June 2, 1970 S. S. KERSHAW, JR 3,515,934

LIGHTNING ARRESTER SPARKOVER CONTROL

Filed Jan. 17, 1968 2 Sheets-Sheet 1

Fig. 1

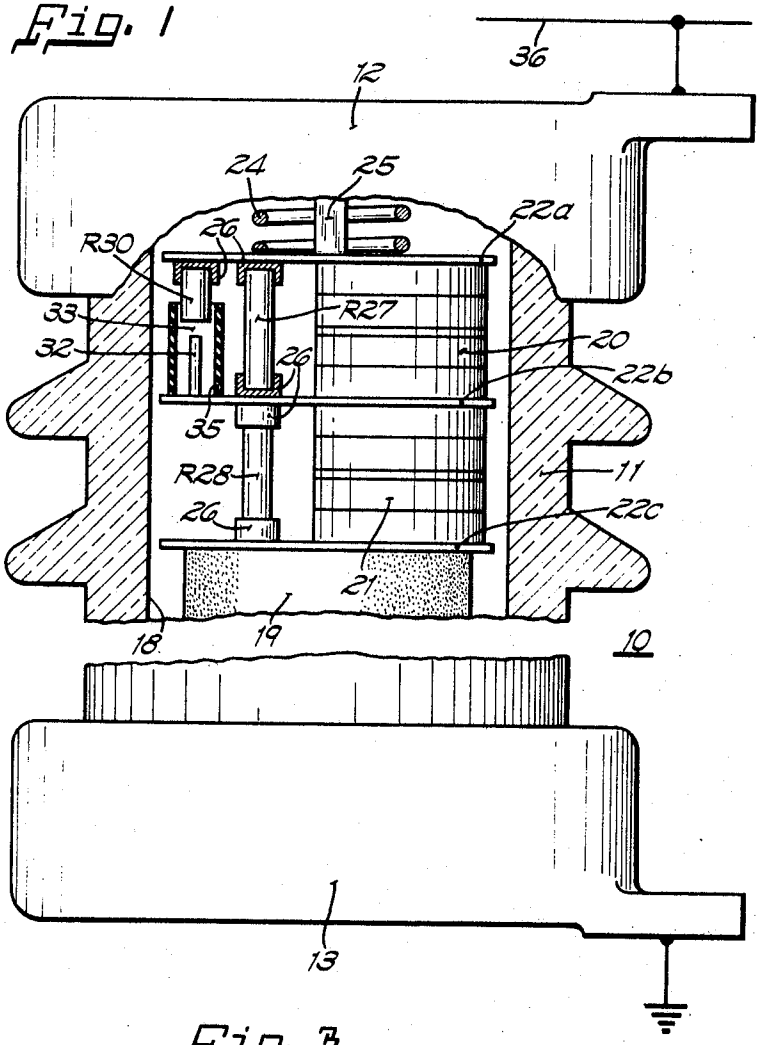

Fig. 2

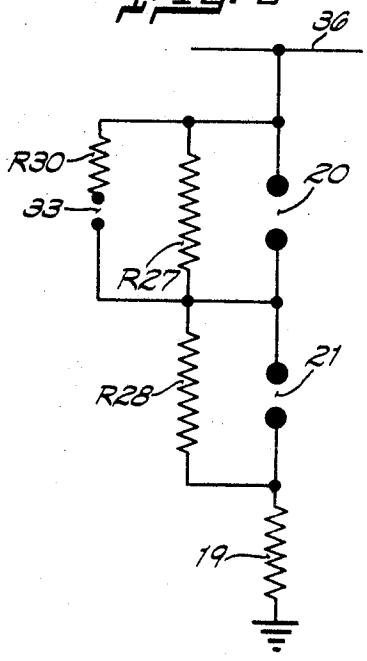

Fig. 3

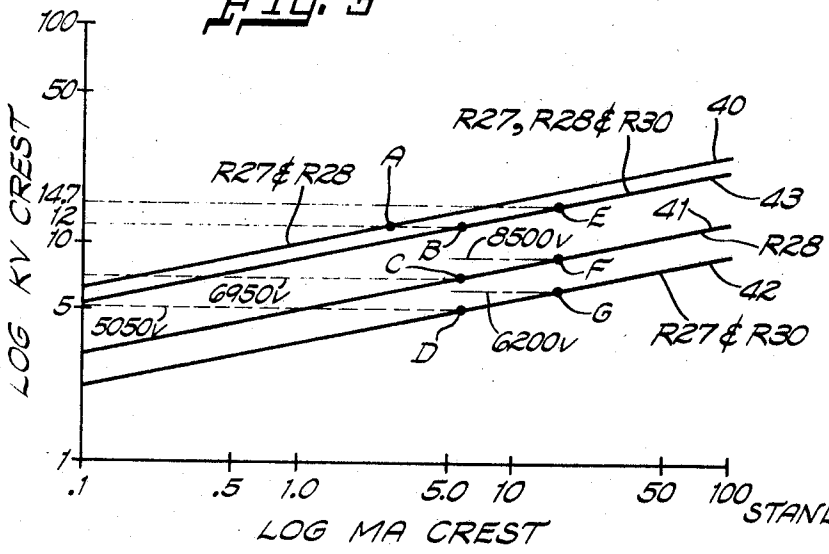

