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Hill et al.

[11] **3,878,423**

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[54] **ELECTRICAL SURGE ARRESTOR HAVING FAIL-SAFE PROPERTIES**

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[51] **Int. Cl.** H01j 1/94; H01k 79/00

[58] **Field of Search** ... 313/267, DIG. 5, 357, 231.1, 313/231.2; 317/62; 315/36; 337/28–33

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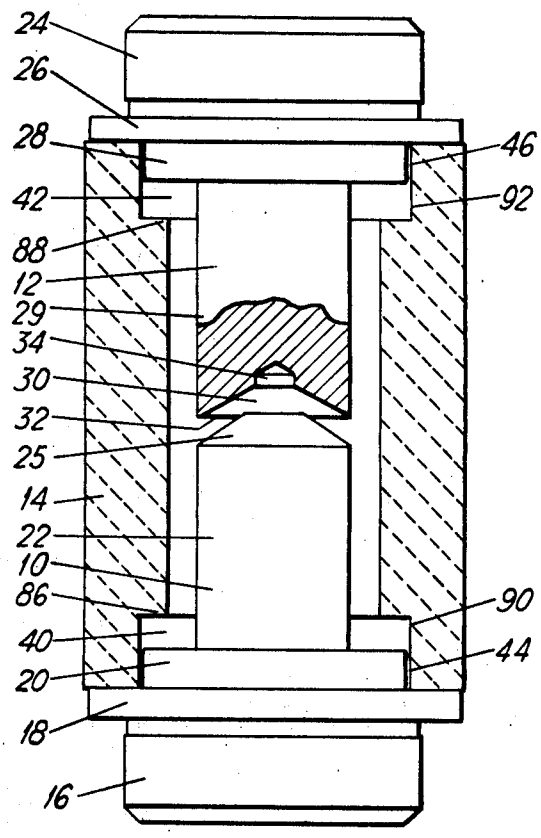
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Assistant Examiner—Wm. H. Punter
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[57] **ABSTRACT**

An electrical surge arrestor having fail-safe properties and providing breakdown at a predetermined region within a sealed structure. The arrestor comprises a pair of axially symmetric electrically and thermally conductive electrodes having integral terminal portions and discharge portions. The discharge portions are disposed coaxially in spaced confronting or nesting relationship within a coaxial ceramic insulative housing to provide a discharge gap at a selected area to form a sealed enclosure. The discharge gap is configured so that the discharge portions of the electrodes will fuse in response to the presence of a predetermined overload condition. The operating lifetime of the surge arrestor may be lengthened by shading an annular inner surface portion of the insulating housing from the discharge gap in order to minimize the deposite thereon of conductive material discharged from the electrodes during breakdown. The electrodes and insulating housing are formed of materials having substantially similar thermal expansion coefficients for providing a metal to ceramic seal resistant to thermal shock.

18 Claims, 8 Drawing Figures



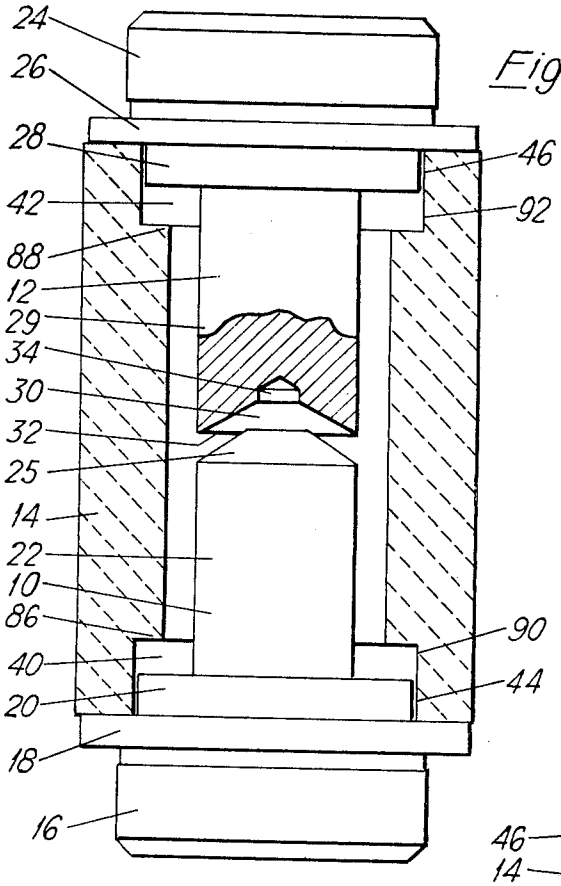


Fig. 1.

