Nov. 21, 1967 E. W. STETSON 3,354,345
LIGHTNING ARRESTER SPARK GAP HAVING ARC-CONFINING CHAMBER WALLS OF GRADED POROSITY
Filed July 6, 1964 3 Sheets-Sheet 1

Fig.1.

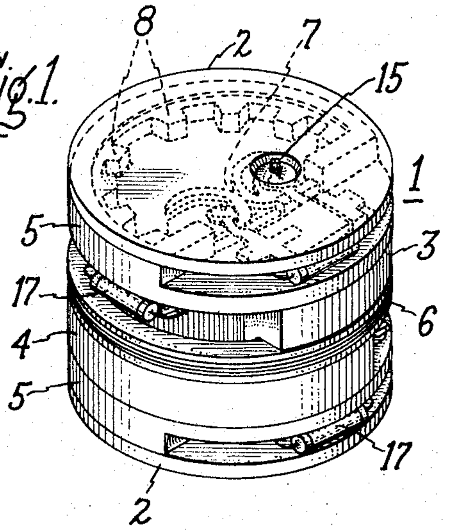


Fig.3.

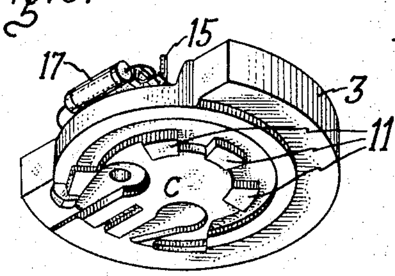


Fig.4.

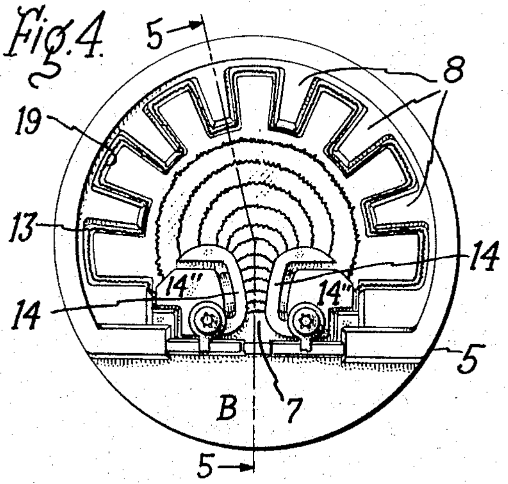
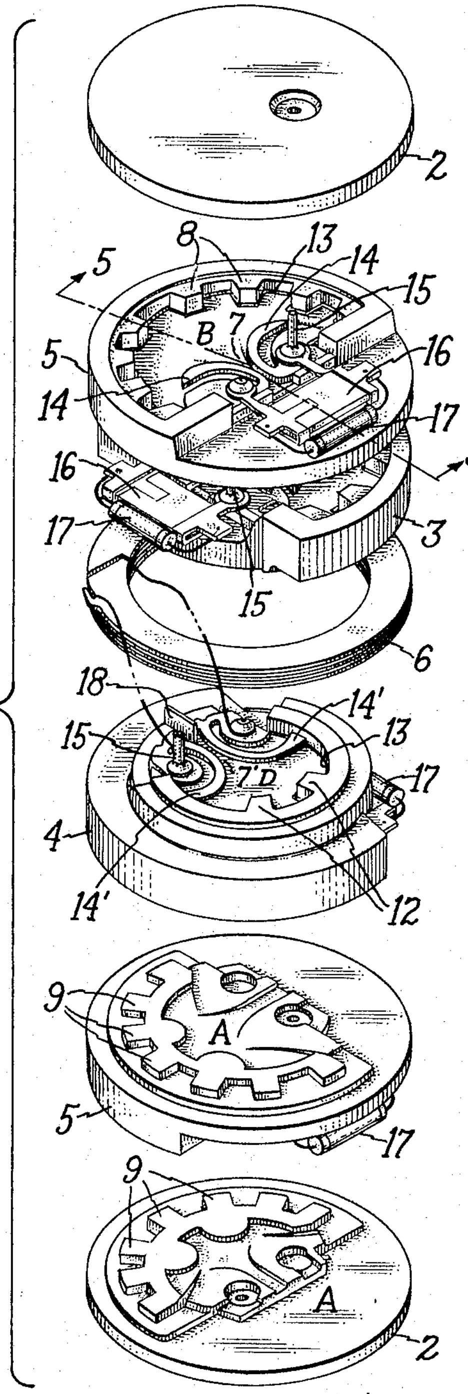


Fig.2.



Inventor,
Earl W. Stetson,
by Gilbert P. Tarleton
His Attorney.

LIGHTNING ARRESTER SPARK GAP HAVING ARC-CONFINING CHAMBER WALLS OF GRADED POROSITY

Filed July 6, 1964 3 Sheets-Sheet 2

Fig. 5.

