

Feb. 25, 1958

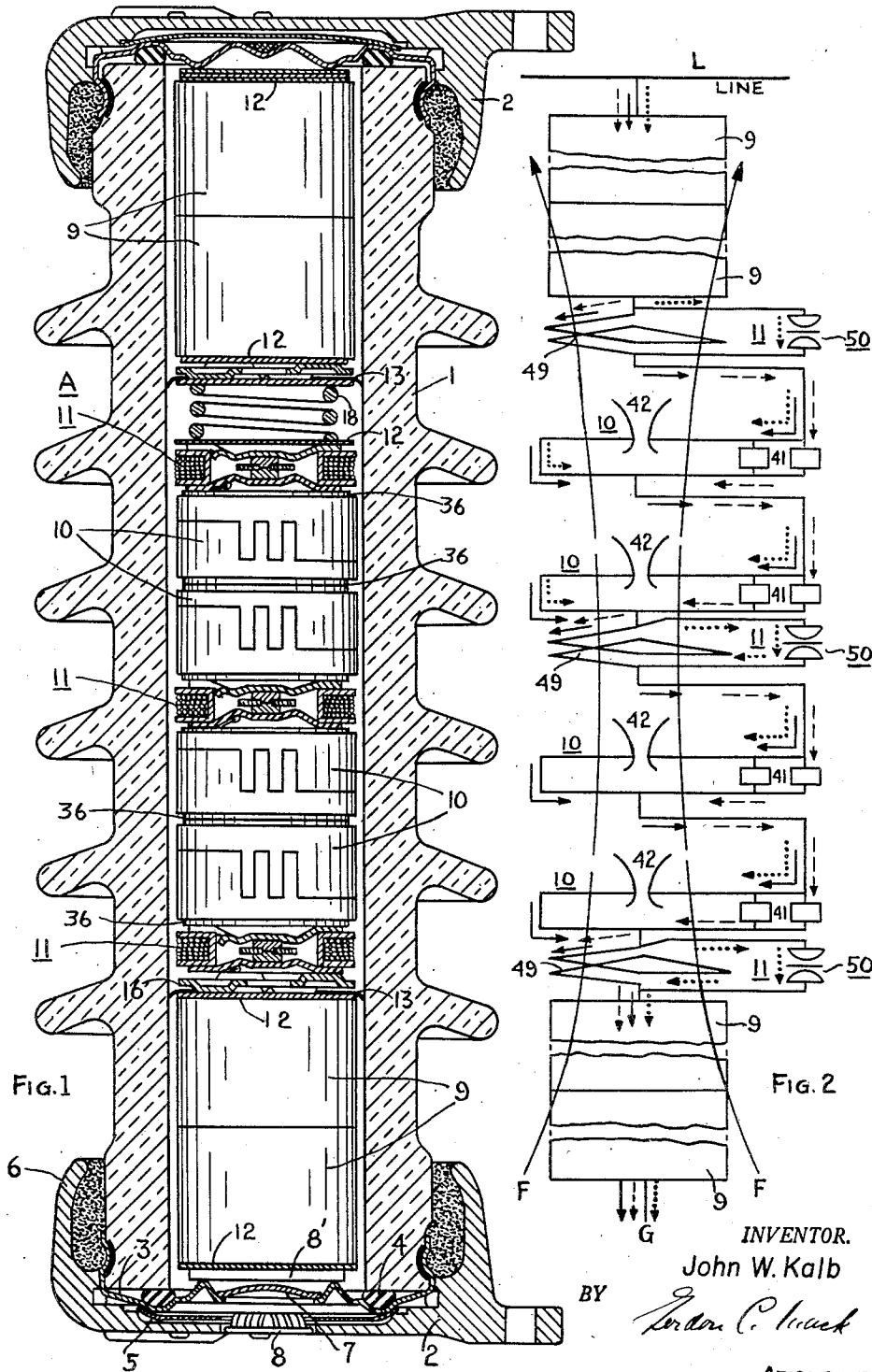
J. W. KALB

2,825,008

LIGHTNING ARRESTERS

Filed June 2, 1953

3 Sheets-Sheet 1



Feb. 25, 1958

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LIGHTNING ARRESTERS

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3 Sheets-Sheet 2

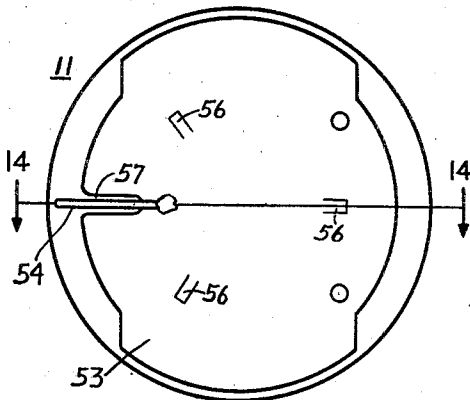


Fig. 13

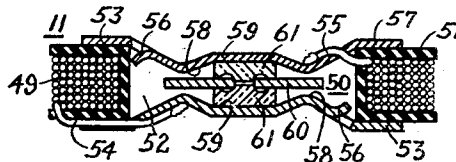


Fig. 14

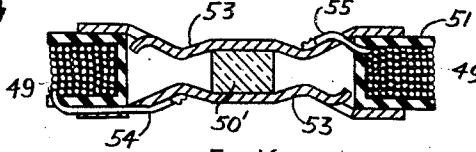


Fig. 16



Fig. 15

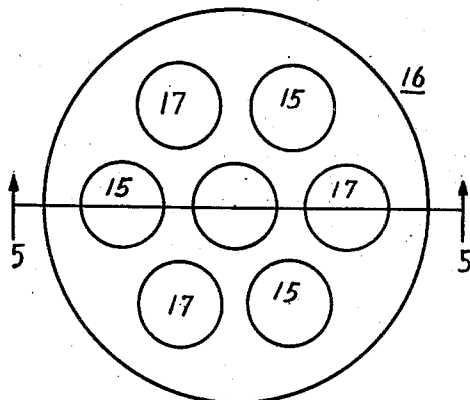


Fig. 4

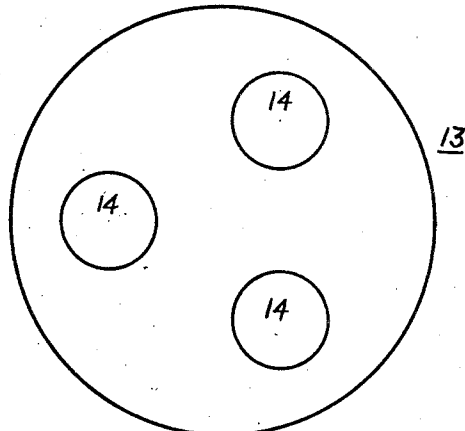


Fig. 3

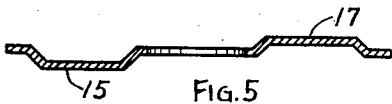


Fig. 5

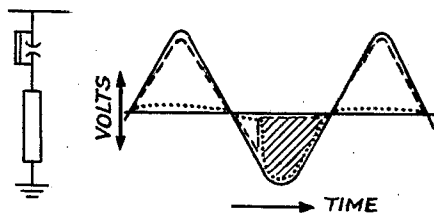


Fig. 17a

Fig. 17b

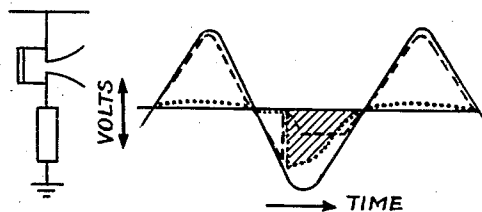


Fig. 18a

Fig. 18b

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LIGHTNING ARRESTERS

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3 Sheets-Sheet 3

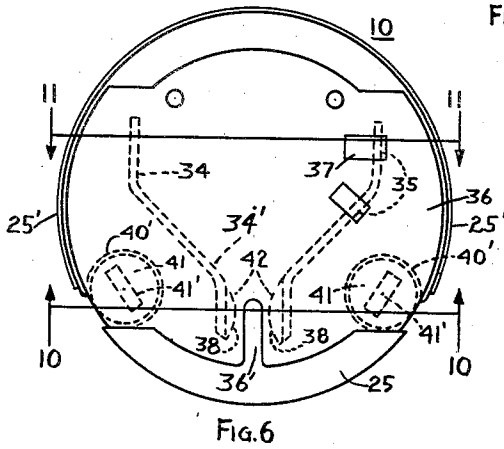
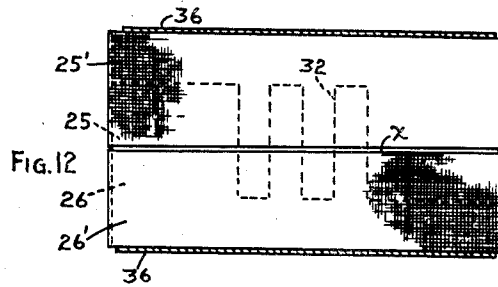
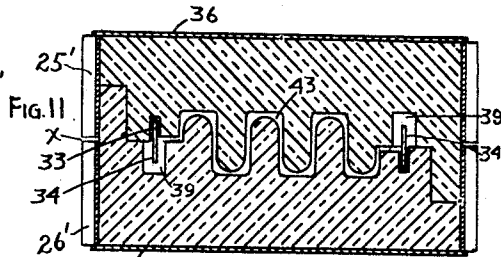
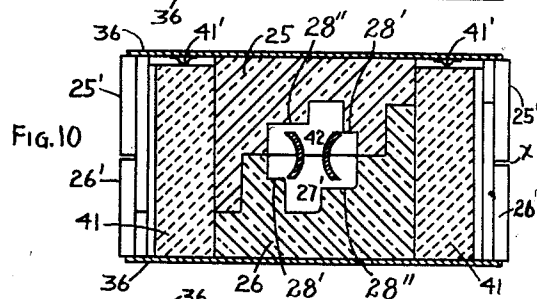
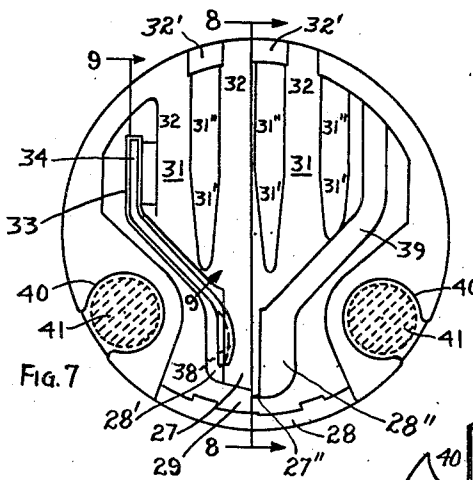
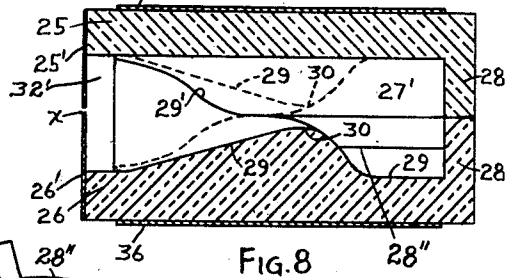
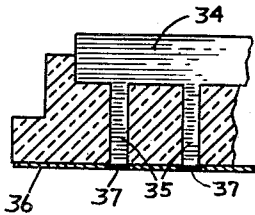


Fig. 9

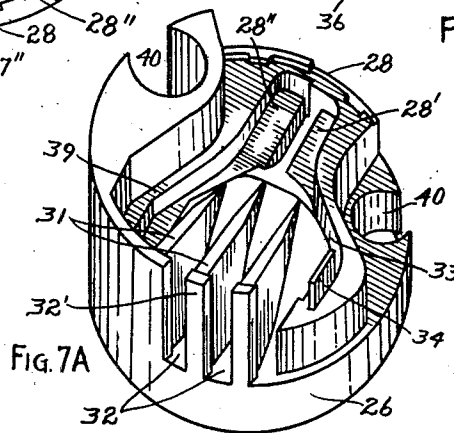


Fig. 7A

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2,825,008

LIGHTNING ARRESTERS

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Application June 2, 1953, Serial No. 359,149

28 Claims. (Cl. 317—70)

This invention relates to circuit protection and arc control devices employing a voltage sensitive valve block or element and an arc gap structure in which the arc is elongated preferably by being moved from its original position of formation. More particularly it relates to an arrester in which the arc is moved by a magnetic field into an arc suppressing chamber where it is extinguished.

The invention includes a new method of operating a lightning arrester or the like. When a sudden surge through the arrester forms an arc across a gap in the arrester, the arc is materially lengthened and confined until eventually it is extinguished. Increasing the length of the arc increases its voltage, and during flow of the power follow current this produces a corresponding decrease in the voltage across the valve resistor element or elements in the arrester.

The arrester is an improvement over that disclosed in U. S. Patent #2,640,096, issued May 26, 1953, to J. W. Kalb, and its operation produces new and improved results in the protection of electric circuits and apparatus against overvoltages.

The invention herein disclosed has objects, among others, which are common with practically all present-day arresters of the valve type; namely, to provide a means to be interposed between an electric conductor and the ground—(1) to provide a path to ground when transient surge voltages approach a level which might damage electrical equipment; (2) to interrupt the power-frequency power follow current resulting from gap sparkover in order that the arrester can return to its normal condition of no appreciable voltage across the valve element, (3) to keep the system voltage away from the valve element under normal conditions so that the valve element is not destroyed by excessive heat resulting from continuous current flow.

