

- [54] **SPARKGAP CHAMBER WITH ARC STRETCHING TEETH EMBODYING OPTIMUM HEAT SINK MEANS**

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[51] **Int. Cl.**.....H01j 29/84

[58] **Field of Search**.....313/231, DIG. 5, 325; 315/35,
315/36

[56] **References Cited**

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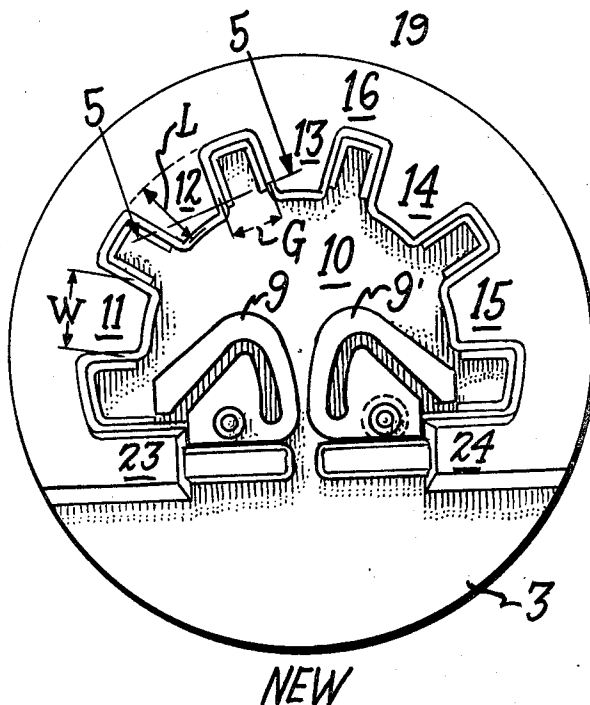