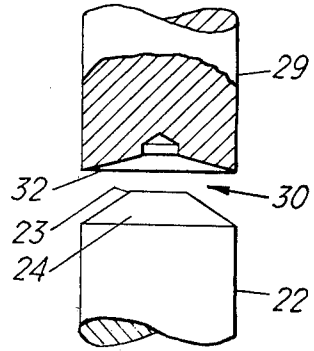


Fig. 2.

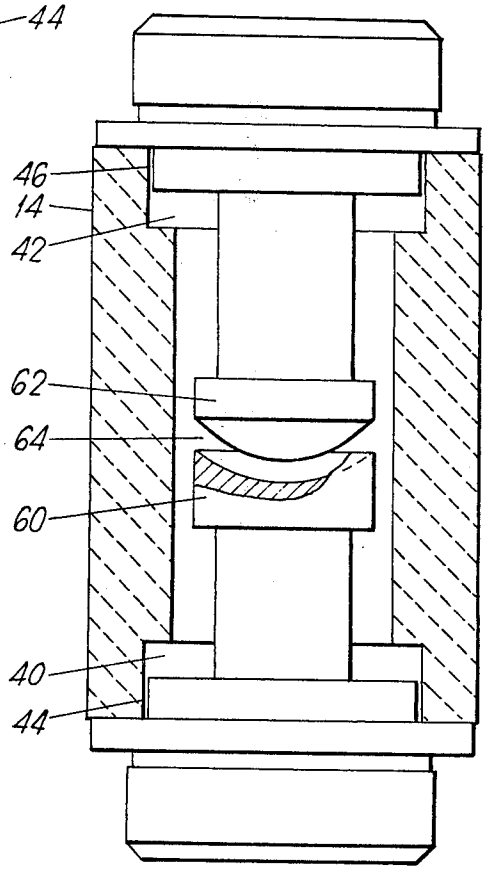


Fig. 3

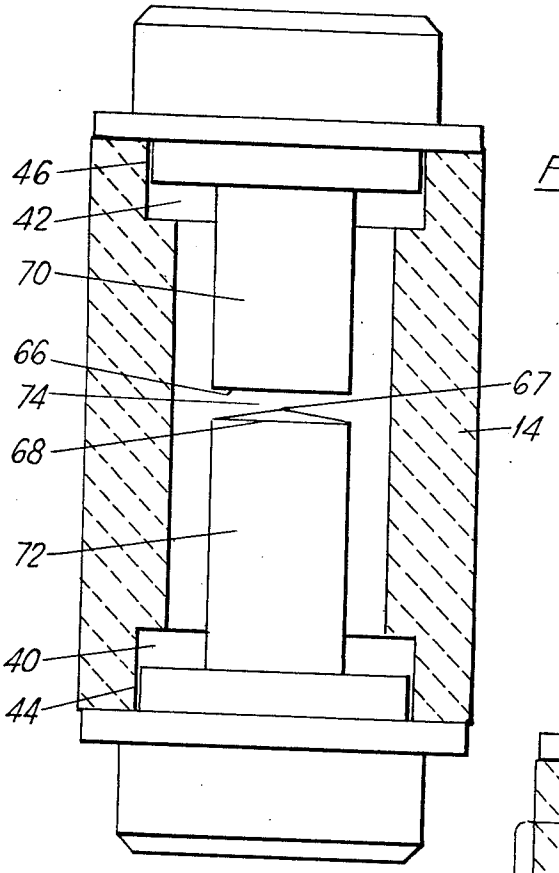


Fig. 4.

