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[54] GAS TUBE TRANSIENT VOLTAGE PROTECTOR FOR TELECOMMUNICATION SYSTEMS

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[51] **Int. Cl.** **H01j 17/04**, H02h 1/00

[58] **Field of Search** ...... 313/231, 217, DIG. 5, 218, 313/311; 317/61, 61.5, 62

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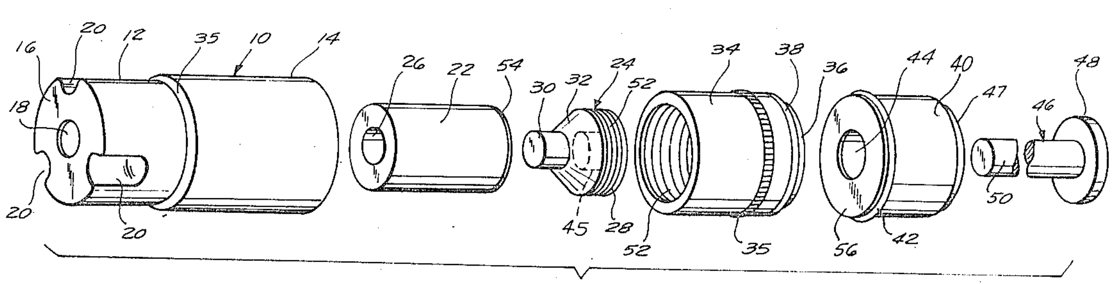
[57] **ABSTRACT**

A transient voltage protector includes a hollow cylindrical housing having an open end and a closed end with a first insulating body mounted in the closed end thereof. An outer electrode in the shape of a hollow cylinder is mounted within the housing between the open end and the first insulating body. An inner electrode is mounted on and supported by the first insulating body, within the outer electrode and spaced therefrom. The inner electrode is provided with a recess on the surface opposite the surface mounted on the first insulating body. A second insulating body is adopted to engage the open end of the housing and is provided with a central bore therethrough. A connecting element is provided having an end portion and a body portion, the end portion being accessible from the exterior of the housing and the body portion extending through the bore in the second insulating body and into the recess in the inner electrode to further impart physical stability to the inner electrode as well as to provide an electrical connection thereto. The opposing surfaces of the inner and outer electrodes are coated with a substance comprising aluminum, magnesium and titanium hydride. The space between the electrodes is filled with a gas comprising hydrogen and argon, and preferably krypton as well. A thin layer of metal coating is situated on the surface of the first insulating body adjacent the inner electrode to enhance the electrical field at the junction between the insulating body and the inner electrode.

