

April 5, 1966

J. J. ASTLEFORD, JR
CURRENT LIMITING FUSE DEVICE AND CORONA FREE
PROTECTIVE LINK FOR USE THEREIN

3,244,838

Filed Sept. 12, 1963

3 Sheets-Sheet 1

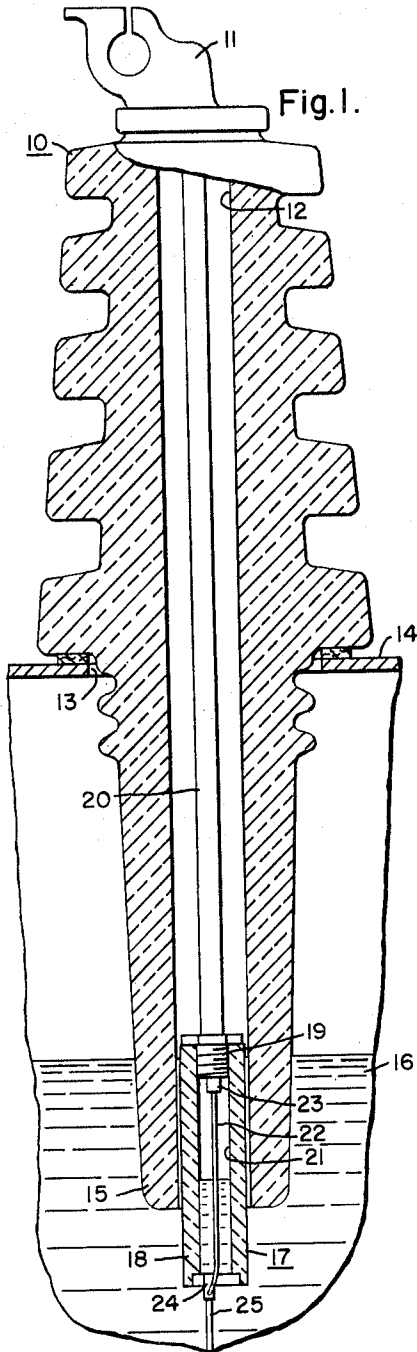


Fig. 1.

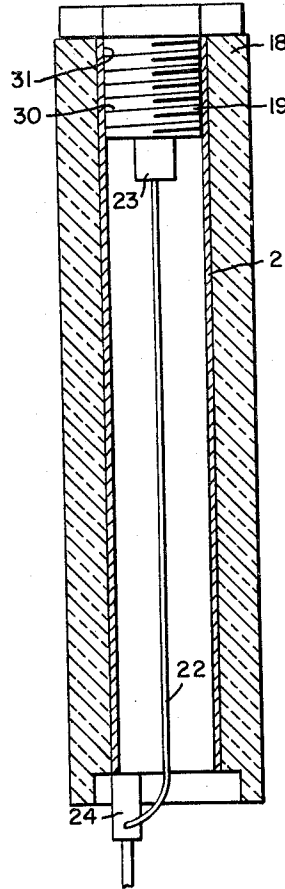


Fig. 2A.

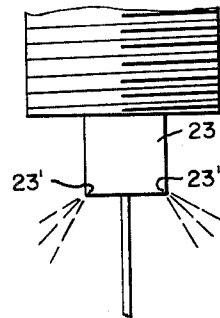


Fig. 2B.

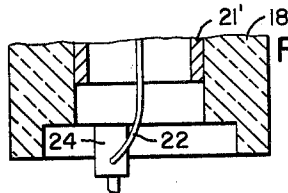


Fig. 2C.

WITNESSES:

Bernard R. Giegney
James F. Young

INVENTOR

John J. Astleford, Jr.