The present-day or conventional lightning arresters, one form being shown in U. S. Patent 2,640,096, are so constructed as to interrupt the arc resulting from the follow current flowing from a conductor carrying alternating current to ground, by reason of the fact that the voltage passes through zero at the mid-point of the cycle and the arc is de-ionized.

The novel objects and purposes of the present invention pertain to a new lightning arrester having:

(1) A gap which will interrupt currents of higher magnitude, thus allowing the use of a given size of valve blocks or elements with higher operative follow currents and resulting in a lower discharge voltage;

(2) A gap which generates a substantial arc voltage during the flow of system or 60-cycle power follow current. Thus, there is less voltage across the valve element during the flow of power follow current and therefore a shorter or smaller valve element can be used;

(3) A gap which interrupts and extinguishes the power follow current at any part of the line voltage cycle, thus allowing the means for accomplishing the arc-over and arc-interruption to be designed independently of the function of the other.

Another novel object of this invention is to provide a device which will interrupt the arc resulting from a power follow current which has no zero, as for instance, when

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the arrester is connected to a conductor carrying a direct or continuous current.

Further objects of this invention are as follows:

To provide a lightning arrester having means to produce a magnetic field whereby an arc formed between electrodes is propelled into an adjacent chamber where the arc is extinguished.

To provide a lightning arrester of the type described with shunted gaps which under normal conditions permit a small current of the order of about 1/2 milliampere to flow past the gaps to supply capacity leakage current to ground without having the current cause uneven voltage drop across the different individual gaps.

To provide shunting means for the coil producing the magnetic field to prevent the voltage across the coil becoming so great during a high frequency lightning surge as to puncture the coil insulation.

To provide an arrester in which the 60-cycle impedance of the coils producing the magnetic field is sufficiently low so that the normal power follow current will flow through the coils and not across their protective gaps whereby the arc will be moved into an adjacent arc interrupting chamber and there be extinguished.

To provide a gap which includes an associated chamber in which the energy of the follow current arc is rapidly absorbed.

To provide a gap which shall be relatively small in size considering the magnitude of the current it suppresses.

A further object is to provide a gap which includes an associated arc suppressing or interrupting chamber, said chamber being protected from damage resulting from high current surges.

The above objects are set forth preliminary to a discussion of the various elements forming the arrester and their combination, and will be better understood from the following discussion and reference to the drawings.