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Fig. 4

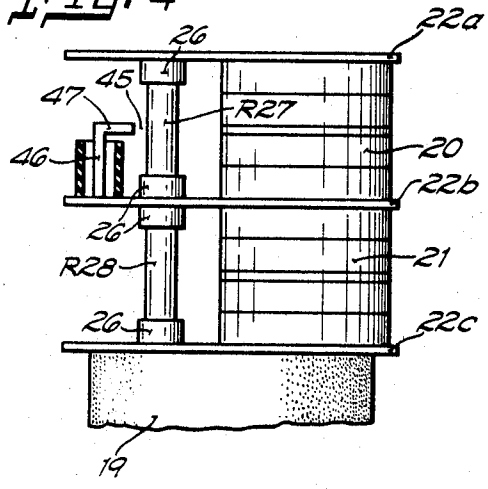


Fig. 5

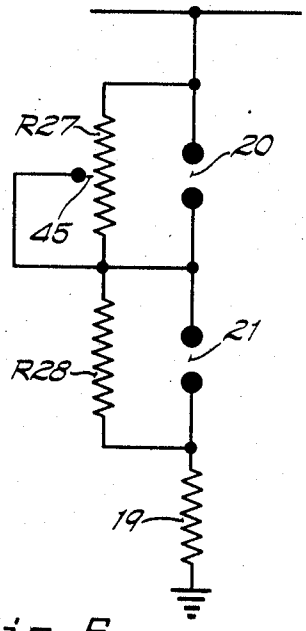


Fig. 7

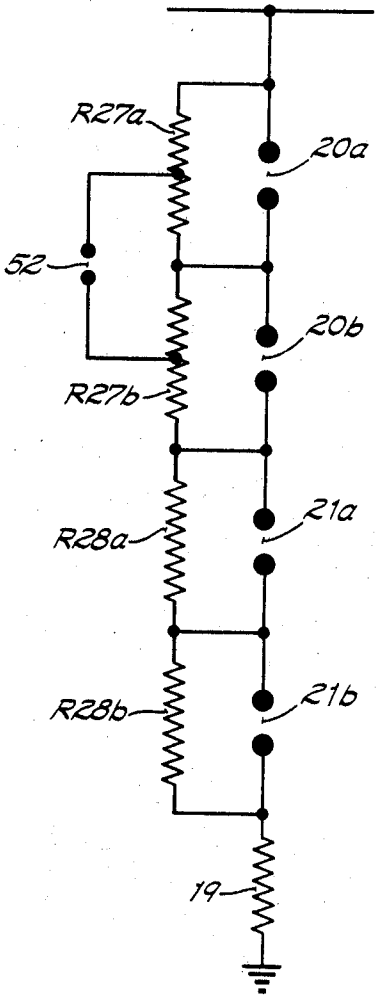
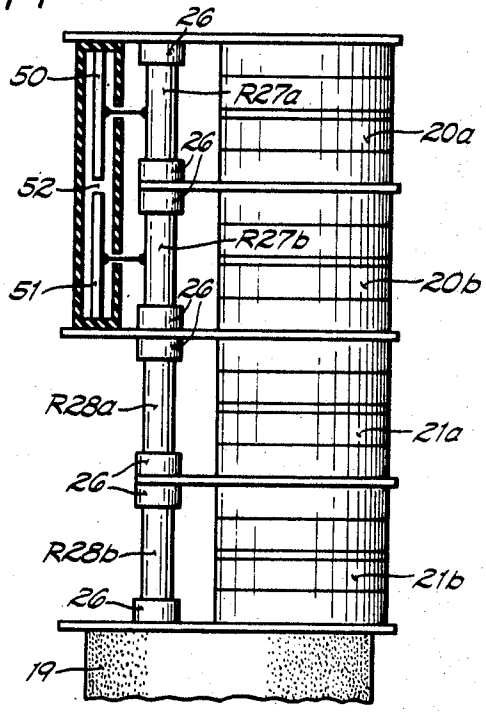


