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ARC-QUENCHING COMPOUND AND ELECTRICAL EQUIPMENT UTILIZING SAME

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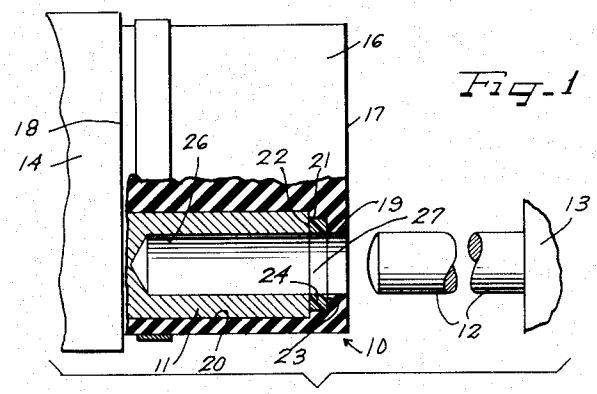


Fig-1

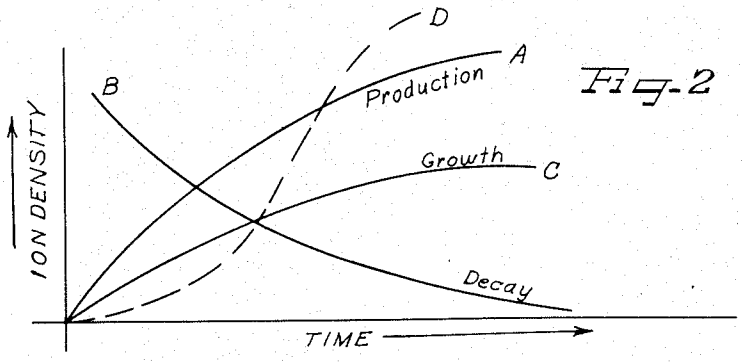
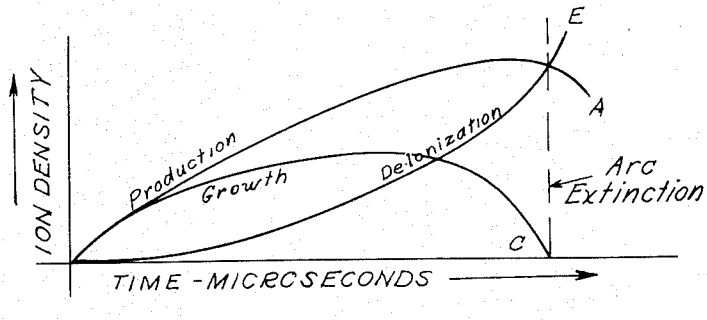


Fig-2

Fig-3



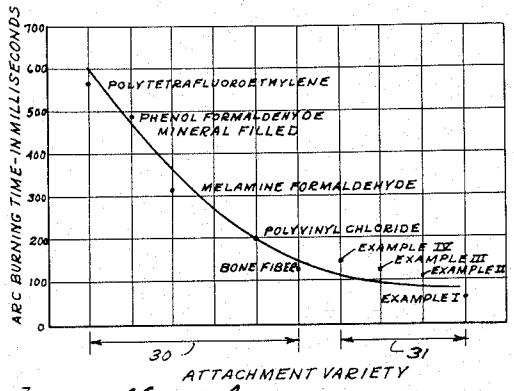


Fig-4

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This invention relates generally to an arc-quenching compound and method and to electrical equipment utilizing the same.

The concept underlying the mechanics of quenching an arc in accordance with the principles of the present invention will be more readily appreciated upon reviewing the nature and phenomenon of an electrical arc discharge. An arc may be initiated by a high voltage glow discharge or by separation of a conductor carrying an electrical current. Upon separation of the conductor, as exemplified by a pair of contacts, a self-sustained discharge is initiated which is capable of supporting large currents and exhibiting a low voltage drop. The arc, at normal room conditions, is composed of a brilliant intense core surrounded by flaming gases. Probable cathode and anode temperatures are in the order of 3500° K. and 4200° K., respectively. The electron temperature of the core may actually reach 40,000° K., whereas the flaming gases will be at approximately their natural exothermic temperatures.

The characteristics of the circuit and the high cathode temperatures favor and propagate the emission of electrons from the cathode in voluminous quantities so that the arc current is composed completely of electrons. These electrons maintain the entire arc discharge.