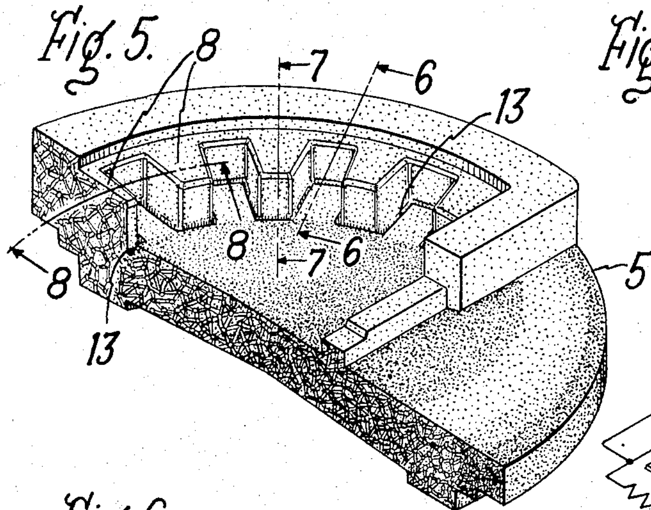


Fig. 9

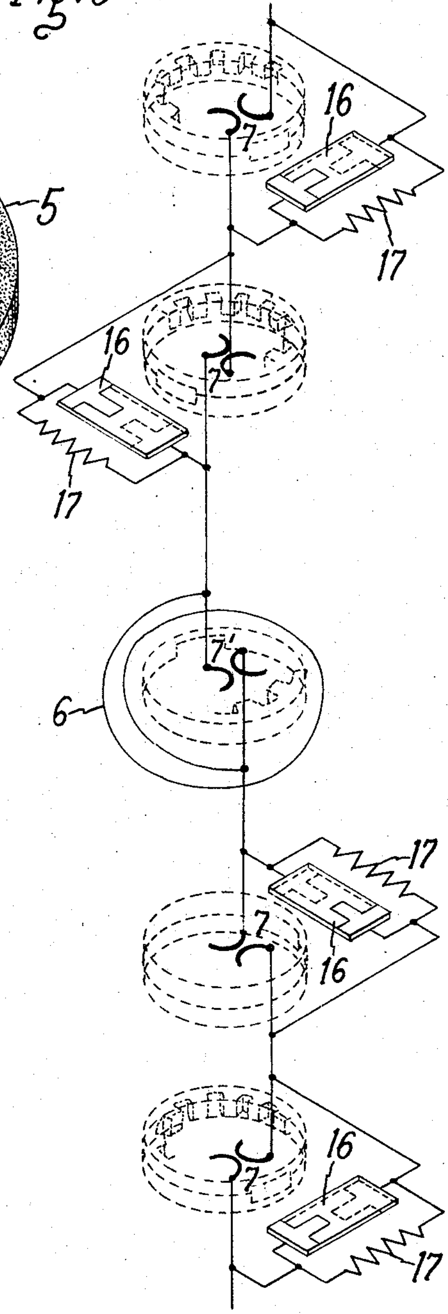


Fig. 6.

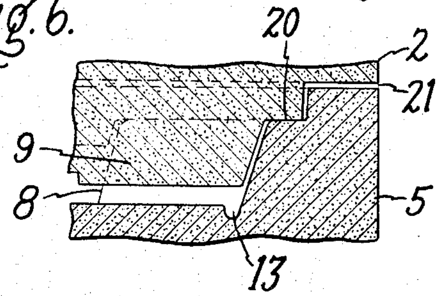


Fig. 7.

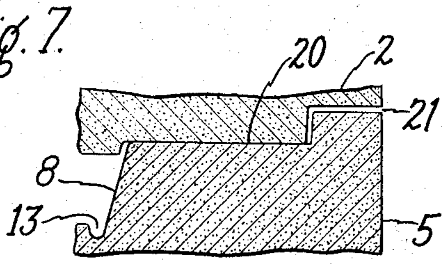
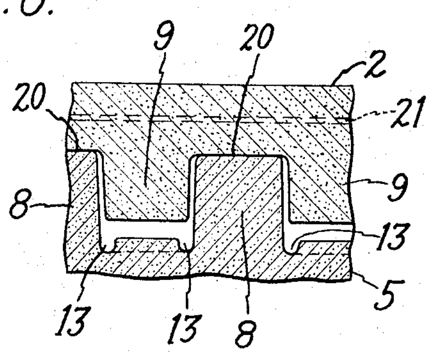


Fig. 8.



Inventor,
Earl W. Stetson,
by Gilbert P. Tarleton
His Attorney.

Fig. 10.

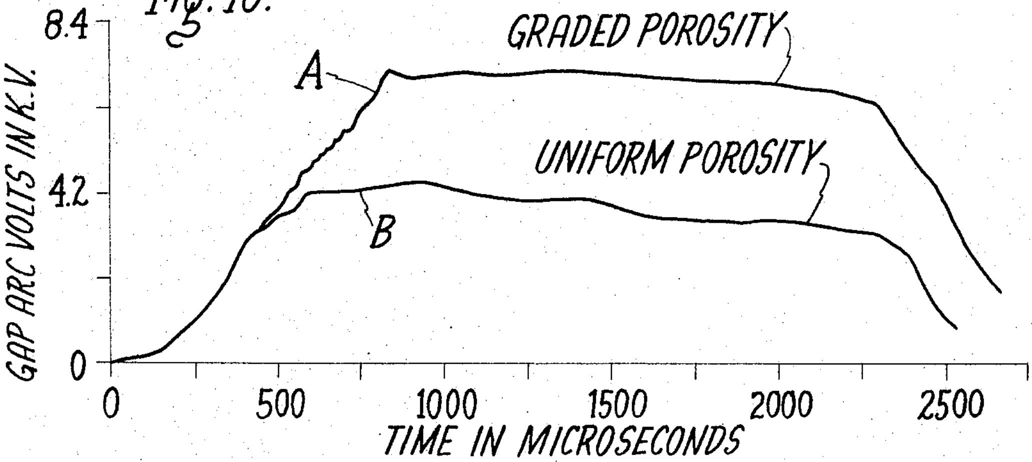


Fig. 11a.

