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ELECTRICAL CONTACT MEMBERS HAVING A PLURALITY
OF REFRACTORY METAL FIBERS EMBEDDED THEREIN

3,254,189

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2 Sheets-Sheet 1

Fig. 1.

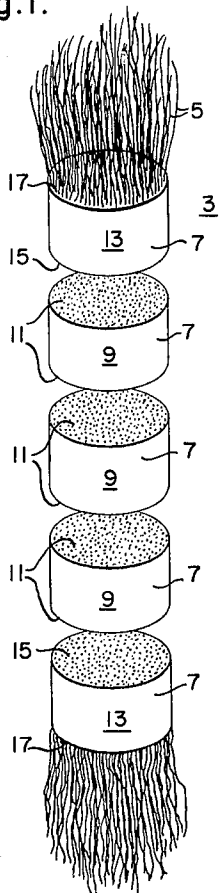


Fig. 3.

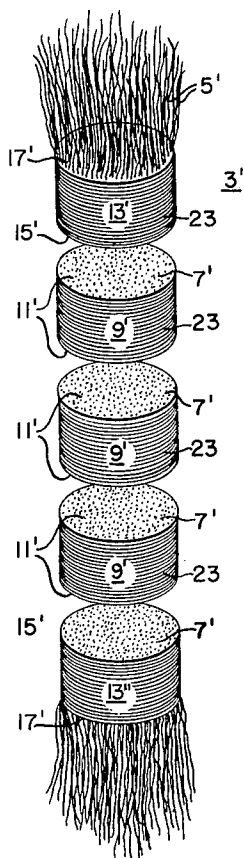


Fig. 4.

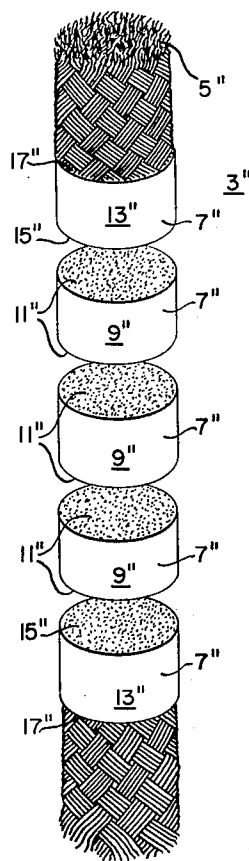


Fig. 2.

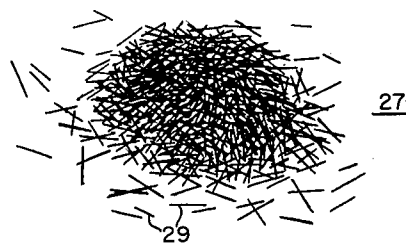
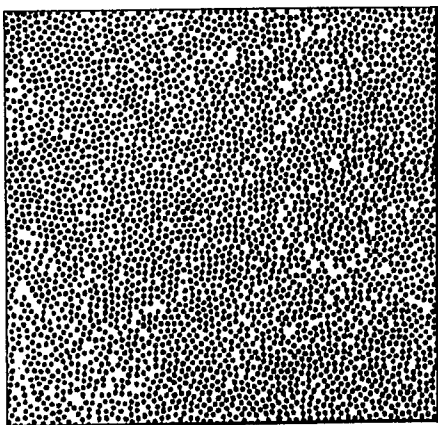


Fig. 5.