BY Mary I. Hull

ATTORNEY

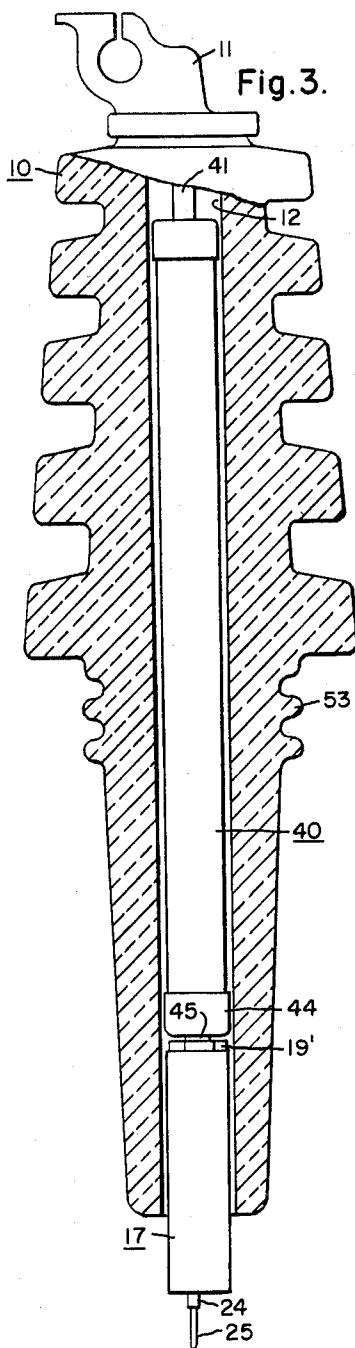
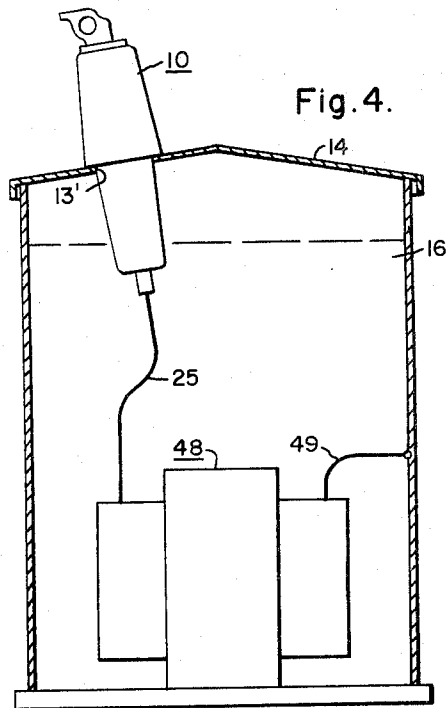
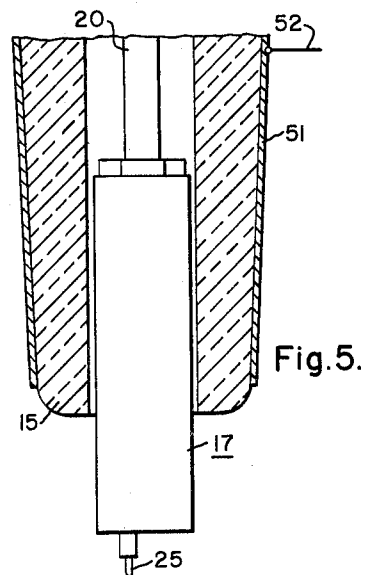
April 5, 1966