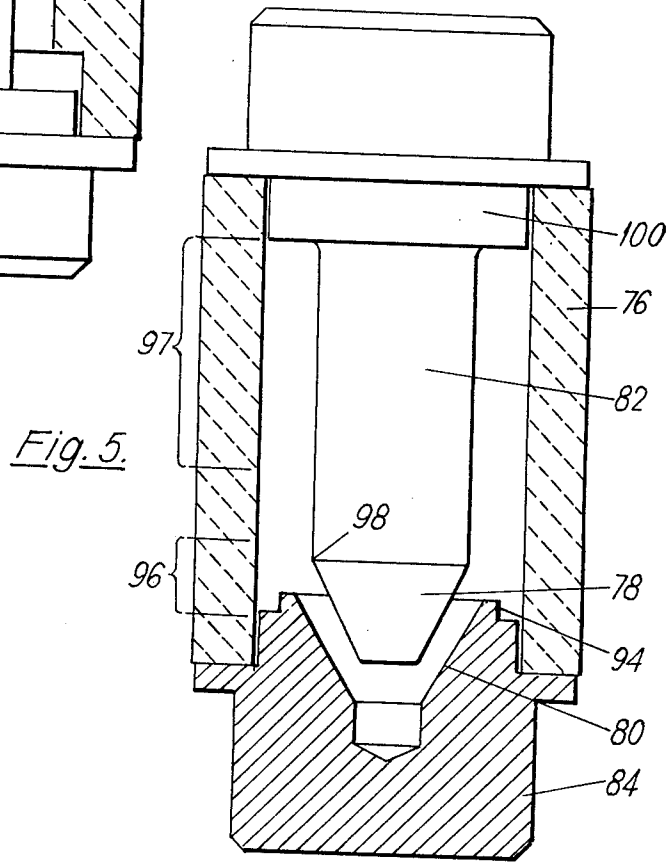


Fig. 5.

Fig. 6.

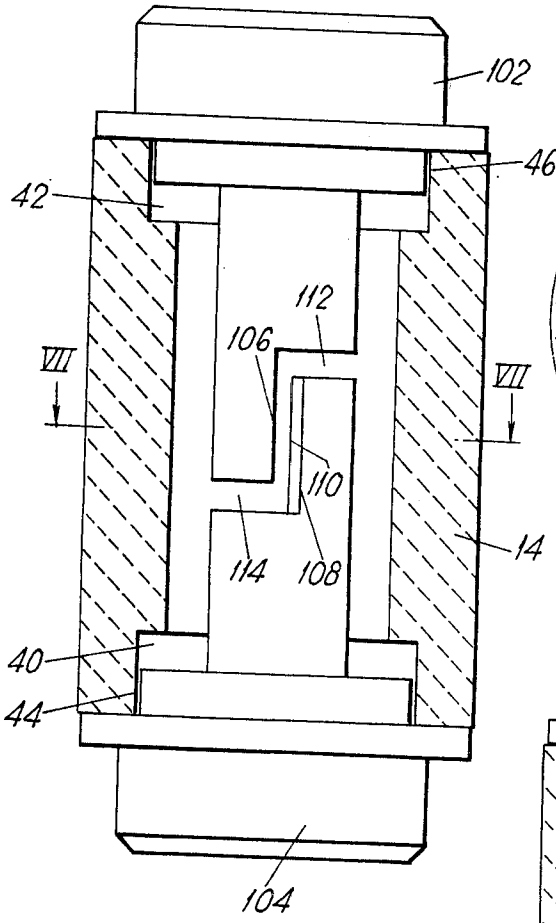


Fig. 7.

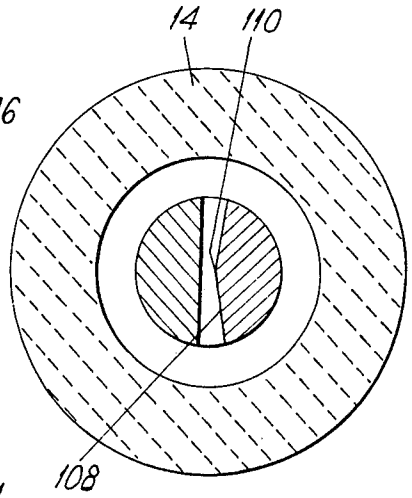
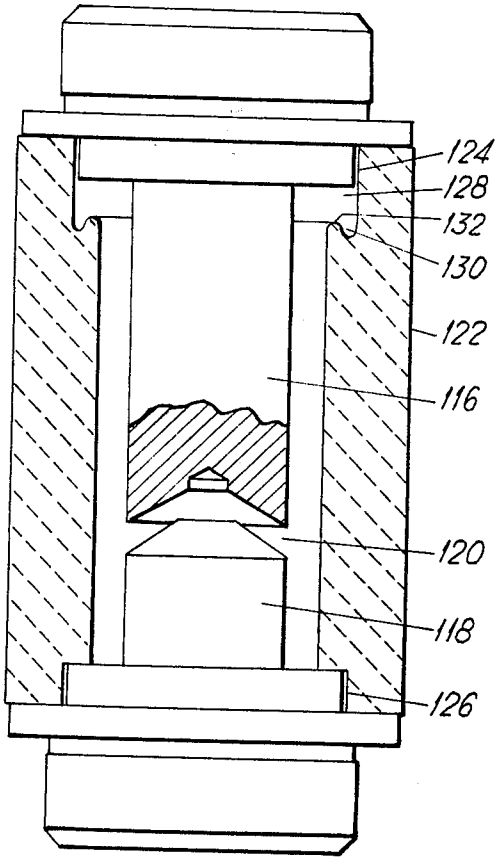


Fig. 8.