36 Claims, 4 Drawing Figures



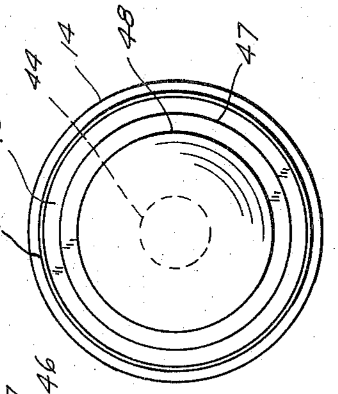


FIG. 3

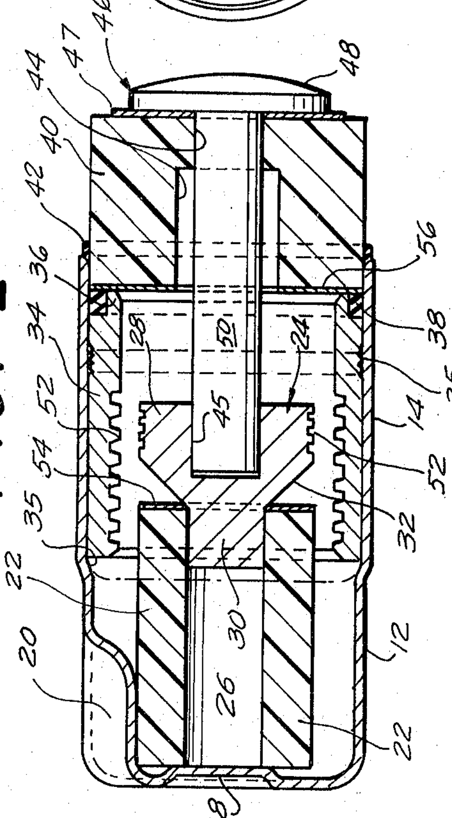


FIG. 2

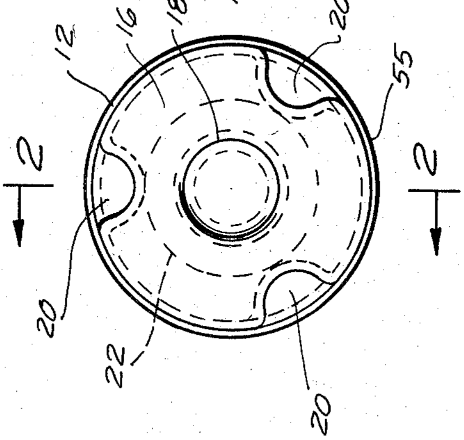


FIG. 1

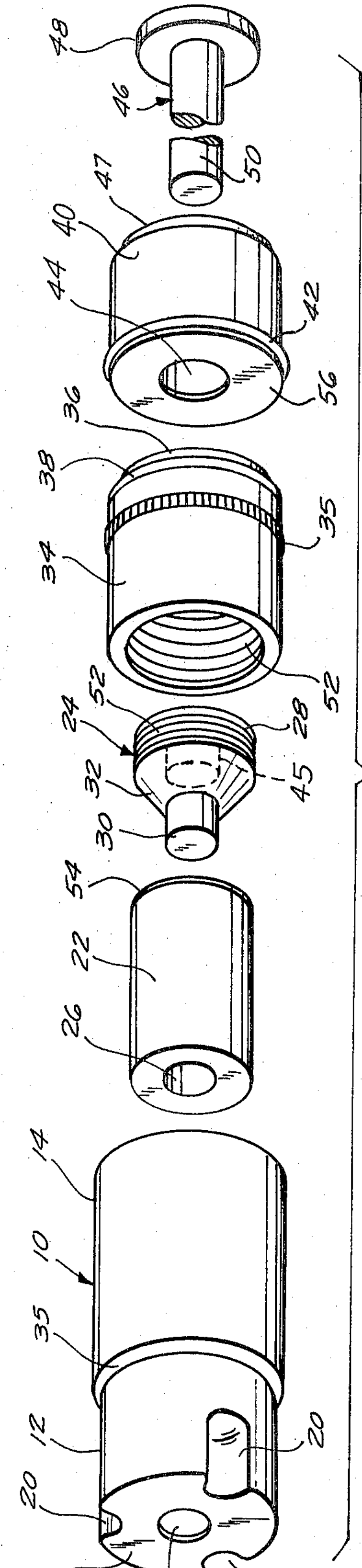


FIG. 4

GAS TUBE TRANSIENT VOLTAGE PROTECTOR FOR TELECOMMUNICATION SYSTEMS

This invention relates to transient voltage protectors and more particularly to a gas discharge type transient voltage protector for use on telephone and other electronic circuits.

Discharge devices of various types are extensively used, for example, in telecommunication systems, military communication equipment, radar systems, avionic control systems and CATV installations as the basic means for limiting extraneous voltages and thereby protecting equipment and personnel who may be operating the equipment. These discharge devices or protectors are heavy-duty devices which are capable of initially intercepting excessive voltage surges appearing on transmission facilities and reducing them to manageable levels. These protectors are normally installed across transmission lines between the current carrying cable line and the ground wires to divert any transient voltage surges to ground, thereby protecting personnel and equipment beyond the point of installation.

The voltage transient may occur due to several different causes, such as lightning striking the transmission line, a power cross or an internally generated switching transient. The transients occur at different speeds, depending upon the source of the transient. For instance, transients due to lightning would be relatively rapid whereas a power cross would cause a relatively slow transient.

Ideally, a protector is a discharge device which is placed between a transmission line and a ground which operates as an open circuit until a predetermined voltage level is reached. Thereafter, any further rise in voltage across the device's terminals causes the device to operate as a closed circuit, the surge thus being bypassed to ground or around sensitive circuit components. This is accomplished by placing two electrodes in close proximity to one another such that when the voltage across the electrodes exceeds a predetermined value, ionization of the gas between the electrodes takes place permitting a spark to jump from one electrode to the other. In this way, the protector acts as a closed circuit when the voltage across its terminals exceeds a predetermined level, thereby permitting unwanted transients to be conducted to ground.

Two types of transient voltage protectors are commonly in use. Carbon block protectors are perhaps the most commonly used and consist of two closely spaced flat carbon electrodes discharging in air at atmospheric pressure. Carbon is the most popular electrode material because when it is properly processed it offers a high melting point surface with considerable ability to sublimate under high arc temperatures, thereby minimizing the accumulation of residues that can produce excessive leakage and, ultimately, permanent grounding. However, carbon block protectors in high lightning areas may develop enough leakage in a short time to cause circuit disturbances, such as impulse noise in carrier circuits. Further, the nature of these protectors necessitates frequent replacement thereof, thus constituting a source of substantial maintenance expense.

Because carbon block protectors discharge in air at atmospheric pressure, the minimum practical gap spacing between the electrodes therein is about 0.003 inch. However, carbon block protectors which employ such small gap spacing are quite susceptible to leakage and

permanent short circuiting from bridging of the gap between the electrodes by residue formed from electrode arcing. Increasing the electrode spacing enough to reduce these effects increases the voltage necessary to produce a discharge beyond acceptable limits for most purposes.