J. J. ASTLEFORD, JR
CURRENT LIMITING FUSE DEVICE AND CORONA FREE
PROTECTIVE LINK FOR USE THEREIN

3,244,838

Filed Sept. 12, 1963

3 Sheets-Sheet 2



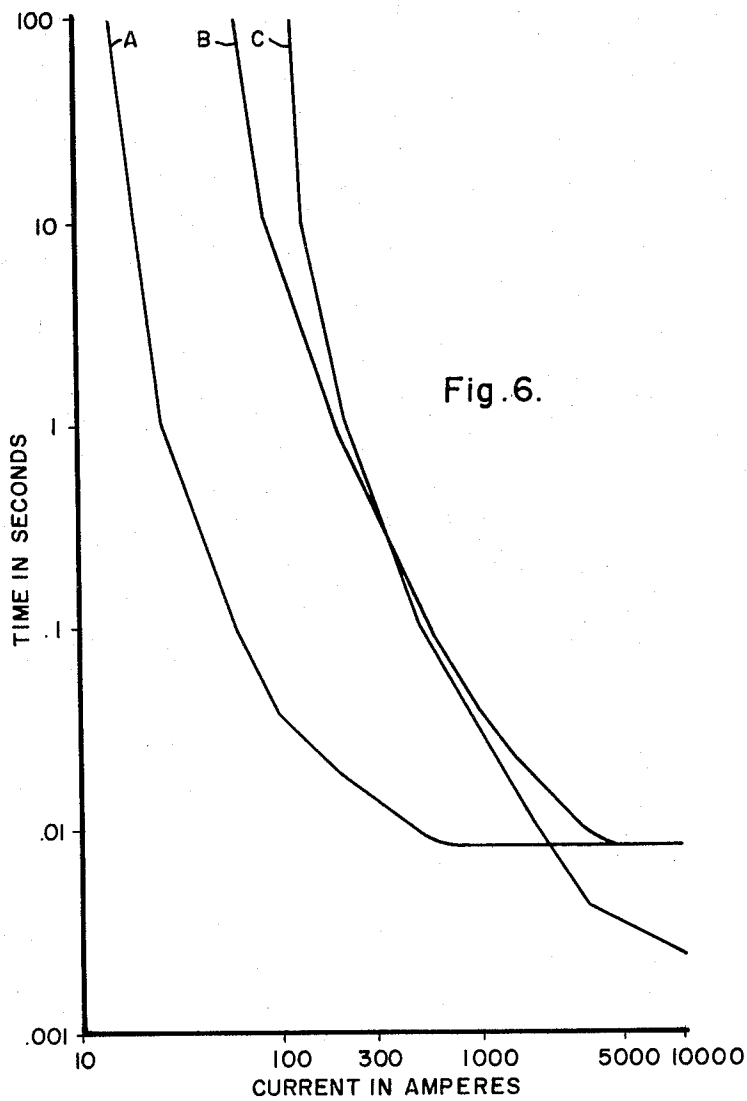
April 5, 1966

J. J. ASTLEFORD, JR
CURRENT LIMITING FUSE DEVICE AND CORONA FREE
PROTECTIVE LINK FOR USE THEREIN

3,244,838

Filed Sept. 12, 1963

3 Sheets-Sheet 3



1

3,244,838

CURRENT LIMITING FUSE DEVICE AND CORONA FREE PROTECTIVE LINK FOR USE THEREIN

John J. Astleford, Jr., Sharon, Pa., assignor to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed Sept. 12, 1963, Ser. No. 308,464

4 Claims. (Cl. 200-120)

This invention relates to improvements in fuse devices, and more particularly to a fuse embodying in one unit a current limiting fuse and a corona free protective fuse link which eliminates radio interference even where the fuse is used in a high voltage line.

Trouble is frequently encountered where high voltage fuses are located in areas of high electric gradients, resulting in the production of corona and the generation of high frequency voltages lying in the radio frequency portion of the radiant energy spectrum and which may interfere with radio reception. A number of factors have in the past contributed to this widespread condition. High voltage fuses mounted inside of transformers, for example, are of necessity located near surfaces which are at a polarity which is opposite to that of the fuse itself, tending to result in a high electrical gradient. This fact, along with the small diameter of the fuse wire and the presence of sharp corners on the stub or electrode to which the fuse wire is attached, creates a high electrical gradient inside the fuse. Radio frequency voltages are generated as a result. This is particularly apt to occur in fuses where air is the surrounding insulation, as it quite often is in a high voltage fuse, in which case usually the electrical gradient exceeds the corona starting voltage of air, which is very low. This invites the production of corona and radio frequency voltages which produce interference.

Several prior art patents have suggested the use of metal shields, or high resistance conductive, resistive or semiconductive coatings on the outside of the tube, or disposed within the walls of the tube in which the fusible element is located, or disposed between an inner tube made of a gas producing material and an outer tube made of a mechanically strong material, to form a corona shield.

These prior art expedients present problems which are difficult if not impossible of solution.

Use of a metal shield presents two conflicting requirements. One is that the shield extend far enough along the fuse tube to shield the corona-producing parts inside the fuse tube. The second is that the shield be short enough that upon fuse operation, sufficient electrical insulation is available to prevent bypassing the fuse through the metal shield by the applied system voltage.

In one prior art device, a high resistance or semiconductive coating extends from one end of the fuse to the other, to shield corona-producing parts, in parallel electrically with the fuse wire. When the fuse wire is melted, the full line voltage is applied across the corona-suppressing coating. The coating must be high enough in resistance so that the leakage current does not burn and track the fuse tube or flashover with a resulting external arc. On the other hand, the resistance must be low enough to adequately shield the fuse wire and parts.