In the drawings—

Fig. 1 is a vertical elevational view in partial section of the lightning arrester embodying the present invention;

Fig. 2 is a schematic view showing the various elements of Fig. 1 and their manner of connection;

Fig. 3 is a plan view of an insulating separator provided with a plurality of openings;

Fig. 4 is a plan view of a metal connecting disc;

Fig. 5 is a section on the line 5—5 of Fig. 4 showing the upwardly and the downwardly projecting contacts;

Fig. 6 is a top plan view of the arc interrupting unit in which the arc is suppressed, comprising two like bodies in registering relation;

Fig. 7 is a plan view of the interior surface of each body of the arc interrupting unit of Fig. 6;

Fig. 7A is a view in perspective of the same, taken from the rear, with the electrode partly broken away;

Fig. 8 is a section of the arc interrupting unit of Fig. 6 taken on a line corresponding to the line 8—8 of Fig. 7, the electrode and the resistor being omitted;

Fig. 9 is a section of a fragment of one of the bodies of the arc interrupting unit of Fig. 6, taken on the line 9—9 of Fig. 7;

Fig. 10 is a section on the line 10—10 of Fig. 6;

Fig. 11 is a section on the line 11—11 of Fig. 6;

Fig. 12 is an elevational view of the far side of Fig. 6 showing the interleaving of ribs formed therein;

Fig. 13 is a top plan view of the magnetic control means and its control or protective gap;

Fig. 14 is a section on the line 14—14 of Fig. 13;

Fig. 15 is an insulator spacer shown in Fig. 14;

Fig. 16 is a section through a modified magnetic control structure;

Figs. 17a and 17b represent the operations of a lightning arrester of the conventional type under normal and surge conditions; and

Figs. 18a and 18b represent the operations of a lightning arrester of the herein improved type under normal and surge conditions.

The lightning arrester

In the embodiment disclosed in Fig. 1, the arrester comprises a housing 1 of porcelain or other suitable insulating material with members 2 of metal at each end functioning as closure, support and terminal means. Other closure means at each end of the housing consist of the rolled-on cap 3 of sheet metal such as copper, soft steel, aluminum, etc., with the interposed ring gasket 4 of an elastic material such as rubber (native or synthetic), neoprene, etc., and the metal spring member or disc 5 of spring steel which is interposed between and in engagement with each end member 2 and the cap 3. When the members 2 are positioned under pressure of several hundred pounds or more and so held by a cement filling 6, a constant follow-up pressure is applied by the disc 5 to the cap 3 and gasket 4 forming a gas-tight seal at each end of the housing.

To relieve internal pressure within the housing as the result of a prolonged discharge of current, one of the caps 3 is provided with a rupturable disc 7 sealed to the cap; the associated end member 2 is provided with an opening which is normally only partially closed by a snap-on cover 8 thus giving access to the atmosphere in case of rupture of the disc 7. The member 8' is an open V-shaped member between the cap 3 and end block 9 which permits the gas pressure to reach the rupturable disc 7 as disclosed in U. S. Patent 2,640,096 above referred to.

The internal members of the housing 1, forming the protecting pile A comprise valve blocks 9 shown at the ends of the pile; the blocks are usually referred to as non-linear or voltage sensitive; also associated with the pile are the arc interrupting units 10 of high-current capacity, and magnetic control means 11 for generating magnetic fields to move the arcs formed in the interrupting units 10.

The numbers of the respective members and their relative arrangement will depend upon the rating and characteristics desired of the arrester. The magnetic control means 11 are usually placed adjacent the arc interrupting units 10 in order to secure the benefit of the magnetic field in controlling the arcs formed within the units 10 which are of a high-current type.

Metal discs 12 are interposed between the several members of the pile A as indicated, and act chiefly as supporting an electrical connecting means between adjacent parts.

Also shown at different points in the pile A are discs 13 (Fig. 3) of insulating material such as press-board. The drawing (Fig. 1) shows one on top of the lower two valve blocks and another just below the upper two valve blocks. Their outer edges hug the inner face of the housing whereby the products produced by the arc are confined between the discs 13.

In order not to break up the electrical continuity of the pile A, each disc 13 (Fig. 3) is provided with openings 14 through which project the downwardly pressed contacts 15 of the metal connecting discs 16, shown in Figs. 4 and 5 as well as Fig. 1; the upwardly pressed contacts 17 engage with the members immediately above.

Positioned between the upper magnetic control means 11 and adjacent block 9 is a compression spring 18 which yieldingly holds the various members of the pile against longitudinal movement and maintains electrical contact between the several members of pile A.

In Fig. 2 is schematically shown the several members of pile A and their electrical relation. The upper terminal 2 of the arrester is usually connected to the line L to be protected and the lower terminal 2 is connected to ground G.

The various members of the pile as described above are connected in series.

The arc interrupting units

It is common knowledge that conventional valve type arresters are provided with voltage sensitive resistor blocks which are composed of a mixture of high resistance materials, principally Carborundum and a binder, formed into blocks and the binder then sintered. Such a valve block is described in U. S. Patent 2,206,792.

Under normal or non-surge conditions the current through the valve blocks may be limited to the order of one milliamperere or less by the use of gap grading resistors later referred to. When the gap sparks over as a result of surge currents on the line, the effective resistance of the valve blocks decreases so that the current increases rapidly and the surge voltage is limited to a reasonable level. As the surge current through the arrester decreases, the resistance of the valve blocks increases until after the surge is over and only normal line voltage is across the blocks, the resulting current is held to a level which the gap can interrupt.

The arc interrupting units 10 are shown in Figs. 6 to 12 inclusive, and differ materially from conventional gaps, both in construction and operation.

The arc interrupting units 10 each consist of a pair of chambered elements or body-members 25 and 26 of like construction, preferably of porcelain or glass, which when placed in registering relation form an enclosed arc gap, an arc chamber therefor, and an arc suppressing chamber which is in the magnetic field produced by the magnetic control means 11.

Figures 6 to 11 inclusive show the details of the inner construction of the identical bodies 25 and 26. Each body is formed with an arc cavity 27 bounded at the front by the wall 28, and when the bodies are assembled these cavities form the arc recess chamber 27' (Fig. 10). At the sides of the cavity 27 in each insulating body are the arc-confining ledges 28' and 28'' the purpose of which will be described in connection with the discussion of the electrodes.

The irregularities in the top surface of the wall 28 (Fig. 7A) on one side of the center line 8—8 (Fig. 7) of each body are complementary with those on the other side, so that when the bodies are assembled to form a unit, the irregularities interlock. The interlocking of these irregularities holds the two bodies in exact register. It also forms a tortuous egress for the gases generated in the arc recess chamber 27' during high current discharges. This practically eliminates the amount and intensity of the arc or gases from escaping through the front end of the interrupting unit 10 during the discharge of a large power follow current.

As shown in Fig. 8, the unit 10 has oppositely disposed top and bottom walls 29. These slope rearwardly and toward each other and then diverge gradually sloping toward the rear of the unit (Fig. 8) thereby forming the hump at 30. Although the walls 29 might be flat at the level with that of the recesses 27', the design shown with the humps 30 is preferable. Without the closely spaced humps 30 the flow of gases generated by a high current surge discharge would be so violent in the direction of the rear of the interrupting unit that the arc might be blown out the rear end of the unit. The small clearance between the adjacent surfaces of the humps 30 of the two mating bodies 25 and 26 dampens the excessive arc and gas flow attending such discharges.

Projecting from the surface 29 (Figs. 7, 7A and 8) are a plurality of longitudinally disposed ribs 31 (three disclosed) which start from about the apex of the hump 30 of the surface 29 of each body. The upper edge 29' of each rib curves upwardly and rearwardly on the bottom body, and downwardly and rearwardly on the upper body when the two bodies are assembled (Fig. 8); the forward portions 31' of the ribs have diverging side faces for a predetermined distance back from their front ends; the side faces of the ribs 31 for the balance of their length 31'' are

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parallel, and the space 32 between the ribs of each unassembled body is shown as open to atmosphere (Figs. 7 and 7A).

When the two insulating bodies 25 and 26 are assembled, their construction is such that the rear of the unit 10 is somewhat open to the atmosphere between the rear ends of the interleaved ribs although the thickened ends 32' tend to close off the spaces 32 to atmosphere. Figure 12 illustrates in dotted lines the small space between the thickened ends 32' of the ribs after the two members have been assembled and wrapped with glass tape. A small vent opening to atmosphere is desirable in order to prevent back pressure from the arc, yet confining the arc and preventing its escape to the atmosphere from between the rear ends of the ribs. It is difficult to control the close spacing 32 between the ribs at the thickened ends 32'. However, by covering the exposed ends of the ribs 31 with glass tape cemented to the assembled unit, the opening of the space 32 between the ribs, to the atmosphere, is accurately controlled since the openings or pores through the glass tape are uniform and tapes may be secured with openings of proper size which will prevent the arc escaping to atmosphere but will permit the escape of gases without creating back pressure.

