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LIGHTNING ARRESTER WITH SPARK GAPS WITHIN VOLTAGE SENSITIVE
RESISTOR BLOCKS
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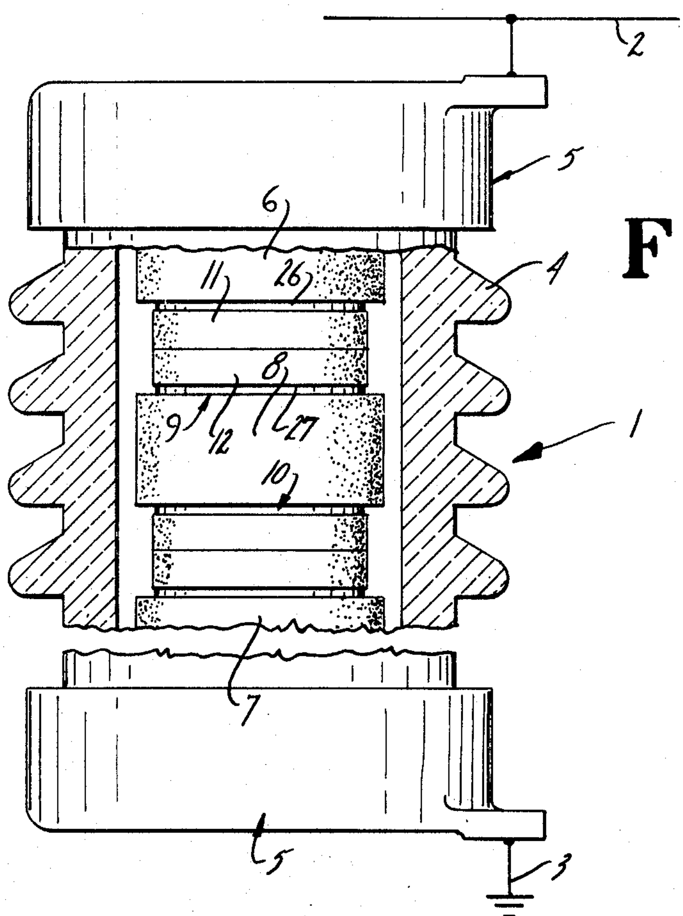
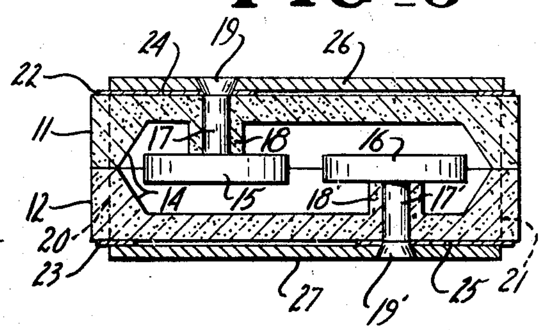


FIG_1

FIG_3



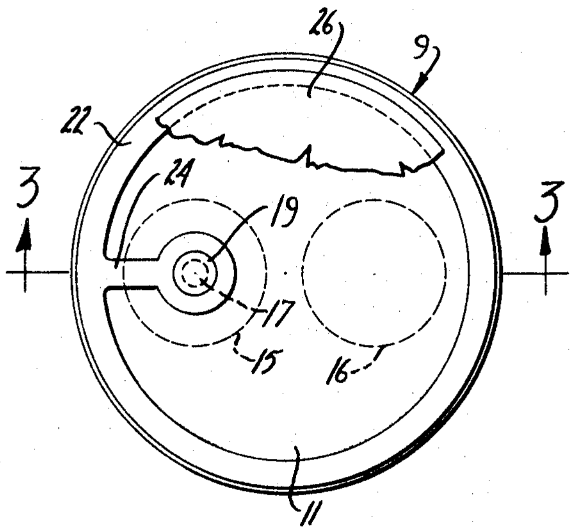


FIG_2

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LIGHTNING ARRESTER WITH SPARK GAPS WITHIN VOLTAGE SENSITIVE RESISTOR BLOCKS

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ABSTRACT OF THE DISCLOSURE

This disclosure relates to a lightning arrester having spark gap devices mounted in stacked series-connected relationship between voltage sensitive resistor blocks.

