contiguous aligned perforations. In FIG. 6 these perforations are shown to be circular, but they may have any other desired shape consistent with their purpose of defining points of restricted cross-sectional area where fusion will be initiated at the occurrence of fault currents. Strip 18 of a metal in the nature of soft, low fusing point solder is arranged parallel to lines 19a formed by perforations, and it adheres to sheet 19 in such a way as to cover a predetermined portion of the constituent perforation of one of lines 19a. As shown in FIG. 6, strip 18 covers 50% of the area of the constituent perforations of one line 19a and its right edge 18c coincides with the point of minimum cross-sectional area defined by the central line of perforations 19a. As a result, the area of the sheet material 19 situated to the left of edge 18c will be cooled by overlay 18 when sheet 19 is used to carry current whose direction of flow is substantially at right angles to arrow S. The semi-finished product shown in FIG. 6 may be cut into strips of any desired width, depending upon desired current-carrying capacity, at right angles to arrow S, and each such strip is adapted to be used as a fuse link, or fusible element, in a time-lag fuse. The particular arrangement of strip 18 shown in FIG. 6 makes it possible to minimize the number of break-forming points for a given voltage and current rating. This is due to the fact that breaks will form at the points or line of minimum cross-sections associated with strips 18, both on occurrence of small protracted overload currents, and on occurrence of large short-circuit currents. On occurrence of large short-circuit currents the temperature rise at all points of restricted cross-sectional area, including those associated with overlay 18, will be rapid and the cooling effect of strip 18 will be negligible under such conditions. Therefore the five lines of perforations provided in the structure of FIG. 6 will result in the formation of five series breaks on occurrence of fault currents involving a relatively rapid rate of rise of current flow. On occurrence of relatively small protracted overloads strip 18 will operate as an effective cooling and heat absorbing means for the points of narrowest cross-section of sheet 19 associated with strip 18. In this instance blowing of the fuse link will be delayed until such time when the points of narrowest cross-section of sheet 19 associated with strip 18 reach and exceed the fusing temperature of the metal of which strip 18 is made and the base metal of which sheet 19 is made begins to dissolve in the metal of which overlay strip 18 is made.

Fuse links made of the semi-finished link material shown in FIG. 6 and described in connection with FIG. 6 have a mode of operation which is similar to that of the fuse links disclosed in the patent application of Frederick J. Kozacka, Ser. No. 764,293, filed September 30, 1958 for Time-Lag Fuses, assigned to the assignee as the present application. The particular position of the strip 18 shown in FIG. 6 makes it possible to achieve a better or faster cooling action of the points of minimum cross-sectional area defined by the center line of perforations provided in the link. Therefore this position of the overlay is conducive to achieving longer delay times. The

6

method shown in FIGS. 3 and 4 of affixing the overlay strip 18 to the base sheet 19 is also conducive to a better control of heating and to faster rates of production than the method of providing an overlay on a base sheet disclosed in the above Kozacka application. Fuse links manufactured according to the present invention may be embodied to advantage in the fuse structure disclosed in the above Kozacka application.

Referring now to FIG. 7, showing a longitudinal sectional view of a fuse comprising a fuse link embodying this invention, reference numeral 21 has been applied to indicate a pair of blade contacts to which the axially outer ends of a ribbon type fuse link have been conductively connected by such means as brazing. The above mentioned fuse link comprises base metal 19 and overlay 18. Blade contacts 21 project into a tubular casing 22 of insulating material closed on both ends by asbestos washers 23 and brass caps 24. Each blade contact 21 is provided with a bore 26 into which a circularly bent spring 24 is inserted. The axially outer ends of spring 24 project into holes in casing 22 arranged in alignment with the holes in blade contacts 21 which receive the center portions of springs 24. Fuse link 18, 19 is submerged in a pulverulent arc-quenching filler 25 inside casing 22 as, for instance, quartz sand. Link 18, 19 is provided with three parallel lines 19a of circular perforations of which the axially inner line of perforations is associated with overlay 18 of a low-fusing point metal, e.g. tin. The base sheet 19 of link 18, 19 may consist of copper.