My invention represents an improvement and advance over these prior art devices. In summary, the corona-reducing portion of my invention includes, but is not limited to, a protective fuse link having an electrostatic shield disposed between the fuse wire and the surface of opposite polarity. The shield is preferably a coating of conductive or semiconductive paint on the inside wall of the tubular container for the fusible element, and the

2

shield is separated from the fuse wire by a small air space or oil filled space. The fusible element or wire carries the current. The coating may be electrically connected at one or both ends to the fuse wire, but where it is electrically connected at both ends the resistance ratio of the fuse wire to the coating is made sufficiently small to prevent any detrimental current flow through the coating. The material of the coating is such that it is eroded away by the arc when the fuse flows, resulting in a completely interrupted circuit.

My invention further provides a current limiting fuse mounted integrally with a protective fuse link of substantially the same diameter, both the current limiting fuse and the protective link being located in the central bore or aperture extending the length of a high voltage bushing, with the protective link portion of the fuse extending below an oil level, if any, which may be the oil level inside a transformer tank or other tanked electrical apparatus, the current limiting fuse providing the interruption requirements for extremely high transformer fault currents by proper coordination with the protective link.

Accordingly, a primary object of my invention is to provide a new and improved corona-free protective fuse link for use with high voltages.

Another object is to provide a protective fuse characterized by the absence of radiation in that portion of the electromagnetic spectrum which produces radio frequency interference.

A further object is to provide a current limiting fuse and a protective fuse link mounted substantially integrally with each other suitable for mounting in a high voltage bushing.

These and other objects will become more clearly apparent after a study of the following specification, when read in connection with the accompanying drawings, in which:

FIGURE 1 is a sectional view of a high voltage bushing and protective fuse link according to one embodiment of my invention;

FIG. 2A is an enlarged sectional view of a portion of the apparatus of FIG. 1;

FIG. 2B is a diagrammatic view showing the generation of corona from sharp corners of a lug or other fuse wire electrode or mounting element;

FIG. 2C is a fragmentary view similar to a portion of FIG. 2A, but showing an embodiment in which the coating is not electrically connected at both ends to the fuse wire.

FIG. 3 is a sectional view according to another embodiment of my invention showing, in a transformer high voltage bushing, a current limiting fuse mounted integrally with a protective fuse link;

FIG. 4 is a view showing the apparatus of FIG. 3 mounted inside a transformer tank;

FIG. 5 is a fragmentary view in which the outside of a bushing which has been coated forms an "opposite polarity surface" of large area; and

FIG. 6 is a graph showing relative clear and melt times of typical protective links and a current limiting fuse, as functions of the current through the fuse device.

Referring now to the drawings, in which like reference numerals are used throughout the designate like parts, for a more detailed understanding of the invention, and in particular to FIG. 1 thereof, there is shown a high voltage bushing generally designated 10, which may be porcelain, having a high voltage line terminal 11, the bushing having a central bore or circular aperture 12 extending longitudinally therethrough, the bushing extending through an exemplary aperture 13 in a tank cover 14 and having the lower end 15 of the bushing extending beneath the surface of oil 16 in the tank. Suitable means

such as a nut, or electroswaging, not shown, may be employed for securing the bushing in place. Disposed in the lower end of aperture 12 is the protective fuse link generally designated 17, the fuse link including a cylindrical sleeve or tube 18 composed of insulating material, which may be fiber, the upper end of tube 18 being threaded internally to receive the threads of a head portion 19 connected by metallic conducting rod 20 to the aforementioned line terminal 11. The inside wall of the insulating sleeve or tube 18 is coated the entire length of the tube with a suitable material to provide an electrostatic shield, the coating being indicated at 21; as will become more clearly apparent hereinafter, the coating 21 may be a conductive paint, a semiconductive paint, a non-linear paint, or the coating may be conductive material deposited by any suitable process, so long as the material will be eroded away by the energy of the fuse arc when the fuse blows. The fuse wire 22 is attached to the electrode portion 23 of member 19, the fuse wire 22 extending downward through substantially the center of tube 18 and being attached at the lower end to a terminal lug or electrode 24 mounted at or in the end of tube 18, and thence to a lead wire 25. The coating 21 is electrically connected to member 19 at the upper end thereof, and if desired it may be electrically connected to stud or electrode 24 at the lower end of tube 18.

Particular reference is made now to FIG. 2A, which shows the insulating tube and fuse element in enlarged detail. In FIG. 2A, the thickness of the coating 21 of paint or deposited metallic conductive material, on the inside wall of tube 18 is shown somewhat exaggerated for clarity of illustration. It is seen that member 19 has threads 30 therein which engage the threads 31 in the adjacent wall portion of the sleeve or tube 18 and also engage the coating of paint thereby making electrical contact therewith. Stud or electrode 24 may also be in electrical contact with coating 21, or the coating may stop short of the lug 24, as in FIG. 2C.