Fig. 6



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LIGHTNING ARRESTER SPARKOVER CONTROL

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Int. Cl. H02h 1/04
U.S. Cl. 315—36 14 Claims

ABSTRACT OF THE DISCLOSURE

A lightning arrester including first and second main gap means, shunted by substantially equal nonlinear resistance means and auxiliary gap operable to reduce the shunt resistance of one main gap means. The sparkover voltage of the auxiliary gap is less than that of the main gap so that, when a low frequency voltage impulse is applied to the arrester, the auxiliary gap will spark over to place a greater proportion of the applied voltage across the second spark gap to produce a cascading breakover effect in the main gaps.

BACKGROUND OF THE INVENTION

This invention relates to lightning arresters and, more particularly, to high voltage lightning arresters having reduced low frequency voltage sparkover.

In high voltage transmission systems, transient voltages that occur as the result of switching operations can exceed the basic insulation level of equipment in the system. Protection of the system from these transient voltage surges is a major consideration in the design of lightning arrester sparkover characteristics. Conventional valve-type lightning arresters generally include one or more spark gaps which are connected in series with a current limiting resistance having nonlinear characteristics in that it will present a relatively high impedance to normal 60-cycle power current and a relatively low impedance to high voltages resulting from lightning or transient voltage surges. The gaps normally isolate the system from ground but sparkover when subject to predetermined voltages so that lightning and transient voltage surges are passed to ground through the current limiting resistance. Because the nonlinear resistance presents a relatively high impedance to 60-cycle power current which follows the voltage surges, the voltage across the gaps is reduced to a value which is insufficient to maintain arcing, and the system is again isolated from ground.

The voltage at which the arrester gaps will spark over as the result of a lightning surge is governed by the physical configuration of the spark gaps, grading resistors which normally shunt the spark gaps and stray capacitance that exists within the lightning arrester assembly. The degree to which each of these parameters affects the arrester sparkover voltage depends upon the frequency or rate of rise of the applied voltage wave. The frequencies of switching surge voltage waves are substantially lower than those of voltage waves generally associated with lightning phenomena. At the relatively low frequencies of switching surge voltage waves, the impedance of the stray capacitance of the lightning arrester is relatively high and, hence, has little effect on arrester sparkover when compared with that of the grading resistances while at the relatively high frequencies associated with lightning surges, the stray capacitance of the arrester has a significant effect on sparkover. As a result, the switching surge sparkover of arresters is controlled, to a great extent, by the gap grading resistors.

It is an object of the invention to provide a new and improved sparkover control means for lightning arrester spark gap units.

Another object of the invention is to reduce the power frequency sparkover voltage of lightning arresters without impairing the arrester's operation at its normal operating voltage.

Yet another object of the invention is to provide a lightning arrester in which the variation in the low frequency sparkover voltage between successive operations is substantially reduced.

These and other objects and advantages of the instant invention will become more apparent from the detailed description thereof taken with the accompanying drawings and the description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, with parts broken away, of a lightning arrester incorporating the instant invention;

FIG. 2 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 1;

FIG. 3 shows the operating characteristics of the lightning arrester illustrated in FIG. 1;

FIG. 4 is a fragmentary view, with parts broken away, showing an alternate embodiment of the instant invention;

FIG. 5 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 4;

FIG. 6 is a fragmentary view, with parts broken away, of yet another embodiment of the instant invention; and

FIG. 7 is a circuit diagram schematically illustrating the lightning arrester shown in FIG. 6.