Strip 18 must be arranged parallel and close to one of the lines 19a of perforations, preferably close to the center line of perforations. Its position can be shifted from that shown in FIG. 7 in such a way that one of the edges of strip 18 forms substantially a tangent to the circular perforations of the adjacent line 19a of perforations, thus doing away with the overlap between the strip 18 and the circular perforations. FIG. 7a shows the shifted position of strip 18. The aforementioned shift of strip 18 has a marked effect upon the current rating of the fuse. The aforementioned shift of strip 18 also eliminates the presence of a relatively substantial mass of low fusing point metal from one of the points of arc initiation. This, in turn, tends to increase the arc voltage generated at the particular point of arc initiation. It is thus apparent that the position of strip 18 in any particular case will depend upon rating considerations and upon the desired magnitude of the arc voltage.

Referring now to FIGS. 8 to 11, when considering the photomicrographs shown in these figures it must be kept in mind that the appearance of these photomicrographs is due to the great difference in hardness between the copper base and the tin overlay. This difference makes it difficult to properly polish and etch the cross-sections of both metals. FIGS. 8 to 11 show a black parting line at the interface between the copper base and the tin overlay. This is no indication of structure but has its optical reasons. In polishing the tin polishes down deeper than the copper. The resulting geometric step appears black in all the photomicrographs. In all photomicrographs the tin phase is lightly etched with 2.5% nitric acid 5% acetic acid (glacial) in water.

The link whose cross-section is shown in FIGS. 8 and 9 has been manufactured by placing a piece of tin on a copper strip, and then placing the copper strip on a hot plate until the tin is melted. FIGS. 8 and 9 clearly show a copper tin intermetallic compound, probably eta tin, at the interface between the two metals. The intermetallic compound is present in the tin grain boundaries over distances of $\frac{1}{4}$ to $\frac{1}{2}$ of the thickness of the tin overlay. The top surface of the tin, visible at the upper left of FIG. 8, allows a good estimation of the relative extent of grain boundary penetration of the intermetallic compound.

7
The microstructure of FIGS. 10 and 11 shows good bonding between the copper and tin surfaces virtually without formation of an intermetallic compound.

As mentioned above, the magnitude of the bonding current flowing through the low fusing point overlay material during the manufacturing process of the link material is of relatively minor significance in regard to the present process. This applies to the bonding current flowing through pellet 11 (FIGS. 1 and 2) as well as to the bonding current flowing through strip 18 (FIGS. 3 and 4). Several experiments were made to determine the part played by that current in the present process. In one of these experiments a composite top roll was substituted for the uniform top roll 14 shown in FIG. 4. The composite roll comprised an axially inner portion of insulating material and two axially outer portions substantially identical with the axially outer portions or flange portions 14b shown in FIGS. 3 and 4 and described in connection therewith. That test set-up was found to work satisfactorily as long as the axially inner insulating portion which precluded the flow of current through strip 18 was adapted to firmly press strip 18 against base sheet 19. The relatively small current flowing through the overlay metal may be helpful where it is desired to change the shape of the overlay during the bonding process as, for instance, shown in FIGS. 1 and 2 and described in connection therewith.

The term "soldering" is generally understood to mean joining two metal surfaces by means of another metal, or alloy, that is applied in molten condition. It will be apparent that the term "soldering" does not apply to the present process if the above definition of "soldering" is adopted.

The process which has been described above is, in effect, a resistance welding process applied to join a metal in the nature of soft low fusing point solder to a high fusing point metal such as copper or silver.

In order to obtain good adherence of the overlay to the base metal the latter must be as clean as possible. It is necessary or desirable to pre-treat the high fusing point base metal with an appropriate flux as generally used in soldering operations. Since rosin flux may impair the conductivity of the set-up, acid flux should be used for carrying this invention into effect.

