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**(54) Fusible element assembly and
a high voltage current limiting
fuselink incorporating same**

(57) A plurality of high-melting fusible elements 15 and a plurality of low-melting fusible element assemblies 19 are connected in series between conductive terminals 11 at the ends of an insulating barrel 10. The elements 15 and assemblies 19 are respectively wound around a relatively wide

portion 13 and a relatively narrow portion 14 of an insulating former 12, and a granular dielectric material 21 surrounds these parts. Each of the assemblies 19 is composed of a flat conductor having an overlay of low melting point eutectic alloy at about its mid-point, the overlay being covered by a coating of refractory cement. A flexible thermally insulating sleeve surrounds the conductor, and plugs of silicone grease seal the ends of the sleeve.

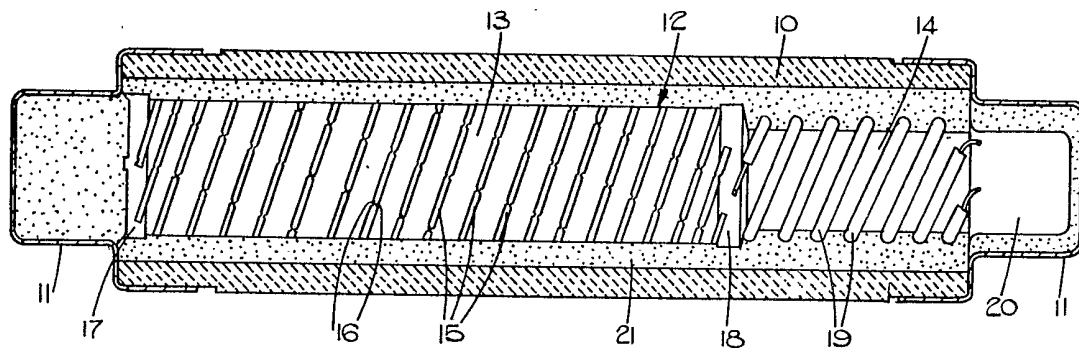


FIG. 1.

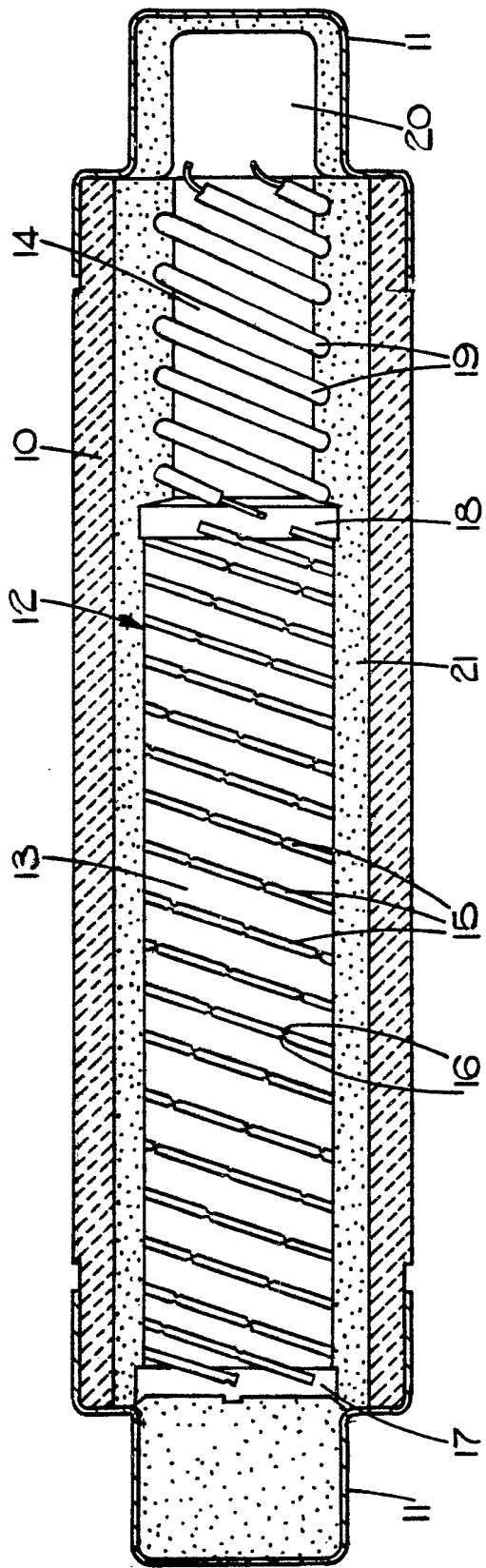


FIG. 1.

