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[54] **LIGHTNING ARRESTER COOLING APPARATUS**
22 Claims, 5 Drawing Figs.

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 H02h 7/24, H02h 9/06

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 25, 45; 315/36, 50; 317/61, 62, 63, 64, 65, 69, 70,
 77, 78

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ABSTRACT: A lightning arrester having voltage-grading resistors that generate heat due to leakage currents therethrough, in combination with heat exchanger means adapted to cool the grading resistors and other internal components. In one form of the invention the grading resistors are biased into contact with the interior wall of the insulating housing of the lightning arrester by resilient spring means to assure optimum thermal conduction between the resistors and the housing.

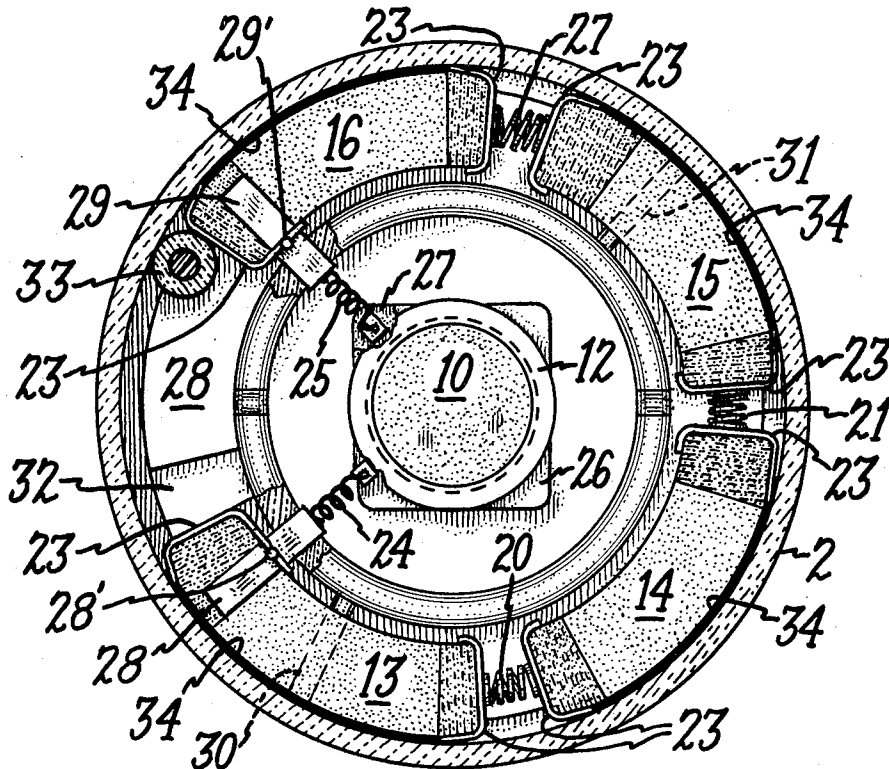


Fig. 3.

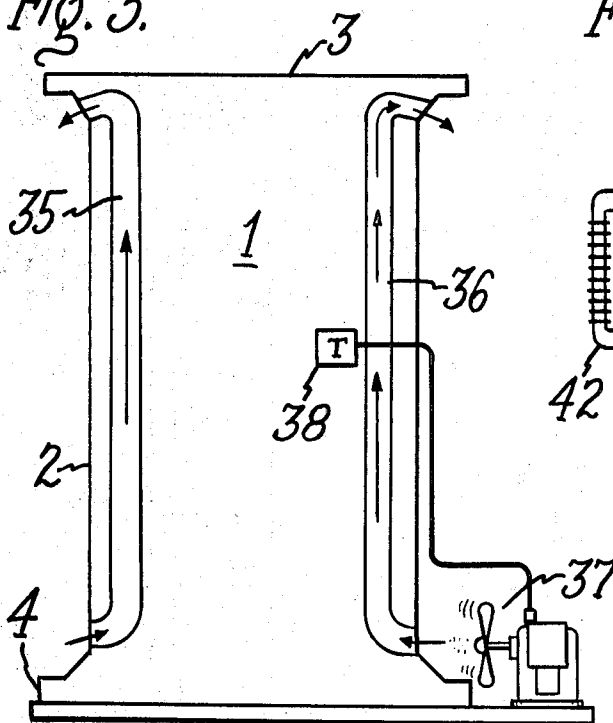


Fig. 4.