The glass tape is secured to the bodies 25-26 after their assembly by means of cement and the cement may inadvertently cover some portion of the opening to atmosphere. The tape may be applied in two strips 25' and 26' as shown in Fig. 12, leaving a small space *x* between strips at the openings at the outer ends of the ribs or applied in a single strip with a slot *x* cut therethrough which will extend across the openings at the outer ends of the ribs. The preference is to use a single tape with proper size pores as previously described.

Each insulating body 25 and 26 is provided with a groove 33 in which the rear portion of one of the horn-shaped electrodes 34 is secured by means of integral prongs 35 adjacent the rear end of the electrode 34 which extend through openings through the body to its outer surface (Fig. 9). The groove 33 extends to a point just forward of the hump 30, and its bottom is on a level with the surface of the ledge 28'. Each body is faced by a thin metal disc 36 to which the prongs 35 are attached by solder 37 (Fig. 6 and Fig. 9) thereby electrically connecting each electrode with a disc 36 on the surface of the body and securing the electrodes and discs in fixed relation to their respective bodies.

Each body 25 and 26 is also provided with the wider longitudinal horn-shaped groove 39 corresponding to groove 33 into which the exposed half of the electrode of the cooperating body projects when the bodies are in registering relation. The electrode ends 38 are free and convexed on the surfaces facing each other and project slightly forward from the ledges 28' into the enclosed arc recess chamber 27' and form the main or arc gap 42 (Figs. 6 and 10).

When two insulating bodies 25 and 26 are assembled in registering relation, the ribs 31 will be interleaved and spaced with respect to each other, forming a transverse zig-zag passage which serves as an arc-elongating and arc-suppressing chamber 43. As the arc is moved from the arc recess chamber 27' into this arc-suppressing chamber 43 and thence to the rear of the unit 10, the length of the passage from one electrode to the other gradually increases as the ribs get higher; and until the arc reaches the space 32 between the parallel portions 31' of the walls of the ribs, the passage gets gradually narrower. The cooling effect of the wall surfaces increases as the length of the passage increases.

The magnetic control means

The movement of the arc from the gap 42 into the passage or chamber 43 will be explained after first describing the magnetic control means 11 which produce

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the magnetic field. Each means includes the coil 49 and non-linear protective means in the form of gap 50; the coil 49 being so wound as to rest upon and be interspersed with the arc interrupting units 10 and is positioned in a casing 51 of insulating material such as a suitable plastic. The plane of the coil is parallel to the plane of the arc interrupting units 10 with its axis coinciding with the axis of the units 10.

The opening 52 of the casing is closed by metal discs 53 held against opposite faces of the casing. Figure 13 shows the lower face of the magnetic control means 11. The terminals 54 and 55 of the coil 49 are electrically connected to the discs respectively as shown in Figs. 13 and 14 as by soldering.

Each disc 53 is provided with three turned-in lugs 56 which center the discs with respect to the casing 51 and each disc is also provided with a short radial slot 57 to accommodate the coil terminals. In assembling the arrester parts this slot is made to coincide with the slot 36' in the disc 36 of the adjacent arc interrupting element 10.

The protective gap 50 comprises an annular and inwardly depressed portion of each disc 53 with a less-depressed flat central portion 59, the annular and inwardly depressed portions forming a pair of spaced and annular gap members 58. A third gap member 60 in the form of a flat metal disc is positioned between the gap members 58 in spaced relation thereto. The disc 60 is supported in insulated relation to the discs 53 and to the annular gap members 58 by ceramic spacers 61 (Fig. 15) preferably porcelain, thereby forming two series gaps shunting the coil winding. Projections at the center of the spacers 61 engage a central hole in member 60, holding it in place.

Movement of arc into arc-suppressing chamber

In order to move the arc into the arc-suppressing chamber 43 it is necessary that the coils of the magnetic control means 11 be so wound that their axial magnetic field is of opposite polarity to the field produced by the arc itself on the side of the arc nearest the arc-suppressing chamber. The current through the arrester may be of either polarity. Figure 2 assumes positive current flowing downward through the arrester. Referring to Fig. 6, this same current would flow through the solder patches 37 of the upper block down through the prongs 35 into the right-hand electrode. On formation of an arc, the arc strikes from this electrode to the left-hand electrode, and thence down through the other arrester elements. In this case the field produced around the arc moves down on the side of the arc nearest the arc-suppressing chamber, then under the arc and up on the opposite side (which is the side at the bottom of Fig. 6).

The coils are wound in a counterclockwise direction starting from the lead at the top of each coil. This produces a magnetic field up through the arrester, as shown by the arrows F of Fig. 2.

When an arc forms across the main or heavy-duty arc gap 42 (Fig. 6) between the electrode ends 38 it will be confined for an instant only in the arc recess chamber 27' (Fig. 10) and will then immediately be directed into the arc-suppressing chamber 43 through the action of the magnetic field set up by the magnetic control means 11. The arc will be driven into the arc-suppressing chamber 43 at right angles to the direction of its original orientation in the arc recess chamber 27' between the electrodes 38.

As the arc moves into the passage 43 it is spread out, greatly lengthened and attenuated which, together with the effect of its contact with the cooling surfaces of the ribs, causes the arc to be finally suppressed as it moves through the narrow passages of the arc-suppressing chamber 43.

The arc-confining ledges 28' and 28'' prevent the ends of the arc from terminating on the edges or back sides

of the electrodes. Once the arc ends terminate on or beyond the electrode edges it becomes extremely difficult for the magnetic field to correct this condition in order that the arc can move properly into the arc-suppressing chamber. It has been found that by keeping the solid insulating surfaces (preferably porcelain or glass) no more than .20 inch from the electrode edges in the arc recess chamber this unwanted termination of the arc ends can be prevented so that the arc contacts only the electrode faces. The surfaces 28' and 28'' are at different levels and the end wall 28 of each insulating body is stepped at 27'' because each electrode 34 must at all points be separated by a certain minimum of atmosphere from the porcelain body to which it is not fastened. The electrode 34 can touch its own insulating body without harm. This is explained under "Electrode mounting."

Electrode mounting

In the gap herein disclosed, the upper porcelain body 25 and the upper electrode 34 of each interrupting unit 10, tend to be at the same potential because the porcelain body makes broad contact with the metallic contact disc 36 to which the electrode is secured. The same is true of the lower body 26 and its electrode 34.

This means there is practically no potential difference between an electrode and the surface of the porcelain body in which it is mounted but almost full gap voltage appears between this electrode and the other porcelain body.

This voltage between an electrode and the insulating body to which it is not fastened will cause corona at a voltage level depending upon the shapes of the electrode and insulating body in the region of proximity as well as the minimum distance between the two. If they are not separated sufficiently, corona will occur at the ordinary power frequency voltage level of the gap. This cannot be tolerated since it would cause continuous radio interference. By separating the two by a controlled thickness of atmosphere the voltage level at which corona starts can be made higher than normal gap power frequency operating voltage. To accomplish this the groove 39 and the ledge 28'' of each body are made sufficiently wide and deep so that the electrode of either body is at all points separated from contacting the other insulating body by a controlled thickness of atmosphere. The front wall 23 of the arc cavity 27 is stepped at 27'' in order to provide a like thickness of atmosphere between this wall and the mating electrode.

When the electrode 34 is of too stiff metal, the sudden pressure within the recess 27' resulting from an arc, acts upon the arc or free end of the electrode thereby transmitting such pressure directly to the body at the bight 34' (Fig. 6) in the form of an impact blow; the clearance between the electrode and body at 34' is very small or may not exist at all. The tendency of this impact blow is to break the body, but by making the arc end of the electrode free as already described and forming the electrode from rolled metal (preferably copper) and of such size and temper as will permit the free end of the electrode to yield under the sudden pressure within the recess 27', breakage of the body is prevented.