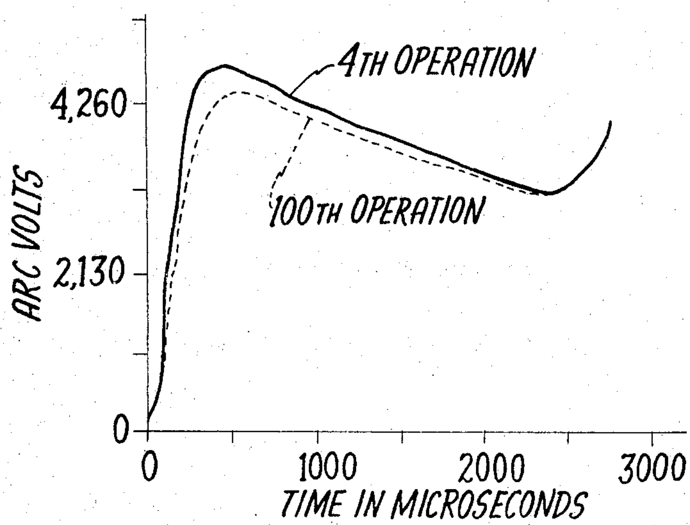
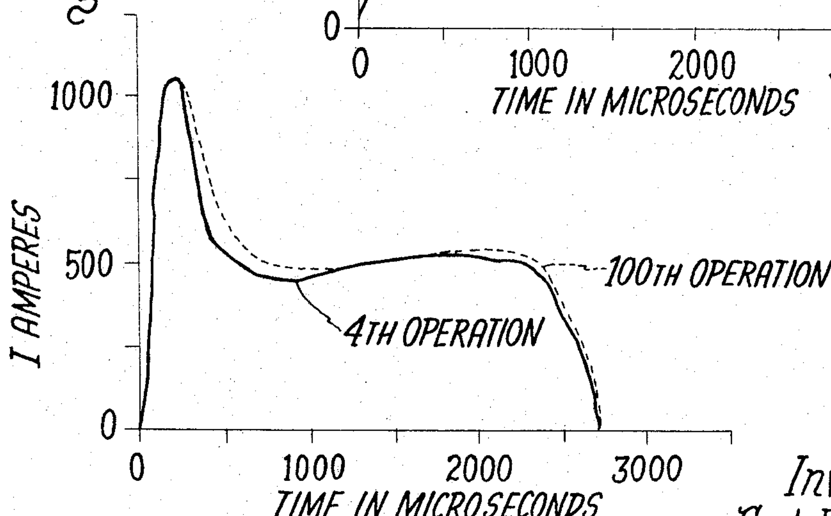


Fig. 11b.



Inventor,
Earl W. Stetson,
by Gilbert P. Tarleton
His Attorney.

United States Patent Office 3,354,345
Patented Nov. 21, 1967

1

3,354,345

LIGHTNING ARRESTER SPARK GAP HAVING ARC-CONFINING CHAMBER WALLS OF GRADED POROSITY

Earl W. Stetson, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

Filed July 6, 1964, Ser. No. 380,422
18 Claims. (Cl. 313—153)

ABSTRACT OF THE DISCLOSURE

A spark gap, for lightning arresters, of the magnetically arc elongated type having arc confining chamber walls of heterogeneous or non-uniform porosity ceramic material with minimum porosity adjacent where the arc is struck and maximum porosity adjacent where the arc has its greatest elongation.

This invention relates to an electric current interrupter and more particularly to improvements in spark gaps for electric power system lightning arresters.

A lightning arrester is an electrical safety valve for protecting the insulation of a charged electrical conductor, such as of cables, transformer and electric power lines, from the insulation rupturing effect of excess electrical pressure or voltage which can be caused by lightning or switching surges. However, in the electrical and mechanical arts the meaning of the terms "open" and "closed" is reversed when referring to a valve. Thus when an electric valve or switch is said to be open it is non-conductive whereas when a mechanical valve is open it is conductive. Similarly when an electric valve or switch is said to be closed it is conductive whereas when a mechanical valve is closed it is non-conductive. Therefore, a lightning arrester is a normally open electrical safety valve and a mechanical safety valve is a normally closed valve. However, they both operate the same way to prevent the escape of normal pressure while allowing the escape of excess pressure.

A typical power system lightning arrester comprises a so-called gap unit and a so-called valve resistance, usually of the negative-resistance-voltage characteristic type, connected in series between ground and the conductor whose insulation is to be protected against overvoltage by the arrester. At normal voltage no discharge current flows through the arrester and practically all the voltage is across the gap unit. On the occurrence of excess voltage the gap unit breaks down electrically (sparks over) allowing the flow of current through the arrester. As the initial electrical resistance of an arc between gap electrodes is low, compared to the resistance of a gap when there is no arc, most of the excess voltage will then be across the valve resistance whose resistance practically instantaneously falls to a low value because of its negative resistance-voltage characteristic. Consequently, the arrester can conduct large voltage-surge-produced discharge currents to ground while holding the voltage down to a safe value. After the surge of excess voltage has been drained off through the arrester, the normal system voltage tries to maintain the flow of so-called power follow current through the arrester but as the voltage on the valve resistance is now very much reduced its resistance increases thus reducing the magnitude of the power follow current to a value which the gap unit can interrupt.