In order to maintain a conducting path for the flow of current, i.e., the flow of electrons from the cathode to the anode, an ionized atmosphere is necessary. This atmosphere, composed of atoms positively charged by the loss of an electron, may be produced by electron or atomic collision which transmits energy to the atom, or through radiant energy absorbed in the form of a photon, or by molecular collisions induced by high temperatures. These processes occur in combination in an electrical discharge.

Although the art of arc quenching is relatively highly developed, most prior art practitioners have approached the problem of quenching arcs from the standpoint of a fire fighter seeking to extinguish the flaming gases which are symptomatic of the actual arcing problem. For example, according to the prior art, arc inhibiters have been provided which take the form of either solids or liquids, and which are intended to produce relatively inert gases or atmospheres upon initiation of the arc so that the arc will be extinguished by replacing the ionized column with an inert atmosphere, or to reduce the temperature of the arc below a so-called "kindling" temperature. In this regard, the prior art has used arc inhibiters which upon chemical reaction with the arc will produce moisture, the purpose and intent of which is to reduce the temperature of the arc. Other prior art arc quenching arrangements have contemplated the provision of mechanical means for varying the composition or mobility of the surrounding medium such as by blow-outs, explosion pots, or expulsion mechanisms.

In employing chemical compositions such as aminoplast materials as arc inhibiters, prior art practitioners have specifically intended to break the carbon to nitrogen bond because they wanted nitrogen gas for snuffing purposes. In other words, the ionized column of the arc was intended to be replaced with an inert atmosphere.

In accordance with the principles of the present invention, it is contemplated to transfer energy from the arc source at a molecular level to an adjoining energy sink, thereby minimizing the size and duration of the arc.

The energy sink comprises a compound of low electronegative elements forming a weak-linked structure which sublimates directly under radiant energy without carbonization. Typical of such a compound is an organic polymer having a long hydrocarbon chain which is highly branched. By locating such a compound in proximity to the arc the material undergoes change, absorbs energy and sublimates into gas as the energy transfer occurs. The gases which are produced are merely a by-product, however, which is helpful because the gases, in turn, absorb more energy. By having a long chained, highly branched organic polymer, the linkage characteristics of the material are weak enough so that energy is taken from the arc before the arc is fully developed, thereby minimizing the size and duration of the arc. Moreover, amorphous carbon is not produced and an arc inhibiter is provided which will be effective for a far greater number of operations than has heretofore been available.

It is an object of the present invention, therefore, to provide an arc quenching compound and electrical equipment utilizing same wherein energy transfer occurs at a molecular level to minimize the size and duration of any arc drawn by mechanical separation of current-continuing means.

Another object of the present invention is to provide improved apparatus and processes for suppressing an arc by transferring energy at a molecular level to an adjoining energy sink to minimize the size and duration of the arc.

A further object of the present invention is to provide an improved arc-extinguishing compound.

Still another object of the present invention is to provide an arc-extinguishing process and apparatus wherein electron energy is removed from the arc source.

A still further object of the present invention is to provide an energy sink adjacent an area of arc development which is capable of absorbing energy without an adverse change of physical structure.

Yet another object of the present invention is to provide an energy sink for absorbing electrons made of a long chained, weak-linked carboniferous structure.

Many other advantages, features and additional objects of the present invention will become manifest to those versed in the art upon making reference to the detailed description which follows and the accompanying sheet of drawings in which a preferred structural embodiment of an electrical connector incorporating the principles of the present invention is shown by way of illustrative example.

On the drawings:

FIGURE 1 is a fragmentary view of an electrical connector incorporating the principles of the present invention;

FIGURE 2 is a graph illustrating the phenomena associated with ionizing energy involved in this invention;

FIGURE 3 is a graph illustrating cumulative ionization processes in connection with the use of the present invention; and

FIGURE 4 is a graph plotting structure complexity against arc-burning time, thereby to compare the composition of the present invention to prior art arc inhibiters.

As shown on the drawings:

An electrical connector is indicated generally at **10** and comprises current-continuing means such as a female contact member **11** and a male contact member **12**.