The second type of protector in common use is the gas tube protector. Gas tube protectors provide a solution to the dilemma of the gap spacing in carbon arc protectors. It is an experimentally established fact that the voltage necessary to produce a discharge in a gas tube protector depends essentially on the product of the electrode spacing and the gas pressure. This means that if the gas pressure is reduced by a multiple of four, the electrode spacing can be increased by the same multiple and the discharge potential will remain approximately the same. Therefore, gas tube protectors offer a variety of design advantages which are not possible in carbon block protectors. Further, it is also possible to design gas tube protectors which are interchangeable electrically and physically with carbon block protectors. Therefore, as carbon block protectors wear out they can be replaced by gas tube protectors at a minimal conversion cost. This characteristic is particularly important in view of the fact that telephone companies around the world have been using carbon block protectors, and therefore have literally millions of these protectors presently in use. To convert such a system to a gas tube protector system would be an extremely expensive proposition if the protectors were not interchangeable.

There are six basic operational characteristics by which the functional capabilities of a transient voltage protector may be judged. These are the DC breakdown voltage, impulse ratio, transition time, holdover-voltage, failure mode and usable life of the protector. Each of these characteristics is important in itself and also in relation to the others.

The DC breakdown or discharge voltage is perhaps the most important of the functional characteristics of the device. The breakdown or discharge voltage is that voltage which causes the protector to change from an open circuit condition to a closed circuit condition. Thus, it is at this voltage level that the device becomes conductive and therefore any voltages occurring above the breakdown level are diverted from the protected equipment.

Since voltage transients occur at different speeds according to their sources, it is extremely important that protectors have the ability to respond equally quickly to different types of pulses which occur at a variety of speeds. A fast pulse having a steep voltage ramp often causes a variance in the breakdown voltage of a protector. Because the pulse has a steep ramp, the breakdown voltage of the protector may rise to a higher level, thus causing the protector to respond more slowly to such pulses and perhaps overload the protected circuitry before the protector can respond. A measure of this response time is called the impulse ratio of the device and is calculated by taking the breakdown voltage when a rapid pulse voltage is applied and dividing it by the DC breakdown voltage. The impulse ratio of conventional gas discharge transient protectors may vary from about 3 to 5 for an applied voltage ramp of 5KV/μs. Of course, it is desirable to obtain as low an impulse ratio as possible, preferably close to unity. An impulse ratio of one would indicate that the protector has a breakdown voltage which does not depend upon the steepness of the voltage ramp applied.

The high impulse ratios of conventional gas tube protectors are due to two causes which are inherent in gas discharge devices. The first cause is the statistical delay time which is necessary for a free electron to occur to initiate the electron avalanche process. The initiation of free electrons is due to such causes as cosmic rays or random escapes of electrons from the electrode surfaces. The second cause is the time in which it takes an electron avalanche to form, thereby to cause sufficient ionization for a spark to bridge the gap between the electrodes.

In the past, manufacturers of two-electrode gas discharge type transient protectors have used various methods to keep the impulse ratio to an acceptable level. One of these methods is to place an insulating material directly between the two conducting electrodes, thereby filling the entire void (or alternatively a portion of the void) between the electrodes. This type of device, however, utilizes the principle of surface breakdown which has only limited usefulness, because after a few discharges a "tracking" of the insulator results in a short circuit of the device. Another method used to lessen the impulse ratio is to stongly illuminate the cathode electrode surface with ultraviolet light, thereby resulting in the emission of photoelectrons in sufficient quantity to effectively eliminate the statistical time lag necessary for an electron to occur to initiate the electron avalanche. However, the avalanche formation time still remains in this instance, thereby causing an impulse ratio greater than one. A third method of design to achieve low impulse ratios is to use an auxiliary discharge such as may be obtained from an adjacent pair of electrodes placed in close proximity to the main protection electrodes. However, such devices have limited usefulness due to large size of the units and the complicated circuitry which is required.

The third functional characteristic of a gas tube transient voltage protector is referred to as the transition time. The transition time is that finite amount of time necessary for the protector to switch from the open circuit to the closed circuit mode. The transition time is more specifically defined as being the time interval between the instant breakdown occurs (on the leading edge of the applied voltage wavefront) and the instant that the voltage across the device has dropped to the arc voltage level. Under normal circumstances, the transition time may range in an uncontrolled manner from less than 1 μs to greater than 10 μs in the same device. However, it is very desirable that a transient voltage protector have a transition time which is as short as possible, preferably always less than 1 μs. In this way, the equipment or components being protected will not be subject to an uncontrolled overvoltage condition for excessive time periods before the protector becomes conductive.