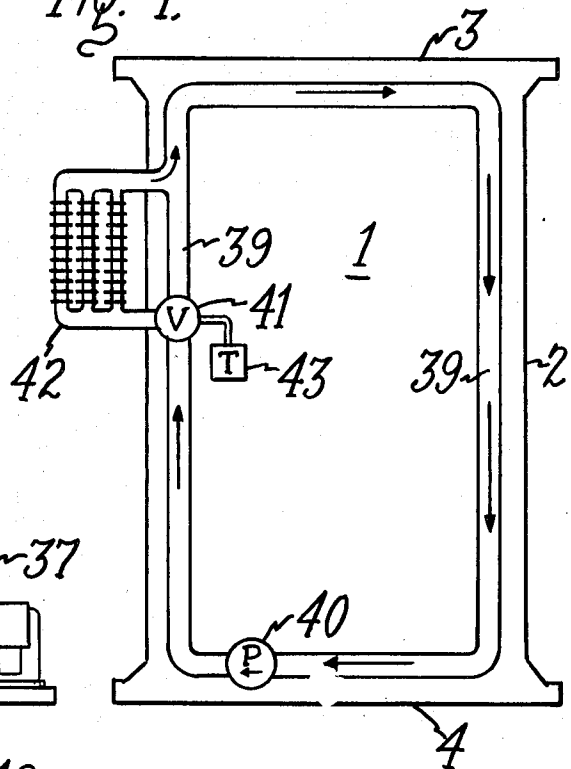
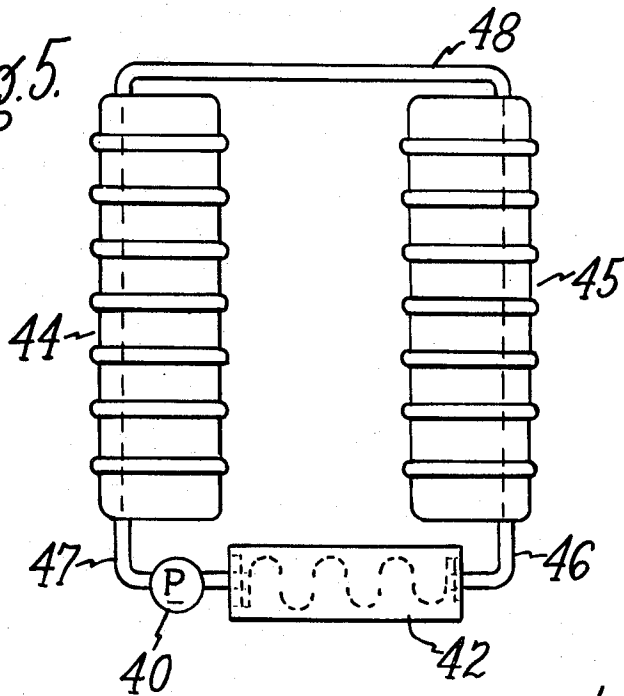


Fig. 5.



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LIGHTNING ARRESTER COOLING APPARATUS

This invention relates to improvements in lightning arresters, and more particularly, to lightning arresters having nonlinear resistance voltage-grading means that are subjected to voltages which cause a substantial heat-generating leakage current through the resistances.

It is common practice in conventional high-voltage lightning arresters to uniformly grade the voltage drop occurring between the high-voltage terminal of the arrester and ground potential so that voltage increments of substantially equal value are distributed across the series connected spark gaps of the arresters. By grading the voltage drop in this manner, the sparkover voltage of the series-connected spark gaps can be accurately predetermined within close tolerances, and manufacturing economies are realized because each of the spark gaps can be made substantially identical in structure and voltage rating.

With the advent of high-voltage direct current systems it has been found that the wattage that has to be dissipated by such grading resistors is much greater than is the case with comparable alternating current systems. The reason for this is that in the direct current systems the flow of current is virtually constant whereas in the alternating current system the current is pulsating, varying considerably with the magnitude of the applied voltage.

Nonlinear grading resistors of the type used have a negative temperature characteristic that makes it necessary to carefully guard against runaway conditions that can occur if the resistors are allowed to become too warm. Due to this negative characteristic the resistance of the grading resistors drops as their temperature rises; therefore, if suitable means are not provided for cooling the resistors, their currents will continually increase and the resistors will be arced over or fail by being punctured. Such failures result in the entire arrester being rendered useless.