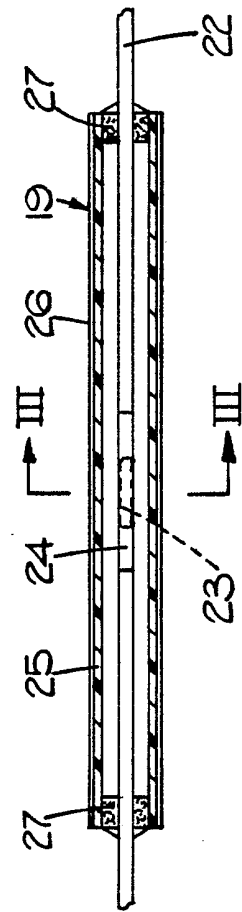


FIG. 2.

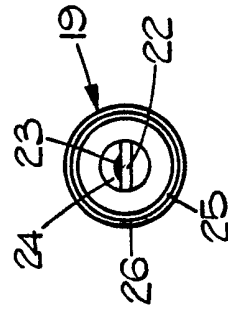


FIG. 3.

SPECIFICATION

Fusible element assembly and a high voltage current limiting fuse incorporating same

This invention relates to a fusible element assembly, and also to a high voltage current limiting fuselink incorporating same. More particularly, the invention is concerned with fuselinks of the so-called general purpose or full range class.

In one type of fuselink of this class low-overcurrent breaking capability is assisted by the use of a flexible insulating sleeve placed around a portion of each fusible element. In fuses of this kind it is usual to have one or more wire or ribbon elements in parallel; these are of silver or similar high conductivity metal and usually have a plurality of serially related constrictions (such as holes or notches) to assist in the current-limiting action which takes place during major short-circuit operation. Such elements are commonly wound in helical fashion upon an insulating former, and are embedded in granulated quartz within a ceramic or other type of fuse barrel. The fuse barrel is terminated at its ends by copper or brass end-caps which also serve as external electrical connections.

In such fuses, a serially related portion of each element is arranged to melt at a lower current than the remaining portion(s), i.e. this portion (henceforth referred to as the "low-melting" portion) will melt first under low-overcurrent fault conditions leaving the remaining portion(s) (henceforth referred to as the "high-melting" portion(s)) intact. Flexible insulating sleeving is placed around the low-melting portion of the element and this by means of the expulsion fuse principle, familiar to those skilled in the art, assists in extinguishing the arc formed during operation. Various methods are known for ensuring that such serially related portions melt at lower currents than the remainder of the fusible element. For example, the low-melting portion may be formed of a low-melting alloy or metal wire such as tin connected physically in series with the silver or copper strip. Alternatively, the low-melting portion may be a length of unconstricted silver or copper wire having a eutectic alloy overlay (known as 'm' effect) over part of its length, or the element may be homogeneous throughout its length, with the presence of 'm' effect at one point together with the thermal insulating effect of the surrounding flexible sleeve sufficing to ensure a lower melting current in that region.

The type of fuselink described above operates in the following manner. At high fault currents, the high-melting portions of the fusible elements are partially vapourised and absorb fault energy from the external system by converting the granulated quartz into a silver-sand slag known as fulgurite. On cooling, this fulgurite attains a high electrical resistance, so that the fault current is interrupted safely and effectively. At lower fault currents, however, this process become

ineffective and the low-melting portions of the fusible elements take over. Melting is initiated within the flexible insulating sleeves and the resulting arc generates ionised gas under pressure which is expelled from the open ends of the sleeve. De-ionisation is assisted by the cooling effect of gas vapourised from the inner walls of the sleeve by the heat of the arc itself.

