

[72] Inventors **Eugene C. Sakshaug**  
**Lanesborough;**  
**James S. Kresge, Pittsfield, Mass.**  
 [21] Appl. No. **803,589**  
 [22] Filed **Mar. 3, 1969**  
 [45] Patented **Feb. 23, 1971**  
 [73] Assignee **General Electric Company**

*Primary Examiner*—James D. Trammell  
*Assistant Examiner*—Harvey Fendelman  
*Attorneys*—Vale P. Myles, Francis X. Doyle, Frank L. Neuhauser and Oscar B. Waddell

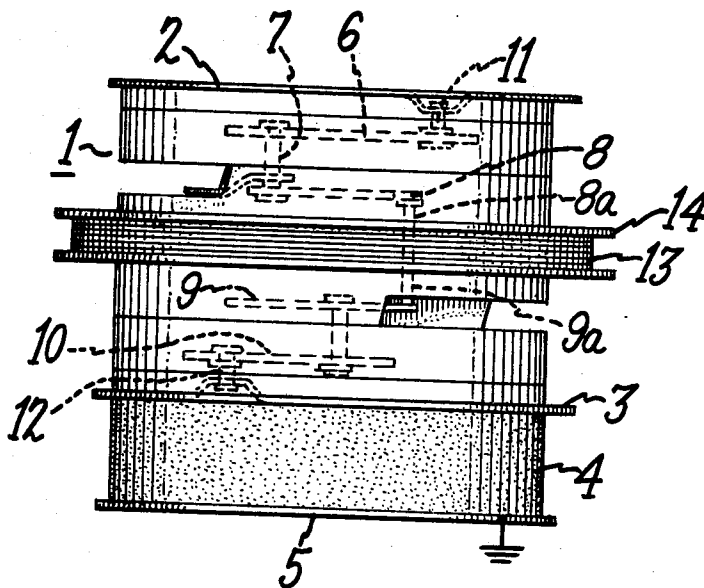
[54] **DISCHARGE ARC CONTROL MEANS FOR A LIGHTNING ARRESTER**  
 10 Claims, 3 Drawing Figs.