Each spark gap device includes a pair of shallow, round, cup-shaped shells secured in face-to-face relation to define a spark gap housing. The housing is formed of a semiconductor material, such as a ceramic bonded silicon carbide, boron carbide and the like. The housing constitutes an integral grading resistor member electrically connected in parallel with the spark gap.

Similar disc-shaped plate electrodes are each provided with a central terminal rod. A pair of the electrodes are located in side-by-side relation within the spark gap housing with the terminal rods projecting outwardly through hubs formed in the opposite base walls of the shells. The outer ends of the terminal rods are flared and firmly clamp the electrode to the corresponding shell and in firm electrical connection thereto. A ring of conducting paint is applied to the exterior base of each shell and connected by an integral strip projecting inwardly beneath the flared portions. The rings adjust the total current flow and equalize the current density throughout the shells.

This invention relates to a spark gap apparatus and particularly such apparatus as a voltage sensitive protective element in a lightning arrester or other similar device which protects a power system against transient voltages and the like.

Lightning arresters employing one or more series-connected spark gap units to connect a power line to ground, are well known for both alternating current and direct current systems. The spark gap units normally present an open circuit or high impedance path as a result of the gap construction. The presence of a high voltage transient, however, breaks down the gap and establishes a relatively low impedance circuit path to ground. In this manner, the electrical equipment connected to the power line is protected from the transients which in turn are essentially suppressed. After the disappearance of the transient, the spark gap apparatus returns to the high impedance or open circuit condition.

Generally, each spark gap unit includes an electrical and arc confining insulating housing within which spark gap electrodes are mounted and connected in series circuit through outwardly extending terminals. A plurality of the spark gap units are connected in series with voltage sensitive resistors to define an arrester. Such devices inherently introduce distributed capacitance between the power system and ground. The voltage drop will vary from gap to gap. Compensation has generally been provided by special, separately connected shunting devices of either a resistance or a capacitance characteristic which establishes and maintains a minimal current across the gap circuit to ground. The resistors are selected and connected to establish an essentially equal voltage drop across each of the individual spark gap devices or unit.

Although such devices have provided satisfactory and reliable protection, the separate grading elements and their interconnection into the circuit have required special devices with a corresponding increase in the initial cost.

The present invention provides an improved spark gap unit for a lightning arrester or the like which is inexpensive and readily mass produced. The unit of this invention further provides a resistive shunted gap which maintains a desired grading current and may provide an essentially constant voltage drop across each of a series of units under widely varying current values.

The present invention is particularly directed to such a spark gap apparatus which is adapted to be mounted in stacked series-connected relationship and wherein the gap electrodes are physically and electrically connected to the gap housing. The housing is formed, not of an insulating material, but of a semiconducting material such that the housing directly constitutes an integral functioning grading resistor of the gap structure. The gap structure may therefore take any one of many physical shapes as long as the material, of which the basic supporting structure is made, is formed with a sufficient current-carrying capacity to maintain resistive grading without adverse effect on the ability of the gap structure to maintain normal insulation between the powerline or system and ground.

The semiconductor material for the enclosure is preferably selected to establish a nonlinear voltage current relationship such that an essentially constant voltage is maintained across each gap in the presence of relatively large current differences. The current value will vary because of the distributed capacitance inherent in a stack of series-connetced gap devices. Applicant has found that unusually satisfactory results are obtained with an granular silicon carbide or a boron carbide bonded into a solid mass by a suitable ceramic binder.

A particularly novel and practical construction in accordance with the present invention includes a pair of abutting, shallow, cup-shaped bodies or shells disposed in face-to-face relation to define a spark gap enclosure. The shells are preferably round and formed of a suitable semiconducting material. Similar disc-shaped plate electrodes are each provided with a central terminal rod. A pair of the electrodes are located in side-by-side relation within the spark gap enclosure with the terminal rods projecting outwardly through the opposite base walls of the shells. The outer ends of the terminal rods may be flared or otherwise suitably provided with a clamping surface which cooperates with the electrode proper to firmly clamp the electrode to the corresponding shell and in firm electrical connection thereto.