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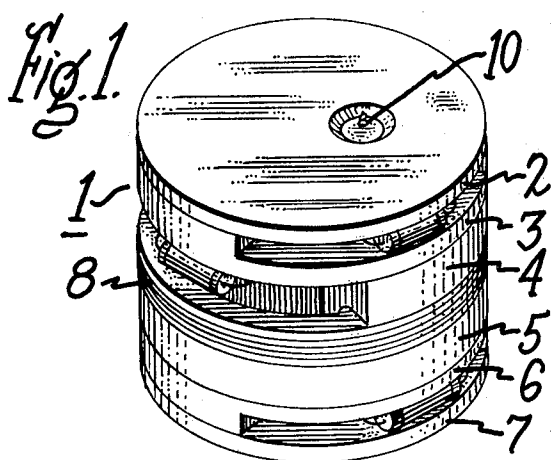
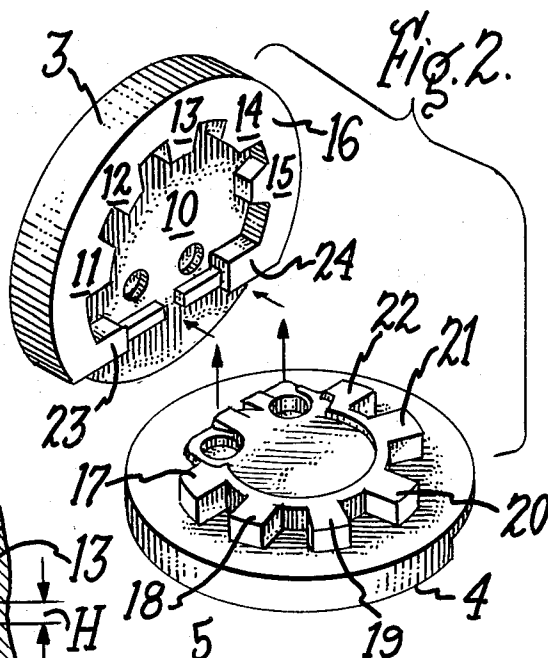
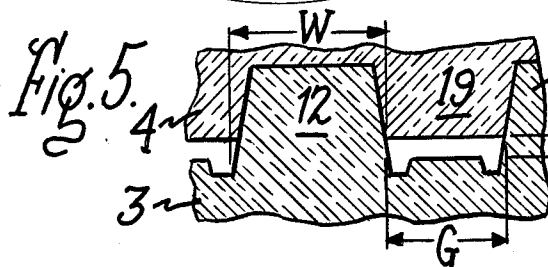
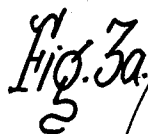
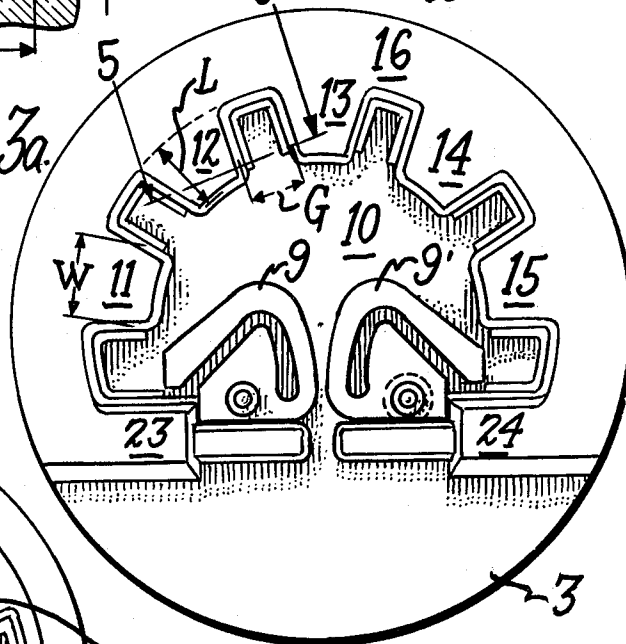
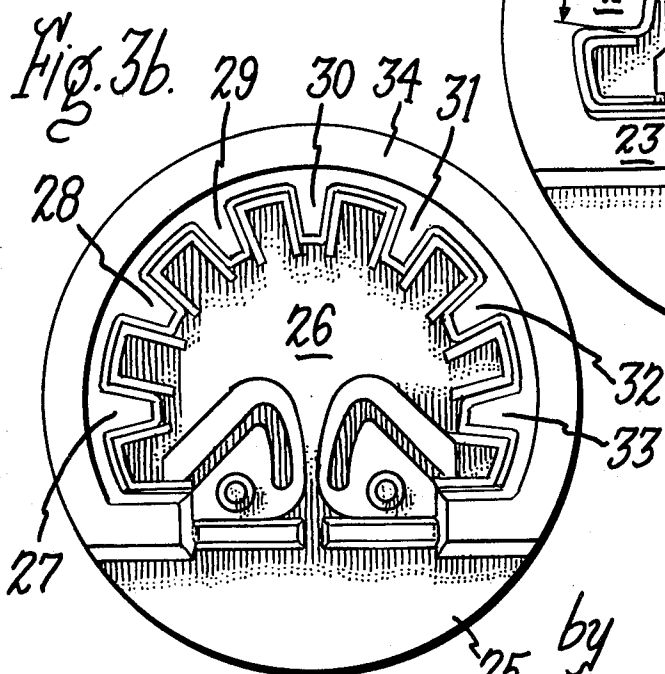
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[57] ABSTRACT