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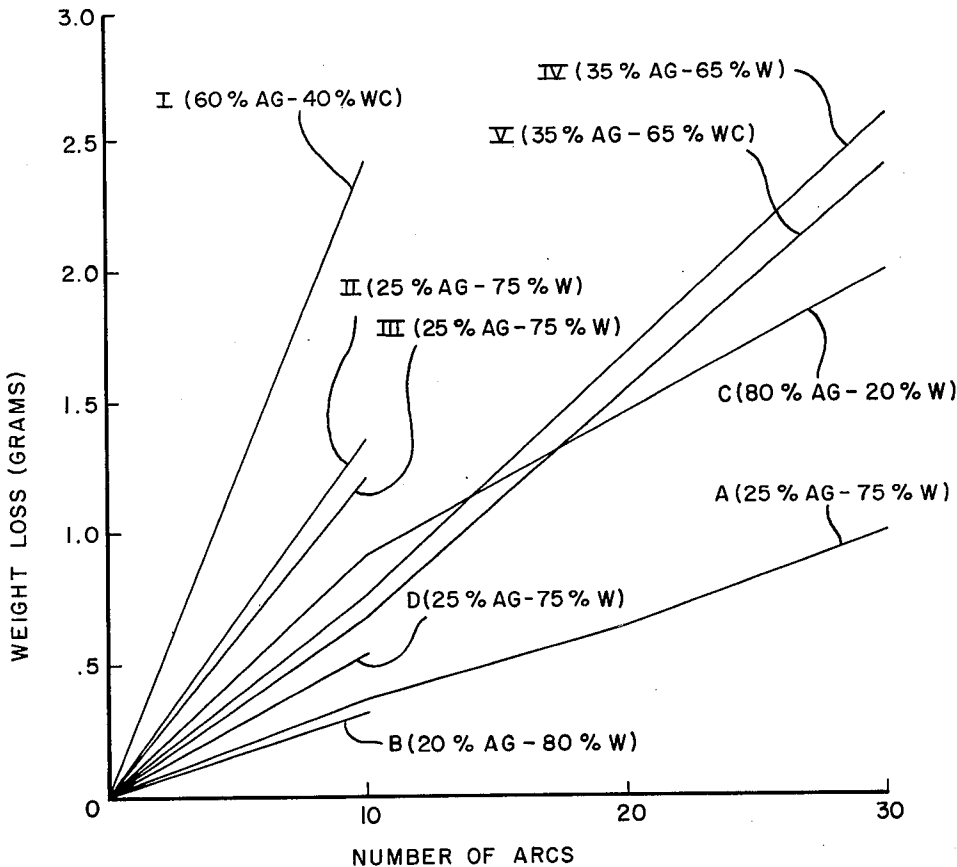


Fig. 6.



Fig. 7.

Fig. 8.



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ELECTRICAL CONTACT MEMBERS HAVING A PLURALITY OF REFRACTORY METAL FIBERS EMBEDDED THEREIN

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This invention relates to electrical conductors and more particularly to electrical contact members and methods of making the same.

In the past, most high-current electrical contact members have been made by powder metallurgical techniques. Although their compositions and structures are tailored for this special use, none of these contact members exhibit ideal behavior under the rigors of severe electrical arcing. Theoretically, the loss of material in arcing should be only that material vaporized by the heat of the arc. Actually, much greater material losses are experienced because of two other factors. First, the high temperatures accompanied by large electrostatic and magnetic forces cause the lower melting constituent of the powder contact member to become molten and then to be blasted away, carrying some of the refractory metal with it. Secondly, thermal cracks are formed from the stresses induced by the very high thermal gradients at the contact surface. These cracks may eventually cause spalling and flaking off of relatively large parts of surface material. This latter situation can be critical to effective and dependable operation of a circuit breaker where the loosened parts may cause short-circuits or mechanism jamming.

Accordingly, an object of this invention is to provide improved electrical contact members that have increased operating life under high-current arcing environments.

Another object of the invention is to provide improved contact members comprising a novel composition of refractory and good conducting metals.

Other objects of the invention are to provide improved methods of making electrical contact members.

For a more complete understanding of the nature and objects of the invention, reference is made to the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is an elevational view of a composite contact bar that has been formed in accordance with the principles of this invention and cut into a plurality of contact members;

FIG. 2 is an enlarged view of a section of the contact surface of one of the contact members shown in FIG. 1;

FIGS. 3 and 4 illustrate different embodiments of the invention shown in FIG. 1;

FIG. 5 illustrates a plurality of short fibers or wires of refractory metal;

FIG. 6 illustrates the refractory fibers shown in FIG. 5 after they have been compressed into the form of a contact member;

FIG. 7 illustrates a contact member made by infiltrating the compressed form of FIG. 6 with a good-conducting metal; and,

FIG. 8 is a graph illustrating results of tests conducted on contact members embodying the present invention.