Two comparatively recent developments have greatly increased the energy absorbing duty imposed on the gap unit. One results from the deliberate conversion of the gap unit into a current limiting gap which, by the use of a magnetic coil and other means, causes it rapidly greatly to increase its arc voltage or arc resistance up to a relatively high value compared with traditional gaps. This permits reducing the amount of valve resistance material in the arrester because the current limiting gap also performs the function of a valve resistance. The other development is the increase in power system operating voltage to values where switching surges impose a greater energy absorbing duty on the arrester than lightning surges. The transition occurs at voltages of about 230 kv. (RMS line-to-line) on a conventional open air line of a three-phase power system and at lower voltages on a cable line because of the higher capacitance per unit length of a cable operating at the same voltage. Switching surge energy is approximately proportional to both system capacitance and the square of the system operating voltage. In general, higher voltages mean longer lines and the combination of long lines and bundled conductors means increased line capacity. Thus at 700 kv., for which systems are currently being designed and constructed, the switching surge energy can be many times the lightning surge energy.

Lightning arresters are rated in terms of the applied voltage at which they will interrupt power follow current. Thus the rating of a lightning arrester is proportional to the system operating voltages. For voltages above about 345 kv., it has been proposed to provide additional valve resistance material in the arrester to aid in absorbing the switching surge energy (which is proportional to the square of the system operating voltage) and to shunt the added valve resistance material with a current switching gap which, like a current limiting gap, rapidly increases its arc voltage or resistance after sparkover so as to switch power follow current and switching surge current into the additional valve resistance material.

In accordance with this invention, there is provided a new and improved gap unit which is particularly adapted for use as a current limiting series gap in high voltage (above 230 kv.) lightning arresters, but which is also useful in lower voltage distribution arresters and as a current switching shunt gap for extra high voltage (above 345 kv.) arresters. Among other things it is characterized by arc chambers having variable, in the sense of non-uniform, or heterogeneous porosity ceramic walls with minimum porosity and maximum mechanical strength adjacent to where an arc is first struck, and maximum porosity in a region where the arc is elongated electromagnetically to greatest length for providing increased arc cooling and arc elongating actions for developing maximum arc voltage up to an instantaneous value approximately equal to the peak voltage of its 60-cycle rating. It is also characterized by a new and improved structural combination and arrangement of an arc chamber producing and gap electrode supporting porous ceramic plates. It is further characterized by the ability to absorb high arc energies many times without materially changing its characteristics.

An object of the invention is to provide a new and improved current interrupter.

Another object of the invention is to provide a new and improved gap unit for lightning arresters.

A further object of the invention is to provide a gap unit for lightning arresters which can repeatedly absorb high arc energy discharges without materially changing its operating characteristics.

An additional object of the invention is to provide a new and improved series current limiting gap for lightning arresters.

A still further object of the invention is to provide a new and improved current switching shunt gap for extra high voltage lightning arresters.

The invention will be better understood from the following description taken in connection with the accompanying

2

drawings and its scope will be pointed out in the appended claims.

In the drawings,

FIG. 1 is a perspective view of an assembled gap unit in accordance with a preferred embodiment of the invention,

FIG. 2 is an exploded view of the gap unit shown in FIG. 1,

FIG. 3 is a view showing the reverse or underside of one of the plates of the gap unit,

FIG. 4 is a top view of another one of the plates in the gap unit and showing how an arc is elongated,

FIG. 5 is an enlarged perspective view partly in section on broken lines 5—5 of FIGS. 2 and 4,

FIG. 6 is a still further enlarged detailed sectional view taken on line 6—6 of FIG. 5 but with the adjacent upper plate in place,

FIG. 7 is a view similar to FIG. 6 but taken on line 7—7 of FIG. 5,

FIG. 8 is a view similar to FIGS. 6 and 7 but taken on line 8—8 of FIG. 5,

FIG. 9 is a schematic view showing the electrical connections of the gap unit,

FIG. 10 is a graph of gap unit voltage versus time for showing the effect of varying or graded porosity as compared with uniform low porosity,

FIG. 11 is a pair of graphs illustrating the ability of the gap unit to withstand many repeated heavy switching surge discharges without material impairment of its operating characteristics.

Referring now to the drawings and more particularly to FIG. 1, there is shown therein a gap unit **1** comprising a stack of plates of electrical insulating material. They are shown by way of example as comprising six diameter coaxially contiguous circular discs of which the two end discs **2** are sub stantially identical. The two center discs **3** and **4** are substantially different from each other and from the end discs **2** and the two intermediate discs **5** are substantially identical with each other but different from the other discs. An electromagnetic coil **6** is mounted coaxially with the discs between the center discs 3 and 4. Thus although there are six discs in the unit there are only four different kinds of discs. The five pairs of contacting surfaces of the five pairs of adjacent discs are complementarily shaped and mate with each other to form arc chambers in each of which there is a horn gap **7** and meshing teeth **8** to form an elongated tortuous arc cooling and quenching wall or passageway, the elements **7** and **8** being shown in phantom in FIG. 1.