Grading resistors

Each insulating body 25 and 26 is provided with two transverse cylindrical pockets 40 which register with the pockets 40 of the other body to form the two pockets 40' (Fig. 6) and in each pocket 40' is positioned a grading resistor 41, each sufficiently long to nearly equal the length of a pocket 40' between the discs 36; in order to assure electrical connection of each resistor 41 with the two discs, a spring element 41' is interposed between each resistor and at least one disc as shown in Figs. 6 and 10. This construction assures the gap 42 formed by the electrodes 34 to be shunted by the two grading resistors 41 in parallel when the blocks are assembled.

Difference in current flow under normal conditions, during surge, and during follow current

The current flow through the arrester under normal conditions, that is, while the arrester is not functioning under surge conditions, is represented by the broken (dashed) arrow lines in Fig. 2; the only current flowing is the small amount of about 1/2 milliampere permitted by the grading resistors 41 which is a sufficient flow of current down through the protective pile A (Fig. 1) and in shunt with the arrester gaps to supply capacity current to ground without having this current cause uneven voltage drop across the different individual gaps 42. Under this normal operation the grading resistors 41 which are of special resistance material are by far the highest impedance of the series circuit consisting of valve blocks 9, coils 49 and grading resistors 41. Therefore, substantially the entire normal 60-cycle voltage between line and ground appears across the resistors and hence across the associated gap 42.

When a high voltage surge affects the line, the path of the current is indicated by the dotted arrow lines. In this case the inductive impedance of the coils 49 of the magnetic control means 11 is so great that the high current, high frequency lightning surge generates sufficient voltage to sparkover the coil protective gaps 50. These gaps 50 protect the insulation of the associated coil 49 from puncture due to the excess voltage across the coil 49. The resistance of the grading resistors 41 is so high that a current of even a substantial fraction of one ampere will cause a sufficient voltage drop across the resistors to sparkover the gap 42.

During this condition, substantially all the arrester voltage is across the valve blocks 9, since the other series elements are short-circuited by gaps 42 and 50.

After passage of the high-frequency surge current and during normal follow current flow, the current path is indicated by the solid arrow line. The 60-cycle impedance of the coils 49 is sufficiently low that the follow current prefers to go substantially through the coils rather than continue through their protective gaps 50. The flow of follow current through the coils produces the axial field shown by the long broken arrow lines F (Fig. 2), and this field results in movement of the arc from the main or arc gap 42 between the electrode ends 38 into the enclosed arc-suppressing chamber 43 (Figs. 8 and 11) of the arc interrupting unit 10 formed by the interleaved ribs 31 where the arc is finally suppressed.

The shunted magnetic control means

The protective gaps 50 are preferably provided with two series breaks which is superior to a single break gap as it insures sufficient arc voltage in the gap to cause low frequency currents to go through the coil 49 thus generating the magnetic field necessary for moving the arc from the gap 42 into the arc-suppressing chamber 43 of the arc interrupting unit 10.

The protective gap 50, in normal operation, sparks over only on impulse current, the low frequency follow current preferring to go entirely through the coil. However, during the flow of certain types of long duration surges (lasting, for example, longer than 100 microseconds), the surge current may continue to flow through the shunting or protective gap 50 during a considerable portion of the follow current, and the coil protective gap thus short-circuits the coil while the coil is supposed to be generating a magnetic field.

The voltage across the single gap is about 20 volts, somewhat independent of the current magnitude; so, while the gap is conducting there is about 20 volts forcing current through the coil. In the arrester disclosed herein, the normal power follow current is about 200 crest amperes and this current flows through the coil 49, producing the magnetic field to move the arc.

With a single gap protecting the coil 49, the coil current resulting from the coil gap voltage is so low that the arc

in the main gap 42 is not assured of sufficiently rapid movement. Therefore, the herein described arrester is equipped with two gaps in series to protect each coil and this increased gap arc voltage at 50 forces sufficient current through the coil to move the arc in the gap 42 even when the gap 50 continues to conduct as the result of a long duration lightning surge.

It is preferred that the impedance of the coil 49 and its protective gap 50 be proportioned so that the current through the coil, when the protective gap is conducting long duration surge currents, will be at least 20 percent of that which occurs during normal follow current flow when the protective gap 50 is not conducting.

For example, in the arrangement of the coil and gap shown in Fig. 1, with a normal arrester follow current of about 200 crest amperes current (as described above), each coil may have between 50 and 100 turns of wire. The use of a double gap at 50 rather than a single gap to shunt this coil assures that at least 40 amperes (20 percent of 200 amperes) flows through the coil while the gap is conducting long duration lightning currents.

Another and perhaps more effective non-linear means of approaching relatively constant current through the coil is illustrated in Fig. 16. Here the coil is shown protected by a valve-resistance element 50' rather than a gap. This valve resistor is of similar characteristics to the elements 9 of Figs. 1 and 2—that is, the voltage occurring across it changes but little with large variations in current through it.

Thus the voltage appearing across the coil while the arrester is conducting surge currents or power frequency follow currents is relatively constant. Therefore, the current through the coil and the resulting magnetic field is quite constant regardless of variations in follow current magnitude or the presence or absence of long duration surge currents.

This principle of shunting the field-producing coil by a non-linear resistance or impedance can be used advantageously in other current interrupters such as certain types of circuit breakers, etc.

Electrode connections

When the impulse which sparks over the main or arc gap 42 is of high current, the blast of expanding gas assists the magnetic field set up by the coil 49 in moving the arc toward the arc-suppressing chamber 43. This is undesirable since, if the effect of the coil is sufficient to satisfactorily move the arc, the effect of the gas blast added to the sufficiency of the coil may be great enough to move the arc completely out the rear end of the chamber 43 unless means to counteract the gas blast is present.

This effect of the gas blast is overcome to some extent by bringing the current connections to the electrodes 34 at a point remote from the discharge ends 38 of the electrodes as shown in Figs. 6 and 9 since the flow of current in the electrodes tends to set up a field counter to that of the coils.

During normal follow current flow, the field set up by the current in the electrodes 34 is insignificant compared to the field set up by the coil 49 and does not adversely affect the movement of the arc by the coil.

During the flow of high current due to impulse, which sparks over the gap 42 and before the field has built up sufficiently in the coil due to the high inductance of the coil, the magnetic-field effect of current flow in the electrodes tends to predominate. Thus the tendency of the expanding gases to blow the arc toward the arc-suppressing chamber 43 is counteracted by the magnetic field of the electrodes tending to start the arc in the wrong direction.

Lengthening arc permits use of smaller valve block

A number of lightning arresters now in commercial use employ an arc gap and a valve block of the voltage sensitive or non-linear type in which the resistance de-

creases as the voltage impressed thereon increases and vice versa. Such an arrester assembly is disclosed in my Patent 2,640,096. The arresters covered by this patent and the present application have features in common, but the arrester covered by my present application also has much greater capacity and improved operation due to the novel and improved features of construction.

The manner in which the valve block performs also affects the value of current flowing through it which increases or decreases as the resistance of the block decreases or increases respectively. The resistance of the valve block is much lower when both the current due to high frequency surges and the power follow current are flowing through it.

It is desirable to use a short valve block having a normal low resistance as the lower the resistance the better the protection the arrester offers and the discharge voltage during lightning is lower, however if the block is too short it allows too much voltage stress and current flow during the follow current. This causes failure of the block.

Therefore, having established the basic characteristic of the valve element to best meet requirements, the protection which the arrester can afford is dependent upon the maximum voltage gradient which can be allowed across the valve block during the flow of power follow current.

When lightning strikes the line, a large high frequency surge flows through it, thus raising the voltage thereon with respect to the ground in which case the arc gaps sparkover, the voltage across the gap is very low, being in the order of 20 volts per single gap regardless of the current. Therefore, almost the entire 60-cycle system voltage during follow current flow is across the valve element (see Fig. 17a).

In the commercial arrester referred to above which is of the conventional valve type, the valve blocks (60 mm. high) are used at a maximum rating of 4.7 kv. R. M. S. (6.65 kv. crest), a value arbitrarily chosen, per block. Each block has, in general, four arc gaps in series with it; therefore, during follow current flow the gap element has about an 80 volt drop (4×20), so that the valve element has about 6.57 kv. crest (6.65—.08) across it. A shorter than 60 mm. block would give better protection but as stated above would fail too easily.