General purpose fuselinks constructed on the principles described above, while satisfactory at low current ratings, become difficult to design and construct at larger ratings, for example 50 amperes and above. Nevertheless, such fuselinks are frequently required for the protection of transformers of 500 KVA and above in urban distribution networks. The principal difficulties to be dealt with in constructing a fuselink having a high current rating are as follows:

- (i) At high current ratings, the take-over point between the high- and low-melting portions is of necessity at a higher value of current, and hence higher values of arc energy must be catered for within the flexible sleeves. The sleeves must therefore be provided with a reinforcement, which usually takes the form of glass filament roving or an outer sleeving, to provide mechanical support and prevent rupture. The overall bulk of the sleeving is consequently increased, although the entire fusible element/former assembly must still be accommodated within the overall fuse barrel dimensions laid down by international standards.
- (ii) The higher values of arc energy within the sleeves increases the risk of blockage (for example from metal particles or stray quartz granules), which could cause rupture of the sleeves and hence possible explosive failure of the fuselink itself.
- (iii) An increase in fuse current rating will necessitate an increase in conductor cross-section by a factor of $I_n^{3/2}$, where I_n is the rated current of the fuselink. Thus, a fuselink having a rating of 63A will have conductors which are at least twice the cross-section of a 40A fuselink. Such an increased section entails the use of even larger sleeves if risk of bore blockage is to be avoided. The problems of accommodating such large sleeves within a barrel of standard dimensions are thus exacerbated.
- (iv) The higher the current rating, the greater the number of high-melting portions that are required to co-ordinate correctly with the low-melting portions. The high-melting portions in being helically wound upon the insulating former must have a minimum separation between their adjacent turns of at least 5 mm (for a 12KV fuselink) if the danger of inter-turn flashover is to be avoided. Since the length of the fuselink (and hence that of the former) are fixed by specification, the necessary separation can often only be achieved by making the former of larger diameter. If however the former

diameter is optimised for the high-melting portions, then it is found that the sleeved low-melting portions when wound on the same size of former are too bulky to fit within the fuse barrel.

It is an object of the present invention to overcome these difficulties, and in particular to provide a general purpose fuselink which has a high current rating and yet which is capable of operating in a safe and consistent manner.

According to a first aspect of the invention, there is provided a fusible element assembly comprising a plain flat conductor, a part of the conductor intermediate its ends having an overlay of a material which when it melts will combine with the conductor, a coating of refractory cement provided over said overlay, a flexible thermally insulating sleeve surrounding the conductor at least at said part thereof, and means at the ends of the sleeve providing a seal between the sleeve and the conductor.

The conductor is preferably in the form of a silver or copper strip, and the overlay is preferably formed from a eutectic alloy.

The refractory cement may be a mixture of silicon carbide, silica and carbon.

Desirably, the sealing means comprises a viscous flexible sealing compound such as a high-temperature grease, preferably silicone grease.

The flexible sleeve may be reinforced by glass or silicon fibre roving, conveniently in a tight double layer.

According to a second aspect of the present invention, there is provided a high voltage current

limiting fuselink comprising an electrically insulating barrel having electrically conductive terminals at its ends, at least one high-melting fusible element arranged to melt at a relatively high current, at least one low-melting fusible

element assembly arranged to melt at a relatively low current and connected electrically in series with said at least one high-melting fusible element

between the terminals, the or each low-melting fusible element assembly including a conductor

having a thermally insulating sleeve therearound, an electrically insulating former disposed within the barrel and having a relatively wide portion

around which the or each high-melting fusible element is disposed and a relatively narrow

portion around which the or each low-melting fusible element assembly is disposed, and a granular dielectric material contained within the barrel and surrounding the assembly of the former, the fusible element, the high-melting

fusible element or elements and the low-melting fusible element assembly or assemblies.

The relatively wide and relatively narrow portions of the former may be produced as separate items and secured together.

Alternatively, the former may be produced by cutting a step in a single-piece member of constant width. Where the former is in the form of a ribbed cylinder (known in the art as a "star core"), the relatively wide and relatively narrow

portions of the former are portions of relatively

large and relatively small diameter, respectively.