Referring now to the exploded view shown in FIG. 2, the end discs **2** may have flat outer surfaces which are visible from the top of disc **2** in FIGS. 1 and 2. The opposite side of each disc **2** and one side of each intermediate dis **5** has an arc chamber forming surface A visible on the lowermost end disc **2** and the adjacent intermediate disc **5**. The surface A is shown as having by way of example seven integral teeth **9**. The center discs **3** and **4** and the intermediate discs **5** each have an arc chamber forming surface B on one side thereof which is complementary to the surface A. The surface B is shown most clearly on the top intermediate disc **5** and it includes eight teeth **8**. The complementary surfaces A and B mate with each other in such a way that the seven teeth **9** of the surface A mesh with or fit between the eight teeth **8** of the surface B so as to form a tortuous arc cooling and elongating passageway as will be more fully described and illustrated in connection with FIGS. 6, 7 and 8.

The remaining or underside of the intermediate disc **3** has an arc chamber forming surface of configuration C as shown in FIG. 3 which among other things is provided with three integral teeth **11** and the remaining or top side of the intermediate disc **4** is provided with an arc chamber forming surface of configuration D having a pair of circumferentially spaced integral teeth **12**. The configurations C and D complementarily mate with each other so that the two teeth **12** mesh with or set between the three teeth **11** of configuration C when the discs **3** and **4** are placed together with the electromagnetic coil **6** coaxially therebetween. The arc chamber forming surfaces of the configurations B and D have a serpentine groove **13** running around the base of the teeth **8** and **12** respectively, the function of which will be explained hereinafter.

These same B and D configurated surfaces also each have permanently cemented thereto a pair of electrodes **14** forming a horn gap in each of their respective arc chambers, the electrodes **14'** on surface D forming a coil shunting gap **7'** in the center arc chamber and being somewhat differently shaped from the electrodes **14** forming the main series gaps **7** in the other arc chambers.

Perforations are provided in each of the discs through which pass connectors **15** one of which is shown connected to an electrode of each gap forming pair of electrodes, the free ends of which connectors are connected to an electrode of an adjacent gap so as to complete a series connection of the gaps. The coil **6** is shown connected in shunt with the gap formed by the electrodes **14'**.

Connected across the main series gaps on the B configuration surfaces are a preionizer **16** of any suitable type and a voltage grading resistor **17**. The preionizer for the coil shunting gap formed by the electrodes **14'** may consist of a piece of insulation **18**, such as mica, inserted between the electrodes adjacent to their points of nearest approach and opposite from the sparkover point on the electrodes from where the arc is driven by the combined electromagnetic action of the horn gap and the magnet coil **6**.

Referring now to FIG. 4 which is a somewhat enlarged plan view of a B configuration surface having a main series gap **7** formed by horn gap electrodes **14** which may be made of copper or other suitable material, it will be seen that these electrodes have relatively massive integral portions **14''** which have a substantialy heat sink effect and thus are highly resistant to erosion from long continuous arcing. The arc is driven electromagnetically across the gap shown between the main horn gap electrodes **14** and the heat sink electrode portions **14''**. As shown in this figure, the arc first forms or strikes the at the nearest point between the horn gap electrodes **14** and the magnetic field produced by the current flowing through the electrodes from their terminals to those points reinforced by the magnetic field of the coil **6** drives the arc upward, as viewed in FIG. 4, along the so-called runners of the electrode **14**. The arc is progressively elongated due to the divergence of the runners or electrodes until the arc reaches the tips of the main horn gap electrodes **14** by which time the magnetic field of the coil **6** is powerful enough to cause the arc to jump the gap to the heat sink portions **14''** until the arc finally is forced into the serpentine or tortuous passageway formed by the adjacent teeth **8** of the B configuration surface meshing with the teeth **9** of the mating A surface so that ultimately the arc has the serpentine path represented by the line **19**.

The coil shunting gap **7'** formed by the electrodes **14'** does not need the relatively massive heat sink portions **14''** because as the arc voltage increases due to the elongation of its arc until it finally follows a serpentine path around the meshing teeth **11** and **12** of the C and D configuration surfaces respectively the arc current decreases because more and more of the total current is forced into the coil **6** so that the coil shunting gap **7'** is not called upon to carry as much current as the main series gaps **7**, and the current which it does carry decreases more rapidly than the current decreases in the main series gaps **7**.

Referring now to FIG. 5 which is a further enlarged perspective view of one of the intermediate discs **5** taken on broken line 5—5 of FIGS. 2 and 4, but which is representative of all of the discs, it is composed of varying porosity ceramic material in which the porosity of the relatively thick teeth portions is substantially greater than the porosity of the remaining thinner portions of the disc such as adjacent the point where an arc forms between electrodes. The discs may be made of a mixture of fine particles of aluminum oxide (Al_2O_3) or other suitable refractory particles, a powdered glass frit permanent binder and a temporary binder such as wax. The disc may be formed by charging a cylindrical mold with the proper amount of such mixture dispersed in the proper way and compressing it between dies, each of which has a configuration the reverse of the A, B, C, or D configurations, blanks are formed and inasmuch as there is little or no plastic flow of the sandy mix different portions or zones can have substantially different porosity depending on their degree of compression. For example, with aluminum oxide particles having mean dimensions in the range of 10 mils ± 5 mils the porosity of the teeth can be twice the porosity of other and thinner portions of the disc such as where an arc is formed between electrodes. This is indicated by the spacing between the particles in the sectional showing in FIG. 5. More specifically the sections of high porosity can have a porosity in the range of thirty percent to fifty percent by which it is meant that that percent of any unit volume is not occupied by solid material. Similarly the denser sections can have a porosity of 10 to 20 percent meaning that 10 to 20 percent of a unit volume in the denser zones is not occupied by solid material. After the blanks of the discs **2**, **3**, **4**, and **5** are formed in this manner they are fired at a temperature high enough to volatilize and drive off the temporary binder and melt the permanent binder sufficiently to cause it to wet the surfaces of the aluminum oxide particles and form interconnecting bridges or bonds therebetween. In this connection, it is to be noted that the aluminum oxide particles are not melted or softened and do not enter into any reaction similar to sintering or autogenous fritting for creating the permanent bond which holds the material together.