In the patents to J. K. Ely, Patent No. 2,294,783 and Patent No. 2,295,338, there are described and claimed contact members and the methods of making the same. These contact members are machined from a composite mass that comprises a plurality of elongated bars or rods of refractory metal that are embedded in a matrix of good conducting metal. In one embodiment, this composite mass is made by uniformly spacing the refractory bars

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by setting the bars at one end in a cap that has a series of indentations therein for receiving the bars. The bars or rods are held at the other end by means of a second cap that has a plurality of openings therein; one opening for each of the bars. The difficulty with producing contact members in accordance with the aforementioned patents is that it is time consuming to set and hold the bars in the desired pattern prior to infiltration. Moreover, the percentage of area of refractory material at the contact surface is limited in this type of contact because of the surface area of the holding caps that must hold the refractory rods.

This invention is an improvement over the aforementioned patents in that the contact members of this invention can have a considerably higher percentage of surface area and volume of refractory metal. Moreover, the contact members of this invention are made by means of novel relatively economical methods.

Referring to the drawings, there is shown in FIG. 1 an elongated composite mass or bar 3 made in accordance with principles of this invention, and comprising a plurality of elongated fibers or wires 5 of refractory metal selected from the group of tungsten, molybdenum and their alloys. The refractory fibers 5 are embedded in a matrix of good conducting metal 7 selected from the group of copper, silver and their alloys. The elongated composite bar 3 is cut into five sections as seen in FIG. 1. Each of the three inner sections 9 has two contact surfaces 11 at its opposite ends. The outer sections 13 have finished contact surfaces 15 at their inner ends; but the refractory wires 5 must be machined off of the outer ends 17 before these contact members 13 are ready for use.

The elongated composite mass or bar 3 shown in FIG. 1 is formed by bunching together the elongated tungsten refractory fibers or wires 5 and infiltrating the bunched fibers with the good conducting metal 7. The elongated refractory fibers 5 are bunched together in a generally parallel relationship. It is to be noted, however, that these refractory fibers 5 are randomly distributed in the bunch.

One method of forming the contact members 9, 13 is to bunch the elongated refractory fibers 5 in a generally parallel relationship; the spacing between the fibers being determined merely by contact of the fibers with each other. The elongated bunched fibers 5 are then held together at various points along the elongated bunch by means of wire or fiber wrappings (not shown) or by any other suitable means. The bunched fibers are then infiltrated by continuously running the bunch through a bath of molten infiltrant of good conducting metal 7 selected from the group of copper, silver and their alloys. The infiltrant 7 is allowed to cool and solidify, whereupon the composite bar 3 can be cut as shown in FIG. 1 into individual contact members 9, 13 by means of an abrasive wheel or any other suitable tool. The refractory fibers that protrude from the outer ends of the outer contact members 13 are then cut off with an abrasive tool so that each of these outer contact members will have a contact surface at each end thereof.

FIG. 2 represents a view of one of the contact surfaces 11 or 15 of the contact members 9 or 13 of FIG. 1. In the particular contact surface shown in FIG. 2, refractory fibers having a .005 inch diameter were used in forming the contact members. Although, as seen in FIG. 2 all of the tungsten fibers 5, do not necessarily engage another tungsten fiber at the contact surface, substantially all of these fibers 5 at some part during the length thereof in the original bundle from which the contact member was formed, engaged other fibers 5 so that the distribution of the wires was determined merely by engagement of the fibers with each other. The weight ratio of silver

to tungsten in the contact shown in FIG. 2 is about 25% silver and 75% tungsten. This ratio can be varied to other desirable percentages by varying the compactness of the tungsten fiber bundle and/or by varying the diameter size of the tungsten fibers used in the bundle.

Another method of making the contacts 9, 13 shown in FIG. 1 is to place an amount of powdered or solid good conducting metal, selected from the group of copper, silver and their alloys, into a mold or container (not shown). A plurality of elongated refractory fibers 5, selected from the group of tungsten, molybdenum and their alloys, are then bunched together in a generally parallel relationship. The bunched wires are placed into the container over the powder or solid good conducting metal. About 1% of powdered nickel may also be included with the good conducting metal. The assembly is then charged into a furnace at a temperature at which the good conducting metal is molten, for example approximately 1100° C., with a dry hydrogen atmosphere. The good conducting metal, aided by the wetting property of the nickel, is distributed by capillary action throughout the interstices between the refractory fibers. The assembly is then removed from the furnace and allowed to cool and harden. The hardened elongated composite mass or bar 3 is then removed from the mold or container and sliced as seen in FIG. 1 to produce the individual contact members 9, 13. As was previously described, the refractory fibers 5 at the outer surfaces of the outer contact members 13 are machined off of the outer contact surfaces to complete the manufacture of these outer contact members.