The or each high-melting fusible element preferably comprises a metallic ribbon having therein a plurality of constrictions, for example in the form of notches or holes, the ribbon advantageously being made of silver or copper.

The or each low-melting fusible element assembly preferably has a structure in accordance with the first aspect of the invention described above.

Desirably, the number of the high-melting fusible elements is greater than or equal to the number of the low-melting fusible element assemblies.

The fuselink may further comprise an electrically conductive member positioned at the juncture of the relatively wide and relatively narrow portions of the former, the high-melting fusible element or elements and the low-melting fusible element assembly or assemblies being electrically connected to said member.

Conveniently, the relatively narrow portion of the former occupies substantially one quarter of the total length thereof, and its width (or diameter) may be between 30% and 60% of the width (or diameter) of the relatively wide portion.

The invention will now be further described, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is an axial section through a high voltage current limiting fuselink according to the present invention;

Figure 2 is a sectional plan view of a fusible element assembly which forms part of the fuselink shown in Figure 1; and

Figure 3 is a section taken along the line III—III in Figure 2.

Referring first to Figure 1, the high voltage current limiting fuselink shown therein comprises a tubular barrel 10 made of an electrically insulating material (such as ceramic) whose ends are closed by respective electrically conductive caps 11, which caps provide external terminals for the fuselink as a whole. Disposed in the barrel 10 is a former 12 which is also made of a ceramic material and which has a generally cruciform transverse cross-section. The former 12 has an axial step, so that it comprises a relatively wide or large diameter portion 13 and a relatively narrow or small diameter portion 14. The portions 13 and 14 may be produced separately and cemented together, or alternatively the former 12 may be manufactured by cutting a step in a homogeneous ceramic member having a uniform outer diameter (equal to that of the portion 13). The portion 14 extends for approximately one quarter of the length of the former 12, and its diameter is between 30% and 60% of the diameter of the portion 13.

Wound around the exterior of the portion 13 in a helical configuration are a plurality of high-melting fusible elements 15, each of which is composed of a silver or copper ribbon having a plurality of constrictions 16 at spaced intervals along its length. The constrictions 16 may take

the form of notches (as shown), or may be provided by holes in the ribbon. The elements 15 are connected electrically in parallel with one another between a terminal member 17 which is electrically connected to the cap 11 at one end of the barrel 10, and an intermediate terminal member 18 which surrounds the former 12 at the juncture between the portions 13 and 14.

Wound around the exterior of the portion 14 in a helical configuration are a plurality of low-melting fusible element assemblies 19 of the expulsion type. The construction of these assemblies will be described in detail later. The low-melting assemblies 19 are connected electrically in parallel between the intermediate terminal member 18 and the terminal member 20, which is itself electrically connected to the cap 11 at the other end of the barrel 10. The low-melting assemblies 19 are thus connected electrically in series with the high-melting elements 15 between the terminal members 17 and 20. The number of elements 15 and the number of assemblies 19 actually provided will depend upon the current rating of the fuselink: however, the number of the elements 15 will always be greater than or equal to the number of assemblies 19.

Reference numeral 21 denotes a granular dielectric filler material (such as granulated quartz) which fills the space between the former 12 and the barrel 10.

Referring now also to Figures 2 and 3, each low-melting assembly 19 is composed of a plain flat conductor 22 (i.e. of uniform cross-section and without any constrictions), which is preferably made of silver or copper. A portion of the conductor 22 substantially mid-way between its ends has an overlay 23 of a low melting point eutectic alloy (such as tin/silver or tin/lead). A coating 24 of refractory cement is applied so as to cover the alloy overlay 23 and extend beyond it in both directions. The refractory cement is preferably prepared by mixing together silicon carbide, silica and carbon in the presence of water to form a paste for ease of application, the paste thus applied being air-dried. The conductor 22 is then inserted through a flexible thermally insulating sleeve 25 whose bore is slightly greater in diameter than the width of the conductor, the sleeve being made of a material such as silicone rubber which is capable of withstanding high temperatures and which also has a high insulation resistance. The sleeve 25 is mechanically reinforced by glass or silicon fibre roving 26 provided on its exterior, the roving preferably being formed as a tight double layer. Finally, a small metered quantity of viscous sealing compound (such as high temperature silicone grease) is injected into each end of the sleeve 25 to form a respective insert 27 which seals the sleeve against the ingress of stray particles of quartz dust.