Although the connector **10** may be of the multi-contact type, only one pair of mating contact members is shown by way of illustrative example to exemplify the principles of the present invention. It will be understood

that the male contact member 12 is provided with a suitable insulating structure 13. In like manner, the female contact member 11 is suitably retained in a housing 14. An insulating structure for the female contact member 11 is shown at 16 and comprises a generally cylindrical member having a front face 17 and a back face 18 with a plurality of axially extending passages being formed therein, one for each respective female contact member 11. Thus, as shown in FIGURE 1, there is provided an opening 19 sized to pass with appropriate clearance the male contact member 12 into a recess which takes the form of a counterbore 20 and in which is positioned the female contact member 11.

Between the opening 19 and the counterbore 20, there is provided a smaller counterbore 21, the outside diameter of which is smaller than the outside diameter of the counterbore 20 but larger than the outside diameter of the opening 19.

There are thus provided a plurality of stepped shoulders extending in a radial direction by virtue of the successive bores and counterbores of the opening 19, the counterbore 21 and the counterbore 20. As indicated on FIGURE 1, a shoulder 22 between the counterbore 21 and the counterbore 20 seats and engages against the end face of the female contact member 11. A shoulder 23 between the counterbore 21 and the opening 19 forms a bottom end wall for the counterbore 21 and is in axially spaced relation to the end face of the female contact member 11, thereby to form a recess in which is received an energy sink 24 as contemplated by the present invention. In this form of the invention, the energy sink takes the form of an annular ring having an outer diameter approximately the same as the outer diameter of the counterbore 21 and having an inner diameter which is approximately the same as that of the opening 19 and a recess 26 formed in the female contact member 11. Thus, in assembly, the opening 19 is in full axial register with the recess 26 and with the inner peripheral surface of the energy sink 24, which inner peripheral surface is indicated at 27. It will be understood that other physical shapes and configurations of the energy sink 24 can be used effectively, depending on the environment to which the sink is applied.

It will be noted that the axial spacing dimension between the shoulder 23 and the end face 17 on the insulator structure 16 is only a fraction of the effective axial spacing dimensions of the male and female contact members 11 and 12, but such dimension does permit the opening 19 to operate as a confining means relative to the male contact member 12 as it is inserted into the female contact member or withdrawn therefrom.

Likewise the axial spacing dimension of the energy sink 24 is only a fraction of the total effective axial spacing dimension of the male and female contact members 11 and 12 and in the proportion of FIGURE 1, it will be noted that it is approximately the same or perhaps slightly smaller than the axial spacing dimension of the opening 19.

Whereas prior art arc-extinguishers have attempted to exploit such arc-extinguishing characteristics as eliminating oxygen from the area of the arc by snuffing the same with an inert gas such as nitrogen, or by cooling the arc with moisture produced by chemical reaction, the present invention contemplates exploitation of a different physical phenomenon. Thus, it is contemplated by the present invention that the energy sink 24 will be capable of absorbing energy without a profound change of physical structure and, accordingly, the energy sink 24 preferably comprises a long-chained, highly branched, weakly linked carboniferous material receiving energy by transfer at a molecular level and thereby minimizing arc formation.

As a preface to formulating the compound of the energy sink 24, we analyzed the commercially available compounds exhibiting arc inhibition properties but determined that all of such compounds were primarily intended to produce by-products such as carbon, methane and carbon monoxide or dioxide, in undesirable quantities and forms, together with injurious flames, all contrary to the basic concept of our approach, namely, to transfer energy away from the arc source and thereby prevent the arc from propagating. Moreover, we found the compounds of the prior art subject to rapid deterioration and, accordingly, it has been an object of the present invention to eliminate all undesirable by-products and to supply a compound which will absorb energy without a profound change of physical structure.

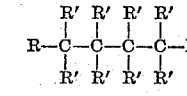
We have discovered that the efficient transfer of energy at a molecular level is enhanced by various chemical and structural changes in the energy sink; for example, by breaking the carbon to carbon bond in a long chained, highly branched, weakly linked carboniferous structure, or by simultaneous or consecutive polymerization, to cause an endothermic chemical reaction. An example of one reaction may be seen to take place when using an organic polymer of the base formula:

$$R—C(R')_2—C(R')_2—C(R')_2—R$$

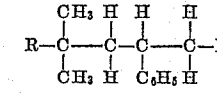
where R is an extension of the cited polymer and R′ may be selected from:

CH_3, (methyl)
H, (hydrogen)
C_6H_5, (phenyl)
C_2H_5, (ethyl)
C_3H_7, (propyl)

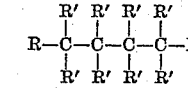
in groups of two or more rather than singularly. Thus, the functional ability of a compound such as provide according to the principles of the present invention is apparently attributable to the affixment of CH_3 (methyl) to C_6H_5 (phenyl) groups as side chains to the structure



so that it appears as a structure



The chemical structure



may define a commercially available plastic such as polyethylene if R′ is a hydrogen atom. In such a compound, arc inhibition is a natural reaction but the material is unsuitable as a commercial arc quencher due to extremely high soot production upon degradation and sustained flaming to destruction.

If in the same structure the R's are replaced selectively with hydrogen atoms and CH_3 (methyl) groups, the arc-quenching property increases slightly and the undesirable by-products decrease slightly.

If many of the R's are replaced by C_6H_5 (phenyl) groups, an improvement in arc-quenching properties equivalent to the example above is noted, but the undesirable by-products are not reduced sufficiently to allow the compound to be functional.

However, if discrete, selected replacement of the R's is made by

CH_3, (methyl)
H, (hydrogen)
C_6H_5, (phenyl)
C_2H_5, (ethyl)
C_3H_7, (propyl)

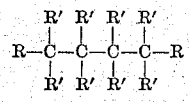
in groups of two or more rather than singularly, an efficient arc quencher is created.

The compound of the present invention takes the form,

therefore, of a heat fusible organic polymer of the structural base

$$RC(R')_2—C(R')_2—C(R')_2—C(R')_2—R$$

or in its structural formula



where R is an extension of the cited polymer and R' can be represented by H, CH_3, C_2H_5, $C_nH_{2n}+1$ or C_6H_5 derivatives or any stoichiometric combinations of the above.

Example I

The preferred substance incorporated in the energy sink 24 comprises a (poly) isobutylene-(poly) styrene-butadiene copolymer, one specific example of which represented by the following compound:

Ingredient:	Parts
Tetramethylthiuram disulfide	2
Tellurium diethyldithiocarbamate	2
Isobutylene isoprene copolymer	100
Stearic acid	2
Zinc oxide	10
Styrene butadiene copolymer	100
Sulphur	4
Mercaptobenzothiazole	1

In formulating this exemplary compound, we banded butyl on an open mill and then added and blended stearic acid with a roll temperature of approximately 160° F. Thereafter, we added and blended the zinc oxide and raised the roll temperature to 225° F. whereupon we added the styrene and blended.

The mix was then removed from the mill and cooled. We thereupon banded the stock on the cool mill and added the sulphur, the mercaptobenzothiazole, the tetramethylthiuram disulfide and the tellurium diethyldithiocarbamate. After cross cutting and blending, the compound was removed from the mill.

Although the resulting stock may be thereafter calendered, extruded or die-cut to form any suitable perform for injection, compression, transfer or plunger molding operation, we made an energy sink in the specific form illustrated in FIGURE 1 of the drawings by molding an annular ring under heat and pressure, thereby to form the energy sink **24** in the shape illustrated in the drawings. The resulting article constituted a flexible, or semi-flexible material.

We then incorporated the article into an electrical connector constructed generally in accordance with the physical form illustrated and described in connection with FIGURE 1 and the article was subjected to a standard control arc of 519.8 milliseconds duration in free air.

While the most efficient arc exhibiter found available commercially was found to reduce an individual arc to 120 milliseconds duration, such commercially available arc inhibitor deteriorated so rapidly that the 32nd successive arc it was destroyed.

The compound of Example I, however, reduced the arc at the thirty-second successive arc to 80 milliseconds at which time deterioration of the compound was only slight. No carbonization occurred on the inner surface.

Since the compound of Example I has low electronegative groups which produce a weak-linked structure, the material apparently sublimates directly or undergoes change in response to absorption of electron energy without carbonization. The low electronegative property of the attached groups allows rapid and immediate deliberate change of the compound into useful forms for further enhancing the arc-quenching process. In this regard, it appears from our observations that the process of arc-quenching is started at the instant that an arc is created. The transfer of energy at a molecular level from the arc source causes sublimation and change of the compound incorporated in the energy sink **24** in direct proportion to the energy created by the arc. This is the first energy transfer from the arc. By absorption of such energy, the duration of the arc and the size of the arc is minimized.