ELECTRICAL SURGE ARRESTOR HAVING FAIL-SAFE PROPERTIES

FIELD OF THE INVENTION

This invention relates to electrical surge arrestors and more particularly to an arrestor having electrodes provided within a sealed enclosure and providing fail-safe operation in the presence of a predetermined overload condition.

BACKGROUND OF THE INVENTION

Surge arrestors are known in the art for providing an electrical discharge path in the presence of predetermined overvoltages, such as can occur from a lightning stroke, or current surges from other causes. For many purposes it is intended that the arrestor provide fail-safe operation; that is, the arrestor must provide a permanent short circuit discharge path in the presence of a predetermined overload.

One prior art arrestor is shown in U.S. Pat. No. 3,649,874 in which an inner (male) cylindrical electrode is disposed within a surrounding coaxial outer (female) cylindrical electrode. The electrodes are maintained in predetermined spaced relationship by means of a ceramic ring, the area along the surface of the ceramic ring between the electrodes being shielded to prevent deposition of evaporated conductive material thereon which could affect performance of the device. The male electrode is formed as a solid cylinder which is attached at one end to an end cap serving as one terminal of the device, the external surface of the female electrode constituting the other terminal. The end cap and the female electrode are bonded to respective opposite ends of the ceramic ring by means of compression seals employing glass as the sealing medium. Four separate parts are employed in the construction of the arrestor, and it is necessary to provide alignment between the male electrode and the end cap and in turn between the end cap and the female electrode during manufacture in order to provide proper alignment between the contact portions of the arrestor.

Another prior art arrestor is shown in U.S. Pat. No. 3,651,380 having contact portions comprising inner and outer cylinders and in which the thermal characteristics and dimensions of coaxial inner and outer cylindrical electrodes are selected to ensure melting and bending of the inner electrode only thereby to provide physical contact therebetween upon the application of a predetermined over-load to the arrestor. The respective electrodes are attached to thin metal wall sections which in turn are sealed onto a ceramic ring to form a vacuum-tight housing. The arrestor is formed of five separate pieces which must be separately attached whilst being maintained in alignment in order to provide an arrestor having contact portions having the desired alignment.

U.S. Pat. No. 3,454,811 shows a non-fail-safe surge arrestor in which the electrodes are separated by an annular ceramic housing. The areas of the inner surface of the ceramic housing adjacent the respective electrodes are shielded from the deposit of sputtered conductive material by a series of setbacks on the ceramic housing and steps on the electrodes. Respective contact portions of the electrodes are formed by axially centered confronting, spaced, flat raised portions thereof. Contact portions of the electrodes are coated with carbon to reduce pitting and to lower the arc discharge voltage thereacross.

Furthermore, the arrestor relies upon the sputtered material deposited upon the ceramic walls to assist initiation of a discharge and also refers to the statistical probability of sputtering activity occurring in the vicinity of the setbacks thus giving rise to the need for two such setbacks in order to ensure long operational life.

Although the first two examples of prior art are of the fail-safe variety, they are designed so that fusion of the outer electrode does not occur in the overload condition in order to avoid perforation thereof, the short circuit that does occur is as a result of the tip of the inner electrode melting and forming a bead which touches the outer electrode without actually fusing therewith.

The last example is not designed to short circuit upon overload and therefore does not fall within the category of the invention.

The prior art arrestors discussed hereinabove display a complexity in construction which requires additional assembly steps to provide the desired alignment between the electrodes. Misalignment which can occur during the manufacture of such prior art arrestors can result in malfunctioning arrestors and reduce the yield of the manufacturing process. Furthermore, the relative complex assembly and alignment steps can increase the cost of the arrestor.

SUMMARY OF THE INVENTION

Aims of the invention are to provide surge arrestors in which: one electrode fuses with the other upon occurrence of a predetermined overload; there is a tendency for sputtered electrode material to be deposited upon a defined zone of the housing wall instead of generally overall; the components are self-aligning in assembly and of such design and material that thermal stresses therebetween are avoided.