The strip-process illustrated in FIGS. 3 and 4 and described in connection therewith calls for an overlay material which can readily be bent without having a tendency to break. Tin with small additions of antimony complied well with this particular requirement. The addition of antimony may be in the order of 5% by weight.

It will be apparent from the foregoing that the method according to this invention minimizes alloying during the bonding operation of the overlay, and makes it possible to achieve a complete control and standardization of whatever minimal alloying occurs.

It will be understood that I have illustrated and described preferred embodiments of my invention and that various alterations may be made in the details thereof without departing from the invention as defined in the appended claims.

I claim:

1. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under pressure upon a relatively thin sheet defining zones of reduced cross-sectional area and having a relatively large surface area and being made of a metal having a relatively high fusing point and a relatively high conductivity immediately adjacent one of said zones of reduced cross-sectional area a relatively thick overlay having a relatively small surface area and being made of a low fusing point metal in the nature of soft solder; and of passing an electric current through said sheet adjacent the interface between said sheet and said overlay, said current being sufficiently high and of sufficiently long duration to cause fusion of said overlay at said interface, and said current being sufficiently small and of sufficiently short duration to preclude fusion of said overlay at portions thereof remote from said interface.
2. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under pressure upon a relatively thin sheet defining zones of reduced cross-sectional area and having a relatively large surface area and being made of a metal having a relatively high fusing point and a relatively high conductivity immediately adjacent one of said zones of reduced cross-sectional area, a relatively thick overlay having a relatively small surface area and being made of a low fusing point metal in the nature of soft solder; of passing an electric current through said sheet adjacent the interface between said sheet and said overlay and of causing said current to be denser at the surface of said sheet supporting said overlay than on the surface thereof remote from said overlay, said current being sufficiently high and of sufficiently long duration to cause fusion of said overlay at said interface and said current being sufficiently low and of sufficiently short duration to preclude fusion of said overlay at portions thereof remote from said interface.
3. A method for manufacturing fuse links for time-lag fuses comprising the steps of causing engagement under pressure between a relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity and a pre-measured pellet of a metal having a relatively low fusing point and a relatively low conductivity, and of passing an electric current through said sheet adjacent the interface formed between said sheet and said pellet, said current being sufficiently high and of sufficiently long duration to cause fusion of said pellet at said interface, and said current being sufficiently small and of sufficiently short duration to preclude fusion of said pellet at portions thereof remote from said interface.
4. A method for manufacturing fuse links for time-lag fuses comprising the steps of causing engagement under pressure between a pre-measured relatively thick pellet of a low fusing point metal in the nature of soft solder and a relatively thin sheet of copper, and of establishing a flow of current through said sheet around said pellet while progressively increasing the pressure between said pellet and said sheet, said current being sufficiently high and of sufficiently long duration to cause fusion of said pellet at the interface formed between said pellet and said sheet, and said current being sufficiently small and of sufficient short duration to preclude fusion of said pellet at portions thereof remote from said interface.
5. A method for manufacturing fuse links for time-lag fuses comprising the steps of causing engagement under pressure between a pre-measured relatively thick pellet of a low fusing point metal in the nature of soft solder and a relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity, of establishing a closed electric circuit including said pellet and said sheet and passing an electric current through said circuit while progressively increasing the pressure between said pellet and said sheet, and of establishing in said circuit a current path through said sheet immediately adjacent the interface formed between said pellet and said sheet, said current path shunting the path of the current through said pellet and having a smaller electric resistance than said pellet.
6. A method for manufacturing fuse links for time-lag fuses comprising the steps of placing a relatively thick pre-measured pellet of a metal in the nature of soft solder into a cavity defined by a first electrode; of causing engagement between a portion of said pellet protruding outside said cavity and a relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity and of causing engagement between said sheet and a second electrode; of applying

sufficient pressure by said first electrode and said second electrode upon said pellet and said sheet to compress said pellet by said sheet into said cavity in said first electrode; and of simultaneously passing an electric current through said first electrode, said sheet and said second electrode, said current being sufficiently high and of sufficient duration to cause fusion of said pellet at the interface formed between said pellet and said sheet.