In conventional arresters grading resistors are mounted in an inner assembly that makes firm structural contact with each end of the arrester housing and sometimes, due to movement of the assembly, comes in contact with the inner wall of the arrester's porcelain housing. In this type of construction, heat is transferred to the outside of the arrester primarily through convection and radiation and by a small incidental conduction at the points where the resistors contact the housing. Transfer of heat from the grading resistors across the comparative dead air space in the arrester to the adjacent porcelain wall is poor and some manner of improving this is generally desirable. An understanding of this problem will be facilitated by considering the following expression which concerns the rate of heat transfer that is occasioned for a given temperature differential between two points:

$$\text{Rate of Heat Transfer} = \frac{K \times \text{area of heat transfer path}}{\text{Length of transfer path}}$$

where values for K for selected materials are given approximately below:

Material:	K	Ratio ¹
Air	.013	1
Helium	.080	6
Hydrogen	.115	9
Porcelain	.6	46
Quartz	4.0	308
Lead	20	1,540
Iron	27	2,080
Aluminum	118	9,080

¹ K of other materials to K of air.

In one preferred form of the invention grading resistors are mechanically biased into firm heat-exchanging relation with the interior surface of an arrester housing. It can be seen by reference to the foregoing formula that the rate of heat

transfer is, thus, improved by reducing the length of the internal airpath and in many areas by eliminating the airpath and substituting the more effective heat-conducting porcelain path for it. By using suitable interface material between the grading resistors and the housing even better conductivity can be assured through a greater transfer path area.

Accordingly, a primary object of this invention is to provide efficient means for removing heat generated in a lightning arrester housing therefrom.

A second object of the invention is to provide a high-voltage direct current lightning arrester having a nonlinear voltage-grading resistance network possessing improved electrical characteristics.

Another object of the invention is to provide heat exchanger means for removing heat from the interior of a lightning arrester housing.

A still further object of the invention is to provide a lightning arrester housing having nonlinear voltage-grading resistance elements therein which are maintained in good thermal conducting relation with the outer housing of the arrester to improve the transfer of heat from such elements.

Yet another object of the invention is to improve the operating characteristics of a high-voltage lightning arrester by providing means for circulating air or more effective fluids through the arrester and in heat-exchanging relationship with a unit that can be operated at near ground potential.

Further objects and advantages of the invention will become apparent as the following description proceeds and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In accordance with these and other objects of the present invention, there is provided a lightning arrester adapted to protect an extra-high voltage direct current power transmission system and including means for facilitating transfer of heat generated within the arrester to the exterior thereof. In one preferred form of the invention, nonlinear voltage-grading resistors that generate a substantial amount of heat within the lightning arrester housing due to the passage of leakage current through them are mechanically biased into firm heat-exchanging relation with an interior surface of the lightning arrester housing to assure adequate heat conduction from the resistors to the larger and cooler surface of the arrester housing. In other embodiments of the invention, heat exchanger means are provided to transfer heat from the interior of a lightning arrester to the exterior thereof by inducing convection currents to flow through suitably arranged, electrically isolated, heat exchanger means.

For a better understanding of the present invention, reference may be had to the accompanying drawings wherein:

FIG. 1 is a side elevation, partly in cross section and partly in phantom, of a high-voltage lightning arrester embodying one form of the invention.

FIG. 2 is a top plan view of the lightning arrester shown in FIG. 1 taken through the plane 2-2 in FIG. 1.

FIG. 3 is a schematic diagram of a lightning arrester housing of the type illustrated in FIG. 1 showing one embodiment of a heat exchanger means arranged pursuant to the teaching of the invention.

FIG. 4 is a schematic view of a lightning arrester housing similar to the type illustrated in FIG. 1 showing a second embodiment of a heat exchanger means arranged pursuant to the teaching of the invention.

FIG. 5 illustrates still another embodiment of the invention showing a plurality of lightning arrester housings interconnected with heat exchange means adapted to cool the interior of the housings pursuant to the teaching of my invention.