Operation of the fuselink is as follows. Under high fault current conditions (e.g. greater than six times the current rating of the fuselink), the high-

melting elements 15 have insufficient time to transfer heat to the surrounding quartz filler 21, and melting takes place at each of the constrictions 16. The arcs which result from such melting are cooled and extinguished by contact with the quartz filler 21 in a conventional manner. This operation takes place very quickly, usually in under 2 seconds. For such a short operating time, the alloy overlay 23 in each low-melting assembly 19 has insufficient time to melt and diffuse through the material of the respective conductor 22. The assemblies 19 therefore remain intact under high fault current operation.

Under low fault current conditions (e.g. less than six times the current rating of the fuselink), the high-melting elements 15 are cooled by the close proximity of quartz filler 21 and remain below their melting temperature. Thus, these elements remain intact. However, the low-melting assemblies 19 attain a much higher temperature because of the thermal insulation provided by the sleeves 25. This temperature is sufficient to cause the alloy overlay 23 to melt and combine with the material of the conductor. At this time, the refractory cement coating 24 holds the molten alloy in place and prevents it from running and being dissipated along the length of the conductor 22. Melting and separation of the conductor 22 therefore ensues rapidly and at a temperature which is sufficiently low to avoid damaging the sleeve 25.

At the instant when the circuit is broken by separation of the conductor 22, an arc is struck across the break in the latter, which is within the sleeve 25. The resultant blast of high temperature ionised gas blows the inserts 27 out of the ends of the sleeve 25, and the gas is itself expelled along the bore of the sleeve and out from both ends thereof, thereby extinguishing the arc by conventional expulsion principles.

Because each low-melting assembly 19 employs a comparatively thin strip of conductive material (as opposed to a relatively bulky round wire), a continuous venting space is created on either side of the conductor within the circular bore of the sleeve 25. Consequently, the risk of the bore becoming blocked is greatly reduced.

The provision of the refractory cement coating 24 ensures that the alloy overlay 23 does not become dissipated along the conductor 22, as described previously, and in combination with the overlay 23 ensures that the melting temperature will not be excessive.

The high temperature silicone grease inserts 27 at the ends of the sleeve 25 ensure that no blockage can occur through ingress of stray grains of the quartz filler 21, while at the same time the flexible nature of the seal ensures that it will easily be blown clear by the blast of ionised gas during operation.

By making the portion 14 of the former 12 of reduced diameter as compared with the portion 13, the sleeve 25 of each low-melting assembly 19 can be made of adequate diameter without the risk of the assemblies 19 jamming against the

internal wall of the barrel 10 during insertion of the former/fusible element assembly into the barrel. At the same time, the portion 13 is able to remain of sufficiently large diameter that the necessary number of high-melting elements 15 of adequate length can be wound therearound whilst still achieving the separation between adjacent turns required to avoid insulation breakdown or inter-turn flashover.

10 Claims (Filed on 6 Sept 83)

1. A fusible element assembly comprising a plain flat conductor, a part of the conductor intermediate its ends having an overlay of a material which when it melts will combine with the conductor, a coating of refractory cement provided over said overlay, a flexible thermally insulating sleeve surrounding the conductor at least at said part thereof, and means at the ends of the sleeve providing a seal between the sleeve and the conductor.

2. A fusible element assembly as claimed in claim 1, wherein the conductor is in the form of a silver or copper strip.

3. A fusible element assembly as claimed in claim 1 or 2, wherein the overlay is formed from a eutectic alloy.

4. A fusible element assembly as claimed in claim 1, 2 or 3, wherein the refractory cement is a mixture of silicon carbide, silica and carbon.

5. A fusible element assembly as claimed in any preceding claim, wherein the sealing means comprises a viscous flexible sealing compound.

6. A fusible element assembly as claimed in claim 5, wherein the sealing compound is a high-temperature grease.

7. A fusible element assembly as claimed in claim 6, wherein the sealing compound is silicone grease.

8. A fusible element assembly as claimed in any preceding claim, wherein the flexible sleeve is reinforced by glass or silicon fibre roving.