In such structure, the electrodes are not symmetrically located with respect to the housing proper and consequently, a uniform grading current density does not exist. In order to provide for a more uniform grading current density and to adjust the total current flow to a desired value by distribution of the current throughout the semiconductor shells, special highly conductive paths may, in accordance with another aspect of this invention, be applied to the exterior portion of the shell with a connection directly to the corresponding terminal to provide current directional circuit paths to the corresponding shell. For example, a silver paint may be applied to the exterior end surface with a connection to the clamping portion at the outer end of the terminal rod.

The drawing furnished herewith illustrates a preferred mode presently contemplated by the inventors for carrying out the present invention in which the above advantages and features are clearly disclosed, as well as others, which will be readily understood by those skilled in the art from the following description of such drawing.

In the drawing:

FIG. 1 is a side elevational view of a lightning arrester with parts broken away and sectioned to show inner details of construction;

FIG. 2 is a top plan view of one of the spark gap units shown in FIG. 1, and more particularly constructed in accordance with the present invention; and

FIG. 3 is a vertical section taken on line 3—3 of FIG. 2.

Referring to the drawing and particularly to FIG. 1, the present invention is shown incorporated in a lightning arrester **1** interconnected between a powerline **2** and ground **3**. The arrester **1** generally includes an outer tubular housing **4** which in accordance with known construction is formed of porcelain or other suitable insulating material. Suitable end cap terminals **5** are similarly sealed to the opposite end of the housing **4** and simultaneously function as a closure, a physical support and electrical terminal means for the lightning arrester, for example, similar to the assembly shown in U.S. Pat. 3,242,376 to F. J. Schultz. The end caps **5** may be formed of any suitable, highly conductive metal and are normally sealed to the housing in a hermetic manner to enclose a series of electrical components which may include resistors **6** and **7** adjacent the end cap terminals **5** and an intermediate centrally located resistor **8**, with spark gap units **9** and **10** located respectively to the opposite sides of resistors **8** and completing the circuit therethrough. Generally, the resistors **6** through **8**, inclusive, are suitable voltage-sensitive resistor blocks of a suitable material having a high resistance in the absence of current flow therethrough. When the spark gap units **9** and **10** break down, as the result of a surge or transient voltage of a minimum voltage, and permit current flow through the arrester **1**, the effective resistance of the resistors **6** through **8** rapidly decreases such that the current correspondingly increases and the surge or transient voltage is limited to a reasonable value. Conversely, as the transient voltage current decreases, the resistance of the resistors **6** and **8** increases until such time as normal line voltage again appears across the arrester. The gap units **9** and **10** reset and current flow through the arrestor essentially ceases.

The present invention is particularly directed to the construction of the several spark gap units **9** and **10** which are similarly constructed, and the unit **9** is shown in detail in FIGS. 2 and 3.

The unit **9** includes an outer enclosure or housing defined by a pair of shallow, cup-shaped shell or body members **11** and **12**. The body members are mounted in face-to-face contact to define an arc chamber **13** having internal, peripheral, V-tapered sidewalls **14**. The tapered configuration of the sidewalls of the cavity or chamber provides improved arc confining characteristics. A pair of disc-shaped, solid metal electrodes **15** and **16** are located generally in the central plane of the chamber **13** and in side-by-side spaced relation.

Each of the electrodes **15** and **16** is similarly constructed and mounted and electrode **15** is particularly described with the corresponding elements of electrode **16** identified by corresponding primed numbers.

The electrode **15** is a generally solid metal disc having a terminal rod **17** centrally secured to one side or face thereof. The terminal rod **17** extends outwardly through an apertured hub **18** in the base of the shell or body member **11**. The hub **18** is located to one side of the chamber and housing and terminates slightly inwardly of the outer plane of the housing. The metal disc abuts the hub and is located centrally of the depth of the assembled cup-shaped shells **11** and **12**. The outer end of the terminal rod **17** is flared as at **19** to firmly clamp the disc within the apertured hub **18**.

The electrode **16** is similarly formed and mounted within the shell or body member **12** which is then assembled with the body member **11**.

The electrodes **15** and **16** are thus disposed to diametrically opposite portions of the arc chamber **13** with the terminal rods **17** and **17′** projecting outwardly in opposite directions through the bases of the corresponding body members **11** and **12**.