A sparkgap assembly for a surge voltage arrester is provided with arc-elongating teeth and arcing chamber wall means that, in combination, afford an optimum heat sink arrangement for cooling and extinguishing arcs formed therein by sparkover of the arrester. The characteristic heat sink means of the assembly operates to stabilize its mechanical and thermal characteristics so that the re-seal voltage of the arrester is increased without developing excessive arrester arc voltage, thus, affording performance characteristics that were not possible with prior art sparkgap assemblies.

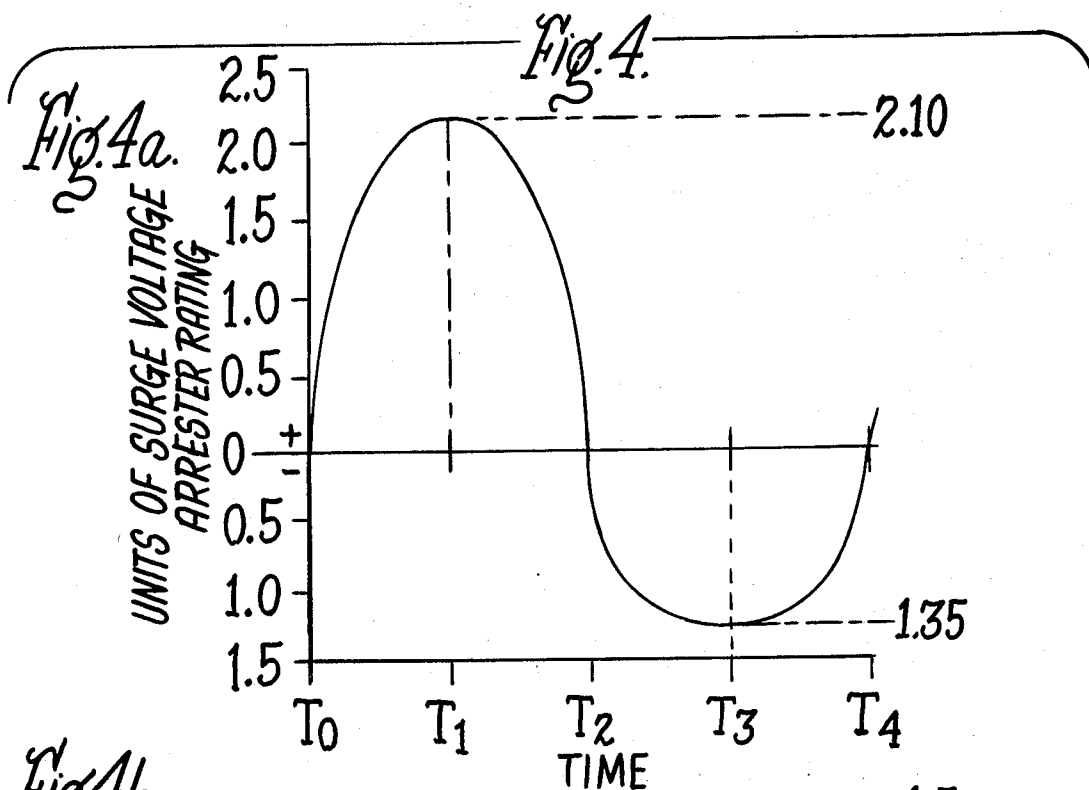
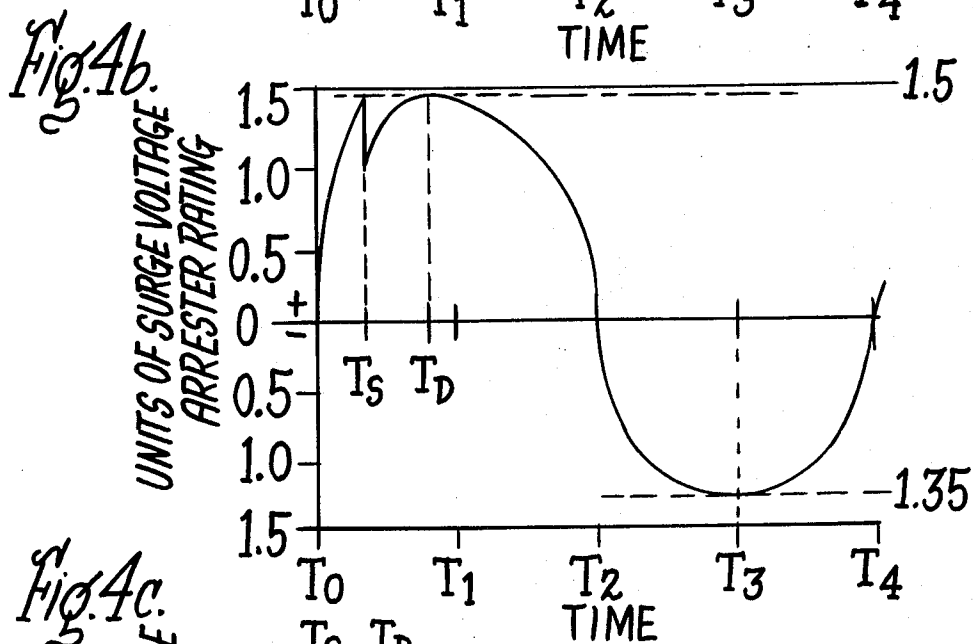
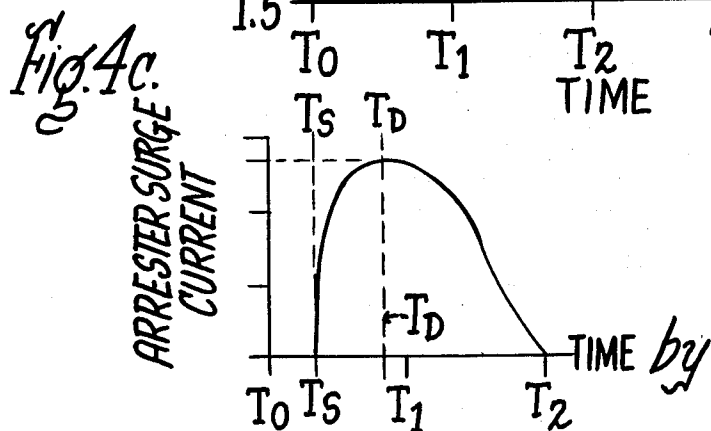
9 Claims, 9 Drawing Figures





PRIOR ART

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SPARKGAP CHAMBER WITH ARC STRETCHING TEETH EMBODYING OPTIMUM HEAT SINK MEANS

BACKGROUND OF THE INVENTION

The present invention relates to sparkgap assemblies and more particularly to improvements in the structural features of the type of such assemblies that find common application as surge voltage protectors for electric power transmission and distribution systems.