7. A method for manufacturing fuse links for time-lag fuses comprising the steps of causing engagement under pressure between a relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity and a relatively thick strip of a low fusing point metal in the nature of soft solder; of establishing an electric circuit through said sheet comprising a pair of parallel current paths in said sheet each situated adjacent the interface formed between said sheet and said strip; and of passing an electric current through said parallel current paths, said current being sufficiently high and of sufficiently long duration to cause said strip to adhere to said sheet, and said current being sufficiently small and of sufficiently short duration to preclude total fusion of said strip.

8. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under pressure upon a metal in sheet-form having a relatively high fusing point and a relatively high conductivity a pre-measured amount of a metal in nature of soft solder; of maintaining pressure between said first mentioned metal and said second mentioned metal and simultaneously establishing a local heat concentration at the interface between said first mentioned metal and said second mentioned metal by passing an electric current through said first mentioned metal immediately adjacent said interface, said current being sufficiently high and of sufficiently long duration to cause fusion of said first mentioned metal at said interface and formation of a fusion joint with said second mentioned metal at said interface, and said current being sufficiently small and of sufficiently short duration to preclude fusion of said first mentioned metal at points remote from said interface.

9. A method for manufacturing fuse links for time-lag fuses comprising the steps of placing a pre-measured amount of a metal in the nature of soft solder and a sheet of a metal having a relatively high fusing point and a relatively high conductivity between a pair of spaced electrodes forming part of the secondary circuit of a transformer; of reducing the spacing between said pair of electrodes and applying pressure with said pair of electrodes upon said first mentioned metal and said sheet; and of causing the flow of an electric current in said secondary circuit transversely across said sheet on both sides of the interface formed between said first mentioned metal and said sheet to heat said interface from two juxtaposed regions, said current being sufficiently high and of sufficiently long duration to cause fusion of said first mentioned metal at said interface, and said current being sufficiently small and of sufficiently short duration to preclude fusion of said first mentioned metal at points thereof remote from said interface.

10. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under

pressure upon a relatively wide, relatively thin sheet of a metal having a relatively high fusing point and a relatively high conductivity and defining a substantially straight zone of reduced cross-sectional area, parallel to said zone of reduced cross-sectional area by a rolling motion successively contiguous points of a relatively narrow, relatively thick strip of a metal in the nature of soft, low melting point solder; of successively passing an electric current through aligned points of said sheet adjacent the interface formed between said sheet and said strip, said current being sufficiently high to cause said strip to fuse at the interface formed between said strip and said sheet and to be bonded to said sheet, and said current being sufficiently low to preclude fusion of said strip throughout the entire mass thereof.

11. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under pressure upon a relatively thin and relatively wide sheet of a metal having a relatively high fusing point and a relatively high conductivity and defining a straight line of reduced cross-sectional area, successively parallel to said straight line a relatively thick and relatively narrow strip of a metal in the nature of soft low melting point solder; of passing an electric alternating current through successively engaging points of said strip and said sheet while maintaining pressure at said points; said current having a sufficiently high R.M.S. value to cause said strip to fuse and to be bonded at the interface between said strip and said sheet to said sheet, and said current having a sufficiently low R.M.S. value to preclude fusion of portions of said strip remote from said interface.

12. A method for manufacturing fuse links for time-lag fuses comprising the steps of superimposing under pressure a relatively thin and relatively wide sheet of copper defining a straight line of reduced cross-sectional area, successively parallel to said straight line a relatively thick and relatively narrow strip of a metal in the nature of soft, low fusing point solder; and of causing sequential local heating of aligned points of said sheet when being sequentially engaged by said strip by passing an electric current through said sheet adjacent the interface between said sheet and said strip, said current being sufficiently high to result in formation of a bond between said strip to said sheet, and said current being sufficiently low to preclude fusion of said strip at points remote from said interface.

13. A method for manufacturing fuse links as specified in claim 12 wherein said strip consists of tin with a small addition of antimony.

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