Referring now to FIG. 1 of the drawing, there is shown an extra-high voltage direct current lightning arrester 1 having a tubular porcelain housing 2 that is sealed on its opposite ends respectively by metallic end cap terminals 3 and 4. The end cap terminals 3 and 4 may be sealed to the housing 2 in any suitable manner, but in the preferred embodiment of the in-

vention illustrated in FIG. 1, it can be seen that a resilient annular washer 5 is disposed between the housing 2 and the end cap 4 to assure a fluidtight seal therebetween when these component parts are in assembled positions. The end cap 4 is secured to the housing 2 by a suitable cement 6 such as sulfur, that fills the channel defined between the housing 2 and the upturned peripheral edge of the end cap 4. The end cap 3 may be sealed to the housing 2 in a similar manner or in any other suitable conventional manner. It will be understood that the insulating housing 2 will normally be provided with conventional petticoats or rain shields to increase the creepage distance between the end cap terminals 3 and 4 in a manner well known in the lightning arrester art. Such petticoats are not illustrated in FIG. 1 because they do not form an important part of the present invention and their omission simplifies the illustration of the invention.

Resting on the end cap 4 is a suitable plate 7 that supports the arrester's functional components. The components of the arrester, which allow it to perform its primary functions of discharging a high-surge voltage to ground, and then resealing the discharge path to prevent power follow current from flowing through the arrester, are a plurality of series-connected spark gap assemblies, two of which are shown as spark gap assemblies 8 and 9. Electrically connected in series with the series-connected spark gap assemblies 8—9, etc., are a plurality of nonlinear valve resistors, one of which is depicted as resistor 10, which has an electromagnetic coil 11, mounted in an insulating channel 12, disposed around its periphery to provide means for electrodynamically moving arcs formed within the arc gaps of the assembly 9 into cooling relation with arcing chamber sidewalls in a manner well known in the lightning arrester art. It will be understood that various series arrangements and combinations of nonlinear valve resistors, such as the depicted resistor 11, and spark gap assemblies, such as the assemblies 8 and 9, can be employed to provide various desired electrical characteristics within given lightning arresters. As will be seen, such modifications do not form an essential part of the present invention but they are within the scope of the various contemplated applications of the invention.

The series-connected spark gap assemblies 8, 9, etc. are each shunted by voltage-grading nonlinear resistors, such as the resistors 13, 14, 15 and 16, shunting gap assembly 9 (also see FIG. 2). Each of the nonlinear resistors 13—16 is electrically connected in series by coil springs 20, 21, and 22, to form an electrical circuit between the metallic end clips 23 that are biased into electrical engagement with each of the respective ends of the nonlinear resistors 13—16, as shown in FIG. 2, when the lightning arrester components are in assembled position. The respective opposite extremities of the series resistance formed through the resistors 13—16 are electrically connected by suitable metallic connections 24 and 25 to terminal plates 26 and 27 on the outermost ends of the spark assembly 9. Of course, these plates 26 and 27 are connected to the series gaps within the assembly in a manner well known in the art. For example, see U.S. Pat. No. 3,151,273 — Stetson et al. assigned to the same assignee as the present invention. The opposite ends of the connections 24 and 25 are electrically and mechanically connected to metallic clips 28 and 29 respectively to complete the shunt circuit across the spark gap assembly 9, defined by the series connections 24 and 25 and the nonlinear resistance elements 13—16 therebetween. In order to assure good electrical contact between the clips 28 and 29 and the resistors 13 and 16, the end clips 23 on these resistors are riveted at 28' and 29' to the clips 28 and 29.

It will be appreciated by those skilled in the art that a greater or lesser number of the spark gap assemblies 8, 9 etc. may be shunt connected across various predetermined numbers of the nonlinear resistors, such as resistors 13—16, to provide a given voltage-grading arrangement, and such modifications are contemplated within the scope of my invention. However, in order to simplify the description of the invention, a single series-connected group of nonlinear resistors

13—16 is illustrated and will be described with reference to a single spark gap assembly 9. The nonlinear grading resistors 13—16 are supported on an annular ceramic insulating member 28 which is generally L-shaped in cross section to define a resistor-supporting ledge and an annular ridge near its inner circumference, which contacts and supports an identical L-shaped ceramic insulating support member 29 stacked above it in the housing 2. Of course, additional ceramic supporting members will be utilized as needed in the remaining portion of the lightning arrester housing 2 in order to provide adequate means for supporting the number of sets of grading resistors required to properly distribute voltage over the spark gap assemblies utilized in the arrester to provide its desired rating. In the preferred embodiment of the invention, the L-shaped supporting members 28, 29, etc. are spaced in the center of the annular housing 2 and maintained in that position by a plurality of insulating dowels 30 and 31 (see FIG. 2) which are disposed in preformed grooves on the upper surface of the ledge portion of the supporting members 28, 29 etc. and which have predetermined lengths such that they fit snugly between the inner surface of the insulating housing 2 and the outer surface of the vertical leg of the L-shaped members 28, 29, etc. It will be understood that other suitable means may be utilized to maintain these basic supporting elements in their predetermined spaced relation within the insulating housing 2.