In accordance with the present invention, each of the body members **11** and **12** is formed of a semiconductor material, such as a silicon carbide, a boron carbide and the like. The body members **11** and **12** may be bonded to each other by a suitable adhesive for ease of handling or direct compression mounted within the assembly as desired. As the electrodes **15** and **16** are firmly clamped to the body members **11** and **12** and therefore in electrical connection thereto, the voltage applied across the electrodes and particularly the gap therebetween, is correspondingly applied directly across the body members **11** and **12**. As a result, a small current will flow between the terminals **17** and **17′** through the semiconductor material of the housing. A schematic circuit path is shown in FIG. 3 by the dashed lines **20** and **21**, and a continuous small current flows through the lightning arrester for purposes of voltage grading.

With the structures described to this point, it will be seen from a review of FIGS. 2 and 3 that the asymmetrical location of the electrodes and terminals may result in a nonuniform current density throughout the members defining the housing or enclosure.

In accordance with a preferred construction of the present invention, a conductor **22** is applied to the exterior of member **11** and a similar conductor **23** is similarly applied to member **12** to distribute and establish a more uniform current density. The conductors **22** and **23** may also provide means for adjusting the amplitude of current flow prior to breakover of the spark gap unit **9**.

In the illustrated embodiment, conductors **22** and **23** are ring members, applied to the outer peripheral portion of the base of each body member **11** and **12**. Each ring conductor is interconnected by an integral inwardly projecting conductor **24** and **25**, respectively, terminating in a circular tab encircling the corresponding terminals **17** and **17′**.

The circular tabs establish electrical contact between the terminals **17** and **17′** and the corresponding ring conductors **22** and **23** such that the current is distributed across the outer peripheral portion of the housing. The current flow is thereby generally distributed throughout the housing and concentrated in the outer peripheral portion or sidewalls of the housing defined by members **11** and **12**. The distribution of the current provides a more uniform current density. The conductors **22** and **23** also provide a means for direct adjustment of the effective resistance and thereby the total grading current through the arrester. Applicant has applied a thin film of silver paint in the order of 2 to 5 mils to the members **11** and **12**, as shown in FIGS. 2 and 3, to form satisfactory control conductors.

Conducting plates **26** and **27** are disposed to the opposite sides of the spark gap unit and secured in contact with the housings **11** and **12** by the flared ends **19** and **19′** of the terminals **17** and **17′**. The diameters of plates **26** and **27** are smaller than the conducting rings **24** and **25** and establish firm electrical contact with the resistors **6**, **7** and **8**.

As previously noted, in a lightning arrester employing a column of gap units and resistor elements, the distributed capacitance tends to cause current differences with a corresponding voltage distribution. In the preferred construction of the present invention, the semiconducting material of the body members **11** and **12** is selected to have a nonlinear voltage versus current characteristic and in particular, one which maintains an essentially constant voltage drop in response to the differences of current flow therethrough encountered in practical power systems.

Any semiconductor which has a current-carrying capacity sufficient to establish proper grading without affecting the ability of the gap structure to provide normal insulation between ground and the powerline may be employed. Applicant has found, however, the unusually satisfactory results are obtained employing a ceramic bonded granular silicon carbide; for example, a 240-grit carbide which is bonded by a clay-feldspar material has been found to provide satisfactory results. A similar material would be a ceramic bonded boron carbide. Such materials are semiconductors and have the desired nonlinear voltage-current characteristic and readily are mass produced with a predictable and same characteristic for the several members of a corresponding construction. The particular compositions and firing temperature will be determined by the desired electrical properties required.

In operation, a minimal current flow normally of the order of ½ milliamp will flow through the lightning resistor **1** and in particular, through the voltage sensitive resistors **6–8** and the grading resistance established by the body members **11** and **12** of the units **9** and **10**. The flow is in shunt with the gaps defined by the electrodes **15** and **16** and as the semiconductor members **11** and **12** are of a substantially larger resistance than resistors **6–8**, the voltage appears across the gap units. The normal voltage is insufficient to establish spark-over. If a surge voltage appears on line **2**, the voltage across the electrodes **15** and **16** is sufficient to spark-over and provide essentially short circuit paths between the resistors **6–8**. The surge voltage is thus applied across the resistors **6–8** in series and shunted to ground.

