

[54] **GAS DISCHARGE OVER VOLTAGE ARRESTER FILLED WITH A NOBLE GAS**

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[56] **References Cited**

**UNITED STATES PATENTS**

2,427,086 · 9/1947 Arnett et al. ....313/214

**FOREIGN PATENTS OR APPLICATIONS**

714,139 11/1941 Germany

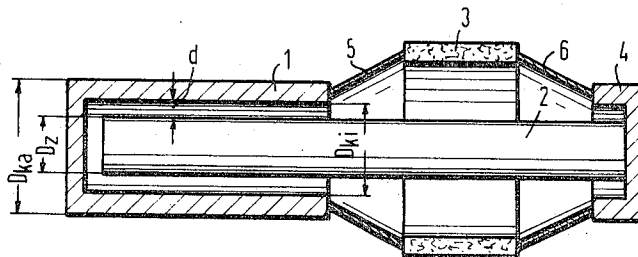
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[57] **ABSTRACT**

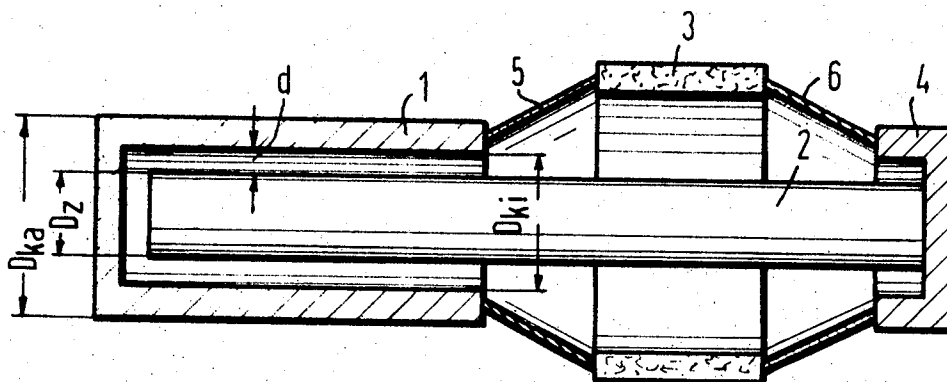
A gas discharge over voltage arrester having a cylindrical electrode coaxially surrounded by a hollow tubular electrode which forms a part of a gas filled vacuum-tight housing. The cylindrical electrode carries an end cap which with the hollow electrode, an intermediate annular insulator and a pair of thin wall connecting portions forms the vacuum-tight housing. The arrester is constructed and arranged to withstand brief high loads and extended low loads, and is dimensioned materially and geometrically to provide optimum performance and to provide a short circuit very rapidly without rupture when overloaded by alternating and lightning loads.

**5 Claims, 1 Drawing Figure**



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# GAS DISCHARGE OVER VOLTAGE ARRESTER FILLED WITH A NOBLE GAS

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to a gas discharge over voltage arrester with a vacuum-tight housing having preferably a noble gas filling, and more particularly to an arrester in which a solid cylindrical electrode carrying an end cap on one end thereof is coaxially surrounded by a hollow electrode in the form of a hollow cylinder having an end wall, the end cap and the hollow electrode and an annular insulating body being connected to form the vacuum-tight housing.

### 2. Description of the Prior Art

Voltage arresters of the type mentioned above are generally known in the art; see, for example, German Pat. No. 714,139, in which, however, unlike the present-day constructions, the hollow electrode does not form a part of the vacuum-tight housing. In addition to small dimensions and low acquisition costs, these over voltage arresters are supposed to have the following properties which in part contradict one another:

The over voltage arrester is to be able to lead off or drain atmospheric discharge of high current strength, i.e., bolts of lightning;

In such action it must tolerate current pulses of up to 20 sec. duration and up to 100 ka. of current repeatedly;

Current strengths of lesser magnitude must also be led off, but over longer durations of time, for example, in the case where inductive influencing of telecommunication lines or contact of telecommunication lines with high current lines is concerned; and

In both types of load situations, brief loads of high current and extended loads of low current, it is required that the arrester respond extremely rapidly. Only if ignition takes place immediately upon the occurrence of the over voltage that the installation which is to be protected is effectively protected.