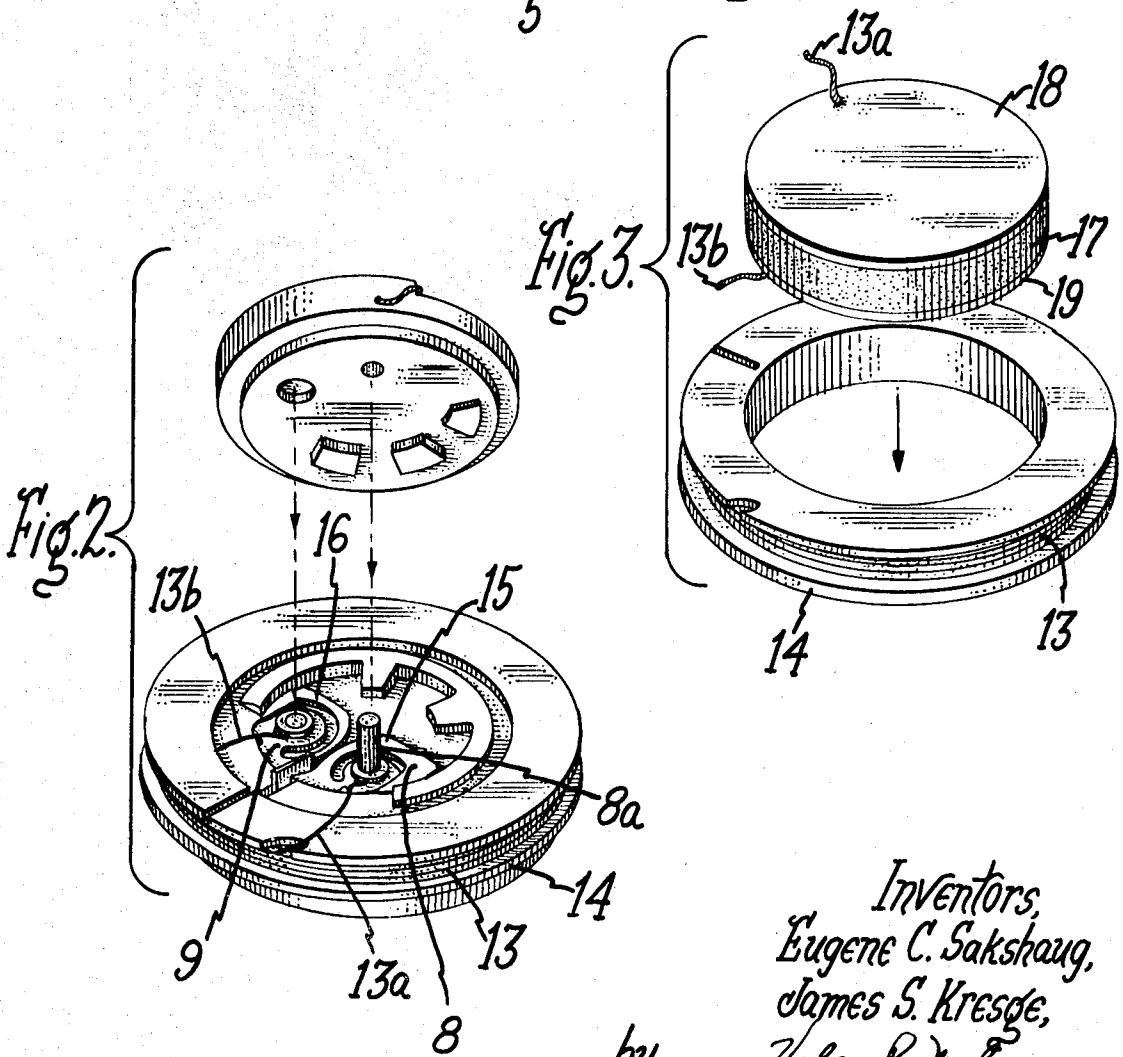
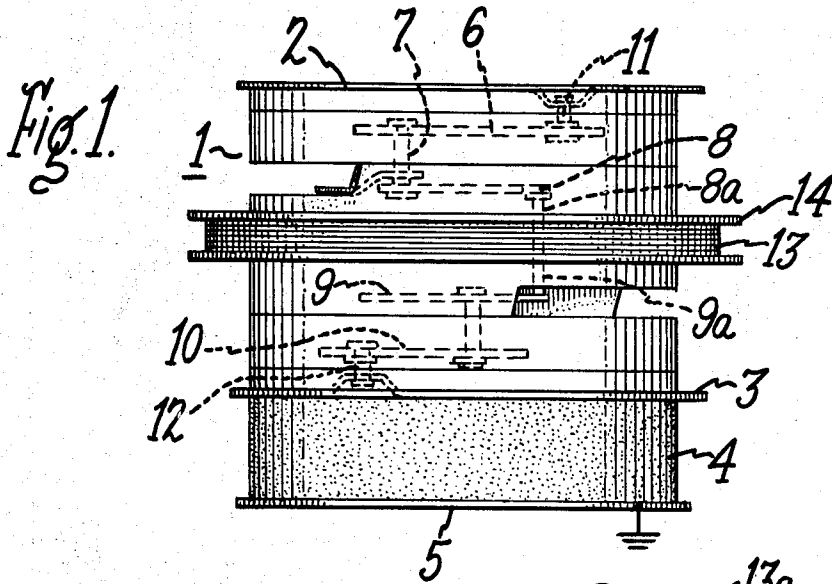
[52] U.S. Cl. .... 317/74,  
 317/78; 200/147  
 [51] Int. Cl. .... H02h 9/06  
 [50] Field of Search..... 317/78, 74;  
 200/147, 128, 144 (apri)