The fourth important characteristic of the transient voltage protector is the holdover voltage. When a gas discharge device has been subjected to a transient surge current, there is a consequent heating of the electrodes which normally results in the emission of electrodes for an extended time period. This time period generally lasts as long as the electrodes remain heated. The voltage level (bias voltage) which may be applied continuously to the device, i.e., during and after the current pulse has transpired, without causing the device to become continuously conductive is termed the holdover voltage. It is desirable that the holdover voltage be as high as possible. For the telephone industry, it is necessary to provide protectors which have a holdover voltage rating of greater than 160 volts.

A fifth important functional characteristic of a transient voltage protector is the failure mode thereof, which must always be a shorted condition. The protector must be designed such that after repeated use, the erosion of the electrodes causes a bridge to form therebetween, thus assuring a closed circuit failure of the device. Were the protector to fail in the open circuit mode it would be impossible to tell that it was no longer operational thereby leaving equipment and personnel unprotected. Therefore, the geometrical design of the components of the device must be such to insure that there is no way in whch an internal discharge can cause a punch through of the hermetic enclosure and thereby cause a fail-open condition.

The final functional characteristic desirable in a transient voltage protector is longevity. Since there are so many of these protectors utilized in a communications system such as the telephone system, it is necessary, from an economic point of view, that these protectors be able to be utilized for a substantial amount of time before the shorted condition occurs. Although the average number of discharges in the life of a protector depends at least partially upon the type of waveforms to which the protector is subjected, it is of course preferable to have a device which can react to as many discharges as possible before shorting occurs.

Each of these characteristics is a result of one or more aspects of the physical design of the device or the chemical composition of the elements thereof. In order to produce a device having suitable characteristics, many design trade-offs must be made as well as a careful selection of materials which, in conjunction with the particular design chosen, achieves the desired results.

In addition to these operational characteristics, the protectors must be durably built to reliably function under extreme environmental conditions as they are used all over the world. Further, they must be built to withstand physical shocks without breaking or malfunctioning as well as to be vibration resistant such that they function effectively under a wide variety of conditions. Moreover, because of the widespread use of carbon block protectors, it is extremely desirable that the gas tube protectors be interchangeable both physically and electrically with carbon block protectors to reduce changeover costs and make these protectors more economically feasible.

In the past, gas tube type transient voltage protectors have been produced which are capable of controlling a few of these operational characteristics in a suitable fashion. However, because certain of the design aspects of the device determine or affect more than one of the characteristics simultaneously, (sometimes in a mutually exclusive manner) it becomes increasingly difficult to design the device as more and more of these characteristics need to be controlled. The present invention relates to a protector which is capable of controlling all six of these functional characteristics through a novel geometric design and appropriate choice of materials for the various elements which make up the protector.

In accordance with the present invention a transient voltage protector is provided having a hollow, generally cylindrical housing with an open end and a closed end. A first insulating body is mounted in the housing adjacent the closed end and an outer electrode in the shape of a hollow cylinder is mounted in the housing between the open end and the first insulating body. An inner electrode is mounted on the first insulating body within the outer electrode and spaced therefrom. A second insulating body is adopted to engage the open end of the housing. This second insulating body has a bore therethrough. An electrical connectng element is provided with an end portion and a body portion. The end portion is accessible to the exterior surface of the second insulating body, and the body extends through the bore in the second insulating body and engages the inner electrode to impart physical stability to the inner electrode as well as to provide an electrical connection therewith.

of the design features which strongly effects both transition time and holdover voltage is the type of electrode surface coating used. If the coating is very active, i.e., characterized by a low work function, the transition time will be very short (less than 1 μs) but the holdover voltage will be very low (less than 80 volts). To obtain a balance in design such that low transition time and high holdover voltage are achieved, the coating must be of intermediate activity, i.e., characterized by a work function of approximately 3.0 to 4.0. In the present invention an electrode coating composed of aluminum, magnesium and titanium hydride is utilized. This combination of materials not only permits the device to have the appropriate transition time and holdover voltage but also reduces the erosion of the electrodes such that many discharges may be handled without degradation of the device.

The holdover voltage is also affected by the composition of the fill gas which is present in the gap between the electrodes. In the present invention, a fill gas comprised of hydrogen and argon is utilized to achieve the necessary high holdover voltages. In addition, amounts of a radioactive substance such as krypton (isotope 85) are preferably incorporated in the fill gas to provide electrons necessary for avalanche to occur.

The impulse ratio demonstrated by the present invention is kept to a uniquely low level by the use of a solid dielectric-metal junction which is constructed by pressing the inner coaxial electrode into intimate contact with the first insulating body. The angle between the insulator and the electrode is adjusted to about 45°, which has been experimentally found to provide maximum enhancement of the impulse ratio. To activate the ceramic in the insulating body, a thin layer of metal coating is applied to the surface of the insulating body which is adjacent to the inner electrode. This coating serves to enhance the electric field at the junction and thereby enhance the emission characteristics of the junction.