The relatively low porosity or high density of the plates near their center and remote from the teeth provides high mechanical strength for resisting the explosive forces of arcs formed during lightning discharges.

Referring now to FIGS. 6, 7, and 8 which are enlarged detailed sectional views taken on lines **6**, **7**, and **8** respectively of FIG. 5 but with an adjoining disc such as disc **2** with an A surface mating with the B surface of the disc **5**, these figures show details of the tortuous or serpentine ultimate arc elongating path or passageway having walls of high porosity. Thus FIG. 6 shows a tooth **9** of a disc **2** and in dashed outline or in phantom a tooth **8** of disc **5** and also shows the groove **13** where it extends between the roots of teeth **8**. This figure also shows that the plates **2** and **5** have zero clearance at the area **20** while having greater clearances radially outward of that area as indicated at **21**. Thus the tortuous passageway is effectively closed or sealed between zero clearance fit **20**.

In the view shown in FIG. 7 a tooth **8** is shown in section and the groove **13** around the end of this tooth is shown.

In FIG. 8 the groove **13** is shown where it runs along the sides of the teeth **8**. Except for the fact that this is a sectional view, it is similar to the configuration that confronts the arc as it is driven into the serpentine passageway.

The purpose of the groove **13** is to encourage the arc to follow the total length of the tooth geometry over wider ranges of follow currents and also to provide additional high porosity surface area for cooling the arc. In this connection, the high porosity of the surface of the tortuous passageway permits the arc actually to penetrate into the material whereby there is still further increased surface contact between the arc and the porous material for providing still more effective cooling.

While FIGS. 6, 7, and 8 are illustrative of the A and B configurations, they are also representative of the C and D configurations in which the teeth **11** and **12** mesh and there is a groove **13** around the teeth **12** in the D configuration.

FIG. 9 shows the electric circuit of the gap unit with the four main gaps **7** connected in series with each other and with the coil **6**, the latter being shunted by the gap **7'** and each of the main gaps **7** being shunted by a preionizer **16** and a voltage grading resistor **17**.

Referring now to FIG. 10, curve A shows the relation between the voltage developed by the gap unit **1** of the present invention versus time in microseconds as compared to the voltage versus time characteristic of an otherwise similar gap but having substantially uniform porosity discs with a porosity comparable to the low porosity sections of the discs of the present invention. As can be seen from curve A, the gap unit of FIG. 1 after about 400 microseconds of arc current flow begins to develop a higher arc voltage than the substantially uniform porosity disc gap unit whose characteristic curve is labeled B. It is at about the 400 microsecond point that the arc begins to enter the tortuous passageway and the effect of the decreased porosity in this passageway produces the higher arc voltage represented by the difference in curves A and B.

FIG. 11*a* shows the remarkable constancy of the arc voltage versus time characteristic of the gap of FIG. 1 after numerous repeated high switching surge current discharges through it, the solid curve being after the fourth operation and the dashed curve being after the one hundredth operation. FIGURE 11*b* shows a similar current versus time comparison, the solid curve being taken after the fourth operation and the dashed curve after the one hundredth operation. These curves show that there is very little deterioration of the gap after a large number of repeated high current discharges through it. This indicates the effectiveness of the high porosity toothed sections of the plates which because of the increased space between the particles do not tend to plug up with fused material and thus retain much longer their original high porosity for providing maximum penetration by and cooling of the arcs.

While there has been shown and described a particular embodiment of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and therefore it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a current interrupter, an arc chamber having ceramic walls each of which has a porosity gradient, a pair of electrodes in said chamber between which an arc is struck, said chamber having a region with relatively low porosity walls adjacent where an arc is struck between said electrodes, said chamber having an arc cooling region with relatively high porosity walls, and means for electromagnetically driving said arc from said region of low porosity walls into said region of high porosity walls.

2. A current interrupter as in claim **1** in which the porosity of the high porosity walls is about twice the porosity of the low porosity walls.

3. A current interrupter as in claim **1** in which said arc cooling region provides an arc path which is many times longer than the arc initially struck between said electrodes.

4. A lightning arrester spark gap comprising, an arc chamber having walls of graded porosity ceramic material, a pair of electrodes with varying spacing forming a spark gap mounted in said arc chamber with their point of minimum spacing at one side of said arc chamber, said electrodes divergently extending into said arc chamber and terminating at opposite ends of a continuous tortuous arc elongating and cooling passageway forming a generally opposite side of said arc chamber, the porosity of the walls of said passageway being substantially greater than the porosity of the remaining walls of said arc chamber, and an electromagnetic coil coaxially adjacent said arc chamber connected to said electrodes for forcing an arc initially formed between said electrodes at their point of minimum spacing into said arc chamber along said electrodes to their termini and into said tortuous passageway.