Another method of manufacturing the contact members 9, 13 shown in FIG. 1 is to bunch the elongated refractory wires 5, selected from the group of tungsten, molybdenum and their alloys, together in a generally parallel but randomly distributed relationship and insert this bunch into a mold or container. A good conducting metal 7 selected from the group of copper, silver and their alloys is then preheated to a molten condition and poured into the mold or container to flow into the mold and fill the interstices between the tungsten wires. The assembly is then allowed to cool after which the hardened composite mass or bar 3 is taken from the mold or container and sliced as shown in FIG. 1.

FIGS. 3 and 4 illustrate different embodiments of the invention shown in FIG. 1. The parts in FIGS. 3 and 4 that correspond to like parts of FIG. 1 have the same reference characters as the like parts in FIG. 1 except that the like reference characters of FIG. 3 are primed and the like reference characters of FIG. 4 are double primed.

The contact members 9' and 13' as shown in FIG. 3 are formed by means of the same methods hereinbefore described with reference to the contact members 9 and 13 shown in FIG. 1, except that the bunched together elongated refractory metal fibers 5' are wrapped and secured together, prior to the infiltration with the conducting metal, with an elongated wire or fiber 23 selected from the group of tungsten, molybdenum and their alloys. The wrapping fiber 23 forms a collar around the bundle of refractory wires 5' that gives additional strength to the contact members 9' and 13' and also serves as the securing means to secure the fibers 5' of the elongated bundle together during the manufacturing operation.

The contact members 9'' and 13'' shown in FIG. 4 are formed by means of the same methods hereinbefore described with reference to the contact members 9 and 13 shown in FIG. 1 except that, as can be seen in FIG. 4, the bundle of refractory fibers 5'' comprises a plurality of refractory fibers that are braided or stranded into a cable prior to being infiltrated with the good conducting metal 7''. The embodiment shown in FIG. 4 has particular significance in the method of manufacture wherein the bundle of refractory fiber is passed through

the molten good conducting metal 7'' during which operating the metal infiltrates into the bundle in the same manner previously described. During this operation, the braid of the fibers 5'' serves to hold the fibers together so that additional securing means are not needed.

Another embodiment of the invention is shown in FIGS. 5, 6 and 7. FIG. 5 illustrates a pile 27 comprising a plurality of short lengths of refractory fibers or wires 29 selected from the group of tungsten, molybdenum and their alloys. These short fibers 29 are placed into a closed-type die, such as the type used in metal powder compaction, and pressure is applied to compact the short refractory fibers into the desired shape and density. FIG. 6 illustrates a compacted mass 31 formed from the short refractory fibers shown in FIG. 5. The compacted mass of refractory fibers 31 (FIG. 6), after being removed from the die, is inserted into a container for infiltration. Prior to insertion of the compacted refractory mass 31 into the container, an infiltrant of good conducting metal selected from the group of copper, silver and their alloys is deposited in the container in the form of a powder or a solid piece. The container is then charged into a furnace at a temperature above the melting point of the good conducting metal and below the melting point of the refractory metal. At this temperature the good conducting metal melts and is distributed by capillary action throughout the interstices between the refractory fibers. It may be desirable to put a small percentage of powdered nickel into the container with the good conducting metal so that the wetting property of the nickel will aid the capillary action. The mold is then removed from the furnace and allowed to cool whereupon the composition solidifies. The composition is then ejected from the mold in the form of a contact member 33 as shown in FIG. 7.

Although the preferable method of forming the contact member shown in FIG. 7 is to have the good conducting metal in the container under the compacted mass 31 of refractory metal, it will be understood that the good conducting metal can be placed on top of the compacted mass 31, before the assembly is charged into the furnace so that the good conducting metal when melted will flow down through the compacted mass 31 to infiltrate into the openings within the mass 31.