To the accomplishment of the above, and to such other objects as may hereinafter appear, the present invention relates to a transient voltage protector as defined in the appended claims and as described in the specification, taken together with the accompanying drawings wherein like numerals refer to like parts and in which:

FIG. 1 is a side elevational view of one end of the preferred embodiment of the present invention;

FIG. 2 is a side cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a side elevational view of the other end of the preferred embodiment of the present invention; and

FIG. 4 is an isometric exploded view of the preferred embodiment of the present invention.

The transient voltage protector of the present invention comprises a housing, generally designated **10**, in the form of a hollow generally cylindrical metallic body having a first section **12** and a second section **14**. First section **12** has a diameter which is slightly less than the diameter of second portion **14**. First section **12** is provided with a closed end **16** having a central recess **18** therein. Three radially inwardly extending recesses or crimps **20** are located in an evenly spaced relationship around the wall of first section **12** adjacent end **16**. A first insulating body **22** of cylindrical shape is provided having an outer diameter which permits it to be inserted between crimps **20** in the interior of first section **12** such that the leading end thereof contacts the interior surface of recess **18**. First insulating body **22** is formed of a ceramic insulating material, preferably aluminum oxide (Al_2O_3) because of the ability of this substance to withstand exposure to the intense heat of the electric arc. Body **22** also functions to provide a mounting platform for an inner electrode **24** such that inner electrode **24** is electrically isolated from housing **10**. First insulating body **22** is provided with a central bore **26** to facilitate positioning and mounting electrode **24** thereon.

Inner electrode **24** is formed of a metallic material, preferably copper or cold rolled steel. Inner electrode **24** has an active portion **28** of cylindrical shape and a mounting portion **30**, also of cylindrical shape, but having a diameter substantially less than the diameter of active portion **28**. A conical portion **32** is formed between mounting portion **30** and active portion **28** and serves to enhance the field characteristics at the electrode-insulating body junction, as described more fully below. The diameter of mounting portion **30** is slightly less than the diameter of central bore **26** on first insulating body **22** such that mounting portion **30** may be inserted into bore **26** until the most tapered portion of conical section **32** rests on the surface of first insulating body **22**.

An outer electrode **34** is provided having a hollow cylindrical shape. The outer diameter of electrode **34** is slightly less than the diameter of second section **14** of housing **10**. Outer electrode **34** has a peripheral protruding band **35**, preferably in the form of a knurled edge or flange, around the outside thereof. Electrode **34** is inserted into housing **10** and press fitted into place such that band **35** partially collapses spreading out between electrode **34** and housing **10** to insure a snug fit therebetween. The outer end of outer electrode **34** is provided with a lip **36** having a diameter slightly less than the diameter of outer electrode **34**. A brazing ring **38** is provided to fit within the recess formed by lip **36** and housing **10**.

A second insulating body **40** made of the same nonconductive material as body **22**, is provided having an outer diameter approximately to the diameter of outer electrode **34**. Second insulating body **40** is inserted into the open end of second section **14** until the leading surface thereof contacts lip **36**. A second brazing ring **42** is then located around second insulating body **40** at the edge of second portion **14.** Second insulating body **40** is provided with a central bore **44** which aligns with a recess **45** on the outer surface of inner electrode **24.**

A connecting element **46** is provided having an outer or end portion **48** and an elongated body portion **50.** End portion **48** has a diameter which is substantially larger than the diameter of bore **44** in second insulating body **40.** Body portion **50** is adopted to be inserted through bore **44** such that the leading edge thereof is situated adjacent the bottom surface of a recess **45** on inner electrode **24.** After insertion, end portion **48** rests on the outer surface of second insulating body **40** and is thus accessible from the exterior of the protector. Connecting element **46** is made of electrically conductive material to provide an electrical connection between inner electrode **24** and the outer surface of the protector. Moreover, connecting element **46** imparts additional physical stability to inner electrode **24** by preventing any movement of inner electrode **24** relative to the remainder of the device. This geometric configuration assures equal gap spacing between inner electrode **24** and outer electrode **34** and serves to maintain the relative position between inner electrode **24** and outer electrode **34** regardless of mechanical shocks or vibrations to which the device may be subjected.

The outer surface of active portion **28** of inner electrode **24** and the inner surface of outer electrode **34** are each provided with a plurality of grooves **52.** Each groove **52** is provided with sharp corners which tends to enhance the electrical field at these corners. Each of the sets of grooves **52** may comprise a plurality of separate annular grooves or a single helical groove having the desired pitch. It is preferable to have a groove density of approximately 40 grooves per inch.