It is proposed therefore to provide a surge arrestor in which electrical discharge is caused to occur at a precisely defined region within a sealed gas tight enclosure and which in the presence of a predetermined overload condition causes fusion of one confronting electrode with the other in the defined region to thereby provide fail-safe operation. Such an arrestor comprises a pair of solid axially symmetric conductive electrodes having integral discharge surfaces in nesting or confronting arrangement and each having a thermally massive and integrally formed terminal portion at one end thereof. The discharge surfaces are disposed in confronting spaced relation thus defining a predetermined discharge gap therebetween. The electrodes are sealed within and in intimate engagement with an electrically insulative housing to provide a gas tight enclosure.

Accordingly the invention provides an electrical surge arrestor comprising:

axially symmetric first and second solid, electrically conductive, electrodes of fusible material each formed with a terminal portion at one end thereof and a cylindrical portion extending co-axially from said terminal portion, terminating in a discharge surface;

axially symmetric insulative housing adapted to receive in hermetically sealed engagement said first and second electrodes thereby forming a sealed chamber, said first and second electrodes being held by said housing in axial alignment one with the other and with said respective cylindrical portions extending towards each other thus to define a discharge gap between the

juxtaposed respective discharge surfaces, the shape of said respective discharge surfaces and the material of said electrodes being such that discharge occurs therebetween when an overvoltage occurs and that, in the presence of a predetermined overload i.e. a function of voltage and time, the cylindrical portions of said electrodes will melt and fuse together.

The materials from which the insulative housing and electrodes are formed have matching coefficients of thermal expansion such materials being, in one aspect of the invention, a ceramic material for the insulative housing and a nickel-iron alloy for the electrodes, the ceramic material containing a major proportion of alumina the nickel-iron alloy containing between 40 and 52 percent nickel.

The two discharge surfaces may be mutually parallel i.e. providing a discharge gap of constant magnitude, but in practice it has been found advantageous to so shape the discharge surfaces that the discharge is encouraged to predominate in a zone which is situate between said discharge surfaces and of smaller volume than that of the discharge gap defined by said discharge surfaces. For example, the discharge gap may be of greatest magnitude at the radially outermost edge of the discharge surfaces decreasing smoothly in magnitude with decreasing radius towards the central and mutual axis of the electrodes. Such zonal concentration of the discharge between the electrodes is believed to assist in the fusion of one electrode with the other in an overload condition.

Accordingly, the discharge surface of said first electrode may be substantially convex in configuration whilst that of said second electrode may be substantially planar, both surfaces being symmetrical about the central axis and having radially outermost edges which lie in mutually parallel planes. Furthermore, the discharge surface of said second electrode may be substantially concave in configuration instead of planar, and the discharge surfaces may be either both of sperical radius or conical in shape. The depth of the concave surface may be such that the discharge gap is disposed within the second electrode.

Further according to the invention, the radially outermost edges of the discharge surfaces of said first and second electrodes may lie in planes parallel with the central axis and disposed on either side thereof. At least one of the discharge surfaces may be shaped so as to provide a discharge gap of least and constant magnitude across and along the central axis.

So that the possibility is reduced of a short-circuit occurring between the electrodes due to deposition of sputtered electrode material upon the internal walls of the insulative housing, the housing may be provided with at least one annular surface facing away from said discharge gap. Such an annular surface may conveniently be provided with a co-axial annular groove so that a lip is created which shields the groove surface from deposition of electrode material. The provision of such a groove permits the use of a single annular surface only, especially when the surface is situated adjacent the terminal portion of said second electrode when the electrode is provided with a concave discharge surface, i.e. a discharge gap which tends to direct sputtered material away from the terminal portion of said second electrode. In practice it has been found that a deep concave discharge surface, with suitably nesting convex discharge surface, directs sputtered material away from the terminal portion of said second electrode sufficiently well to obviate the need for any form of annular surface, i.e. setback.

The terminal portions of said first and second electrodes may be each provided with a cylindrical location surface and said insulative housing is recessed at opposite ends thereof to receive and hold the electrodes in the desired axial alignment. The electrodes may then be bonded to the housing by known ceramic to metal bonding techniques such as, for example; using titanium-cored silver solder in a neutral or reducing atmosphere; pre-metallising the ceramic and then brazing the electrodes thereto; using glass as an intermediate material.