In addition to the short response time, "fail-safe" properties are required. This means that if the arrester, despite its capacity to bear both alternating current loads and lightning loads, is overloaded, it must bring about a certain short circuit. This function is fulfilled only if in the casing or housing of the device the electrodes fuse together before the arrester loosens or ruptures. The certainty of establishing a short circuit in response to an overload condition is extremely important in that the apparatus to be protected is in fact protected from penetration by an over voltage, although the apparatus may be temporarily inoperative. The cause or place of fault can then be easily identified and corresponding corrective action can be taken.

## SUMMARY OF THE INVENTION

All of the over voltage arresters heretofore known in the prior art fulfill some, but not all, of the above requirements. It is therefore the primary object of the present invention to remedy this situation.

In order to realize our improved voltage arrester of the above-mentioned type we propose that the cylindrical electrode consist of a first electrically conductive material (z) and has a diameter dimensioned in accordance with the expression

$$D_z > \left[ \frac{I^2 t}{0.625 \ln(1 + \alpha_z \Delta T_z)} \right]^{1/4}$$

and that the coaxially disposed hollow electrode consist of a second electrically conductive material (k) with an inner diameter  $D_{ki}$ , at most  $2d$ , equal to 2 mm., greater than the diameter  $D_z$  of the cylindrical electrode, and an outside diameter  $D_{ko}$  which is at most 15 mm. and dimensioned in accordance with the expression

$$D_{ko}^2 - (D_z + 2d)^2 > D_z^2 \left[ \frac{Q_k \cdot \ln(1 + \alpha_z \Delta T_z)}{Q_z \cdot \ln(1 + \alpha_k \Delta T_k)} \right]^{1/2}$$

where  $d$  is the spacing between the cylindrical electrode and the hollow electrode,  $Q$  is a quotient of two products formed by, on the one hand, the temperature coefficients  $\alpha(1/^\circ \text{C.})$  of the electrical resistance and the specific electrical resistance  $\zeta(\Omega \cdot \text{cm.})$  of the particular electrode material and, on the other hand, by the mean specific heat  $c(\text{Wsec./g.}^\circ \text{C.})$  and the specific weight  $\gamma(\text{g./cm.}^3)$  of the particular electrode material,  $\Delta T$  is the temperature difference between the operating temperature of a material and its melting temperature,  $I(\text{A})$  is the maximum current, and  $t(\text{s})$  is the mean time duration of the current flow.

In a gas filled voltage arrester according to the invention the cylindrical electrode and the hollow electrode would ordinarily be made of the same material. In this case the rule for dimensioning the hollow electrode with respect to the diameter  $D_z$  of the cylindrical electrode is simplified and expressed by the relation

$$D_{ko}^2 - (D_z + 2d)^2 > D_z^2.$$

If one proceeds assuming iron as a particularly advantageous electrode material and assumes that the maximum current strength of the most severe flashes of lightning does not exceed 100 ka. and that the mean duration of this lightning does not exceed  $10^{-4}$  seconds, the diameter of the cylindrical electrode according to this invention amounts to at least 3 mm.

The metal parts of the vacuum-tight housing of a gas filled voltage arrester, according to another feature of the invention, include wall portions which are thinner in the transition zone from each electrode to the intermediate annular insulating body than the wall thickness at other zones of the housing. This constructional feature provides between the electrodes, on the one hand, and the insulating body, on the other hand, a heat-conduction brake, which prevents the immediate transfer of heat to the insulating body upon the generation of heat at the electrodes during operation of the gas discharge excess voltage arrester. It is thereby assured with absolute certainty that, upon the occurrence of an overload condition, the cylindrical electrode will fuse first, before the gas discharge over voltage arrester could possibly loosen through cracking of the insulating body due to thermal effects.