It is common practice in the design of electric power transmission and distribution systems to utilize surge voltage arresters at strategically located points throughout such systems to protect insulated electrical apparatus from damage that might otherwise be caused by peak voltages which inevitably occur periodically on the system. Such peak voltages are normally caused either by lightning striking portions of the system or by electrical transients created during system switching operations. On high voltage power transmission systems having line-to-line RMS voltages of about 230 kilovolts or greater, the energy dissipated by a surge voltage protector during switching surges usually exceeds that dissipated while discharging lightning impulses. Accordingly, it has now become common practice to design surge voltage arresters for such systems based on the maximum switching surge voltage that can be anticipated as possibly occurring on the system due to various combinations of transient current and voltage conditions resulting from predictable sequences of switching operations throughout the system. In other words, it is possible to design surge voltage arresters for such systems by analyzing its switching surge requirements, with the knowledge that an arrester suitable for discharging such switching surges will, generally, safely discharge any peak voltages caused on the system by lightning striking it.

In selecting surge voltage arresters for power systems, it is not only necessary to provide adequate protection for the system equipment but the surge arrester selected must also be able to withstand severe switching surges and then re-seal on the system voltage. The higher the rating of the arrester selected, the more re-seal capability it will have, but, of course, the arrester protective values are also increased. Therefore, in many instances the final arrester selected for a given application embodies operating characteristics that represent a compromise between these considerations. It is apparent then that an arrester having a relatively high re-seal capability, after a switching surge has been discharged through it, will permit the use of an arrester having a relatively low rating for a given application. Consequently, a better protective values are provided for the system by such an arrester. Furthermore, the ability of a surge arrester to maintain the level of its overvoltage re-seal capability relatively constant, after repeated switching surge discharges through it, is important in order to prevent arrester damage or failure following such switching surge discharges. Of course, significant economic advantages are also obtained for an electric utility company that can safely resort to the application of lower rated arresters for given application on its system.

A primary object of the present invention is to provide a sparkgap assembly for a surge voltage arrester that constitutes a new and improved sparkgap assembly structure that affords significant improvements in the above-designated performance areas.

Another object of the invention is to provide a sparkgap assembly having heat sink means therein that stabilize the mechanical and thermal characteristics of the assembly during and after repeated arc discharge operations thereof.

A further object of the invention is to provide a surge voltage arrester having operating characteristics that allow the arrester to clear and re-seal following a switching surge discharge at a voltage level within 10 to 15 percent of the maximum switching surge voltage sparkover rating of the arrester while simultaneously preventing any dynamic arrester voltages after initial arrester sparkover, from exceeding the maximum switching surge sparkover voltage rating of the arrester.

Additional objects and advantages of the invention will become apparent to those skilled in the art from the following description of it taken in connection with the accompanying drawing.

SUMMARY OF THE INVENTION

In one preferred embodiment of the invention, a sparkgap assembly for a surge voltage arrester is provided with means defining an insulated arcing chamber therein. The arcing chamber is characterized by having a novel heat sink means in the form of porous arc-stretching teeth of a predetermined size and spacing that is critical, in combination with wall means of the chamber backing the teeth, because the novel size and spacing of the teeth enables the arcing chamber to have mechanically and thermally stable characteristics. This critical arcing chamber heat sink means operates to prevent the maximum voltage across the assembly after its initial sparkover from exceeding the maximum desired switching surge sparkover voltage of the arrester, while enabling the arrester to have a re-seal, or clearing, voltage rating after a switching surge discharge that is within approximately 10 to 15 percent of the maximum switching surge sparkover voltage rating of the arrester.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a perspective view of a sparkgap assembly for a surge voltage arrester, which is constructed pursuant to the teaching of the present invention.

FIG. 2 is a perspective view of the interior of one of the sparkgap arcing chambers of the sparkgap assembly depicted in FIG. 1.

FIG. 3 illustrates a prior art sparkgap assembly plate (FIG. 3a) and a sparkgap assembly plate for the assembly depicted in FIGS. 1 and 2 (FIG. 3a), so that a comparison may be made between the related structural features of these assemblies.