If we now consider replacing the four regular arc gaps of the said commercial arrester which are in series with each block by an arc gap 10 of the described heavy-duty type, the voltage division between gap and valve element will be the same as in the said commercial arrester until the gap sparks over. When the gap first sparks over, the voltage of the gap arc is very low, but as the arc is swept into the arc-suppressing chamber 43 by the magnetic field resulting from the energization of coil 49, a relatively steady arc voltage is generated of about 1,000 volts crest as the result of lengthening the arc. This means there is only 5.65 kv. crest (6.65—1.00) across the block instead of 6.57 kv. crest as in the said commercial or other conventional type arc gaps. This allows one to shorten the valve block until the voltage gradient is the same (4.7 kv. per 60 mm. length) as with the said commercial gap. This shorter block means lower total resistance and better protection.

The principle of generating high arc voltage by lengthening and confining the original arc is well known. However, the use of such an arc in an arrester with valve-resistance elements is novel and by providing for an increase in the arc length sufficient to produce a substantial reduction in the voltage across the resistors so as to permit the use of relatively short resistors is novel in a lightning arrester. The reduction in average voltage across the resistors during power follow current contemplated by this invention may be as much as 10 percent or even considerably more, as illustrated by the conditions set forth in the foregoing example.

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To generate significant voltage in an arc suppressing chamber composed of porcelain or similar inert material and still protect against overvoltage satisfactorily with the main gap 42, it was found that the arc length must be at least about forty times as great in the arc-suppressing chamber 43 as in the main gap 42. In the device illustrated the length of the gap 42 is about 0.140 inch and the length of the arc in the zig-zag suppressing chamber 43 is about six inches or 40 times the length of the arc gap 42. A device which provides for lengthening the arc to an appreciably less final length could be made provided the insulating surfaces in the arc suppressing chamber could be spaced sufficiently close to provide more rapid cooling than in the device herein described more particularly. However, this closer spacing results in malfunctioning as described in the following section of the specification.

Figures 17a and 18a are voltage diagrams of the performance respectively of the said commercial arrester referred to above using a conventional type of arc gap and the herein described arrester using the main gap 10 shown in Figs. 6 to 12 inclusive. The heavy line represents the 60-cycle system voltage, the dashed lines represent the voltage appearing across the gap elements and the dotted lines represent the voltage appearing across the valve elements. During the follow current flow, the voltage across the valve element in the said commercial arrester and the herein disclosed arrester using the main gap are represented respectively by the hatched areas in Figs. 17a and 18a.

Cooling arc in arc-suppressing chamber

The relatively high arc voltages obtainable with the gap herein described are generated in the following manner:

An arc loses thermal energy by dissipation of the heat generated in the arc column. The rate of this energy loss is a measure of power loss in the arc. This power loss must be equaled by a power input from the electric circuit or the arc will not be maintained. In an electric circuit instantaneous power is equal to the instantaneous product of voltage and current. Therefore, if an arc current is I amperes, the arc voltage V will automatically become sufficient to make $I \times V$ in watts equal to the rate of arc heat loss in watts.

In the more common open air gap the heat loss in the arc is relatively low for a given length of gap, being limited to ordinary radiation and convection. In the gap herein disclosed, the arc is lengthened and forced between the closely spaced walls of relatively inert insulation, such as porcelain. The intimate contact between the arc column and the walls results in very rapid heat transfer; that is, heat loss which must be supplied from the electric circuit to which the arrester is connected. This means that the arc voltage must become relatively high in order that the electrical input IV can equal the rate of arc heat loss.

The arc interrupting unit 10 possesses novel features of construction which tend toward protecting the arc-suppressing chamber 43 against lightning damage. If a high current lightning surge flows through the arc-suppressing chamber 43, the interrupting unit 10 will be destroyed because the long confined path which the arc follows will result in so much pressure that the porcelain body will be shattered. Such a situation is possible if one of the secondary strokes of a multiple-stroke is discharged by the arrester after the arc has been swept from the arc recess chamber 27' into the arc-suppressing chamber 43.

By properly proportioning the spacing of the surfaces included in the arc-suppressing chamber 43, the voltage generated within the chamber by the passage of a current surge can be made great enough to cause the starting gap to restrike before the current in the suppressing chamber 43 has built up to damaging magnitudes.

In the arc interrupting unit 10 the surfaces 29 of the walls of the arc-suppressing chamber 43 do not converge

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neither are they parallel, but rather they diverge, and while the side faces of the portion 31' of the ribs 31 which project from the surfaces 29 are tapered for a short distance away from the restricted opening adjacent the arc recess chamber 27', the parallel faces of the portions 31'' of the ribs are spaced quite close.

If now the interrupting unit 10 is made of porcelain or similar inert material and the spacing between the faces of the portions 31'' of the ribs has been made an average of 20 mils, and the developed arc length has been at least .30 inch per 1 kv. R. M. S. sparkover voltage of the starting gap 42, the interrupting unit 10 will be self-protecting and at the same time the arc will be confined and lengthened, thus removing significant voltage from across the valve element during following current flow.

It has been found that if the arc interrupting unit 10 is made of porcelain or similar inert insulation of comparable mechanical characteristics, the adjacent surfaces of the said spaced ribs 32'' should approach a spacing within the suppressing chamber 43 of 10 to 30 mils and a developed arc length of more than .30 inch per 1 kv. R. M. S. of starting gap sparkover voltage.

If the said surfaces within the arc-suppressing chamber are spaced apart more than 30 mils, it would be necessary to make the suppressing chamber 43 impractically large in order to generate sufficient arc voltage during a power follow current to be of significant benefit to the valve block. If, on the other hand, the average surface spacing is less than 10 mils, there is too much danger of the arc stopping at a point of close clearance and heating the surface to incandescence thus causing failure.

The spacing of the surfaces of the arc suppressing chamber 43 has been described as being substantially constant over most of its length, that is the spacing between the walls 31'' should be maintained between 10 and 30 mils.

If the ribs 31 are gradually thickened in the region 31'' so that the space between them becomes less than 10 mils near the rear of the chamber the interrupting unit will not function properly in combination with a valve resistor element. In such circumstances the arc will become stationary during power follow current flow where the spacing has become too close and will overheat and contaminate with electrode vapors this localized strip of the chamber surfaces while the power follow current continues to flow until its normal zero point. This destroys the current interrupting ability of the unit.

It is to be understood that the foregoing description is not intended to restrict the scope of the invention and that various rearrangements of the parts and modifications of the design may be resorted to. The following claims are directed to combinations of elements which embody the invention or inventions of this application.

What I claim is:

1. A lightning arrester which comprises a tubular housing of insulating material with metallic terminal means at each end of the housing, a control pile positioned within the housing, the pile comprising the series connection of a plurality of voltage sensitive valve blocks and a plurality of electro-magnetically controlled arc interrupting units having near the arc extinguishing point an appreciable voltage drop relative to the voltage drop of said valve blocks, each arc interrupting unit comprising a pair of chambered insulating bodies of vitreous material in registering relation, each pair of bodies in assembled relation having parallel faces at right angles to the longitudinal axis of the pile and an arc recess chamber positioned at one side of the assembled bodies and substantially closed to the arrester atmosphere, a pair of gap electrodes with spaced terminals within the arc recess chamber forming a fixed arc gap, an arc suppressing chamber connected to the arc recess by a restricted opening, a plurality of ribs integral with each

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body and extending from the said opening to and through the opposite side of the assembled bodies, the ribs being substantially parallel and interleaved with restricted spaces between adjacent ribs through which spaces an arc formed in the arc recess chamber is passed whereby the arc is materially lengthened and eventually suppressed, the spaces opening to arrester atmosphere at the said opposite side of the assembled bodies and means partially closing the said openings, electro-magnetic control means associated with at least one face of each arc interrupting unit and comprising a coil in series connection with the electrodes of the arc interrupting unit, the plane of the coil being parallel to the arcing plane of the gap electrodes for moving an arc between the electrodes into the arc suppressing chamber and a non-linear resistor means in shunt with each coil for limiting the current through the coil and controlling the movement of the arc.