Surge arrestors according to the invention are preferably filled with an atmosphere of ionised gas, or gas of low ionisation potential so that the breakdown potential threshold may be pre-determined.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more fully understood from the following described examples, with reference to the accompanying drawings, wherein:

FIG. 1 is a sectional elevation view of a surge arrestor provided with conical discharge surfaces;

FIG. 2 is a partially cutaway sectional view of the discharge portions of a surge arrestor such as that illustrated in FIG. 1;

FIG. 3 is a sectional elevation view of another surge arrestor having discharge surfaces of sperical radius;

FIG. 4 illustrates in sectional elevation still another surge arrestor having one planar and one convex discharge surface;

FIG. 5 is a sectional elevation view of still another surge arrestor in which the use of setbacks is avoided;

FIGS. 6 and 7 show in section yet a further example of surge arrestor having discharge surfaces aligned parallel with the central axis of the device; and

FIG. 8 illustrates in sectional elevation an arrestor of the type illustrated in FIG. 1 but having only one setback which is grooved to provide improved shielding.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An electrical surge arrestor constructed according to the invention is shown in typical embodiment in FIG. 1 and comprises male and female electrodes **10** and **12** disposed co-axially within an electrically insulative ceramic housing **14.** Male electrode **10** is a solid, axially symmetric, integral member and includes a generally cylindrical terminal portion **16,** flange **18,** a first cylindrical portion **20,** a narrower second cylindrical portion **22,** and truncated conical section **25** which forms the discharge surface thereof. Female electrode **12** is an axially symmetric integral member comprising a terminal portion **24,** a flange **26,** a first cylindrical portion **28** and a second cylindrical portion **29.** Terminal portions **24** and **16** may be of identical configuration and first cylindrical portions **28** and **20** will generally be of identical diameter for a purpose which will hereinafter be described. An axially symmetric cavity **30** is formed in cylindrical portions **29** having its opening at the inward facing end thereof to provide a discharge surface for the female electrode. In the embodiment of FIG. **1,** cavity **30** includes a truncated conical section **32** and a generally cylindrical section **34.** The exact configuration of cylindrical section **34** does not affect the per-

formance of the surge arrestor and is the result of employing conventional electrode fabrication techniques.

Insulative housing **14** is of hollow, generally cylindrical configuration and includes annular recesses or setbacks **40** and **42** at the inner surface of the respective opposite ends thereof. Male and female electrodes **10** and **12** are mounted coaxially onto respective opposite ends of insulative housing **14**, the respective cylindrical portions **20** and **28** in intimate engagement with the inner surfaces **44** and **46** of insulative housing **14** at setbacks **40** and **42**, to preserve the desired alignment of the discharge portions thereof. In the embodiment of the arrestor illustrated in FIG. **1**, the discharge gap between the electrodes is defined by confronting nonuniformly spaced surfaces of conical section **25** and cavity **30** which, as previously noted are arranged in axially symmetric nesting relationship, the gap therebetween being greatest at the outermost radius and least adjacent the central axis. FIG. **2** illustrates this nonuniformity clearly, in operation a discharge occurring between edge **23** and surface **32**.

The electrodes are formed of a nickel-iron alloy typically containing 40–52 percent nickel, while the insulative housing is formed typically of 95 percent alumina. The thermal expansion coefficients of the nickel-iron electrodes and the insulative housing are substantially similar to provide matched expansion during the often extreme temperature variations encountered during operation. Respective electrodes are hermetically sealed at their respective flange portions **18** and **26** to insulative housing **14** by brazing the electrodes onto metalized ends of the ceramic insulative housing, and which may be easily accomplished, for example, in a furnace. Alternatively the electrodes may be sealed to the insulative housing by means of a metal-glass-ceramic seal. By employing either seal embodiment, a seal is provided which will not fail during breakdown and during overload until fusion of the electrodes occurs. The flanges **18** and **26** are relatively thin and thus are somewhat flexible to withstand thermal shock without loss of hermeticity.

An atmosphere of argon may be provided within the sealed arrestor or alternatively a radioactive gas such as argon having a trace of krypton **85** may be employed to provide an ionized atmosphere for enhanced electrical discharge. As a further alternative, a radioactive paste or other material may be deposited within the arrestor enclosure typically at section **34** to provide the desired ionized atmosphere.

An alternative embodiment of the invention is illustrated in FIG. **3** wherein the discharge portions of the electrodes comprise concave and convex spherical sections **60** and **62**, disposed in confronting spaced and nested arrangement to provide a discharge gap **64** therebetween. The concave spherical cavity having a greater radius than the radius of the convex section to provide a tapered discharge gap.

In a further embodiment of the invention as shown in FIG. **4**, the discharge portions of the respective electrodes are confronting flat end surface **66** and slightly conical surface **68** of respective cylinders **70** and **72** providing a discharge gap **74** across their confronting areas, preferential discharge occurring between peak **67** and surface **66**.