Although illustrated of a circular configuration with the electrodes diametrically, any other desired configuration and electrode arrangement can of course be employed. Forming of the housing by bonding of finely divided semiconductor material particularly permits design of the housing to an optimum configuration.

The present invention thus provides an improved grading resistor construction which is particularly adapted to mass production of a series of units having corresponding characteristics and a long, useful, and reliable life.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

We claim:

1. A spark gap apparatus adapted to at least momentarily conduct a large current comprising an enclosure defining a spark gap chamber, a pair of spaced electrode means mounted within said chamber and having individual connection means extending through and connected to said enclosure, and said enclosure being formed of an electrically semi-conducting material and conducting sufficient current for voltage grading.

2. The spark gap apparatus of claim **1** wherein said semiconducting material has a nonlinear current versus resistance characteristic to maintain an essential constant voltage drop across said electrode means.

3. The spark gap apparatus of claim **1**, wherein the enclosure is formed of a ceramic bonded finely divided silicon carbide.

4. The spark gap apparatus of claim **1**, wherein the enclosure is formed of a ceramic bonded finely divided boron carbide.

5. The sparkgap apparatus of claim **1**, wherein a conducting medium is applied to the exterior of the enclosure at each of said individual connection means to control the current magnitude and distribution through the enclosure.

6. The spark gap apparatus of claim **1**, wherein each of said pair of spaced electrodes includes an individual connection rod extending in opposite directions through the opposite walls of the enclosure, and clamping means secured to the outer ends of said connection rods to clamp the electrodes to the enclosure.

7. The spark gap apparatus of claim **1**, wherein said electrodes are located in side-by-side spaced relation generally centrally of the enclosure and having individual rod-like terminal means extending through opposite end walls of said enclosure, and said enclosure is formed of a ceramic bonded finely divided material.

8. The spark gap apparatus of claim **1** wherein said electrodes are disposed in a common plane.

9. The spark gap apparatus of claim **1**, wherein said enclosure includes a pair of shallow cup-shaped members secured in face-to-face relation, said pair of spaced electrodes being similar disc members mounted in alignment with the mating edges of said members and having individual connection rods extending through the opposite base walls of the enclosure, each of said base walls including an integral hub portion locating said electrode, and means secured to the outer end of the rod to securely and firmly clamp the electrode to the corresponding shallow cup-shaped member.

10. The spark gap apparatus of claim **9** having a separate conducting medium secured to the exterior base wall of each cup-shaped member and extended from said individual connections to control the current magnitude and distribution through the enclosure.

11. The spark gap apparatus of claim **1**, wherein said enclosure includes a pair of shallow cup-shaped members with the edges secured in face-to-face relation to define the spark gap chamber, said electrodes being located in generally side-by-side spaced relation in the plane of said edges and having individual connection rod-like terminal means extending through opposite base walls of said cup-shaped members, said enclosure being formed of a ceramic bonded finely divided semiconducting material, a conducting film secured to the peripheral portion of each cup-shaped member and having a connecting portion extending inwardly and connected to said rod-like terminal means.

12. The spark gap apparatus of claim **11** wherein said electrodes are disposed in a common plane.

13. A lightning arrester having a pair of power terminals and a plurality of similar spark gap devices connected in series, each spark gap device including an enclosure defining a spark gap chamber, a pair of spaced electrodes mounted within said chamber and having individual connection means extending through and connected to said enclosure, and said enclosure being formed of an electrically semiconducting material and conducting sufficient current for voltage grading, and means supporting said gap devices in stacked relation with said individual connection means being series connected between said power terminals.

14. The lightning arrester of claim **13**, wherein said spark gap devices are disposed in stacked relation between voltage sensitive resistance blocks, and said electrodes being located in side-by-side spaced relation generally centrally of the enclosure and having individual connection rod-like terminal means extending through opposite end walls of said enclosure, and said enclosure being formed of a ceramic bonded finely divided semiconducting material.

References Cited

UNITED STATES PATENTS

1,754,158	4/1930	Goodwin	315—36
2,495,154	1/1950	Zimmerman	315—36
3,126,499	3/1964	Rabus	315—36
3,222,566	12/1965	Ynokers	315—36
3,313,978	4/1967	Miller	315—36
3,366,832	1/1968	Sarbach	315—36

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