As to any arc which is sustained upon separation of the male and female contacts **11** and **12**, within microseconds, free electrons of the arc current enter into the degradation process of the compound by recombination and attachment with the ions of degradation. This is the second energy transfer from the arc.

The positive ions of air created by the arc simultaneously lose their charge by diffusion to the walls of the compound not in process of degradation. This is a third energy transfer from the arc.

The gases emitted from the compound which do not enter into any of such processes as enumerated above generally are CO_2, H_2 and CO which exhibit high ionization potential, such as 14.4, 15.6, 14.1 volts, respectively, for the first electron loss. This property, useful in degradation, also proves useful in the substitution of an inert gas for the ionized atmosphere of the arc column as in conventional arc suppressors heretofore provided.

These processes and the energy transfers effected therein cause a drastic change in the ionization-deionization cycle. Normally, in a gaseous discharge, the production of ionization is greater than the natural deionization so that the cumulative result is a continuous ionized state for as long as the electrical discharge continues. This is true in spite of the fact that the rate of deionization is greater than the rate of ionization because the discharge represents a fairly constant source of ionizing energy.

With the use of the energy sink **24**, the cumulative deionization processes effected with the use of the compound of Example I causes a reversal of the growth curve to one of decay.

This phenomenon is illustrated in the graph of FIGURE 2 wherein curve A is the production of ionization due to the discharge. Curve B is the decay of ionization when the energy input is stopped. Curve C is the growth of ionization while energy input is constant and represents the difference found by subtracting curve B from curve A.

With the use of the compound of Example I, an additional curve D illustrates how the cumulative deionization processes cause a reversal of the growth curve to one of decay. In the second graph of FIGURE 3, curve E is the sum of natural decay of ionization plus the deionization processes illustrated as curve D in the first graph of FIGURE 2.

To test the characteristics of the compound of Example I and to compare the same to the prior art, we made up devices similar to FIGURE 1 and operated at 30 amperes, 300 volts D.C. A mechanical device was used to effect insertions and extractions under uniform testing conditions. We observed and obtained test record in terms of the arcing time by use of an oscillograph.

The use of a prior art substance such as phenol formaldehyde reduced the control arc to 154 milliseconds at the first extraction but by the 32nd extraction, no influence was exerted on the arc. Using other prior art substances such as bone fiber or cellulose, the control arc was reduced to 129 milliseconds at the 1st extraction but after the 64th extraction, it reduced the arc to 187 milliseconds. At the 129th extraction, it was entirely consumed and thus no longer influenced the control arc.

With the use of Example I, the control arc was reduced to 70 milliseconds at the first extraction, 93 milliseconds at the 64th extraction, 220 milliseconds at the 128th extraction, and 256 milliseconds at the 230th extraction. At this point, the compound of Example I had lost only 75% of its original volume and was still capable of further use.

To further test the performance of the compound of

Example I, a 200 ampere connector was connected to a power source under the following conditions:

3 phase
700 volts open circuit
300 amps
75% power factor

In accordance with our testing procedures, we first used a standard connector without the compound of the present invention and with modified mineral filled phenolic formaldehyde female insulations. An arc of about 2" long was apparent when the plug was extracted from the receptacle while the circuit was energized. Failure by faulting between phases occurred in different samples between 10 and 80 extractions.

With a structure modified in accordance with the arrangement of FIGURE 1 to provide a cylindrical insert made of the compound of Example I and having a ⅛" wall and ⅜" length, no arc was visible, no smoke or flame occurred and after 200 extraction no damage to the connector was evidenced.

Furthermore, whereas with modified mineral filled phenolic, the contacts sustained extensive erosion at 50 extractions, erosion with a connector constructed in accordance with the present invention, as shown in FIGURE 1 and embodying the compound of Example I, was slight at 200 extractions.

Example II

Another example of the substance incorporated in the energy sink **24**, according to the present invention, comprises polyisobutylene-diene-polystyrene butadiene copolymer, one specific example of which is represented by the following compound:

100 parts styrene buta diene polymer (solid)
50 parts isobutene diene polymer (solid).

In formulating this compound, we mixed the two polymers with sufficient plasticizer to make a cohesive stock from which we made an energy sink in the specific form illustrated in FIGURE 1 of the drawings by molding an annular ring thereby to form the energy sink **24** in the shape illustrated in the drawings.