One other alternative embodiment of a surge arrestor is shown in FIG. **5** in which the insulative housing **76** of the arrestor is formed without setbacks. The respective conical discharge portions **78** and **80** of the male and female electrodes **82** and **84** are nested one within the other to define a discharge gap lying substantially within the female electrode.

In the operation of the surge arrestor of the invention, electrical discharge, otherwise termed "breakdown", will take place across a discharge gap in response to the application of a predetermined potential across the arrestor. The arrestor will continue to discharge until the potential needed to sustain discharge is no longer exceeded. Should, however, the discharge potential of the arrestor continue to be exceeded for a predetermined length of time or if an overload potential of sufficient magnitude is applied across the arrestor, the heat generated by current flow through the electrodes causes the electrodes to melt and fuse together at their discharge surfaces to form a highly conductive electrical path across the arrestor, effectively short circuiting the overload potential to ground.

During normal breakdown across the discharge gap, electrode material is sputtered and evaporated from the discharge portions of the electrodes into the enclosure. If a substantial amount of such conductive material is deposited onto the inner wall of the insulative housing an electrical pathway may be formed between the electrodes along the inner wall of the insulative housing which can cause short circuiting of the surge arrestor or otherwise materially affect its breakdown characteristics. Edges **86** and **88** defined by respective setbacks **40** and **42** enable surface portions **90** and **92** of the wall which lie within the setback to be shaded from direct sputtering thereon of conductive material from the region of discharge gap. Although this shading does not absolutely prevent the deposition of conductive material onto the annular areas, it minimizes the amount of sputtered material deposited thereon thus delaying the establishment of an electrical pathway between electrodes along the inner wall of the insulative housing. As a result, the operative lifetime of the surge arrestor is lengthened.

In the embodiment of the invention illustrated in FIG. **5** in which insulative housing **76** includes no setbacks, edge **94**, defined by concave discharge portion **80**, in the female electrode provides a limited amount of shading from the deposit of sputtered material on annular surface **96** of the inner wall of insulative housing **76**, the amount of shading decreasing with distance from the female electrode. Edge **98**, defined by conical section **78** and the inner cylindrical portion of male electrode **82** similarly provides limited shading from deposit of sputtered material onto an annular surface **97** surrounding the male electrode, the amount of shading decreasing in proportion to the distance from first cylindrical section **100**. Although this shading does not absolutely prevent the deposition of conductive material onto any portion of the inner wall of insulative housing **76**, it minimizes the amount of sputtered material deposited thereon and thus, similarly to the embodiment of the arrestor employing setbacks, delays the establishment of an electrical pathway between electrodes along the wall and lengthens the operative lifetime of the arrestor.

Referring to FIGS. **6** and **7**, the surge arrestor depicted has electrodes **102**, **104**, having respective discharge surfaces **106** and **108** facing one another in spaced axial alignment, surface **108** being ridged to provide a preferential discharge path between ridge

110 and surface 106. End gaps 112 and 114 are greater than the gap between ridge 110 and surface 106.

The arrestor depicted in FIG. 8 has electrodes 116 and 118 of the type shown in FIG. 1, having a discharge gap 120 therebetween, and bonded into ceramic housing 122 being inserted into respective recesses 124 and 126 thereof. A single recess or setback 128 is provided which has an annular lip 132 which shields an annular groove 130 from deposition of sputtered metal. Such a groove and lip affords improved shielding and a longer operational life than a plain recess, such as 42 of FIG. 6 for example. The provision of a grooved recess obviates the desirability of two plain recesses and is preferably situated adjacent the terminal of whichever electrode bears a concave discharge surface.

The surge arrestor of the invention may be employed with either electrode connected to ground or a reference potential without affecting the breakdown or fail-safe properties of the arrestor. While the invention has been described in typical embodiment, it will be appreciated that the novel apparatus may be constructed in a variety of embodiments in addition to those exemplified hereinabove, the provision of electrodes having mutually parallel discharge surfaces of conical, planar or other suitable shape being but one such variation. Accordingly it is not desired to limit the scope of the invention by what has been particularly shown; the invention is limited only by the claims which follow.