It has been discovered that a shield of an aluminum-filled, oil-resistant paint coating the inside wall of the fuse tube 18 is satisfactory. The resistance of the aluminum paint may be 80,000-90,000 megohms/square inch at low voltages and may be voltage sensitive in a direction to lower the resistance on an increase in applied voltage gradient.

Further, for the protective link, the range of fuse wire resistance may vary from 0.275 ohm for an exemplary #28, A.W.G. wire alloy of the non-ferrous variety containing 94.8 to 96.0% copper, 3 to 4% silicon, and 1.0 to 1.2% manganese to 0.000384 ohm for an exemplary #12 A.W.G. copper wire.

To keep the leakage current in a two-end connected corona shield coating down in the microampere region to prevent excessive I^2R heating of the coating, the fuse wire to inside coating resistance ratio can be designed to be about 1 to 10,000, with these resulting lower limits on coating resistance:

2,750 ohms (#28 alloy)
3.84 ohms (#12 copper)

If the coating were not consumed, the lower limit of the coating resistance would become 14,000 megohms, where for example a system voltage of 14 kilovolts was employed, and the coating current was limited to 1.0 microampere.

In FIG. 2B, to which particular reference is made, the electrode 23, to which fuse wire 22 is attached, is shown as it might appear under high voltage electrical stress with respect to, for example, the tank cover 14, which is at opposite polarity or opposite potential with respect thereto. It is seen that at the sharp corners 23' and 23'' corona discharges take place, these being indicated by the dashed lines extending outward from the corners of member 23. The sharp points of member 23 result in a high electrical gradient. This gradient is ineffective to produce radio

frequency noise, however, because of the electrostatic shield afforded by the conductive cylindrical shield 21 formed by conductive paint or deposited conductive material. It can be shown mathematically that a round cylinder of the diameter of the shield or tube 18 has a much lower electrical gradient than a sharp-cornered part, and the presence of the cylindrical shield provides that the corona starting voltage of the fuse is considerably increased. For example, without the shield, a typical high voltage bushing-mounted protective ling has been found to have a corona starting voltage of 4.4 kilovolts. With a conductive coating applied to the fuse tube bore, the corona starting voltage was increased to 26 kilovolts.

As aforementioned, the material of the shield 21 must limit current flow therethrough, and the shield must be of a material which is eroded away by the energy of the fuse arc when the fuse blows, in order to interrupt the circuit properly. Accordingly, the internal shield arrangement is preferably limited to fuses of the expulsion type.

In FIG. 2C, an embodiment of the invention in which the shield or coating 21' is electrically connected at only one end of the fuse, is shown, the lower end of the coating being well spaced from electrode 24.

Particular reference is made now to FIG. 3 where another embodiment of the invention is shown. In FIG. 3, the bushing 10 has disposed in the bore or central aperture 12 therein a current limiting fuse generally designated 40, the upper end of the current limiting fuse 40 being connected by connecting rod 41 to the line terminal 11, the protective current limiting fuse 40 having a cap 44 at the lower end thereof which is connected by suitable screw or bolt 45 to the member 19' of protective fuse link 17.

The protective fuse 40 may include a number of parallel fuse wires, twisted together if desired. Fuse 40 is preferably of the type in which the material of the fuse emits or evolves no gas as a result of the melting of the fuse element or elements. The embodiment of FIG. 3 provides a convenient current limiting fuse and a protective fuse connected together to be withdrawn at the same time through the bore 12 in the bushing 10.

An important advantage of this construction in which the protective link is mounted inside the high voltage bushing (rather than on a terminal block or elsewhere inside the transformer), is that at the transformer primary, the protective link of my invention will interrupt about three times as much current as a terminal block mounted link. For example, at 13.2 kilovolts, the bushing mounted link will interrupt 3,000 amperes, whereas the block-mounted link will interrupt only about 1,000 amperes, because of flashover during link operation.

The importance of this performance improvement is this: for some applications, the maximum cross-over or coordination current level is preferably nearly equal to or slightly below the maximum fuse interruption current. The higher this coordination current, the greater the range of transformer ratings that can be protected by a single design and current rating of the current limiting fuse.