A major feature of the present invention is the spring-biasing means, illustrated in FIG. 2 by the springs 20—22, which force the series-connected nonlinear resistors 13—16 outwardly into firm thermal contact with the insulating housing 2. It will be seen that one end of the nonlinear resistance block 13 abuts a raised projection 32 formed in the upper surface of the ceramic supporting member 28, and the free end of nonlinear resistance block 16 abuts a removable insulating dowel 33 that is releasably affixed to the ceramic insulating member 28 in a suitable manner. Thus, with the springs in the position shown and the removable dowel 33 in position, the springs 20—22 exert sufficient compressive pressure to hold the resistors 13—16 firmly against the insulating housing 2. In order to improve the thermal conduction of the junctions between the insulating blocks 13—16 and the insulating housing 2, in one embodiment of the invention a thermal-setting material 34, such as a suitable epoxy, having a coefficient of expansion between the related coefficients of expansion of the nonlinear resistance blocks 13—16 and the porcelain insulating housing 2, is positioned between each of the nonlinear resistance blocks 13—16 over a substantial portion of their exterior peripheral surface. In a modification of the invention, to further improve the heat exchange relation between the heat generating grading resistors and the housing 2, the interior of the housing is filled with a suitable fluid, such as helium.

In the operation of the invention, when the lightning arrester 1 is electrically connected to protect a direct current transmission system from high-voltage transients, which may be caused by switching on the system, or by natural causes such as lightning, a substantial leakage current will be continuously forced by the DC line voltage through the series circuit formed by the grading resistors, between the high-voltage terminal 3 and the ground potential terminal 4 of the lightning arrester 1. This leakage current flows through the plurality of series-connected nonlinear resistance voltage-grading resistors which include the resistors 13—16. Accordingly, these voltage-grading resistors 13—16 serve as heat-generating means that develop a substantial rise in the temperature level within the lightning arrester 1. Since the arrester 1 is hermetically sealed, this heat cannot escape by direct convection currents flowing through the housing; therefore, it is important that the heat generated within the nonlinear grading resistors 13—16 be efficiently removed from the interior of the arrester 1 by other means. Pursuant to the preferred form of my invention, such as efficient heat transfer is effected by spring biasing the grading resistors 13—16 and their counterparts, into good heat conducting relation with the interior of the insulating housing 2. Thus, the ability to conduct heat from the heat-

generating means is substantially improved by shortening the heat transfer path by placing the grading resistors in direct thermal conduction with the porcelain housing, and by increasing the heat-radiating surface area that is in direct thermal contact with the grading resistors and the cooler ambient surrounding the exterior surface of the housing 2, thereby more efficiently cooling the grading resistors 13-16 and their counterparts.

In order to further improve the operating efficiency of the invention, additional heat-removing means may be employed pursuant to the invention to cool the interior of extra-high voltage lightning arrester housings that employ voltage-grading impedance means which develop a substantial amount of heat due to the *PR* losses attributable to leakage current flowing therethrough. Another embodiment of the invention is shown in FIG. 3 in schematic form to illustrate the use of a heat exchanger means to accomplish such a desirable heat transfer. In FIG. 3, there is shown an extra-high voltage lightning arrester 1 having an insulating housing 2 and terminal end caps 3 and 4 sealed thereto in a manner discussed above with reference to FIG. 1. It will be understood that the internal components of the lightning arrester 1 may be similar to those described in detail above with reference to FIGS. 1 and 2. It will also be appreciated that many such units would ordinarily be stacked in series to form a high-voltage lightning arrester. However, in order to simplify the description of this modification of the invention, only one such unit is illustrated in FIG. 3. To further improve the transfer of heat from the interior of the arrester housing 2 to the exterior thereof, a pair of heat exchanger passageways 35 and 36, defined by suitable insulating tubing are arranged to form a convection current passageway from desirable predetermined points near the bottom of the arrester 1 to exhaust ports at the top of the arrester. The respective ends of the passageways 35 and 36 are sealed in a suitable manner to ports formed in the housing wall 2 of the arrester 1 so that the hermetic seal protecting the interior compartment of the arrester 1 from moisture contamination is not broken. It will be understood that the passageways 35 and 36 may be formed directly in the walls of the porcelain housing 2, or they may be formed of tubing suitably mounted within arrester 1.