What is claimed is:

1. An electrical surge arrestor comprising:

first and second axially symmetric electrical discharge electrodes, each formed of a unitary solid block of the same material consistency throughout, each block having an electrical discharge surface formed in one end face thereof, a peripheral flange extending transversely of the central axis of the block, a location portion contiguous with one side of said flange and extending therefrom along said axis and a terminal portion contiguous with the opposite side of said flange and extending therefrom along said axis; and

an insulative sleeve of uniform internal cross-section at least over a major portion of its length and into each end of which said electrodes are respectively received;

said peripheral flange of each electrode being seated against and hermetically sealed to a respective end face of said sleeve to form a sealed chamber and said location portion of each electrode being fitted in a respective end of said sleeve to align the electrodes along a common axis centrally within said sealed chamber;

said electrodes being dimensioned to provide an annular gap between the electrodes and the confronting inner surface of said sleeve and to define a discharge gap between confronting discharge surfaces of said electrodes;

the discharge surfaces of said electrodes being shaped to provide relative male and female confronting surfaces;

said electrodes and said sleeve being constructed of materials having substantially the same coefficient of thermal expansion.

2. A surge arrestor as in claim 1 wherein said insulative housing is formed of ceramic material containing a major proportion of alumina and the material of which said first and second electrodes are formed is a nickel-iron alloy containing between 40 and 52 percent nickel.

3. A surge arrestor according to claim 1 provided with an atmosphere of ionized gas within the sealed chamber to thereby provide a selected breakdown potential threshold across said discharge gap.

4. A surge arrestor as in claim 1 wherein said insulative sleeve is provided with at least one annular surface facing away from said discharge gap.

5. A surge arrestor as in claim 1 wherein the shapes of said discharge surfaces are such that the discharge gap is of greatest magnitude at the radially outermost edge of said surfaces and decreases smoothly in magnitude towards the central and mutual axis of said electrodes.

6. A surge arrestor as in claim 5 wherein the discharge surface of said first electrode is substantially convex in configuration and the discharge surface of said second electrode is substantially planar, both discharge surfaces being symmetrical about the central axis and the radially outermost edges of said discharge surfaces lying in mutually parallel planes.

7. A surge arrestor as in claim 5 wherein the discharge surface of said first electrode is of substantially convex configuration and the discharge surface of said second electrode is of substantially concave configuration, both discharge surfaces being symmetrical about the central axis, the radially outermost edges of said discharge surfaces lying in mutually parallel planes.

8. A surge arrestor as in claim 7 wherein both discharge surfaces of said first and second electrodes are of substantially conical configuration, one being nested within the other.

9. A surge arrestor as in claim 7 wherein the discharge gap is disposed substantially within said second electrode.

10. A surge arrestor as in claim 5 wherein the radially outermost edges of the discharge surfaces of said first and second electrodes lie in planes parallel with the central axis and disposed on either side thereof.

11. A surge arrestor as in claim 10 wherein at least one of said discharge surfaces is shaped so as to provide a gap of least and constant magnitude across and along the central axis.

12. A surge arrestor as in claim 1 wherein the discharge surfaces of said first and second electrodes are shaped to provide a gap therebetween which narrows at least along one transverse axial line toward the aligned central axis of said electrodes, such that discharge is encouraged to predominate in the region of said narrowed gap.

13. A surge arrestor as in claim 1 wherein the discharge surfaces of said first and second electrodes are symmetrical about the central axis thereof and have radially outermost edges lying in mutually parallel planes, said discharge surfaces being shaped to provide a gap therebetween which tapers toward said central axis such that discharge is encouraged to predominate at the central axis region of said gap.

14. A surge arrestor as in claim 1 wherein said location portion of each of said first and second electrodes has a cylindrical location surface conforming to the confronting surface of the respective end of said sleeve, said location surface of each electrode being fitted in a respective end of said sleeve.

15. A surge arrestor as in claim 8 wherein the electrode having said conical discharge surface with re-

spect to which the other conical discharge surface is nested includes a coaxial annular groove contiguous with the outermost edge of said conical discharge surface and said peripheral flange and confronting said chamber and a portion of the inner wall of said sleeve.

16. A surge arrestor as in claim **1** wherein said sleeve includes at least one annular groove provided in the inner wall thereof and having an annular lip operative to shield said groove from deposition of sputtered metal present during a discharge across said gap.

17. A surge arrestor as in claim **1** wherein said sleeve includes an annular groove provided in at least one end of said sleeve and having a circumferential surface of greater dimension than that of the inner dimension of said sleeve and an annular surface facing away from said discharge gap.

18. A surge arrestor as in claim **1** wherein said sleeve includes an annular groove provided in each end of said sleeve and each having a circumferential surface of greater dimension than that of the inner dimension of said sleeve and an annular surface facing away from said discharge gap.

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