5. A lightning arrester spark gap comprising, an arc chamber having walls of graded porosity ceramic material, a pair of electrodes forming a horn gap mounted with their point of minimum spacing at one side of said arc chamber with their horns extending into said arc chamber and terminating at opposite ends of a continuous tortuous arc elongating and cooling passageway forming another side of said arc chamber, the porosity of the walls of said passageway being substantially greater than the porosity of the remaining walls of said arc chamber.

6. A lightning arrester spark gap comprising a closed arc chamber having walls of graded porosity ceramic material, a pair of electrodes forming a horn gap mounted with their point of minimum spacing at one side of said arc chamber with their horns extending into said arc chamber and terminating at opposite ends of a continuous tortuous generally curved arc elongating and cooling passageway forming another side of said arc chamber, the porosity of the walls of said passageway being substantially greater than the porosity of the remaining walls of said arc chamber, and an electromagnetic coil around said arc chamber connected to said electrodes for increasing the force and the rapidity with which an arc formed between said electrodes is forced into said tortuous passageway.

7. A high arc voltage developing spark gap unit for lightning arresters comprising, in combination, at least three stacked gradiently porous ceramic body plates adjacent faces of which form therebetween a pair of closed arc chambers, a separate horn gap mounted eccentrically in each arc chamber with its diverging horns terminating respectively near the opposite ends of a continuous tortuous arc elongating path on the opposite side of its enclosing arc chamber, each of said arc elongating paths being formed by a series of loosely interfitting integral radically and outwardly extending arcuately disposed teeth on the adjacent faces of said body plates, said teeth having about twice the porosity of the remaining walls of said arc chamber, a magnetic coil around said gap unit connected in series with one of said horn gaps, and means for connecting the other horn gap in shunt with said coil.

8. A high arc voltage developing spark gap unit for lightning arresters comprising, in combination, at least three stacked gradiently porous ceramic body plates adjacent faces of which form therebetween a pair of central closed arc chambers, a separate horn gap mounted eccentrically in each arc chamber with its diverging horns terminating respectively near the opposite ends of a continuous tortuous arc elongating path centered on the opposite side of its enclosing arc chamber, each of said arc elongating paths being formed by a series of loosely interfitting integral radially extending arcuately disposed teeth on the adjacent faces of said body plates, at least one of the faces of each pair of adjacent faces having a continuous groove extending around the base of its teeth to provide a path of easy access for arc gas into said tortuous arc elongating path, said teeth having about twice the porosity of the remaining walls of said arc chamber, a magnetic coil around said gap unit connected in series with one of said horn gaps and means for connecting the other horn gap in shunt with said coil.

9. In a lightning arrester, a high energy absorbing spark gap for rapidly developing a high arc voltage after sparkover for the duration of repeated switching surges on a high voltage power system without materially imparting the gap's operating characteristics, comprising a pair of porous ceramic discs defining an arc chamber therebetween, a pair of electrodes in said chamber forming a horn gap, said horn gap being in a plane parallel to the planes of said discs and symmetrical with respect to a diameter of said discs but eccentrically located in said chamber with respect to the axis of said discs with the horns of said electrodes extending into said chamber from their point of confluence, said discs near their periphery remote from the point of confluence of the horn gap electrodes having axially thickened sections with radially extending integral interfitting teeth forming a tortuous end wall of said arc chamber, the porosity of said discs varying with the axial thickness of their sections and being generally proportional to such thickness, and a magnetic coil connected to said gap for providing a magnetic field for rapidly moving an arc between said electrodes to the tips of their horns and into the high porosity tortuous end wall of said arc chamber, the porosity of said discs adjacent the point of confluence of the horn gap electrodes being relatively low compared to that of said thickened toothed sections to provide adequate mechanical strength for resisting the explosive force of a high energy arc initiated at that point.

10. A lightning arrester as in claim **9** in which said discs are composed of vitreously bonded irregularly shaped ceramic particles having cross sectional dimensions in the range of 10 mils ±5 mils, the porosity of said discs varying from a maximum of between 30% to 50% at their thickest portions to between 10% to 20% at their thinnest portions, said numerical percentages being the percentage of the volume of the respective portions not occupied by solid material.

11. A lightning arrester as in claim **9** in which said discs are composed of glass bonded irregularly shaped granules of aluminum oxide having cross sectional dimensions in the range of 10 mils ±5 mils, the porosity of said discs varying from a maximum of between 30% to 50% at their thickest portions to between 10% to 20% at their thinnest portions, said numerical percentages being the percentage of the volume of the respective portions not occupied by solid material.

12. A lightning arrester as in claim **9** in which the tips of the horns of said electrodes nearest said tortuous end wall of said arc chamber are comparatively massive pieces of copper compared with the electrodes near their point of confluence so as to provide a heat sink for withstanding prolonged high energy arcing at the surface of said tips.

13. A gap unit comprising at least four coaxially contiguous varying porosity ceramic plates of which the two end plates are identical with each other and the two center plates are different from the end plates and from each other, the end plates each having a flat outer side and an arc-chamber-forming opposite side of configuration A, the center plates having different arc-chamber-forming surfaces on opposite sides thereof of configurations B and C for one center plate and configurations B and D for the other center plate, the B configurations of the center plates being complementary to and mating with the A configurations of the end plates, the C and D configurations being complementary to and mating with each other, a separate horn gap mounted off center in each of the three arc chambers formed between the three pairs of contiguous plates, an electromagnet coil coaxial with the plates and connected in shunt with one horn gap, and means for connecting said gaps in series with each other with such polarity that when current flows through the series connection the magnetic field of said coil aids the inherent horn gap action of the gaps to move the arcs of all of said gaps across the center of their respective arc chambers from a region of low porosity walls into an elongated region of high porosity walls.