In many applications, the normal convection currents flowing through the heat exchanger passageways 35 and 36 afford adequate heat transfer to assure stable operation of the voltage grading resistor means. However, in still another embodiment of the invention, a fluid-moving means such as an electrically energized fan 37 is provided to force a fluid, such as air, through the heat exchanger passageway 36 and around the outer surface of the insulating housing 2 to increase the cooling efficiency of these means. In this forced-coolant embodiment of the invention, a thermostat 38, disposed on the interior of the arrester 1 adjacent a preselected nonlinear grading resistor near the center of the housing 2, is provided to regulate the actuation of the fan 37 in response to predetermined temperature variations within the arrester housing 2. It has been found that arresters tend to develop and maintain maximum temperatures near the center of the housing 2, therefore, locating the thermostat 38 at this point affords accurate and efficient temperature regulation.

A still further embodiment of my invention is shown in FIG. 4 where, again, like reference numerals will be used to identify parts similar to those shown in the preceding FIGS. Thus, a lightning arrester 1 is schematically shown having an insulating housing 2 and end cap terminals 3 and 4. A completely enclosed hermetically sealed and electrically insulated heat exchange passageway 39 is provided with an integral fluid pump 40, a valve 41 and a bypass heat exchanger in the form of a radiator 42 disposed outside of the arrester 1. It will be understood that the radiator 42 is electrically isolated from the energized portions of the arrester. The valve 41 is controlled by the thermostat 43 which is mounted at a predetermined point within the arrester housing, near the center thereof, and controls the valve to cause heat exchanger fluid

to be transferred between the radiator 42 and the shunting portion of the heat exchange passageway 39 in response to predetermined variations in the temperature of the fluid passing through the valve 41.

In FIG. 5, there is shown a further embodiment of my invention in which a plurality of lightning arresters are interconnected in a heat-transferring system to improve the thermal stability of each of the arresters. Such an arrangement is particularly desirable on direct current arresters of the flip-flop type, which are more fully described in U.S. Pat. application Ser. No. 624,297, filed Mar. 20, 1967 and assigned to the assignee of the present invention, wherein substantially identical arresters are electrically connected in parallel with each other and in series with additional spark gaps. However, it is apparent that this embodiment of the invention is also applicable to other arrangements of closely spaced lightning arrester housings. Although a plurality of lightning arresters can be utilized in such a system, again, in order to simplify the description, only two lightning arrester housings 44 and 45 are shown in FIG. 5. Each of the arrester housings 44 and 45 normally comprise a plurality of stacked spark gap assemblies similar to the assemblies described above with reference to FIGS. 1 and 2 and, of course, such an embodiment is within the intended scope of my invention. A heat-exchanging radiator 42 is connected by the ducts 46 and 47 to an hermetically sealed passageway 48 that passes in heat exchange relation through both of the lightning arresters 44 and 45. A pump 40, which may be thermostatically controlled in the manner noted above with reference to FIGS. 3 and 4, is provided to facilitate movement of the heat exchange fluid through the passageways 46-48.

Since the fluid-conducting passageways 46-48 extend generally from the high-voltage end of the arrester housings 44 and 45 to the ground potential end thereof, it will be appreciated by those skilled in the art that these passageways must be suitably insulated to prevent flashover of the arrester. In one modification of the invention, the passageways 46-48 are sealed at their respective ends to the opposite ends of the housings 2 and simply serve to form conduits between the housings 44 and 45 and the heat exchanger 42. In this embodiment, the coolant circulates freely through the interior of the housings 44 and 45 in heat exchange relationship with the heat-generating means, such as the grading resistors, therein.

While this invention has been shown and described with reference to particular embodiments thereof, it is to be understood that the description is intended to be illustrative and not limiting and it is my intention to cover by the appended claims any modified forms of structure or use of mechanical equivalents which may be reasonably included within the true spirit and scope of the claims.