2. A lightning arrester comprising a tubular housing of insulating material, metallic terminal means at each end of the housing, a control pile comprising a valve block positioned in the housing and electrically connected with the terminal means, a magnetically controlled arc interrupting unit having near the arc extinguishing point, an appreciable voltage drop relative to the voltage drop of said valve block, comprising a pair of enclosure bodies having a longitudinal axis which is common with the axis of the housing, the arc interrupting unit having a pair of spaced and fixed electrodes in a plane at right angles to the said axis and forming a fixed arc gap, each unit having an arc suppressing chamber extending transversely of the axis from the arc gap with interleaving ribs for lengthening the arc upon transverse movement thereof and a restricted opening adjacent the arc gap through which an arc formed at the arc gap may move into the arc suppressing chamber, coil means associated with the arc interrupting unit arranged in a plane perpendicular to the axis and connected to one electrode to produce a magnetic field along the axis and perpendicular to the electrode plane under arcing conditions to move the arc transversely into the arc suppressing chamber, and a protecting gap in shunt with the coil whereby sufficient arc voltage is insured in the gaps to cause low frequency currents to flow through the associated coil thereby effecting the necessary magnetic field for moving the arc from the arc gap into the arc suppressing chamber.

3. An arc interrupting unit comprising a pair of like registering bodies of inert rigid insulating material forming an arc recess chamber and an arc suppressing chamber connected by a restricted passage with converging surfaces from the recess chamber to the restricted passage, a pair of spaced electrodes positioned between the said bodies forming an arc gap of fixed length within the gap recess chamber at the one ends thereof and the remaining ends diverging along the outside of the passage and arc suppressing chamber, the arc suppressing chamber having opposed diverging surfaces between the electrodes and starting at the restricted passage to receive the arc formed at the arc gap, a plurality of interleaved ribs integrally formed on each body and extending inward toward the said opposed diverging surfaces, each rib increasing in height proceeding from the passage and defining with the diverging surfaces of the bodies an arc path of increasing length between the electrodes.

4. An arc interrupting unit for a lightning arrester comprising a pair of like registering bodies of insulating material with parallel exterior faces normal to the axis of the bodies, the bodies forming an arc recess chamber and an arc suppressing chamber connected thereto by a restricted passage, metallic terminal means substantially covering the parallel faces, a pair of spaced metallic gap electrodes positioned between the said bodies with the one ends thereof disposed within the gap recess chamber to constitute an arc gap and the remaining ends diver-

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ing along the outside of the passage and arc suppressing chamber, the arc suppressing chamber having opposed diverging surfaces starting at the restricted passage to receive the arc formed at the arc gap, and means to counteract the blast of expanding gases set up by the arc at the arc gap under high current conditions, the said means comprising conductor means electrically connecting the said remaining ends of the horn gap electrodes remote from the arc gap to the said terminal means.

5. In a lightning arrester, a valve block, an arc interrupting unit having two divergent electrodes constituting an arc gap adjacent the ends thereof, and in series therewith magnetic control means for producing a magnetic field in the arc interrupting unit adapted to move an arc therein between the electrodes, the magnetic control means including a coil parallel to the arcing plane of the electrodes and a plurality of gaps in series relation shunted across the terminals of the coil.

6. A protective device for discharging impulses induced in an energized conductor system, comprising an elongate ceramic housing having an open interior, metallic closure means at each end of the housing and constituting terminal means for the device, and a plurality of elements disposed in serial relation between the terminal means with spring means for holding the said elements in electro-conductive relationship, the said elements comprising at least a valve block, an arc interrupting unit, and a magnetic control unit associated therewith, the arc interrupting unit comprising two registering ceramic members having terminal plates on the outward faces thereof, each ceramic member having a gap electrode supported by the member and connected to the associated terminal plate for mutual positioning relationship, the said electrode having the one end thereof formed as an arc face to cooperate with the electrode of the associated member to form an arc path in a plane normal to the axis of the elements and the housing, and the two electrodes diverging to form an arc path of increasing length as an arc moves away from the arc faces along the electrodes, interleaved ribs on the two ceramic members with the ribs increasing in height away from the arc faces to form a sinuous arc path between the gap electrodes of increasing length away from the arc faces, and the magnetic control unit comprising a coil with the plane thereof parallel to the arc path of the interrupting unit and having conductive plates disposed on opposite sides thereof in engagement with the adjacent elements to connect the coil in series with those elements, and non-linear conductive means in shunt with the coil for providing a low impedance path to impulsive discharges and a high impedance path to system energizing currents.

7. The invention in accordance with claim 6, with axial recesses in the registering ceramic members and grading resistors received in the recesses and contacting the terminal plates to constitute a grading means for the gap electrodes.

8. A gap unit for a lightning arrester comprising two similar ceramic bodies in opposed cooperative relationship, each body comprising a generally circular base part, a gap chamber part integral with the base part on one side thereof and extending axially upward and transversely from the base part, the gap chamber part having two elongated electrode recesses inwardly from the face thereof with the two electrode recesses joined at one end to form an arc recess and then separating and spreading outwardly at points transversely across the body from the arc recess, an elevated part to form a restricted entrance opening and a plurality of axially projecting ribs tapered upwardly with the gap chamber part between the ribs sloping downward from the elevated part to form an arc suppressing chamber, all disposed between the electrode recesses, an integral holding part projecting axially upward on one side of the gap chamber part and a holding recess defined by the base part and the gap

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chamber part on the opposite side of the gap chamber part each outwardly from the associated electrode recess, two gap electrodes each disposed in an electrode recess of one of the bodies and comprising an elongated metallic member having an arc face formed at one end thereof in the arc recess and a lug at the remaining end extending through an opening axially through the base part from the bottom of the recess to the external face of the base part and a metallic plate disposed over the outer face of each of the base parts and connected to the associated lug and constituting a terminal for the gap unit, the two bodies having the holding part of each part received in the holding recess of the other body with the recesses of the two bodies in registering relationship and the ribs in interleaved spaced parallel relationship for receiving and elongating an arc formed between the arc faces upon movement thereof along the electrodes through the restricted opening and into the arc suppressing chamber.

9. The invention in accordance with claim 8 in which the portions of the two chamber parts between the gap members at first converge and then diverge between the ribs proceeding transversely across the body from the arc recess.

10. The invention in accordance with claim 8 in which the ribs are tapered at the entrance portion of the arc suppressing chamber to facilitate entrance of the arc into the confined space between the ribs.

11. The invention in accordance with claim 8 in which the ribs extend to the lateral extremity of the chamber part with substantially uniform spacing between the surfaces of the ribs and the cooperating part and have cooperating enlarged end portions for providing an abrupt reduction in the cross section of the arc path.

12. The invention in accordance with claim 11 in which the enlarged portions at the ends of the ribs are spaced slightly to provide an escape for ionized gases and the openings thereof are covered with a layer of glass cloth to provide a barrier to prevent escape of the arc.

13. The invention in accordance with claim 8 in which the lug of the gap member and the metallic plate are bonded each to the other in mutual positioning and restraining relationship.

14. The invention in accordance with claim 8 in which the said bodies have aligned axially directed openings extending to the outer faces of the base parts, and resistor means positioned in the opening and in electrical contact with the metallic plates and constituting a grading resistor for the said gap unit.

15. An arc interrupting unit for a lightning arrester, comprising a pair of bodies of inert rigid insulating material forming an enclosure when assembled in registering relation, a pair of electrodes positioned in fixed relation between the bodies forming an arc gap adjacent one edge of the unit and diverging in a direction transversely across the bodies, an arc suppressing chamber formed by the bodies between the diverging portions of the electrodes comprising oppositely disposed side walls having diverging surfaces, the walls forming a restricted passage at the point of minimum divergence adjacent the arc gap and converging surfaces on the arc gap side of the restricted passage, a plurality of upstanding ribs extending through the chamber in the direction of the electrodes and perpendicular to an arc between the electrodes integrally formed with the bodies and increasing in height from adjacent the restricted passage toward the transverse extremity thereof for increasing the length of an arc moved outwardly along the electrodes from the arc gap and means at the transverse extremities of the ribs partially closing the openings between the ribs for confining an arc within the unit.

16. The invention in accordance with claim 15, in which the last named means includes a strip of glass

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cloth attached to the bodies about the exterior thereof and covering the openings.