[56] **References Cited**  
**UNITED STATES PATENTS**

2,825,008	2/1958	Kalb .....	200/147X
3,151,273	9/1964	Stetson et al. ....	317/74X

**ABSTRACT:** A surge voltage arrester having means for retarding the build up of appreciable current limiting voltage therein for a predetermined interval of time after sparkover of the arrester comprising, a current limiting spark gap assembly having an electromagnetic coil electrically connected in series with it and disposed adjacent to it for moving arcs within the assembly in a manner such that arc voltage is increased. The coil is shunted by a current limiting means and is provided with enough turns to give it a substantial inductance so that an overvoltage surge may be discharged through the assembly for a predetermined interval of time before the coil develops enough magnetic flux to move arcs within the assembly sufficiently to build up an appreciable current limiting arc voltage. Additionally, the highly inductive coil provides the arrester with a high inductive reactance such that at the moment of clearing the current is forced slowly to zero providing a "gentle" clearing so high induced voltages are not produced in inductive protected circuits.





Inventors,  
Eugene C. Sakshaug,  
James S. Kresge,  
Vale P. Nyles  
Their Attorney.

by

## DISCHARGE ARC CONTROL MEANS FOR A LIGHTNING ARRESTER

This invention relates to circuit protection and surge voltage control devices incorporating a spark gap assembly and a block of nonlinear resistance valve material adapted to be electrically connected in series between a protected circuit and ground. More particularly, it relates to means for controlling the arc extinguishing characteristics of a lightning arrester of the type wherein arcs are moved by a magnetic field into arc suppressing chambers where they are extinguished. In addition to novel lightning arrester structure, the invention includes a new method of operating a lightning arrester.

It is conventional practice in manufacturing present day current limiting lightning arresters to provide means for increasing the length of a discharge arc within the arrester to increase its voltage thereby to extinguish the arc and prevent power follow current from flowing through the arrester valve block to ground. The current limiting lightning arrester disclosed and claimed in U.S. Pat. No. 3,151,273, issued Sept. 29, 1964 to E. W. Stetson et al. provides an example of one type of current limiting lightning arrester in common use at the present time. In such arresters, build up of arc voltage is accomplished by lengthening the discharge arc to a point where it comes in contact with the walls of arc chambers that act as a heat sink to rapidly cool and extinguish the arc.

A major problem has been encountered in attempting to apply conventional electromagnetic arc quenching techniques to lightning arresters used for protecting extra high voltage power transmission lines, particularly when such lines are utilized to transmit direct current. In essence, this problem involves the failure of such known techniques to afford consistent and reliable arc extinguishing characteristics in high voltage direct current lightning arresters. In fact, it has been found that in certain applications it is difficult to obtain adequately rapid clearing of a lightning arrester on even the first discharge cycle of the arrester. And, more frequently, such difficulties have been encountered in attempting to clear extra high voltage arresters that have been subjected to repeated discharge arc quenching cycles. A second major problem is encountered in applying conventional arresters to protect high voltage direct current converters connected to a high voltage transmission line via large series reactors of the type commonly referred to as a smoothing reactor. When discharging overvoltage surges from a transmission line such an arrester may, at the time of clearing force the discharge current to zero at such a rapid rate as to cause a high "inductive kick" voltage across the reactor and, consequently, across the arrester and the equipment being protected. This induced voltage may be high enough to damage the protected equipment.

The invention disclosed herein has as a primary object the provision of an extra high voltage surge arrester incorporating arc discharge regulating means that substantially improve the operating characteristics of the arrester.

A further object of the invention is to provide a surge voltage arrester with arc voltage control means that retard the rate of arc voltage buildup after initiation of arrester sparkover until a predetermined time interval has passed.

Still another object of the invention is to provide high speed, automatically operable voltage control means for regulating arc voltage buildup in a lightning arrester.