9. A fusible element assembly as claimed in claim 8, wherein the roving forms a tight double layer.

10. A high voltage current limiting fuselink comprising an electrically insulating barrel having electrically conductive terminals at its ends, at least one high-melting fusible element arranged to melt at a relatively high current, at least one low-melting fusible element assembly arranged to melt at a relatively low current and connected electrically in series with said at least one high-melting fusible element between the terminals, the or each low-melting fusible element assembly including a conductor having a thermally insulating sleeve therearound, an electrically insulating former disposed within the barrel and having a relatively wide portion around which the or each high-melting fusible element is disposed and a relatively narrow portion around which the or each low-melting fusible element assembly is disposed, and a granular dielectric material contained within the barrel and surrounding the

assembly of the former, the high-melting fusible element or elements and the low-melting fusible element assembly or assemblies.

11. A fuselink as claimed in claim 10, wherein the relatively narrow portions of the former are produced as separate items and are secured together.

12. A fuselink as claimed in claim 10, wherein the former is produced by cutting a step in a single piece member of constant width.

13. A fuselink as claimed in claim 10, 11 or 12, wherein the former is in the form of a ribbed cylinder, and the relatively wide and relatively narrow portions of the former are portions of relatively large and relatively small diameter, respectively.

14. A fuselink as claimed in any one of claims 10 to 13, wherein the or each high-melting fusible element comprises a metallic ribbon having therein a plurality of constrictions.

15. A fuselink as claimed in claim 14, wherein the constrictions are in the form of notches or holes.

16. A fuselink as claimed in claim 14 or 15, wherein the ribbon is made of silver or copper.

17. A fuselink as claimed in any one of claims 10 to 16, wherein the conductor of the or each low-melting fusible element assembly is a plain flat conductor and a part thereof intermediate its ends has an overlay of a material which will combine with the conductor, a coating of refractory cement being provided over said overlay, the thermally insulating sleeve of the or each low-melting fusible element is flexible and surrounds the respective conductor at least at said part thereof, and means is provided at the ends of the sleeve to form a seal between the sleeve and the conductor.

18. A fuselink as claimed in claim 17, wherein the conductor in the or each low-melting fusible element assembly is in the form of a silver or copper strip.

19. A fuselink as claimed in claim 17 or 18, wherein the overlay in the or each low-melting fusible element assembly is formed from a eutectic alloy.

20. A fuselink as claimed in claim 17, 18 or 19, wherein the refractory cement in the or each low-melting fusible element assembly is a mixture of silicon carbide, silica and carbon.

21. A fuselink as claimed in any one of claims 17 to 20, wherein the sealing means in the or each low-melting fusible element assembly comprises a viscous flexible sealing compound.

22. A fuselink as claimed in claim 21, wherein the sealing compound is a high-temperature grease.

23. A fuselink as claimed in claim 22, wherein the sealing compound is silicone grease.

24. A fuselink as claimed in any one of claims 17 to 23, wherein the flexible sleeve in the or each low-melting fusible element assembly is reinforced by glass or silicon fibre roving.

25. A fuselink as claimed in claim 24, wherein the roving forms a tight double layer.

26. A fuselink as claimed in any one of claims 10 to 25, wherein the number of the high-melting fusible elements is greater than or equal to the number of the low-melting fusible element assemblies.
27. A fuselink as claimed in any one of claims 10 to 26, further comprising an electrically conductive member positioned at the juncture of the relatively wide and relatively narrow portions of the former, the high-melting fusible element or elements and the low-melting fusible element assembly or assemblies being electrically connected to said member.
28. A fuselink as claimed in any one of claims 10 to 27, wherein the relatively narrow portion of the former occupies substantially one quarter of the total length thereof.
29. A fuselink as claimed in any one of claims 10 to 28, wherein the width of the relatively narrow portion of the former is between 30% and 60% of the width of the relatively wide portion.
30. A fusible element assembly substantially as hereinbefore described with reference to the accompanying drawings.
31. A high voltage current limiting fuselink substantially as hereinbefore described with reference to the accompanying drawings.