SUMMARY OF THE INVENTION

A lightning arrester including, first and second main gap means, nonlinear resistance means in series circuit relation with said main gap means, first and second resistance means respectively shunting the first and second main gap means, auxiliary gap means having a sparkover voltage less than the main gap means and constructed and arranged to reduce the resistance of the first shunt resistance means, so that when an increasing voltage is applied to the arrester the auxiliary gap will spark over to place a greater proportion of the applied voltages across the second spark gap to cause the second spark gap to flash over.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows the lightning arrester **10** according to the preferred embodiment of the instant invention to include a hollow, generally cylindrical housing **11** with a suitably insulating material, such as porcelain or glass and which is closed at its upper and lower ends by end assemblies **12** and **13**.

The housing **11** is provided with a central cylindrical bore **18** for receiving one or more nonlinear resistance elements **19** and spark gap assemblies **20** and **21**. Those skilled in the art will appreciate that, in high voltage station-type lightning arresters, a plurality of resistance elements **19** and spark gap assemblies **20** and **21** may be arranged in a series circuit relation within an elongate housing and that a plurality of such housings may be physically connected by suitably joining the end assemblies **12** and **13**.

The resistance elements **19** may have a generally cylindrical configuration and may be composed of a material such as silicon carbide, which has a nonlinear voltage characteristic whereby it presents a lower resistance to surge currents and a high resistance to the normal power current of the system. The elements **19** are coaxially arranged within the housing **11** and are separated from each other and from the spark gap assemblies **20** and **21** by conductive end plates **22***a*, **22***b* and **22***c*.

A metallic compression spring **24** may be disposed between the upper end assembly **12** and the uppermost conductive end plate **22***a* to firmly hold the assembly in position and in good electrical engagement, and spring **24**, in turn, may be electrically shunted by a conductive shunt member **25**.

The spark gap assemblies **20** and **21** may be of any type well known in the art, and the details thereof will not be discussed in detail for the sake of brevity. For a more complete description of spark gap assemblies **20** and **21**, reference is made to U.S. Pat. No. 3,242,376, issued Mar. 22, 1966, and assigned to the assignee of the instant invention.

A nonlinear grading resistor R27 is mounted between the end plates **22***a* and **22***b* on each side of the spark gap assembly **20** and is supported by a metallic, generally cup-shaped terminal member **26** which is suitably secured to the end plates **22** in an opposed coaxial arrangement. This places the grading resistor R27 in a parallel circuit arrangement with the spark gap assembly **20**, as seen in FIG. 2. A grading resistor **R28** is similarly connected in a parallel circuit arrangement with the spark gap assembly **21**. The grading resistors R27 and R28 thereby shunt the main gaps **20** and **21** to assure uniform distribution of 60-cycle voltage across the spark gap assemblies **20** and **21** and the nonlinear resistance elements **19**. A nonlinear resistance element **R30** is also shown in FIG. 1 to be supported by a terminal member **26** from the upper end plate **22***a* to extend a partial distance toward the next succeeding end plate **22***b* and in general parallelism with the nonlinear resistance element R27. Extending upwardly toward the terminal end of the nonlinear resistance element R30 is a conductive rod **32** which is affixed at its lower end to the end plate **22***b*. The element R30 and the rod **32** are disposed in a generally coaxial aligned relation, and their terminal ends are separated by a gap **33**. A tubular insulating member **35** extends upwardly from the end plate **22***b* and in surrounding relation to the rod **32** and the gap **33** and the lower end of the nonlinear resistance element R30. This electrically isolates the rod **32** from the intermediate portions of the grading resistor R27.

With reference to FIG. 2, it can be seen that the grading resistance R30 and the spark gap **33** are connected in series circuit relation and the series combination is connected in parallel with the grading resistor R27 and the main gap **20**.

During a lightning surge, which has a steep wave front or high frequency, a capacitive impedance path across the gaps **20** and **21** is relatively much lower than that provided by the grading resistors R27 and R28. As a result, lightning surges will follow the low impedance path through the main spark gaps **20** and **21** which arc over and through the nonlinear resistances **19** which present a relatively low impedance to surge currents. Because of the nonlinear resistance characteristic of the resistances **19**, they readily pass the surge current and then restore the system to its normal operating condition after the voltage across the device has returned substantially to the line voltage of the system by limiting the flow of current to a value which is insufficient to sustain the arcing in the spark gap assemblies **20** and **21**. The spark gap assemblies **20** and **21** thereby will again isolate the line conductor **36** connected to the upper end assembly **12** from the grounded lower end assembly **13**.