Yet another object of the invention is to provide arc voltage control means for a lightning arrester that operate to protect the arrester's arcing chambers from excessive erosion or wear during their arc extinguishing cycles.

Another object of the invention is to provide a surge voltage arrester having means for limiting the rate of change of discharge current as arrester clearing is approached after a surge discharge, so that excessive induced voltage will not be encountered when the arrester is used to protect a highly inductive circuit.

In a preferred form of the invention, a lightning arrester is provided with a high inductance coil electrically connected in series with the arrester's discharge path and in shunt circuit relation with a protective spark gap circuit. In operation, when the arrester sparks over, inductance of the coil prevents rapid current buildup in the coil during the initial discharge stage of operation, then after the majority of the overvoltage surge is discharged through the shunting gap, the coil passes enough current to develop a magnetic field that rapidly moves the arcs in the arrester toward their lengthened, arc extinguishing position. This operating characteristic allows a major portion of the discharged overvoltage surge to be dissipated to ground before the arc is stretched into a lengthened arc cooling and extinguishing position against the peripheral wall of the arcing chambers. In addition to thus facilitating the quenching operation, the invention prevents erosion and destruction of the walls of the arcing chamber, because high current arcs are not allowed to burn against these walls for a sustained period of time prior to being quenched. Furthermore, the high inductance of the coil prevents too rapid a decrease in discharge current as a current zero is approached upon clearing and thus limits the induced voltage which may occur in the series inductance of the source from which the discharge was obtained. In other words, the high inductance exhibited by the arrester at the moment of clearing forces it to clear "gently" in highly inductive circuits so that dangerous "inductive kicks" which could damage systems protected by an arrester embodying the invention are not obtained.

The foregoing objects and advantages of the invention will be better understood from the following discussion and reference to the drawings.

In the drawings:

FIG. 1 is a side elevational view, partly in phantom, of a lightning arrester spark gap and nonlinear valve material block embodying an electromagnetic coil constructed and arranged pursuant to the teachings of the present invention.

FIG. 2 is an exploded perspective view of a coil and coil-shunting gap structure manufactured according to one form of the invention.

FIG. 3 is an exploded perspective view of a coil and a block of nonlinear resistance valve material, made according to a second embodiment of the invention.

Referring now to FIG. 1 of the drawing, there is shown a spark gap assembly 1 disposed between metallic terminal plates 2 and 3 and electrically connected in series with a block of nonlinear resistance valve material 4 which is resting on another terminal plate 5. It will be understood by those skilled in the lightning arrester art that the spark gap assembly 1 and nonlinear resistance valve 4 are relatively conventional types of elements that are used as building blocks in making lightning arresters, and for the purpose of disclosing the present invention any suitable conventional spark gap assemblies and nonlinear valves can be used to afford equivalent functions in combination with the present invention. For example, a spark gap assembly and valve resistor similar to that shown in the above mentioned Stetson et al. Pat. No. 3,151,273 may be utilized with the invention disclosed in detail below.

It will also be understood that a plurality of spark gaps and nonlinear valves may be stacked in series and electrically connected to provide various ratings of interrupting voltage, as is well known in the art. Moreover, although an outer housing for a conventional arrester is not shown in the drawing, it will be understood that any conventional housing, such as that shown in the above noted patent, can be used in combination with the illustrated spark gap 1 and nonlinear valve 4 to electrically isolate these elements and provide suitable protection for them against the weather. The spark gap assembly 1 may be made in a manner similar to that explained in detail in the aforementioned Stetson et al. patent, and it includes a plurality of electrode pairs arranged to form a series of spark gaps that are isolated from one another in individual arcing chambers. In FIG. 1, one electrode of such an electrode pair 6 is shown in phantom in the uppermost arcing chamber and it is

electrically connected by a copper pin 7 to a second electrode pair 8 in a second arcing chamber disposed directly underneath the uppermost arcing chamber. In like manner, electrode pairs 9 and 10 are electrically connected in series with electrode pairs 6 and 8 and are disposed in their respective separated arcing chambers. Terminal plate 2 is electrically connected to one electrode of the uppermost electrode pair 6 by a copper pin 11 that is riveted to that one electrode and plate 2 or otherwise fastened in any conventional manner. Also, one electrode of the electrode pair 10 is connected by a copper pin 12 to the bottom terminal plate 3 in like manner.