14. A gap unit comprising at least four coaxially contiguous equal diameter varying porosity ceramic discs of which the two end discs are identical with each other, the two center discs are different from the end discs and from each other, the end discs each having a flat outer side and an arc-chamber-forming opposite side of toothed configuration A, the center discs having different arc-chamber-forming surfaces on opposite sides thereof of configurations toothed B and C for one center disc and toothed configurations B and D for the other center disc, the B configurations of the center discs being complementary to and mating with the A configurations of the intermediate discs and having a continuous groove around the base of their teeth, the C and D configurations benig complementary to and mating with each other, a separate horn gap mounted off center in each of the three arc chambers formed between the three pairs of contiguous discs, an electromagnet coil coaxial with and between the center discs and connected in shunt with the horn gap in the arc chamber formed by the center discs, and means for connecting said gaps in series with each other with such polarity that when current flows through the series connection the magnetic field of said coil aids the inherent horn gap action of the gaps to move the arcs of all of said gaps across the center of their respective arc chambers from a region of low porosity walls into an elongated meshing teeth serpentine region of high porosity walls.

15. A gap unit comprising six coaxially contiguous varying porosity ceramic plates of which the two end plates are identical with each other, the two center plates are different from the end plates and from each other, and the two intermediate plates are identical with each other but different from the other plates, the end plates each having a flat outer side and an arc-chamber-forming opposite side of configuration A, the intermediate plates having different arc chamber forming surfaces of opposite sides thereof of configurations B and A respectively with the B configuration being complementary to the A configuration and each B configuration interfitting with the A configuration of an end plate, the center plates having different arc-chamber-forming surfaces on opposite sides thereof of configurations B and C for one center plate and configurations B and D for the other center plate, and B configurations of the center plates mating with the A configurations of the intermediate plates, the C and D configurations being complementary to and mating with each other, a separate horn gap mounted off center in each of the five arc chambers formed between the five pairs of contiguous plates, an electromagnet coil coaxial with the plates and connected in shunt with one horn gap, and means for connecting said gaps in series with each other with such polarity that when current flows through the series connection the magnetic field of said coil aids the inherent horn gap action of the gaps to move the arcs of all of said gaps across the center of their respective arc chambers from a region of low porosity walls into an elongated region of high porosity walls.

16. A gap unit comprising six coaxially contiguous

equal diameter varying porosity circular ceramic discs of which the two end discs are identical with each other, the two center discs are different from the end discs and from each other, and the two intermediate discs are identical with each other but different from the other discs, the end discs each having a flat outer side and an arc-chamber-forming opposite side of toothed configuration A, the intermediate discs having different arc chamber forming surfaces of opposite sides thereof of toothed configurations B and A respectively with the B configuration being complementary to the A configuration and each B configuration interfitting with the A configuration of an end disc, and having a continuous groove around the base of its teeth, the center discs having different arc-chamber-forming surfaces on opposite sides thereof of configurations B and C for one center disc and configurations B and D for the other center disc, the B configurations of the center discs mating with the A configurations of the intermediate discs, the C and D configurations being complementary to and mating with each other, a separate horn gap mounted off center in each of the five arc chambers formed between the five pairs of contiguous discs, an electromagnet coil coaxial with and between the center discs and connected in shunt with the horn gap in the arc chamber formed by the center discs, and means for connecting said gaps in series with each other with such polarity that when current flows through the series connection the magnetic field of said coils aids the inherent horn gap action of the gaps to move the arcs of all of said gaps across the center of their respective arc chambers from a region of low porosity walls into an elongated serpentine region of high porosity walls between meshing teeth.

17. In a current limiting gap unit for a lightning arrester section having a predetermined voltage rating, a magnet for moving an arc struck in said gap unit and, means including graded porosity arc chamber walls for causing said gap unit to develop an arc voltage substantially equal to said voltage rating.

18. In a current limiting gap unit for a lightning arrester section having a predetermined alternating voltage rating, a magnet for moving an arc struck in said gap unit and, means including graded porosity arc chamber walls for causing said gap unit to develop an arc voltage substantially equal to the instantaneous peak value of said alternating voltage rating.

References Cited

UNITED STATES PATENTS

2,772,334	11/1956	Latour	200—144
3,019,367	1/1962	Kalb	315—36
3,151,274	9/1964	Snell	315—36

JAMES W. LAWRENCE, *Primary Examiner.*

S. A. SCHNEEBERGER, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,354,345 November 21, 1967

Earl W. Stetson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 14, for "lines" read -- line --; line 34, after "six" insert -- equal --; line 54, for "dis" read -- disc --; column 4, line 38, for "substantialy" read -- substantial --; line 43, strike out "the", second occurrence; column 5, line 9, for "disc" read -- discs --; column 7, line 44, for "radically" read -- radially --; lines 74 and 75, for "imparting" read -- impairing --; column 9, line 11, for "benig" read -- being --.

Signed and sealed this 18th day of February 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr. — Attesting Officer

EDWARD J. BRENNER — Commissioner of Patents