The contact member 33 (FIG. 7) can be made in another manner by merely placing the compacted mass 31 (FIG. 6) into a container and pouring molten good conducting metal selected from the aforementioned group into the container whereupon the good conducting metal will flow down through the compacted mass 31 to infiltrate within the mass 31.

Another method of forming a contact member such as the contact member 33 shown in FIG. 7 is to merely place the loose short fibers shown in FIG. 5 into a container on top of a powdered or a solid piece of good conducting metal selected from the group of copper, silver and their alloys and charge the container into a furnace whereupon the good conducting metal melts and is infiltrated throughout the openings between the refractory fibers forming a composition that is allowed to cool and solidify and is then ejected from the container as a finished contact member.

It is to be understood that the container used in molding the contact members shown in FIG. 7 can be of considerable depth to produce a composition that is similar to that shown in FIG. 7 but which is much longer. The elongated composition can be sliced by means of an abrasive wheel or other suitable tool into contact members having the desired depth.

The short members 29 (FIG. 5) of refractory metal that are used in manufacturing the finished contact members 33 (FIG. 7) can be ends of wires or chips that might otherwise have been considered scrap. Thus, an advantage of this method of manufacture is that material that might otherwise have been wasted can be utilized in forming improved contact members.

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A modification of the invention shown in FIGS. 5, 6 and 7 comprises the introduction of a portion of the refractory metal in powder form along with the refractory metal fibers. Up to 80% of the weight of refractory metal selected from the group of tungsten, molybdenum and base alloys thereof may be comprised of powdered refractory metal of approximately 100 mesh fineness, the balance being fibers of refractory metal, all being more or less homogeneously admixed and then compacted in the same manner hereinbefore described into a slug or mass similar to the slug 31 seen in FIG. 6 except that the slug comprises the compacted fibers and powder. The compacted slug or mass is then infiltrated with a molten good conducting metal selected from the group of copper, silver and base alloys thereof in the same manner as the compacted mass 31 (FIG. 6) is infiltrated. The refractory fibers that are disposed throughout the finished contact member and at the contact surface in a random orientation, are effective in preventing thermal cracking of the contact under operating conditions.

The following are examples of contacts made in accordance with principles of this invention.

Example I

Pure tungsten fiber of wire, cleaned and straightened was obtained in .010 inch size. The fiber was wound on a two-spindle spool to form an oblong coil about four inches long. Both coil ends were cut and the two halves were brought together to form a fiber bunch approximately $\frac{5}{8}$ of an inch in diameter which bunch was then tightly wrapped with tungsten fiber. This bundle of fiber was positioned vertically in a ceramic crucible containing silver powder plus about 1%, by weight, of nickel. The assembly was charged into a furnace at approximately 1100° C. with a dry hydrogen atmosphere. At this temperature the molten silver, aided by the wetting property of the nickel, was distributed by capillary action throughout the interstices between the tungsten fiber. The assembly was then taken from the furnace and allowed to cool after which the composition was removed from the crucible. Separate contact elements or members were then obtained from this elongated composition by slicing the composition in the manner shown in FIGS. 1, 3 and 4. One of these contact elements was then machined to a $\frac{1}{2}$ inch diameter and a $\frac{1}{4}$ inch height. The composition of this contact element as to silver-to-tungsten ratio was determined by area measurements on a metallographically polished cross-section. Because of the fixed diameter of the refractory tungsten wire, the area percentage is also the volume percentage and this area percentage was determined simply by counting the wires within a fixed diameter circle. The results indicated that this particular contact element had a tungsten volume percentage of 62%, the remaining 38% being the silver infiltrant. These figures convert to a weight percentage ratio of 25% silver-75% tungsten. The results of tests of the contact made by this example are indicated at A in the graph in FIG. 8 which graph illustrates results of tests that will be herein-after specifically discussed.

Example II

Another contact element or member was made in the same manner in which the contact element discussed in Example I was made except that the tungsten fibers were of a .005 inch diameter. The resultant contact element was found to have a 20% silver-80% tungsten weight percentage ratio. The results of tests of this contact are indicated at line B in the graph illustrated in FIG. 8.