As stated hereinabove, the rate of rise or frequency of switching surge voltage waves is relatively lower than those associated with lightning phenomena. As a result, the switching surge sparkover voltage of the gaps **20** and **21** will be controlled by the gap grading resistors R27 and R28 because the impedance of the capacitances across the spark gaps **20** and **21** is high relative to that of said grading resistors.

At operating voltages, the grading resistors R27 and R28, which are connected in series, function to maintain

approximately low voltages across the gaps **20** and **21**. In addition, the voltage developed across resistor R27 is also impressed across the gap **33** which is connected in parallel with resistor R27. The breakdown voltage of gap **33** is chosen so that it will be at some voltage greater than the normal operating voltage of the resistor R27, whereby the latter will retain its voltage grading function.

Assume, for the sake of illustration, that the sparkover voltage of the control gap **33** is 6000 volts and that of each of the main gaps **20** and **21** is 8500 volts. A typical voltage and current characteristic for such a lightning arrester is illustrated in FIG. 3. Here the characteristic **40** represents the voltage across the resistors R27 and R28 connected in series; the characteristic **41** represents the voltage across the resistor R28; the characteristic **42** represents the voltage across the parallel combination of resistor R27 and resistor R30 after the gap **33** has broken down; and the characteristic **43** is the total voltage across the resistors R27 and R28 connected in series and resistor R30 connected in parallel with resistor R27 or, in other words, is the sum of the characteristics **41** and **42**.

Under normal operating conditions the voltage will divide equally across resistors R27 and R28, as represented by the curve **40**. Should a low frequency switching surge occur, the voltage across the resistors R27 and R28 would begin to rise until the voltage reaches 12 kv., as represented by point A in characteristic **40**. At this point 6000 volts would appear across each of the resistors R27 and R28 and across the gap **33**. At 6000 volts the spark gap **33** is calibrated to spark over, whereby resistor **30** is connected in parallel with resistor R27, as represented by characteristic **43**. This decreases the series resistance to increase the current so that the voltage characteristic of the device would now be at point B in characteristic **43** which is the sum of the voltages across resistor R28 as represented by point C in characteristic **41** and the voltage across the parallel combination of resistors R27 and R30, as represented by point D in characteristic **42**. As seen in FIG. 3, the voltage across the gaps **20** and **21** will now become unbalanced with approximately 6950 volts across gap **21** and 5050 volts across gap **20**. As the voltage of the device continues to rise along characteristic **43**, the voltage across the gaps **20** and **21** will rise along the characteristics **42** and **41**, respectively. When the voltage characteristic reaches point E on curve **43**, the voltage across the gap **21** will be at point F which is equal to 8500 volts, and the voltage across gap **20** will be at point G which is equal to 6200 volts. Since 8500 volts is the sparkover voltage of gap **21**, it will fire, thereby placing the entire 14.7 kv. across the gap **20** which also fires. In this manner the switching surge is passed to ground.

It can be seen from the foregoing example that the control gap **33** allows the lightning arrester to operate on switching surges equal to 14.7 kv. If the control gap **33** had not switched the resistor R30 into the circuit, the switching surge sparkover voltage of the lightning arrester would have been twice that of the two gaps or 17 kv. In this manner, the lightning arrester according to the instant invention is able to pass switching voltage surges which are substantially less than the normal sparkover voltage of the arrester. Because voltage surges associated with lightning occur in a relatively brief interval, a peak voltage of predetermined magnitude is not as potentially destructive to the system as switching voltage surges of the same magnitude.

In the embodiment of the invention shown in FIGS. 1 and 2 the resistance in shunt with one of the main spark gaps was reduced by placing a second resistance in parallel therewith. In the embodiment of FIGS. 4–7 alternate methods are illustrated for reducing the resistance in parallel with certain of the spark gaps to create an unbalanced voltage condition. More specifically, in the embodiment of FIGS. 4 and 5 the auxiliary spark gap **45** is formed by a generally L-shaped conductive rod member **46** which has a transversely extending portion **47** which terminates ad-

jacent the midpoint of the resistor R27. When the voltage across resistor R27 is equal to the sparkover voltage of the gap 45 it will fire to short circuit a portion of resistor R27 and thereby to unbalance the voltages across the gaps 20 and 21. In this manner the gaps 21 and 20 will spark over successively in a manner similar to that discussed with respect to the embodiment of FIG. 1.