Particular reference is made now to FIG. 4, where the bushing 10 is shown mounted in aperture 13' in the tank cover 14, lead wire 25 extending to the transformer 48 in the tank, the end of the bushing 10 extending considerably below the level of the oil 16, the other terminal of the transformer 48 being connected to the tank by lead wire 49 so that, as previously stated, the tank cover itself is an opposite polarity surface, and is effective as such in the production of a corona discharge.

The current limiting fuse and high voltage protective fuse link combination shown in FIGS. 3 and 4 provides improved electrical performance.

Particular reference is made now to FIG. 6, in which curves A and B represent the clear time of two exemplary protective links 17 as a function of current, and the curve C represents the melt time of a typical current

limiting fuse 40 as a function of current. Comparing curves B and C, it is seen that a "cross-over" occurs at approximately 300 amperes. For overcurrents above this value, the current limiting fuse breaks the circuit, protecting the equipment; for currents below this value, the protective link interrupts the circuit.

The protective link may be less expensive and easier to replace than the current limiting fuse.

Comparing curves A and C, it is seen that they have a crossover at about 2,000 amperes. Fault currents in excess of this value cause the current limiting fuse to interrupt the circuit.

In the present state of the art, the standard protective link is capable of interrupting, for example, 3500 amperes at 7200 volts, and 3000 amperes at 13.2 kilovolts, which in the previous state of the electrical art may have been ample to protect against the possibility of a bolted high voltage fault inside the transformer. However, electrical loads have doubled every 8 or 10 years and system voltage regulation has been improved with time, with the result that distribution system impedances are much lower than they once were. Fault currents on new and rebuilt systems at 7.2 kv. and 13.2 kv. can now reach 10,000 amperes. To economically interrupt currents of this magnitude, the current limiting fuse and protective link combination described permits the use of a single current limiting fuse to coordinate with the protective link and a circuit breaker, not shown, in all transformer ratings from 5 through 100 kva. of each voltage class. Tests of the current limiting fuse and protective link combination have shown that the bushing mounted link will interrupt 3,000 amperes at 13.2 kilovolts, which allows the current limiting fuse protective link combination point to be as high as 3,000 amperes, so that one fuse rating can cover 5 kva. through 100 kva. ratings.

At currents greater than 3,000 amperes, if a current limiting fuse is not used to help interrupt the fault current, an excessive amount of arc energy is dissipated by the link which will blow off the transformer cover and possibly ignite the insulating oil in the transformer.

In summary, my combination of the current limiting fuse and the protective link obviates the necessity for using a different current limiting fuse for almost every transformer rating, to provide the necessary protection and still coordinate with the transformer circuit breaker.

It is well known in the art to coat the outside of a bushing with conductive material, for one purpose or another. In FIG. 5, an "opposite polarity surface" is provided by a conductive coating on at least a portion of the outside surface of the bushing. It is understood that the coating 51 may be, by choice, connected to a conductor 52 of polarity opposite to that of rod 20.

Obviously, the "opposite polarity surface" effective in producing a corona discharge, need not be a tank cover, but should be a large surface area of any electrical equipment located near the fuse and maintained at opposite polarity, or could be a surface provided specifically for this purpose.

As previously stated, in addition to a conductive material, such as aluminum paint, the shield 21 may be composed of other suitable materials, such as a semiconductor material. One such semiconductor material is a mixture including silicon carbide and having an epoxy or other organic base, known in the trade as "Coranox," the material being selected to have the necessary resistance characteristic.

The material of the coating may be voltage-sensitive if desired, so that the current through the coating is a non-linear function of the applied voltage. If desired, a voltage-current characteristic may be chosen to place an upper limit on the current, so that further increases in voltage beyond a critical value will not result in a further increase in current.

If desired, the material of the coating may be deposited metal, such as tin or aluminum. These and other suit-

able metals may be deposited by any of the well known methods or techniques for depositing metal films on non-conductors, such as the evaporation technique. The thickness of the deposited material is carefully controlled to give the desired resistance ratio between the fuse wire and the coating.

The bore 12, FIG. 1, may be oil filled if desired.

Whereas, I have shown and described my invention with respect to some embodiments thereof which give satisfactory results, it should be understood that changes may be made and equivalents substituted without departing from the spirit and scope of the invention.