It will be understood that the wall members forming the respective arcing chamber may be composed of any suitable insulating material, such as that described in the aforementioned Stetson et al. patent. Electrically connected in series between electrode 8 and electrode 9 is a coil 13 that is wound on a plastic coil housing 14 which serves to retain the coil in a predetermined form and also acts as a mounting means for holding the coil in a desired position with respect to the spark gap assembly 1 such that it provides a magnetic field to move arcs formed between the respective pairs of electrodes outward from the electrodes along their associated horn gaps to lengthen and extinguish the arcs in the manner described in detail in the above noted Stetson et al. patent.

Electrically shunt connected across the coil 13 is a coil spark gap, which is shown in detail in FIG. 2 of the drawing. Referring to FIG. 2 it can be seen that one end of the coil 13a is connected to an electrode 15 and the other end of the coil 13b is electrically connected to a second electrode 16. FIG. 2 also serves to illustrate the manner in which the housing 14 of coil 13 is nested in position between the upper surface of the portion of the spark gap assembly housing electrode pair 9 and the lower surface of that portion of the assembly housing electrode pair 8. The copper pin 8a connected to electrode 15 is also connected to electrode 8 in a suitable manner to assure a good electrical connection therebetween when the spark gap assembly is in finished form. In like manner, the copper pin 9a is electrically connected between electrode 9 and electrode 16. Thus, it will be appreciated that when a high voltage surge is applied across terminal plates 2 and 3, or 2 and 5 to ground, as would be the case if the illustrated assembly were mounted in a lightning arrester that is connected to a circuit to protect it against such surges, the high voltage surge will cause the respective spark gaps to arc over and, thus, form a direct short circuit through the respective gaps and the valve 4 to ground. There will also be a tendency for such a voltage to cause current to flow in coil 13 due to the arc voltage drop across its associated gap.

Pursuant to the invention disclosed herein, the series circuit inductance of coil 13 is carefully designed so that it is high enough to retard the passage of current therethrough for a predetermined interval of time following initiation of sparkover of the spark gap assembly 1. The particular inductive reactance needed to afford optimum operating characteristics will vary depending on the interrupting voltage rating of the associated spark gap assembly 1, but it has been found that for an interrupting rating of 6,000 volts it is desirable to have the inductance of coil 13 in a range between 20 to 30 millihenries and with the resistance of coil 13 in a range of 20 to 30 Ohms. Although such a value of inductance of coil 13 will allow a small current to flow through the coil during initial sparkover of the spark gap assembly 1, this small current develops a relatively weak electromagnetic field that causes the arcs formed in the primary spark gaps to move slowly along their respective horn gaps toward the peripheral wall of the arcing chambers. In addition, this relatively slow movement of the respective arcs is also accomplished in the coil gap shown in FIG. 2, thus, the voltage forcing current through coil 13 is gradually increased following the initial sparkover stages. However, this voltage buildup across coil 13 is slow enough to allow substantially the entire overvoltage surge of power from a lightning or switching surge of average duration to be discharged to ground before the coil gap arc has moved for enough to build