## BRIEF DESCRIPTION OF THE DRAWING

Other objects, features and advantages of the invention, its organization, construction and operation, will be better understood from the following detailed description of an exemplary embodiment thereof, taken in conjunction with the accompanying drawing which carries a single FIGURE thereon illustrating, in a cross sectional elevational view, a gas discharge over voltage arrester constructed in accordance with the principles of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

A gas discharge over voltage arrester is illustrated in the drawing as comprising a hollow electrode 1, a cylindrical electrode 2 and an insulating body 3. The hollow electrode 1 together with an end cap 4 carried by the cylindrical electrode 2 and the annular insulating body 3 are connected to form a vacuum-tight casing which is filled with noble gas. The just-mentioned elements are connected by means of thin wall metal portions 5 and 6 at the transition zones between the electrodes and the insulating body. As is readily apparent in the drawing, the walls of the portions 5, 6 are much thinner than the other zones of the casing; this measure providing the protection of the insulating body 3 from overheating which could occur from the heat generated at the electrodes 1, 2 during an overload condition.

The over voltage arrester represented should be available in particular in a small structural form. In practice this means that the outside diameter  $D_{ko}$  of the hollow electrode 1 should be limited to at most 15 mm., in that diameters in excess of this FIGURE cannot be allowed for an over voltage arrester

because of the high constituent of space requirement and because of the sum of total space occupied by gas filled over voltage arresters in a modern plant. A small structural form, however, raises the problem that high current impacts (i.e., flashes of lightning) could bring about an immediate melting or even evaporation of the electrodes. It has been discovered that this undesirable situation can be avoided with certainty if, as according to the invention, the outside diameter  $D_z$  of the cylindrical electrode 2 is established in accordance with the expression

$$D_z > \frac{I^2 t}{0.625 \ln(1 + \alpha_z \cdot \Delta T_z)} \cdot \frac{Q_z}{\gamma}$$

The significations of the expression are:

$Q = \alpha(\zeta/c\gamma)$

$t$  = time in seconds (s)

$I$  = current flowing through an electrode in amperes (a.)

$\zeta$  = specific resistance of electrode material at initial temperature in ohm-centimeters ( $\Omega \cdot \text{cm.}$ )

$\alpha$  = temperature coefficient of the electrical resistance of electrode material per degree centigrade ( $1^\circ \text{C.}$ )

$\Delta T$  = temperature increase from initial temperature (temperature of the environment) to the melting point of the electrode in degrees centigrade ( $^\circ \text{C.}$ )

$c$  = means specific heat of the electrode material in watt-seconds per gram and per degree Centigrade (Wsec./g.  $^\circ \text{C.}$ )

$\gamma$  = specific weight of an electrode in grams per cubic centimeter (g./cm.<sup>3</sup>)

$D_z$  = diameter of the cylindrical electrode 2 in centimeters (cm.)

$D_{ka}$  = diameter of the hollow electrode 1 in centimeters (cm.)

$z, k$  = indices for the physical properties of the cylindrical electrode ( $z$ ) and the hollow electrode ( $k$ )

In a practical example of execution iron serves as the electrode material. A substitution of the properties of iron in the expression above for the diameter  $D_z$  of the cylindrical electrode 2, and an assumption that the strongest known flashes of lightning will not exceed 100 ka. and a duration of 100  $\mu\text{sec.}$ , the diameter  $D_z$  is provided as equal to or greater than 2.94 mm., or rounded of, to 3 mm. The initial temperature is assumed in this case to be  $20^\circ \text{C.}$

In order that a gas discharge over voltage arrester be possessed of "fail-safe" properties, i.e., in order that a short circuit occurs before destruction in response to an overload condition, it is essential that the hollow electrode 1 withstand a higher heating than the cylindrical electrode 2. It is then certain that the integrity of the housing is assured and the cylindrical electrode 2 melts before the hollow electrode 1 acquires a rupture or holes therein. The distance  $d$  of the hollow electrode 1 from the cylindrical electrode 2 must therefore be no greater than 1 mm. in order to assure a sufficiently short response time. With the observance of these two boundary conditions, and according to the invention, the relationship between the hollow and cylindrical electrodes is established by the expression

$$D_{ka}^2 - (D_z + 2d)^2 > D_z^2 \left[ \frac{Q_k \cdot \ln(1 + \alpha_z \cdot \Delta T_z)}{Q_z \cdot \ln(1 + \alpha_k \cdot \Delta T_k)} \right]^{1/2}$$

This specification for the dimensioning of the outer diameter  $D_{ka}$  of the hollow electrode 1 is considerably simplified if, as is the usual practice, the inner electrode and the outer electrode are made of the same material ( $z=k$ ). The expression then becomes

$$D_{ka}^2 - (D_z + 2d)^2 > D_z^2$$

in which again  $d$  is assumed to be no greater than 1 mm.