The surge handling capability of a gas discharge type transient protector is normally characterized by the material utilized to form the electrodes. Since the type of electrode material used will partially determine the electrical characteristics of the device and particularly the life span of the device, it is extremely important that an appropriate material be selected. Frequently certain refractory metals are used for this purpose. However, these metals are expensive and extremely difficult to fabricate. Because of this, other substances have been tried such as an amalgamation of tungsten and copper which has the advantage of very low erosion for very high surge current pulses. Instead of selecting an electrode material which gives some of the desired electrical characteristics but is expensive to use, the present invention utilizes a coating for the electrode material such that the electrodes may be formed of copper or cold rolled steel. These materials have the advantage of being cheap and readily available as well as being considerably easier to form. Since these base materials have relatively high work functions (copper, 4.4–4.5 and Fe 4.7), it is necessary that the coating serve to replace the high work function of the base metal with a lower value representative of intermediate activity (approximately 3.0 to 4.0). This lower work function serves to increase the electron emission capability during arcing and thereby preserve the base metal electrodes for many more discharges without excessive erosion. The coating material is utilized to cover the two main electrodes in the region where discharge occurs, thereby significantly reducing the amount of degradation of the electrodes caused by a discharge. A typical discharge would be 500 amps. with the waveform 10/1000 μs (rise time/time to half amplitude). This current waveform may be handled repeatedly with protectors of the present invention with a typical device life greater than 1,000 discharges. Ordinary devices made without this coating may have typical life spans of less than 100 discharges for the same surge current pulse.

A coating which has the appropriate work function value and which permits the desired holdover voltage and transition time characteristics to be achieved simultaneously consists of three constituents: aluminum, magnesium and titanium hydride. These substances are powdered and then applied to the device by compacting the coating into the grooves **52** of the two electrodes. Powders of various particle sizes ranging from 100 mesh to 400 mesh have been investigated. All work satisfactorily but powders having particles of higher mesh sizes are preferable. Specifically, it is preferable to have the aluminum powder having particles of 400 mesh atomized, particles of magnesium which are 325 mesh atomized and particles of titanium hydride which have a 325 mesh size. These higher mesh powder sizes also compact more readily into the grooves of the electrodes, thus making the manufacturing process easier.

The major ingredient of the coating is aluminum powder. This ingredient may be varied from 80 to 95 percent by weight of the coating mix with the balance consisting of substantially equal parts of magnesium and titanium hydride. However, the most preferred composition is a blend consisting of 90.5 percent by weight aluminum powder, 4.75 percent by weight magnesium powder and 4.75 percent by weight titanium hydride.

The coating is compacted into the grooves **52** in both the inner and outer electrodes. After compacting, the parts are passed through a furnace at approximately 880°C. At this temperature, the powder is amalgamated with the base copper electrodes. If the magnesium powder were omitted, the amalgamation would not be accomplished. For this reason the purpose of the magnesium is best described as a catalyst for the amalgamation process. By this process the coating is made tightly adherent to withstand shock and vibration exposure. The compacting of the powder into the grooves and the heating of the electrodes normally takes place prior to assembly of the protector. After assembly, the protector is placed in a furnace which is then evacuated. The furnace is heated to approximately 450°C and a fill gas is injected therein under a given pressure. The pressure of the fill gas in the furnace is determined by the temperature of the furnace and the resulting pressure desired in the protector. For example, a protector having a 350 volt DC breakdown rating would necessitate a pressure of approximately 200 millimeters mercury per square inch. Thus, the pressure of the gas within the furnace would be substantially higher than this pressure. The resulting pressure in the protector after it is sealed and cooled can be calculated by means of the well-known gas laws.

In the past, a variety of inert gases have been utilized as fill gases for transient voltage protectors. Among the most commonly used gases for this purpose are hydrogen and nitrogen. However, in order to achieve the favorable holdover voltage characteristics necessary for operation in telephone circuits, a fill gas has been sedown voltage of 350 volts, an impulse ratio of less than 2.0 and will perform an average of 1,000 discharges or more when a typical 500 amp. waveform is applied before it will fail in the shorted mode. The transition time is controlled at less than 1.0 μs and the holdover voltage is held at a level greater than 160 volts DC

A single preferred embodiment of the present invention has been specifically disclosed herein for purposes of illustration. It is apparent that many variations and modifications may be made upon the specific structure disclosed herein depending upon the specific functional characteristics of the protector desired for a particular application. It is intended to cover all of these variations and modifications which fall within the scope of this invention as defined by the appended claims.

We claim:

1. A transient voltage protector comprising a hollow generally cylindrical housing having an open end and a closed end, a first insulating body mounted in said housing adjacent said closed end, an outer electrode in the shape of a hollow cylinder mounted in said housing between said open end and said first insulating body, an inner electrode mounted on said first insulating body within said outer electrode and spaced therefrom, a second insulating body adapted to engage said open end and having a bore therethrough and an electrical connecting element having an end portion and a body portion, said end portion being accessible to the exterior surface of said second insulating body and said body portion extending through said bore and engaging said inner electrode to impart physical stability to said inner electrode as well as to provide an electrical connection therewith.