a substantial enough back voltage to cause significantly larger amounts of current to flow through coil 13. Of course, due to the very large number of turns on coil 13, when a small increase in coil current is accomplished, the magnetic field generated by coil 13 is greatly increased and rapidly drives the respective arcs into their maximum lengthened position against the arc quenching tortuous walls of the respective arcing chambers. As the over-voltage surge is dissipated, the discharge current through the arrester starts to decrease and when it has decreased to the value of the maximum current which has built up in the coil circuit the arc in the parallel gap formed between electrodes 15 and 16 extinguishes. All of the arrester current must then flow through the coil and, since the current is decreasing, the induced voltage in the coil due to this decreasing current is of a polarity that opposes the decrease. That is, the inductive reactance of the coil now acts to retard the rate of decrease of current and slows down the arrester clearing action. This slowing affect forces the arrester to clear very "gently" and prevents the occurrence of high "inductive kicks" from occurring across high inductance elements in the system being protected. It should be noted that the number of turns of the 20 to 30 millihenry coil 13 of the preferred embodiment of the invention will be approximately 450 turns. Of course, other embodiments of the invention may utilize various different numbers of turns to obtain the desired delay in time at which significant gap voltage is developed and to obtain the desired insertion of series inductance as the arrester clears or extinguishes the discharge arc.

Referring now to FIG. 3 of the drawing, there is shown an alternative embodiment of the subject invention. In this embodiment of the invention, rather than utilizing the coil gap shown in FIG. 2 of the drawing, there is shown a block of nonlinear valve material 17 disposed between an upper terminal plate 18 and a lower terminal plate 19 nonlinear valve 17 is electrically connected in series between electrodes 8 and 9 (shown in FIG. 1) and shunted across the coil 13 by coil leads 13a and 13b, which are soldered respectively to the terminal plates 18 and 19. It will be understood that in assembled position the block of nonlinear resistance valve material 17 is positioned in the core of coil 13 and insulated therefrom by the walls of coil housing 14. And the coil 13 will be connected in series with a spark gap assembly such as assembly 1, in the manner discussed above with reference to FIGS. 1 and 2.

In operation, this embodiment of the invention operates in substantially the same manner as the embodiment of the invention discussed with relation to FIG. 2 of the drawing. In particular, when an overvoltage surge is applied across the electrodes 2 and 5 of the spark gap assembly 1 and primary valve resistor 4, the arc is shorted to ground by main spark gaps arcing over so current passes through these gaps and through nonlinear valve resistors 17 and 4 to ground. Due to the high inductance of coil 13, which again is in the range of 20 to 30 millihenries for a 6 KV lightning arrester spark gap assembly, very little current flows in the coil 13. Then, as the voltage and current of the overvoltage surge declines, more current flows through the coil 13 and a very strong arc-moving electromagnetic field is established which rapidly extends the arcs in the main arcing chambers and drives them into arc extinguishing contact with the peripheral walls of these chambers. Similarly, as the arrester clears, the inductance of the coil tends to slow down or "soften" the clearing action but not so effectively as when the coil is paralleled by a spark gap because the parallel valve block is not open circuited as was the gap and therefore it limits the induced voltage occurring across the coil which in turn is what prevents the current from decreasing very rapidly.

It will be appreciated by those skilled in the art that the particular resistance and inductance characteristics of the coil 13 may vary in either of the embodiments discussed above, depending upon the specific initial arc discharge interval desired before appreciable arc movement occurs, and also depending upon the rate of arc quenching desired after arc movement is initiated. However, experimentation has shown that the coil

13 should have an inductance of at least 15 millihenries and a resistance in excess of 10 Ohms to provide adequate arc movement retarding means to allow a lightning arrester surge of average duration to be discharged to ground prior to the time that sufficient back voltage is built up by a shunt connected spark gap or valve resistor across coil 13.

It is also important to note that the arc moving characteristics of the coil 13 and the effective inductance in series with the gaps upon clearing may be regulated by varying other circuit elements in the disclosed arrester circuit. For example, an auxiliary inductance could be connected in series with the coil 13 and the number of turns on coil 13 could be reduced so that a weaker magnetic field for driving arcs outward from the main spark gaps is developed without changing the initial arc-movement retarding affect of the coil. Thus, it will be apparent to those skilled in the art that if it is desired to increase the discharge time afforded the main overvoltage surge and/or further control the induced kicks caused in inductive currents upon clearing, while retaining the rate of arc movement at a relatively slow level, it is only necessary to maintain the number of turns on coil 13 constant while placing additional inductive reactance in series with the coil 13 constant while placing additional inductive reactance in series with the coil 13 in a manner such that this added inductive reactance does not influence the magnetic field developed by the coil 13. Other modifications of the invention will be apparent to those skilled in the art and it is our intention in the appended claims to encompass all such modifications and improvements of the invention.