According to this invention, a gas discharge over voltage arrester is provided which, despite its small dimensions, has with absolute certainty the following properties:

The arrester withstands both brief discharges of high current strength (flashes of lightning) and extended alternating current loads;

In case of overloading the conductors effect a short circuit, and more particularly the electrodes establish the short circuit before destruction of the vacuum-tight casing, i.e., an assured short circuit condition; and

The over voltage arrester ignites so rapidly upon loading with a shock wave that the apparatus to be protected does not suffer damage.

Although we have described our invention by reference to a specific illustrative embodiment, many changes and modifications will become readily apparent and may be made in our invention by those skilled in the art, and it is to be understood that we intend to include within the patent warranted hereon all such changes and modifications as may reasonably and properly be included within the scope of our contribution to the art.

What we claim is:

1. A gas discharge over voltage arrester of the type having a vacuum-tight casing filled with noble gas, a solid cylindrical electrode carrying an end cap which forms a portion of the casing, a hollow electrode which is disposed coaxially of the cylindrical electrode and forming a portion of the casing, and an annular insulating body connecting the end cap and the hollow electrode in a vacuum-tight manner, the improvement therein comprising the provision of the cylindrical electrode of a first electrically conductive material ( $z$ ) which has a diameter  $D_z$  in accordance with the expression

$$D_z > \left[ \frac{I^2 t}{0.625 \ln(1 + \alpha_z \cdot \Delta T_z)} \right]^{1/4} \cdot \frac{Q_z}{\gamma}$$

and the hollow electrode of a second electrically conductive material ( $k$ ) having an inside diameter  $D_{ki}$  which is at most equal to 2 mm. greater than the diameter  $D_z$  and an outside diameter  $D_{ka}$  which is at most 15 mm. greater than the diameter of  $D_z$  as established by the relation

$$D_{ka}^2 - (D_z + 2d)^2 > D_z^2 \left[ \frac{Q_k \cdot \ln(1 + \alpha_z \cdot \Delta T_z)}{Q_z \cdot \ln(1 + \alpha_k \cdot \Delta T_k)} \right]^{1/2}$$

where  $d$  is the spacing between the cylindrical and hollow electrodes, where  $Q$  is the quotient ( $\alpha\zeta/c\gamma$ ) of two products which are formed of the temperature coefficient ( $1^\circ \text{C.}$ ) of the electrical resistance and the specific electrical resistance ( $\Omega \cdot \text{cm.}$ ) of the respective electrode material, as identified by the subscripts  $k$  and  $z$ , and of the mean specific heat  $c$  (Wsec./g.  $^\circ \text{C.}$ ) and the specific weight  $\gamma$  (g./cm.<sup>3</sup>) of the respective electrode material, where  $\Delta T$  is the temperature difference between the operating and melting temperatures of the electrodes in each case as identified by the subscripts  $k$  and  $z$ , where  $I(A)$  is the maximum current strength, and  $t(s)$  is the mean time duration of the current flow.

2. The voltage arrester according to claim 1, wherein the cylindrical and hollow electrodes are of the same material and the outside diameter  $D_{ka}$  of the hollow electrode over the diameter  $D_z$  of the cylindrical electrode is in accordance with the relation

$$D_{ka}^2 - (D_z + 2d)^2 > D_z^2$$

3. The voltage arrester according to claim 2, wherein the factor  $I^2 t$  is established by the maximum current strength of the strongest known flashes of lightning of  $I=100$  ka. and a mean duration of  $t=10^{-4}$ , whereby  $I^2 t=10^8 A^2 s$ .

4. The voltage arrester according to claim 3, wherein the electrode material is iron and the diameter  $D_z$  is at least 3 mm.

5. The voltage arrester according to claim 1, comprising metal portions forming portions of the housing and connecting the annular insulating body vacuum-tight with the hollow electrode and the end cap, said metal portions being thin with respect to the remainder of the housing.

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