2. The protector of claim **1** wherein said inner electrode has a recess therein on the surface opposite the surface mounted on said first insulating body, said body portion extending into said recess to provide engagement between said inner electrode and said element.

3. The protector of claim **1** wherein said first insulating body and said inner electrode have parts thereon adapted to interlock thereby providing engagement between said first insulating body and said inner electrode.

4. The protector of claim **1** wherein said outer electrode is provided with a protruding peripheral band to insure a tight fit between said outer electrode and said housing.

5. The protector of claim **1** wherein the wall of the housing adjacent said closed end has a plurality of indentations therein adapted to frictionally clasp said first insulating member therebetween.

6. The protector of claim **1** wherein said substance comprises from 80 to 95 percent aluminum by weight and approximately equal parts by weight of magnesium and titanium hydride.

7. The protector of claim **1** wherein the opposing surfaces of said inner and outer electrodes are coated with a substance having a lower work function than said electrodes.

8. The protector of claim **1** further comprising a thin layer of metal coating situated on the surface of said first insulating body adjacent said inner electrode.

9. The protector of claim **8** wherein said metal coated insulator surface and an adjacent exposed surface of said inner electrode form about a 45° angle with each other.

10. The protector of claim **9** wherein the space between said electrodes is filled with a gas comprising hydrogen and argon.

11. The protector of claim **10** wherein said gas comprises 5 percent –30 percent hydrogen and 70 percent –95 percent argon.

12. The protector of claim **10** wherein said gas comprises 20 percent hydrogen and 80 percent argon.

13. The protector of claim **11** wherein said gas further comprises a radioactive substance.

14. The protector of claim **13** wherein said radioactive substance is present in quantities of approximately five millicurie per liter of gas.

15. The protector of claim **13** wherein said radioactive substance is krypton.

16. The protector of claim **15** wherein said housing has a first section and a second section, said first section having a smaller diameter than said second section.

17. The protector of claim **16** wherein said first and second sections are joined by an intermediary section forming a shoulder which prevents over-insertion of said outer electrode into said housing.

18. The protector of claim **1** wherein the opposing surfaces of said inner and outer electrodes are coated with a substance comprising aluminum, magnesium and titanium hydride.

19. The protector of claim **18** wherein said substance comprises aluminum 90.5 percent by weight, magnesium 4.75 percent by weight and titanium hydride 4.75 percent by weight.

20. The protector of claim **18** further comprising a thin layer of metal coating situated on the surface of said first insulating body adjacent said inner electrode.

21. The protector of claim **20** wherein said gas comprises 5 percent –30 percent hydrogen and 70 percent –95 percent argon.

22. A transient voltage protector comprising a housing, an inner and an outer electrode mounted within said housing such that said electrodes have surfaces spaced from each other, said spaced surfaces of said electrodes being coated with a substance comprising aluminum, magnesium and titanium hydride.

23. The protector of claim **22** wherein said substance comprises from 80 to 95 percent aluminum by weight and approximately equal parts by weight of magnesium and titanium hydride.

24. The protector of claim **22** wherein said substance comprises aluminum 90.5 percent by weight, magnesium 4.75 percent by weight and titanium hydride 4.75 percent by weight.

25. The protector of claim **22** wherein the space between said electrodes is filled with a gas comprising hydrogen and argon.

26. The protector of claim **25** wherein said gas comprises 5 percent –30 percent hydrogen and 70 percent –95 percent argon.

27. The protector of claim **25** wherein said gas comprises 20 percent hydrogen and 80 percent argon.

28. The protector of claim **27** wherein said gas further comprises a radioactive substance.

29. The protector of claim **28** wherein said radioactive substance is krypton.

30. The protector of claim **22** wherein said electrodes are coaxial and wherein the outer surface of said inner lected which is composed of a mixture of 95–70 percent argon and 5–30 percent hydrogen. However, the optimum composition is 80 percent argon and 20 percent hydrogen. This fill gas cooperates with the coating utilized to maximize the balance necessary for simultaneously achieving the desired holdover voltage and transition time characteristics.

Preferably included in the fill gas is also a small amount of a radioactive substance. Krypton (isotope 85) has been used in the amount of five millicurie per liter with satisfactory results. This substance assists in providing the electron activity necessary to form the avalanche and thus tends to shorten the transition time.

Further, the high holdover voltage characteristics are also enhanced by the elimination from the protector of all materials having extremely low work functions such as sodium (2.1 to 2.5) and potassium (2.0 to 2.5). These materials are common in their occurrence and therefore extreme cleanliness must be obtained during the entire fabrication process. However, it has been found that the expense involved in successfully eliminating low work function materials from the protector pays off in significantly enhanced holdover voltage characteristics.