The characteristics of the compound of Example II were tested under the same conditions as previously described in connection with Example I. With the use of the compound of Example II, the control arc was reduced to 98 milliseconds at the first extraction, 100 milliseconds at the 64th extraction and the compound of Example II operated satisfactorily until the 150th extraction. At this point, the compound of Example II was consumed.

Example III

Another example of the substance incorporated into the energy sink **24** comprises a phthalic anhydride, substituted glycerol, polystyrene butadiene copolymer, one specific example which is represented by the following compound:

100 parts phthalic anhydride, substituted glycerol-styrene polymer (liquid)
50 parts polystyrene butadiene polymer (solid).

In formulating this exemplary compound we mix the phthalic anhydride glycerol-styrene polymer, which is a liquid, with the solid polystyrene butadiene until a uniform mix has been achieved. The mold is then charged with this material or stock to form the energy sink **24** in desired physical shape.

The characteristics of the compound of Example III were tested in the same manner and under the same conditions as previously described in connection with Examples I and II. With the use of the compound of Example III, the control arc was reduced to 116 milliseconds at the first extraction, 137 milliseconds at the 64th extraction and was consumed at the 70th extraction.

Example IV

Another example of the substance incorporated in energy sink **24** comprises a polymelamine isobutene diene copolymer, a specific example of which is represented by the following compound:

100 parts melamine polymer (solid)
30 parts isobutene diene polymer (solid).

The solids were physically mixed as before and the mold charged to form an energy sink **24** in the shape illustrated in FIGURE 1.

Upon testing the characteristics of the compound of Example IV, the same test conditions were imposed as previously described. The control arc was reduced to 123 milliseconds at the first extraction, 255 milliseconds at the 64th extraction, and the compound was completely consumed at the 70th extraction.

The performance of each of the foregoing exemplified compounds can be readily compared with the performance of prior art substances in reference to the graph of FIGURE 4 wherein attachment variety is plotted against arc-burning time. Along the "X" coordinate of the graph (attachment variety) it will be noted that the prior art arc-quenching substances of the usual carbon structure ranging from polytetrafluoroethylene to cellulose materials, is indicated by the distance **30**. As such substances approach the structure of cellulose, it can be said that such substances are chemically characterized by inorganic attachments.

In the area of the graph prescribed by the measurement of attachment variety indicated by the numeral **31**, it will be noted that not only is a long chain carboniferous structure provided, but such structure is highly branched with organic attachments, as exemplified by the compounds of Examples II, III and IV, until the preferred embodiment of Example I shows a long chained, weak-linked, highly branched carboniferous structure with specific organic attachments.

We have disclosed an arc-quenching compound and electrical equipment utilizing same, therefore, which through its compactness and efficiency makes possible the upgrading of existing electrical equipment from present design capabilities in terms of voltage and current so the same equipment is capable of carrying considerable higher electrical loads. As a corollary, it is possible to design equipment utilizing the principles of the present invention in the smaller space than has been heretofore possible under equivalent electrical loads.

Although minor modifications might be suggested by those versed in the art, it should be understood that we wish to embody within the scope of the patent warranted hereon all such modifications as reasonably and properly come within the scope of our contribution to the art.

We claim as our invention:

1. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including a combination of a cross-linked organic polymer and a dienic copolymer, said combination having the properties of vaporizing without carbonization or flaming in the presence of an electrical arc discharge.

2. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including a combination of a cross-linked organic polymer and a copolymer of butadiene and styrene, said combination having the properties of vaporizing without carbonization or flaming in the presence of an electrical arc discharge.

3. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including a combination of an isobutylene-diene copolymer and

a copolymer of butadiene and styrene, said combination having the properties of vaporizing without carbonization or flaming in the presence of an electrical arc discharge.

4. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including a combination of an isobutylene-isoprene copolymer and a copolymer of butadiene and styrene.

5. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including substantially equal parts by weight of an isobutylene-isoprene copolymer and a copolymer of butadiene and styrene.

6. In an electrical connector having separable current-continuing means, the improvement comprising means forming an energy sink adjoining the point of separation of said current carrying means, said energy sink including the combination of a phthalic anhydride-glycerol-styrene copolymer and a copolymer of butadiene and styrene.

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