17. In a lightning arrester having an elongated housing of ceramic material with a longitudinal opening therein and a stack of arrester elements within the opening, a gap unit in the stack comprising two opposed bodies of rigid inert insulating material registering generally in a plane perpendicular to the longitudinal axis of the housing and the said two bodies having the adjacent surfaces thereof formed to constitute an arc recess adjacent one transverse extremity of the unit and an arc suppressing chamber extending from the arc recess to the opposite extremity of the unit with radially extending passages opening at the sides of the bodies, and a sheet of porous glass cloth attached to the two bodies and covering the passages for preventing escape of an arc from within the unit to the opening in the housing.

18. A protective device for discharging impulses induced in an energized conductor system, including a valve block comprising a non-linear valve resistor, a gap unit comprising two metallic electrodes having the first ends thereof opposed to constitute a fixed arc gap and the remaining ends of the two electrodes diverging in the plane of the arc gap at an angle of less than 180° , a coil arranged in a plane parallel to the plane of the arc gap and adjacent the electrodes for producing a magnetic field to move an arc established in the arc gap outwardly along the diverging portions of the electrodes and thereby continuously elongate the arc, arc suppressing means comprising members of rigid inert insulating material arranged at least between the diverging portions of the electrodes having opposed faces thereof spaced apart for receiving and dissipating the energy of an arc elongated between the electrodes and an entrance part adjacent the arc gap for facilitating entry of the arc between the members, a series connection between the said valve block, gap electrodes and coil for connection between a conductor of the conductor system and ground and non-linear conductive means in shunt with the coil for providing a low impedance path to impulsive discharges and a high impedance path to system energizing currents.

19. The invention in accordance with claim 18, in which the impedance of the coil to impulses is greater than the impedance of the non-linear conductive means such that the current through the coil, when the conductive means is discharging impulses, is at least 20% of the current through the coil when the arrester is discharging power follow current for initiating arc movement during impulsive discharges.

20. A protective device for discharging impulses induced in an energizing conductor system, comprising an elongate ceramic housing having an open interior, metallic closure means at each end of the housing and constituting terminal means for the device and a plurality of elements stacked within the housing with conductive means electrically connecting the elements in series between the terminal means, the said elements comprising at least a valve block, an arc interrupting unit and a magnetic control unit associated therewith, the arc interrupting unit including two registering members of rigid inert insulating material and each member carrying a gap electrode having one end thereof formed as an arc face to cooperate with the electrode of the associated member to form an arc path in a plane normal to the axis of the elements, the two electrodes diverging in the plane of the arc faces for continuously lengthening an arc moved from the arc faces along the electrodes, means comprising cooperating surfaces of the two registering members spaced apart between the divergent portions of the electrodes and extending generally in the direction of arc movement between the electrodes to constitute an arc suppressing chamber for dissipating the energy of an arc moved along the electrodes, an enlarged arc recess in the registering members about the arc faces and con-

verging entrance portions from the arc recess to the arc suppressing chamber to facilitate movement of the arc along the electrodes into the arc suppressing chamber and the magnetic control unit comprising a coil with the plane thereof parallel to the arc path of the interrupting unit and having non-linear conductive means in shunt with the coil for providing a low impedance path to impulsive discharges and a high impedance path to system energizing currents.

21. The invention in accordance with claim 20, in which the divergent portions of the electrodes diverge at an angle substantially less than 180° for uniform continuous elongation of the arc.

22. The invention in accordance with claim 21, in which the electrodes diverge to a spacing of at least $\frac{3}{10}$ inch per kilovolt R. M. S. sparkover voltage at the arc faces and portions of the registering members between the diverging portions of the electrodes are spaced apart more than about 10 mils and less than about 30 mils such that the rate of energy removal from an arc in the suppressing chamber, due to the conduction of a subsequent high current impulse through an initial arc, produces an arc voltage greater than the arc voltage of the arc faces and thereby causing the gap to restrike at the arc faces.

23. A gap unit for a lightning arrester, comprising two similar ceramic bodies in opposed cooperative relationship, each formed on the adjacent side thereof with two elongated electrode recesses extending from adjacent one transverse extremity across the body with the two electrode recesses joined at one end and forming an enlarged arc recess and then separating and spreading outwardly at points transversely across the body from the arc recess, an elevated part to form a restricted entrance opening adjacent the arc recess with the walls of the bodies converging smoothly from the arc recess to the elevated part, a divergently depressed portion beyond the elevated part to form a suppressing chamber and a plurality of parallel axially projecting ribs extending through the suppressing chamber to the remaining transverse extremity of the body with the ribs increasing in height above the divergent portions proceeding from the elevated part to the said transverse extremity, two gap electrodes each disposed in an electrode recess of one of the bodies and comprising an elongated metallic member having an arc face formed at one end thereof in the arc recess and the remaining end divergently formed and received within the recess, a terminal member on the outward side of the body and a metallic piece extending from the electrode through the body part to the terminal member for supporting and restraining the electrode and electrically connecting the electrode to the terminal member, the two bodies having the recesses and chamber parts thereof in opposed registering relationship and the ribs interleaved in spaced relationship for receiving and elongating an arc formed between the arc faces upon movement thereof along the electrodes through the restricted opening and into the arc suppressing chamber.

24. The invention in accordance with claim 23, in which the ribs are in plane parallel relationship and the spacing between the adjoining surfaces of the ribs and of the ribs and the body is more than about 10 mils and less than about 30 mils along the greater part of the length of the ribs.

25. The invention in accordance with claim 23, in which the ribs are in plane parallel relationship and the spacing between the adjoining surfaces of the ribs and of the ribs and the body is more than about 10 mils and less than about 30 mils and in which the electrodes diverge to a spacing of at least $\frac{3}{10}$ inch per kilovolt R. M. S. sparkover voltage of the arc faces.

26. The invention in accordance with claim 23, in which the ribs have enlarged end portions at the transverse extremity thereof for providing an abrupt reduction in the cross section of the passages between the ribs and

the passages are covered with glass cloth to provide a barrier for preventing the escape of an arc to the exterior of the gap unit.

27. A protective device for discharging impulses induced in an energized conductor system, including a valve block comprising a non-linear valve resistor, a gap unit comprising two metallic electrodes having the first ends thereof opposed to constitute a fixed arc gap and the remaining ends of the two electrodes diverging in the plane of the arc gap at an angle of less than 180° , a coil arranged in a plane parallel to the plane of the arc gap and adjacent the electrodes for producing a magnetic field to move an arc established in the arc gap outwardly along the diverging portions of the electrodes and thereby continuously elongate the arc, arc suppressing means comprising members of rigid inert insulating material arranged at least between the diverging portions of the electrodes having opposed faces thereof spaced apart more than about 10 mils and less than about 30 mils for receiving and dissipating the energy of an arc elongated between the electrodes and an entrance part adjacent the arc gap for facilitating entry of the arc between the members, a series connection between the said valve block, gap electrodes and coil for connection between a conductor of the conductor system and ground, and non-linear conductive means in shunt with the coil for providing a low impedance path to impulsive discharges and a high impedance path to system energizing currents.

28. A protective device for discharging impulses induced in an energized conductor system, including a valve block comprising a non-linear valve resistor, a gap unit comprising two metallic electrodes having the first ends thereof opposed to constitute a fixed arc gap and the remaining ends of the two electrodes diverging in the plane of the arc gap at an angle of less than 180° to a spacing of at least $\frac{3}{10}$ inch per kilovolt R. M. S. spark-over voltage at the arc faces, a coil arranged in a plane parallel to the plane of the arc gap and adjacent the electrodes for producing a magnetic field to move an arc established in the arc gap outwardly along the diverging portions of the electrodes and thereby continuously elongate the arc, arc suppressing means comprising members of rigid inert insulating material arranged at least between the diverging portions of the electrodes having opposed faces thereof spaced apart more than about 10 mils and less than about 30 mils for receiving and dissipating the energy of an arc elongated between the electrodes and an entrance part adjacent the arc gap for facilitating entry of the arc between the members, a series connection between the said valve block, gap electrodes and coil for connection between a conductor of the conductor system and ground and non-linear conductive means in shunt with the coil for providing a low impedance path to impulsive discharges and a high impedance path to system energizing currents, with the impedance of the coil to impulsive discharges greater than the impedance of the non-linear conductive means such that the current through the coil, when the conductive means is discharging impulses, is at least 20% of the current through the coil when the arrester is discharging power follow current.

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