After the protector has been backfilled with the fill gas, the protector is heated such that the material of brazing rings **38** and **42** flows slightly until it amalgamates with the adjacent metals to form a seal. The hydrogen content of the fill gas is important in this regard because it assists in the brazing process. A hermetic seal **47** is formed between end portion **48** of element **46** and the exterior surface of insulating body **40** in order to prevent gas escaping through bore **44**.

This heating also serves to mount the outer electrode to the housing. Because the inner electrode is made of material with a greater coefficient of linear expansion than the material of the housing, heating the protector causes the electrode to expand more rapidly than the housing thus tending to seal these parts together.

After the protector has been sealed, it is ready for activation. Activation of the coating is achieved by applying a flow of current of sufficient amperage and time duration to cause the coating to vaporize. The vaporized aluminum redeposits in the form of a uniform coating in the region of the grooved part of the electrodes. The primary purpose of the titanium hydride in this process is to provide the surface irregularity needed to insure the occurrence of a transition time of less than 1.0 μs.

It has been found that the impulse ratio may be substantially reduced by the appropriate design of the dielectric-metal junction at the base of inner electrode **24**. The appropriate junction is constructed by assuring intimate contact between the first insulating body **22** and inner electrode **24**. The angle between insulating body **22** and electrode **24** has been found to be of great importance in this regard. Preferably, this angle should be about 45° to provide the maximum enhancement of the impulse ratio. This is the purpose of conical section **32** of electrode **24** which is produced to form a 45° angle with the surface of first insulating body **22**. To activate the insulating body **22**, a thin layer of metal coating **54** is applied to the surface of first insulating body **22** adjacent inner electrode **24**. This thin coating serves to enhance the electrical field at the first insulating body **22** and thereby enhance the emission characteristics of the junction. This design characteristic assures that the voltage required for electron emission from the junction is less than that required to cause breakdown of an ordinary gas discharge device having the same electron configuration and fill gas as described above. Thus, electron emission will commence from the junction as the applied voltage increases but before a discharge occurs. The number of junction electrons introduced into the gap is sufficient (particularly with the krypton in the fill gas) to overcome the statistical delay time and limit the time for breakdown to approximately the time necessary to form the avalanche. The junction is designed with an insulating material which not only provides an enhanced impulse ratio but simultaneously insures that the highest levels of the current waveform may be passed without damage to the junction.

The transition time of the protector is enhanced through the use of the sharp corners of the grooves in combination with the particular coating selected. The coating provides a high current density which is enhanced by the sharp corners of the grooves which tend to concentrate high electrical fields at these corners. These features lead to high current densities being emitted from very small surface regions and the consequent lowering of the transition time. The high current densities insure intense temperature at the cathode with the instantaneous occurrence of the low arc voltage.

Further, the relative stability of the coating material is such that it does not interfere with the breakdown under environmental temperatures of from −55° to 125°C but does insure the low arc voltages during the conduction cycle.

The interior surface of second insulating body **40** is also provided with a coating **56** which is utilized to enhance the pulse breakdown response of the device. Coating **56** may be of a metallic substance similar to the coating **54** or may be comprised of graphite. Various patterns of coating on the second insulating body **40** have proved operational. The pattern may be a uniform coating covering the entire exposed inner surface of second insulating body **40** (as shown herein) or may be of stripes of various widths and designs.

The geometric configuration of the protector of the present invention insures that the device will always fail in shorted mode under wearout conditions. As the discharge occurs repeatedly in the region of the grooves, an accumulation of erosion will "bridge" the gap between the electrodes and consequently cause a fail short at the end of the usable life of the protector. The design insures that an internal discharge cannot cause a punch through of the hermetic enclosure and thereby a fail open condition. This is extremely important because were the protectors to fail in an open circuit condition there would be no indication that the protector is unable to successfully divert the next current surge. This would mean that one would be unable to tell whether or not the protectors were operational. However, because the protector of the present invention fails in a shorted condition, the worn out protector can be immediately located and replaced, thus reducing the possibilities of destruction of equipment and danger to personnel.

The device of the present invention demonstrates the six characteristics which are essential for the optimum operation of a transient voltage protector when used in many telephone circuits. The device has a DC breakelectrode and the spaced inner surface of said outer electrode comprise said spaced surfaces.

31. The protector of claim **30** wherein said substance comprises from 80 to 95 percent aluminum by weight and approximately equal parts by weight of magnesium and titanium hydride.

32. The protector of claim **31** wherein said substance comprises aluminum 90.5 percent by weight, magnesium 4.75 percent by weight and titanium hydride 4.75 percent by weight.

33. The protector of claim **32** wherein the space between said electrodes is filled with a gas comprising hydrogen and argon.

34. The protector of claim **33** wherein said gas comprises 5 percent –30 percent hydrogen and 70 percent –95 percent argon.

35. The protector of claim **34** wherein said gas comprises 20 percent hydrogen and 80 percent argon.

36. The protector of claim **35** wherein said gas further comprises a radioactive substance.

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