In yet a further embodiment of the invention shown in FIGS. 6 and 7, the main gaps 20*a* and 20*b* are each shunted by a resistance R27*a* and R27*b* and the midpoints of each of the latter are connected to rods 50 and 51 which are separated to form an auxiliary spark gap 52. When the combined voltage across the gaps 20*a* and 20*b* exceeds the sparkover voltage of the auxiliary gap 52, it will fire to short a portion of each of the resistors R27*a* and R27*b*, thereby placing a greater proportion of the total voltage across the spark gaps 21*a* and 21*b*. Here again, a greater voltage will appear across main gaps 21*a* and 21*b* than across the gaps 20*a* and 20*b* so that the former will spark over when the total voltage across the lightning arrester is less than the total sparkover voltage of all the gaps.

While the invention has been shown and described with respect to a particular number of spark gaps and grading resistors, those skilled in the art will appreciate that it is also intended to encompass greater numbers of such components as well. In addition, while only a few embodiments of the invention have been shown and described, it is not intended to be limited thereby, but only by the scope of the appended claims.

I claim:

1. A lightning arrester including a plurality of main spark gap means, a plurality of first resistance means each shunting a different one of said main spark gap means, and isolated modifying means in circuit with said first resistance means and responsive to a predetermined voltage to modify the effective resistance of one of said first resistance means, said predetermined voltage being less than the sparkover voltage of said main gaps.

2. The lightning arrester set forth in claim 1 wherein said modifying means is an auxiliary spark gap means whose sparkover voltage is less than that of said main spark gap means.

3. The lightning arrester set forth in claim 1 including nonlinear second resistance means connected in series circuit relation with said main spark gap means.

4. The lightning arrester set forth in claim 1 wherein said first resistance means comprises nonlinear resistance means.

5. The lightning arrester set forth in claim 2 wherein said auxiliary spark gap is operative to reduce the effective resistance of said one of said first resistance means.

6. The lightning arrester set forth in claim 2 wherein said auxiliary spark gap means is connected in a shunt circuit relation with at least a portion of the first resistance means shunting one of said main gap means.

7. The lightning arrester set forth in claim 5 and including nonlinear second resistance means connected in series circuit relation with said main spark gap means.

8. The lightning arrester set forth in claim 7 wherein said first resistance means comprises nonlinear resistance means.

9. The lightning arrester set forth in claim 8 wherein said auxiliary spark gap means is connected in a shunt circuit relation with at least a portion of said nonlinear first resistance means shunting one of said main gap means.

10. The lightning arrester set forth in claim 6 wherein additional resistance means is connected in a series circuit relation with said auxiliary spark gap means, said auxiliary spark gap means being operative to connect said additional resistance means in shunt with said first resistance means to reduce the effective resistance thereof.

11. The lightning arrester set forth in claim 10 wherein said additional resistance means comprises a nonlinear resistance material.

12. The lightning arrester set forth in claim 10 wherein said additional resistance means includes an elongate body of nonlinear resistance means supported at one side of said one of said main spark gap means and said auxiliary spark gap means comprises a conductive rod supported at the other side of said one of said main spark gap means and disposed in general alignment with said resistance material and spaced therefrom.

13. The lightning arrester set forth in claim 6 wherein said spark gap means includes a first conductive member connected to an intermediate portion of a first one of said resistance means and a second conductive member connected to an intermediate portion of the next adjacent resistance means, said members being disposed in general alignment and in spaced relation to form a spark gap.

14. The lightning arrester set forth in claim 6 wherein said auxiliary spark gap comprises a conductive member connected to one side of said one main gap means and having a portion disposed in closely spaced relation to an intermediate portion of said one first resistance means.

References Cited

UNITED STATES PATENTS

3,222,566	12/1965	Yonkers	338—21 X
3,259,792	7/1966	Jensen	315—36
3,377,503	4/1968	Osterhout	317—70
3,348,100	10/1967	Kresge	317—70

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U.S. Cl. X.R.

338—21; 317—70