I claim as my invention:

1. Protective fuse apparatus for use with a high voltage bushing having an aperture extending the length thereof comprising, in combination, a tube of insulating material having at least a portion thereof disposed in said aperture, the tube being internally threaded over a portion of the inside wall thereof near one end, a head member composed of conductive material disposed in said one end of the tube in threaded engagement therein, the head member having a stud electrode portion of a diameter less than the inside diameter of the tube extending therefrom, electrical connecting means extending from said head member through the remainder of the aperture in the bushing, terminal means mounted on the lower end of the insulating tube and adapted to have an electrical connection made thereto, a fuse wire extending from the terminal means through the tube to the stud electrode portion of the head member and making electrical connection therewith, and a coating of conductive material on the inside of the tube along substantially the entire length and over substantially the entire surface thereof to provide an electrostatic shield, the terminal means at the lower end of the tube being electrically insulated from the coating of conductive material, the coating extending to the end of the tube which is internally threaded whereby the head member is in threaded engagement with the coating, the head member having a conductive flange portion adjacent the end of the tube, the flange portion having a diameter at least as great as the outside diameter of the coating of conductive material whereby the creation of an electric field at the upper end of the coating of conductive material is avoided, said coating being of a material which is eroded away by the energy of the fuse arc when the fuse blows, said coating having a high corona starting voltage relative to the corona starting voltage of said stud electrode portion whereby corona is reduced and the production of substantial radiation in the radio frequency portion of the electromagnetic spectrum is avoided.

2. Protective fuse apparatus for use with a high voltage bushing having an aperture extending the length thereof comprising, in combination, a tube of insulating material having at least a portion thereof disposed in said aperture, the tube being internally threaded over a portion of the inside wall thereof near one end, a head member composed of conductive material disposed in said one end of the tube in threaded engagement therein, the head member having a stud electrode portion of a diameter less than the inside diameter of the tube extending therefrom, electrical connecting means extending from said head member through the remainder of the aperture in the bushing, terminal means mounted on the lower end of the insulating tube and adapted to have an electrical connection made thereto, a fuse wire extending from the terminal means through the tube to the stud electrode portion of the head member and making electrical connection therewith, and a coating of conductive material on the inside of the tube extending along substantially the entire length thereof and over substantially the entire surface thereof, the coating of conductive material providing an electrostatic shield, the terminal means at the lower end of the tube being electrically connected to the coating of conductive material, the coating of conductive ma-

7

terial extending to the end of the tube which is internally threaded whereby the head member is in threaded engagement with the coating of conductive material, the head member having a conductive flange portion adjacent the end of the tube, the flange portion having a diameter at least as great as the outside diameter of the coating of conductive material whereby the creation of an electric field at the upper end of the coating of conductive material is avoided, the coating of conductive material being of a material which is eroded away by the energy of the fuse arc when the fuse blows to thereby completely interrupt the electrical circuit, said coating of conductive material having a high corona starting voltage relative to the corona starting voltage of said stud electrode portion whereby corona is reduced and the production of substantial radiation in the radio frequency portion of the electromagnetic spectrum is avoided.

3. Fuse apparatus according to claim 1 in which the high voltage bushing is additionally characterized as being mounted in a tank containing oil, and the lower end of the insulating tube is additionally characterized as extending into said oil, whereby oil flows into the open lower end of the tube and fills a portion of the space within the tube between the fuse wire and the coating of conductive material, the oil within the tube further inhibiting the formation of corona.

4. Fuse apparatus according to claim 2, wherein the

8

high voltage bushing is additionally characterized as being adapted to be mounted in a tank containing oil, and the lower end of the insulating tube is additionally characterized as extending into the oil, whereby oil flows into the open lower end of the tube and fills a portion of the space within the tube between the fuse wire and the coating of conductive material, the oil within the tube further inhibiting the formation of corona.

References Cited by the Examiner

UNITED STATES PATENTS

1,058,143	4/1913	Bitter et al.	200—120
1,730,716	10/1929	Austin	200—131
1,930,804	10/1933	Hart	200—127
2,281,073	4/1942	Leonard	200—120
2,567,236	9/1951	Rawlins et al.	200—120
2,567,768	9/1951	Fahnoe	200—117 X
2,593,426	4/1952	Fahnoe	200—117 X
2,877,322	3/1959	Harner	200—120
2,917,605	12/1959	Fahnoe	200—120 X
3,015,008	12/1961	Chabala et al.	200—120

FOREIGN PATENTS

564,058	9/1944	Great Britain.
---------	--------	----------------

BERNARD A. GILHEANY, *Primary Examiner*.