Example III

Tungsten fiber having a .010 inch diameter was cut up into short lengths similar to that shown in FIG. 5. These short lengths of fiber were poured into a cavity that has been machined in a block of graphite which cavity was 1 inch deep and had a $\frac{5}{8}$ inch diameter. Powdered

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silver was placed on top of the short tungsten fibers, and the assembly was charged into a hydrogen atmosphere furnace for one hour at 1100° C. This allowed the silver to melt and completely infiltrate the tungsten fibers. The assembly was then removed from the furnace and allowed to cool. The contact element was removed from the cavity and machined to a thickness of $\frac{1}{4}$ of an inch and a diameter of $\frac{1}{2}$ inch. The composition of this contact member was determined by measuring its density of water displacement, and converting this figure to composition, with the assumption that the member was 100% dense. The result showed that the contact element had a weight ratio of 80% silver-20% tungsten. The results of tests on this contact element are indicated by the line C on the graph illustrated in FIG. 8.

Example IV

Tungsten fiber having a .005 inch diameter was cut into short lengths similar to that shown in FIG. 5. These short lengths were charged into a closed-type die having a one-half inch diameter die cavity and compacted with a load of 10 tons. The compacted mass was then removed from the die and it was found that this mass had a height of about $\frac{1}{2}$ of an inch and the tungsten fibers occupied about 65% of the volume of the mass. The short tungsten wires interlocked very nicely, resulting in a strong compact mass which retained its shape. The compacted mass was then infiltrated with silver by placing it on top of a 4.0 gram silver disc within a cavity in a graphite block. The assembly was charged into a hydrogen atmosphere furnace for 30 minutes at 1150° C. The assembly was then removed and allowed to cool. The hardened contact member was removed and machined to the desired size for test purposes. The composition of this contact member was determined by measuring the density of the member of water displacement, and converting this figure to composition, with the assumption that the contact member was 100% dense. Results showed the contact member to have a weight ratio of 25% silver-75% tungsten. The results of tests on this contact member are illustrated at line D in the graph illustrated in FIG. 8.

Referring to FIG. 8, there is shown therein a graph illustrating the results of tests conducted on five different commercially successful contacts (I-V) and the four contacts (A-D) made in accordance with the principles of this invention. The test results show the weight loss in grams of the various contacts after the contacts had been subjected to a number of arcs. Each of the tested contacts was one-fourth of an inch in height and one-half of an inch in diameter. Each set of experimental contacts was set up in an arc-erosion tester to an air gap of $\frac{1}{8}$ of an inch. The arc discharge for the standard contacts (I-V) was a 12,000 ampere current (crest) at an arc voltage of 30 volts for seven milliseconds. The test was more severe regarding the contacts (A-D) of this invention in that these contacts were subjected to an arc discharge of a 15,000 ampere current (crest) at an arc voltage of 30 volts for seven milliseconds. Thus, the standard contacts (I-V) were tested with a 12,000 ampere arc current, whereas the contacts of this invention (A-D) were tested with a 15,000 ampere arc current. Since the material loss increases with the arcing current, the curves for the contacts (A-D) of this invention are actually higher with respect to weight loss than they would have been had an arcing current of only 12,000 amperes been applied to these contacts. As can be seen from the graph, the contacts A-D of this invention compare favorably with regard to weight loss.

Although the contact C shows slightly more weight loss after 10 arcs than the contacts IV and V, it should be noted that the contact C has a weight ratio of 80% silver-20% tungsten while the contacts IV and V have ratios of 35% silver-65% tungsten and 35% silver-65% tungsten carbide respectively. Since weight loss gen-

erally increases with an increase in percentage of good conducting metal, it can be understood that the contact C compares favorably with the contacts IV and V after ten arcs. Moreover, it should be noted that after 18 arcs the contact C shows even less weight loss than the contacts IV and V.

The weight losses (FIG. 8) of the contacts that were tested are only those losses that occurred as a result of vaporization of the contact material under the extreme heat and pressures generated by the arcs. In addition to these weight-loss characteristics, the standard contacts (I-V), which contacts were made by means of standard powder metallurgy methods, showed contact surfaces having a considerable number of thermal cracks. Thus, further weight loss and therefore further wear can occur when these thermal cracks weaken the contact member to such an extent that chunks of material spall off of the contacts during operation. This spalling-off of contact material is disadvantageous not only because the contacts, under these conditions, have a shorter life; but also because these chunks can cause short circuits and they can also become lodged in the mechanical structure of the breaker to prevent, in some instances, the occurrence of an automatic tripping operation in which case severe damage can occur to the equipment that is to be protected by the circuit breaker.