FIG. 4 is a series of graphs on which arrester voltage and current are plotted versus time. These graphs illustrate the unique sparkover and re-seal voltage relationships that are afforded with a sparkgap assembly constructed pursuant to the teaching of the present invention.

FIG. 5 is an enlarged, side elevation view, in cross-section, along the plane 5-5 shown in FIG. 3a, illustrating a fragment of the arcing chamber that is formed when the components of the invention are assembled in the form depicted in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 of the drawing, there is shown a sparkgap assembly 1 comprising a stack of insulating plates that are formed of a suitable molded, porous granular insulating material, such as Alurite which is a tradename for a type of material manufactured and sold by General Electric Company at a plant in Pittsfield, Massachusetts. The stacked insulating plates 2, 3, 4, 5, 6 and 7 are respectively formed to rest in self-supporting relationship on one another, and are also formed to define arcing chambers between each adjacent pair of plates. An electromagnetic means in the form of a coil 8 is mounted adjacent the arcing chambers formed between adjacent plates, such as plates 4 and 5, and is coaxial therewith. Each of the arcing chambers has a pair of horn gap electrodes mounted in spaced-apart relationship within it to form a sparkgap therebetween at the point of their closest juxtaposition. As is well known in the lightning arrester art, such horn gap electrodes each include an arc running surface that is arranged to diverge from the arc running surface of the adjacent electrode of the respective sparkgaps so that arcs formed across the sparkgaps are driven electrostatically outward along these respective surfaces. A pair of such horn gap electrodes 9 and 9' are shown in FIG. 3a of the drawing. The two electrodes 9 and 9' illustrated in FIG. 3a happen to be those mounted between the insulating plates 3 and 4 of the sparkgap assembly 1; however, it will be understood that similar pairs of elec-

trodes are mounted in the other arcing chambers of assembly 1.

In order to apply a surge voltage across the respective sparkgaps of assembly 1, suitable electric circuit means are electrically connected to join each of these pairs of sparkgaps in a single series circuit extending from an electric terminal 10 mounted in the top insulating plate 2 to a similar terminal (not shown) mounted in the bottom plate 7. This circuit means may be any conventional type, and it is arranged to series connect the electromagnetic coil 8 with the sparkgaps so it is operable to electrodynamically drive arcs across the respective arcing chambers, when it is sufficiently energized to develop a strong magnetic field within these arcing chambers. In general, the invention as described thus far includes elements that are somewhat similar to those described in my U.S. Pat. No. 3,354,345 which issue Nov. 21, 1967 and is assigned to the assignee of the present invention. Thus, if additional description is desired regarding the general features of construction and mode of operation of such a sparkgap assembly, reference may be had to that earlier patent.

Now reference will be made to FIGS. 2 and 3 of the drawing in order to facilitate a description of the novel structural features of the present invention. Since the arcing chambers defined by the insulating plates 2-7 may each be generally similar to one another in configuration, a single one of these chambers will be described in detail to teach the important features of my invention. Thus, in FIG. 2 of the drawing there is shown a perspective view of insulating plates 3 and 4 which are adapted to fit together in operating position in the manner illustrated in FIG. 1, thereby to define an arcing chamber, generally designated by the identifying numeral 10, therebetween. As can be seen in FIG. 2, arcing chamber 10 comprises a vault having its lowermost surface defined by the upper surface of insulating plate 4, while its upper surface is defined by the bottom surface of insulating plate 3. In addition, one wall of the arcing chamber comprises a generally arcuate surface that is formed by a plurality of arc-stretching teeth 11, 12, 13, 14 and 15 and the outer peripheral wall section 16 of plate member 3, which is arranged to extend downwardly from the roof area of the arcing chamber 10 that is within the generally arcuate curve defined by the teeth 1-15. In a somewhat similar manner, the insulating plate 4 has a plurality of tooth-like portions 17, 18, 19, 20, 21 and 22 that are adapted to fit respectively between the teeth 11-15 and the end abutments 23 and 24 that generally close the flat side wall of the arcing chamber 10.