We claim:

1. In a lightning arrester of the type adapted to protect a high voltage electric power conductor from damage due to overvoltages surges, a housing of insulating material, first and second electrically conductive terminals mounted at spaced-apart points on said housing, a spark gap assembly and a nonlinear resistance valve mounted within said housing and electrically connected in series between said terminals, said spark gap assembly including at least one current limiting gap comprising a pair of horn gap electrodes mounted in an arc confining chamber, an electromagnetic coil disposed adjacent said at least one current limiting gap and adapted when adequately energized to produce magnetic flux for moving an arc formed between the pair of horn gap electrodes along the arc-running surfaces of these electrodes, said coil having an inductive reactance large enough to effectively prevent for a predetermined interval of time after sparkover of the current limiting gap energization of the coil adequate to move an arc along said arc running surfaces, whereby said current limiting gap is prevented from building up a substantial voltage for said predetermined interval, said predetermined interval of time being long enough to allow substantially all of an overvoltage surge discharged through said arrester to bypass the coil.

2. In combination, a current limiting spark gap, an electrically conductive coil disposed adjacent said spark gap and adapted when adequately energized to provide magnetic flux for moving an arc in a predetermined direction in said spark

gap, said coil being operative to prevent its energization sufficiently to move an arc in said spark gap for a predetermined interval of time after sparkover of said spark gap and being further operative to afford adequate energization thereof after said predetermined interval to develop a magnetic flux that moves an arc rapidly in said predetermined direction, said predetermined interval of time being long enough to allow substantially all of an overvoltage surge discharged through said arrester to bypass the coil.

3. The combination defined in claim 2 including means for regulating the energization of said coil comprising nonlinear resistance means shunting said coil in combination with a predetermined number of turns of said coil adapted to provide an inductive reactance substantially greater than the impedance of said nonlinear resistance means during said predetermined interval of time.

4. The combination defined in claim 3 wherein the inductance of said predetermined number of turns is greater than 15 millihenries.

5. The combination defined in claim 3 wherein the inductance of said predetermined number of turns is in the range between 20 to 30 millihenries, inclusive.

6. The combination defined in claim 2 including a nonlinear resistance valve shunt connected across said coil, said valve being adapted to afford a low-resistance path to high surge voltages and a high-resistance path to lower voltages.

7. The combination defined in claim 3 wherein said nonlinear resistance means comprises a voltage-building spark gap.

8. The combination defined in claim 3 wherein said nonlinear resistance means comprises at least one block of nonlinear valve material.

9. In a lightning arrester having at least one current limiting spark gap electrically connected in series with a nonlinear resistance valve the improvement comprising a high inductance coil shunted by coil-current control means, said coil-current control means being operable to bypass substantially all of the discharge current of an overvoltage surge grounded by the arrester around said coil and being further operable to pass all power follow current through said coil after the surge current has been discharge to ground, said arrester cm comprising a pair of terminals respectively mounted adjacent opposite ends thereof, and circuit means connected to form a series circuit between said terminals and said shunted coil.

10. In a lightning arrester having a plurality of main spark gaps electrically connected in series with a nonlinear resistance valve between a line terminal and a ground terminal on said arrester, the improvement comprising a high inductance coil, a current limiting spark gap shunt connected across said coil and series connected with said main spark gaps, the inductance of said coil being high enough to prevent a sudden change in arrester discharge current when the current limiting spark gap clears causing all current through the arrester to pass through said coil, whereby the arrester clears gently without developing a high voltage peak on its line terminal.

60

65

70

75