It is significant that there were no thermal cracks in the contact surfaces of the contacts A-D of this invention after the tests, the results of which are illustrated in FIG. 8. Thus, the improved contacts of this invention have longer operating lives and they are less susceptible to the above-mentioned disadvantageous spalling-off occurrences, than the commercially successful standard-type contacts that were used in the tests. A factor which has significant bearing on the non-spalling characteristics of the contacts of this invention is that a grid is formed on the contact surfaces after they are subjected to a few arcs. The refractory metal vaporizes slower than the good conducting metal, and this grid is simply parts of the tungsten fibers that are left protruding after some of the good conducting metal has been vaporized.

While the invention has been described with reference to particular embodiments and examples, it will be understood that modifications, substitutions and the like may be made therein without departing from the scope of the invention.

We claim as our invention:

1. An electrical contact member having a contact surface and comprising a composite metallic body comprising a plurality of refractory metal fibers, said plurality of fibers being embedded in a matrix of metal of good conductivity, and said fibers having a random distribution at said contact surface.

2. An electrical contact member having a contact surface and comprising a composite metallic body comprising a plurality of elongated refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said plurality of fibers being disposed in a generally parallel relationship, said plurality of fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof, and said fibers appearing at said contact surface in a random orientation.

3. An electrical contact member having two contact surfaces and a side surface, said contact member comprising a composite metallic body comprising a plurality of refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said plurality of fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof, and said side surface being formed by a coiled member.

4. An electrical contact member having two contact surfaces and a side surface, said contact member comprising a composite metallic body comprising a plurality

of elongated refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said fibers being bunched together in a generally parallel relationship in such a manner that the spacing of said fibers is determined by the engagement of said fibers with each other, said plurality of fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof, said fibers appearing at said contact surfaces in a random orientation, and said side surface comprising a coiled wire of refractory metal selected from the group of tungsten, molybdenum and base alloys thereof.

5. An electrical contact member comprising a composite metallic body comprising a plurality of elongated refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said fibers being braided together, and said braided fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof.

6. An electrical contact member comprising a composite metallic body composed of a plurality of refractory metal fibers of varied lengths selected from the group consisting of tungsten, molybdenum and their alloys, said fibers being bunched together in a non-uniform fashion and in a manner such that each fiber of substantially all of the fibers contacts at least one of the other fibers, and said plurality of fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof.

7. An electrical contact member comprising a composite metallic body comprising a plurality of refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said refractory metal fibers being compacted together with each fiber of substantially all of the fibers contacting at least one of the other fibers, said plurality of refractory metal fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof, and said refractory metal fibers being disposed in a random orientation throughout said contact member.

8. An electrical contact member comprising a composite metallic body comprising a compacted mass of refractory metal powder and refractory metal fibers, said refractory metal fibers being disposed in said compacted mass in a random orientation, and said compacted mass being embedded in a matrix of metal of good conductivity.

9. An electrical contact member comprising a composite metallic body comprising a compacted mass of refractory metal powder and refractory metal fibers, said refractory metal powder and fibers being selected from the group consisting of tungsten, molybdenum and base alloys thereof, said refractory metal fibers being disposed in said compacted mass in a random orientation, and said compacted mass being embedded in a matrix of metal of good conductivity.

10. An electrical contact member comprising a composite metallic body composed of a plurality of refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said fibers being bunched together in a non-uniform fashion and in a manner such that each fiber of substantially all of the fibers contacts at least one of the other fibers, and said plurality of fibers being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof.

11. An electrical contact member comprising a composite metallic body comprising a plurality of refractory metal fibers selected from the group consisting of tungsten, molybdenum and base alloys thereof, said refractory metal fibers being bunched together such that each fiber of substantially all of the fibers contacts at least one of the other fibers, said plurality of refractory metal fibers

being embedded in a matrix of metal of good conductivity selected from the group consisting of copper, silver and base alloys thereof, and said refractory metal fibers being disposed in a random non-parallel orientation throughout said contact member.

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