Those skilled in the lightning arrester sparkgap assembly art will recognize that the particular figuration of the arcing chamber 10 defined by the teeth 11-15 and 17-22 on plates 3 and 4, respectively, are somewhat similar to the type of arcing chamber configurations that have been employed in prior art surge voltage arrester sparkgap assemblies. Because of this similarity, it may be helpful in understanding the novel features of the present invention to examine one form of prior art arcing chamber configuration that embodies some of these partially similar features. For this purpose, one such prior art arcing chamber assembly is illustrated in FIG. 3b. Since a primary novel feature of the present invention is the relative relationship between the dimensions of the arc-stretching teeth and the gaps separating the respective teeth, as well as the dimensions of these teeth in relation to the arc-confining peripheral wall of the chamber on which they are mounted, only one insulating plate of the prior art sparkgap arcing chamber is shown for comparative purposes. This plate can be regarded as generally corresponding to the insulating plate 3 of the present invention. Thus, the prior art plate 25 shown in FIG. 3b comprises an arcing chamber area 26 having a plurality of arc-stretching teeth 27, 28, 29, 30, 31, 32 and 33, which are mounted in a generally arcuate arrangement in spaced-apart relationship around the periphery of the chamber 16 defined by a relatively thin outer wall 23.

It is immediately apparent from a visual comparison of the prior art arcing chamber plate 25 and the insulating plate 3 of

the present invention that there are more arc-stretching teeth 27-33 in the prior art configuration, and each of these teeth is relatively narrow with respect to the gap between adjacent teeth. In fact, prior to the present invention, arc chambers were generally designed to maximize the length of arc that could be stretched between the outermost ends of the arc-running electrodes positioned in an arc-confining chamber having a given limited size; therefore, as many relatively thin teeth as possible were characteristically utilized to afford a maximum arc-stretching and cooling surface for the limited area available. This objective generally resulted in the teeth being substantially smaller than the gaps, or open areas, left therebetween, because a certain minimum tooth spacing was necessary in order to allow arcs to be forced between the teeth into contact with the outer peripheral wall 34 of the arcing chamber 26.

A fundamental improvement of the present invention over such prior art configurations is that relatively thick teeth 11-15 are used to provide unique arc-cooling means, as well as being operable as arc-stretching mechanisms. In particular, the advance in the art contributed by the present invention, over prior art sparkgap assemblies, is that each of the teeth 11-15 when reference to a mean arc chamber height H (see FIG. 5) has a predetermined mean width W (see FIGS. 3a and 5) and is spaced from the tooth next adjacent to it by a distance less than the measure of that predetermined mean width W. For example, looking at FIGS. 3a and 5, the space G between tooth 12 and tooth 13 at the mean arc chamber height H is, pursuant to the teaching of the present invention, appreciably less than the span of the mean width W of tooth 12 or tooth 13. It has been demonstrated empirically that this relationship is critical in obtaining the type of advantageous lightning arrester switching surge sparkover and re-seal ratios that were specified at the outset, above. In addition, it has been found that these characteristics are further improved by controlling the number of teeth 11-15 so that there are at least four such teeth around the generally arcuate surface of arcing chamber 10 between the outer ends of electrodes 9 and 9'. It will be apparent that by maintaining this novel relationship of tooth width (W) to gap width (G), a major portion of the generally arcuate surface of the arcing chamber 10, at the mean height H thereof, will be occupied by the teeth 11-15, whereas a minor portion of this generally arcuate surface is formed by the respective areas of the wall means 16 exposed by the gaps (G) between the teeth.

I have also found that the advantageous operating characteristics of a sparkgap constructed pursuant to the teaching of my invention can be optimized by maintaining the mean length L of each of the teeth 11-15 at the mean arc chamber height H sufficiently short so that this mean length is no greater than 133 percent of the mean width W of the teeth. Moreover, it is important to a proper functioning of the heat sink means of my invention that the wall means 16 outward from the base of the teeth 11-15 is sufficiently thick to provide a heat sink that will not be thermally saturated during any arc-cooling operation of the arcing chamber 10. Experimentation has established that the wall means 16 measured outward from the base of the teeth 11-15 to its outer extremity should be substantially equal to the measure of the mean length L of one of the teeth (11-15) when measured at the mean arc chamber height H. In fact, in the preferred embodiment of the invention described herein, the mean length L and the mean width W of the teeth 11-15 when measured at the mean arc chamber height H is approximately equal, because this has been found to afford optimum heat sink properties and thus excellent operating characteristics.