We claim:

1. A lightning arrester having an insulating hollow housing, a pair of end cap terminals mounted respectively over opposed ends of said housing thereby to seal the housing, a plurality of operating components mounted within said housing and electrically connected to form a normally nonconducting surge voltage discharge circuit between said terminals, said discharge circuit being conductive only when a voltage in excess of a predetermined sparkover voltage rating of the arrester is applied to one of said terminals, means defining a second series circuit between said terminals, said second series circuit being normally conductive when a predetermined operating voltage that is smaller than the sparkover voltage of the arrester is applied to said terminals to create a voltage gradient therebetween, in combination with means for removing heat from the interior of said arrester housing when heat is developed by current through said second series circuit.

2. An invention as defined in claim 1 wherein said means comprises heat exchanger means for removing heat.

3. An invention as defined in claim 2 wherein said lightning arrester comprises an insulating housing having a sealed compartment therein, and said heat exchanger means comprises at least one fluid-conducting passageway disposed in heat-

exchanging relation with both the interior and exterior of said compartment.

4. An invention as defined in claim 3 wherein said passageway extends into said compartment.

5. An invention as defined in claim 3 wherein said passageway is sealed with respect to said compartment to prevent an exchange of fluid between said passage and said compartment.

6. An invention as defined in claim 1 wherein said means is a fluid-moving means adapted to control the flow of a coolant in heat exchange relation with said lightning arrester.

7. An invention as defined in claim 6 wherein said fluid-moving means comprises at least one fan mounted in proximity to said lightning arrester, and wherein said coolant is air.

8. An invention as defined in claim 6 in combination with control means for controlling the actuation of said fluid moving means.

9. An invention as defined in claim 8 wherein said control means is operatively responsive to temperature variations.

10. An invention as defined in claim 9 in combination with sensing means for sensing temperature variations at least one predetermined point adjacent said lightning arrester, and means operatively coupling said sensing means to said control means thereby to cause said control means to be responsive to temperature variations at at least said predetermined point.

11. An invention as defined in claim 1 wherein said means comprises a fluid atmosphere confined within said lightning arrester and adapted to improve the transfer of heat from the interior of said arrester to the exterior thereof.

12. An invention as defined in claim 11 wherein said fluid comprises a mixture of gases.

13. An invention as defined in claim 11 wherein said fluid comprises an electrically insulating liquid.

14. A lightning arrester including a hollow insulating housing, means for sealing said housing to define a substantially fluidtight compartment therein, a plurality of series-connected spark gaps and at least one block of nonlinear resistance material electrically connected in series conducting relation therewith within said compartment, in combination with voltage grading means for distributing voltage across said spark gaps in a predetermined manner, and means for removing heat from said voltage grading means.

15. A lightning arrester as defined in claim 14 wherein said voltage-grading means comprises a plurality of electrical impedance means, each of said impedance means being electrically connected in parallel respectively with at least one of said spark gaps, and wherein said means for removing heat comprises holding means for holding said impedance means in heat exchange relation with said insulating housing.

16. A lightning arrester as defined in claim 15 wherein said holding means comprises a spring means mounted within said insulating housing and adapted to bias each of said impedance means into said heat exchange relation.

17. A lightning arrester as defined in claim 16 wherein each of said impedance means comprises a plurality of nonlinear resistance blocks, and said spring means comprises a plurality of separate springs each respectively disposed between at least two of said blocks to bias them toward a position such that said heat exchange relation is enhanced.

18. A lightning arrester having a tubular insulating housing, a plurality of nonlinear resistance blocks, an annular insulating member disposed within said housing and adapted to support said blocks in spaced-apart relation around the periphery thereof, and spring means adapted to bias each of said blocks into heat exchange relation with said insulating housing.

19. A lightning arrester as defined in claim 18 in which thermally conductive material is positioned respectively between said housing and each of said blocks to improve the conduction of heat therebetween.

20. A lightning arrester as defined in claim 19 wherein said material is an epoxy having a coefficient of thermal expansion between the related coefficients of said blocks and said housing.

21. In combination, a plurality of lightning arresters as defined in claim 2 each having an insulating housing and heat-generating means disposed therein, and including heat exchange means for transferring heat between the interior and the exterior of each of said housings.

22. A combination as defined in claim 21 wherein said heat exchange means comprises at least one fluid conducting passageway disposed in heat exchange relation with the interior of each of said housings and the exterior thereof, a fluid disposed in said passageway, and fluid-moving means for circulating said fluid through said passageway.

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