The unique mechanically and thermally stable characteristics for an arcing chamber, which I have observed in tests of my invention, can be explained by the fact that the disclosed novel configuration affords a better heat sink than was heretofore thought to be attainable in a feasible manner, for the arc-stretching and cooling means defined by the teeth 11-15 and the outer wall 16 of arcing chamber 10. Such a heat

sink effect helps prevent the teeth from being unduly eroded away by the melting action of high current arcs that sometimes severely erode relatively thin teeth, such as the teeth 27-33 of a prior art arcing chamber, like the chamber 26 illustrated in FIG. 3b. Further, with my invention the entire length of an arc is uniformly cooled, thus preventing localized areas of the chamber teeth or walls from being heated excessively to thereby cause degradation of the re-seal capability of the assembly. In order to make the present invention further resistant to such mechanical erosion, each of the teeth 11-15 is formed with a pair of generally flat side walls that taper toward one another at the outer ends of the teeth and diverge from one another from the floor to the roof of chamber 10. Moreover, each of the outer ends of these teeth also comprises a generally flat, sloped surface. Therefore, a structurally strong surface is provided which also affords a properly balanced arc-stretching and arc-cooling area. In addition, the generally arcuate wall means 16 and the teeth 11-15 are rigidly formed of an integrally molded, porous, granular insulating material, such as the Alurite designated above, that includes passageways through which arc-generated gases are vented from the arcing chamber 10.

In order to more fully explain the advantages of my invention, reference will now be made to FIG. 4 of the drawing which illustrates the type of improved operating characteristics that are obtained with the invention. FIG. 4a is a graphical representation of a voltage wave form of a type that might be produced at a given point on an electric power transmission system by switching surge transients. In actual practice, the wave form shown may be taken from a system model used to study transients. Such a transient network analysis (TNA) is normally performed in order to determine the type of surge voltage arrester characteristics that will be needed at given points in the system. Typically the voltage wave form of FIG. 4a can be regarded as the most severe overvoltage condition for the given point on the system being evaluated, that a surge voltage arrester placed in service at that point on the system will be required to safely discharge, then subsequently re-seal against. The magnitude of the voltage wave shown in FIG. 4a is plotted on the vertical axis as a function of a surge voltage arrester rating. Thus, the maximum surge voltage for the given point on the system being evaluated is specified as 2.1 times the voltage rating of the surge voltage arrester selected to protect the system at this given point. Also, the maximum succeeding peak voltage is 1.35 times the voltage rating of such a selected arrester. The horizontal axis in FIG. 4a is a time scale. As shown, the plotted voltage wave starts at time T_0 , rises to a maximum at T_1 , then falls to zero at T_2 . The next succeeding peak voltage occurs at T_3 , and is followed by a second zero voltage at T_4 .

In addition to knowing the type of maximum voltage wave form at the given point on the system being evaluated, it is necessary to know the insulation protection levels that must not be exceeded at that point on the system. Such insulation protection levels are normally determined by relatively fixed system parameters, such as the type of insulation installed on transformers or other system apparatus adjacent the given point where the arrester is to be installed. Using such system parameters, a maximum switching surge sparkover voltage is determined for the arrester that is to be selected for use. For the purpose of explaining the present invention, it will be assumed that the maximum switching surge sparkover voltage determined for the given point on the system being evaluated is 1.5 times the voltage rating of the arrester to be selected. FIG. 4b of the drawing shows the maximum voltage wave form that will be applied to the given point on the system being evaluated when an arrester embodying my invention is installed at that point on the system, and a wave form such as that shown in FIG. 4a is impressed across it. Of course, such an arrester is designed to have a maximum switching surge sparkover voltage of 1.5 times the arrester's voltage rating. Thus, the plotted voltage rises from time T_0 to T_s where the arrester sparks over at equal to or less than 1.5 times its rated

voltage, causing the voltage to drop until the current limiting operation of the arrester builds a dynamic voltage during the interval T_s - T_2 . Due to one of the unique characteristics of my invention, the maximum dynamic voltage that can occur in the selected arrester after its initial sparkover at T_s is slightly less than 1.5 times the voltage rating of the arrester. Thus, the system is protected from dynamic voltages exceeding the specified 1.5-times-rated-switching surge voltage level. A second important characteristic of the invention is demonstrated by the wave form between T_2 and T_3 , because it is apparent that the arrester has re-sealed at time T_2 and does not spark over when the voltage reaches 1.35 times the voltage rating of the arrester. The significance of this second feature of the invention is made clearer by reference to FIG. 4c, which illustrates the current that flows through the arrester when the wave form of FIG. 4b appears across it. As shown, the current through the arrester starts at time T_s when the arrester is sparked over and rises to a maximum at approximately time T_D , then falls to zero at time T_2 when the arrester re-seals. In many prior art arresters, such a large, prolonged discharge current would heat the arcing chamber walls of the arrester's sparkgap assemblies to such an extent that they would remain sufficiently ionized to cause the arrester to spark over again at a voltage substantially lower than the voltage of 1.35 times rated voltage that occurs in the next succeeding peak voltage of the wave form depicted in FIG. 4b. Of course, this would require the use of a higher rated arrester with higher protection valves in order to re-seal safely because if succeeding operations occur, the probability of complete thermal arrester failure is greatly increased. Thus it is apparent from the graphically portrayed voltage and current wave forms of FIGS. 4b and 4c that an arrester constructed pursuant to my invention has the following desirable characteristics. First, it prevents dynamic voltages that may be impressed across the arrester after sparkover from exceeding the maximum switching surge voltage of the arrester (1.5 times rated voltage for the selected arrester). Second, the arrester remains sealed against peak voltages immediately following switching surge discharges that are within 10 percent to 15 percent of the maximum switching surge sparkover voltage. (In the illustrated case, the arrester remains sealed against a subsequent peak voltage of 1.35 times rated voltage, even after the heavy current depicted in FIG. 4c has been discharged.) This is a fundamental relationship that must be used in evaluating the performance of a current limiting gap arrester.

From the foregoing description of my invention, it will be apparent that various modifications and alternative embodiments of it may be developed based on the fundamental teaching of the invention. Of course, it is my intention to encompass all such variations of the invention within the spirit and scope of the following claims.

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

1. In a sparkgap assembly comprising an insulating housing having means defining an arcing chamber therein, a pair of horn gap electrodes mounted in spaced-apart relationship within said chamber to form a sparkgap therebetween at the point of their closest juxtaposition, said horn gap electrodes each having an arc-running surface, the respective arc-running surfaces of said electrodes being arranged to diverge from each other and away from said sparkgap, whereby an arc formed across the sparkgap is driven electro-dynamically outward along said surfaces, and circuit means electrically connected to said electrodes for applying a surge voltage to them that is sufficient to develop an arc across said sparkgap; the improvement comprising arc-cooling means positioned around a predetermined portion of the periphery of said arcing chamber outward from the more widely separated ends of said electrodes, said arc-cooling means comprising a wall means having a plurality of arc-stretching teeth integrally formed with one side thereof, each of said teeth having a predetermined mean width and being spaced from the tooth

next adjacent to it a distance less than the measure of said mean predetermined width.

2. An invention as defined in claim 1 wherein said plurality of teeth comprises at least four teeth, and said wall means and teeth define a generally arcuate surface the ends of which are respectively adjacent the outer ends of said electrodes.

3. An invention defined in claim 2 wherein a major portion of said generally arcuate surface is occupied by said teeth, whereas a minor portion of said generally arcuate surface is formed by the respective areas of said wall means between said teeth.

4. An invention as defined in claim 1 wherein each of said teeth has a substantially equal mean length and said mean length is no greater than 133 percent of said mean width.

5. An invention as defined in claim 4 wherein the thickness of said wall means outward from the base of said teeth is substantially equal to the measure of the mean length of one of said teeth.

6. An invention as defined in claim 5 wherein the mean length and mean width of each of said teeth is substantially equal.

7. An invention as defined in claim 5 wherein each of said teeth has a pair of generally flat, side walls that taper toward one another at the outer ends thereof, and the outer end of each tooth also comprises a generally flat surface.

8. An invention as defined in claim 7 wherein said generally arcuate wall means and said teeth are rigidly formed of an in-

tegrally molded, porous, granular insulating material that includes passageways through which arc-generated gases are vented from said chamber.

9. A surge voltage arrester having a sparkgap assembly comprising an insulating housing having means defining an arcing chamber therein, a pair of electrodes mounted in spaced-apart relationship within said chamber to define a sparkgap therebetween, circuit means electrically connected to said electrodes for applying a surge voltage to them that is sufficient to develop an arc across said sparkgap, and heat-sink means mounted around the periphery of said arcing chamber in a position where at least a portion of said heat-sink means is exposed to direct contact by arcs driven outward from said sparkgap across the chamber, said circuit means including electromagnetic means mounted adjacent said chamber for electro-dynamically driving an arc outward from the sparkgap toward said heat-sink means, said sparkgap assembly being mechanically pre-set to have a maximum switching surge sparkover voltage of N volts, said electromagnetic means being operable with said heat-sink means to extinguish an arc formed in said sparkgap at a voltage level less than N volts and greater than 85 percent of N volts after discharging a system switching surge, and said heat-sink means being effective to prevent any dynamic voltages across said assembly after its initial sparkover from exceeding the maximum pre-set switching surge sparkover voltage of N volts of the sparkgap assembly.

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