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LIGHTNING ARRESTER

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Fig. 1.

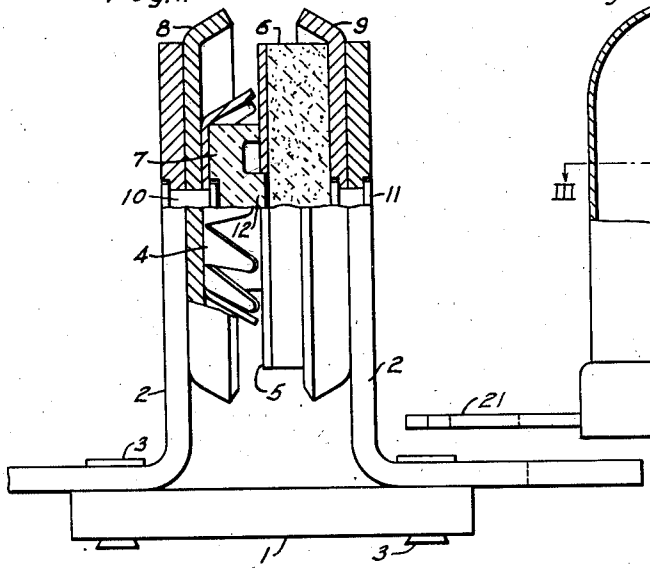


Fig. 2.

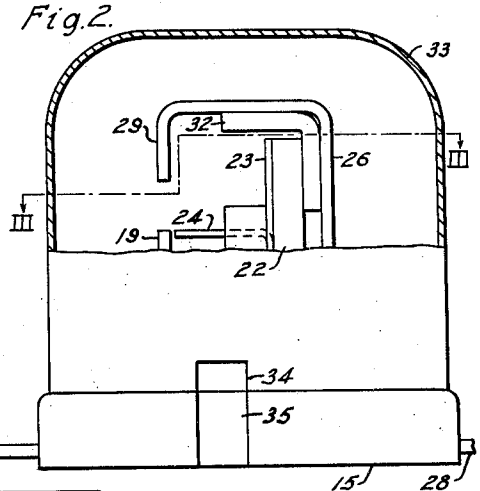


Fig. 3.

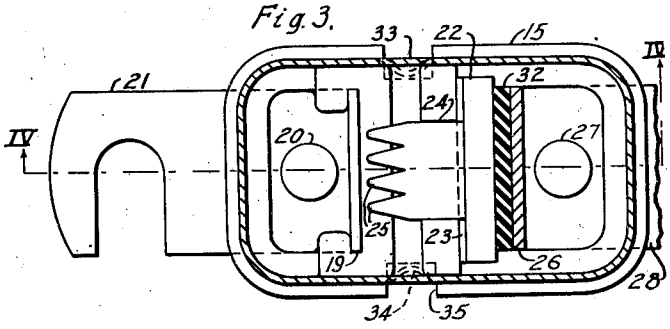


Fig. 5.

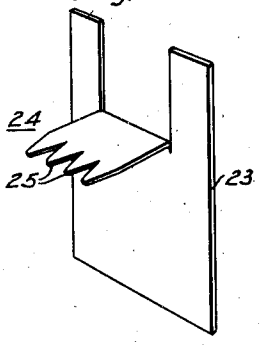
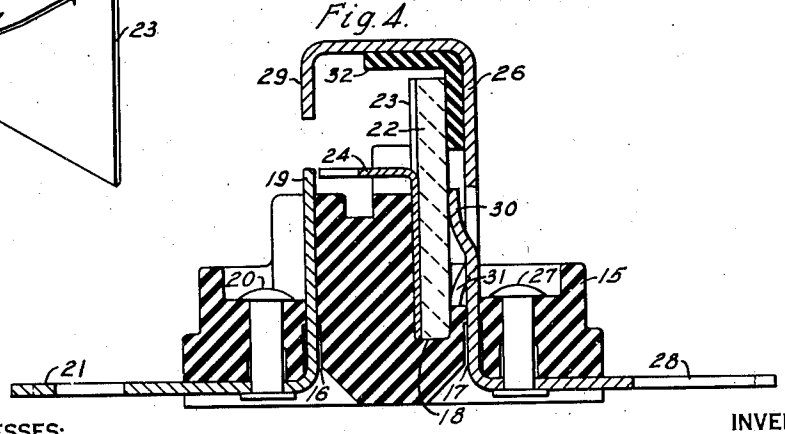


Fig. 4.



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LIGHTNING ARRESTER

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7 Claims. (Cl. 175—30)

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The present invention relates to lightning arresters and, more particularly, to a low-voltage lightning arrester which is capable of discharging very heavy surge currents without damage to itself.

The lightning arrester of the present invention is particularly intended for use on low-voltage circuits, such as railway signal circuits, or other exposed control or signal circuits, where the circuit must be reliably protected against lightning and against accidental grounding. The requirements for a lightning arrester for this service are rather exacting. The arrester must become conducting, and begin to discharge, at a relatively low voltage in order to prevent damage to the apparatus which it is to protect. It must be capable of discharging surge currents of considerable magnitude without producing a discharge voltage across the arrester which would be high enough to endanger the protected apparatus, and it should be able to handle high surge currents repeatedly without damage to itself. In addition, it should not be possible for an arrester for this service to become short-circuited, or permanently conducting, under any conditions, since accidental grounds on such circuits as railway signal circuits cannot be tolerated. In the past, it has been found very difficult to provide a satisfactory lightning arrester to meet these somewhat conflicting requirements, and most types of arresters which have been available for this service have had either good protective characteristics, or good protection against short-circuiting, but not both.

The principal object of the present invention is to provide a low-voltage lightning arrester which is capable of discharging very heavy surge currents repeatedly without damage to itself, and with a relatively low discharge voltage across the arrester during a discharge.

A further object of the invention is to provide a low-voltage lightning arrester which is capable of discharging very heavy surge currents and which has good protective characteristics, but which cannot become short-circuited under any conditions, even in case of damage to, or failure of, a part of the arrester.

More specifically, the lightning arrester of the present invention includes a short spark gap, so as to have the low breakdown voltage required for protection of railway signal apparatus and similar equipment, with a valve element in series with the short gap to limit the power current after a discharge, so that the gap can interrupt it, since the short gap, by itself, would not be capable of

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interrupting the current. One electrode of the gap consists of a plurality of spaced points, so that in case of failure of the valve element, or if for any other reason the current is not interrupted, the point or points involved will burn back until the arc is interrupted. Thus it is impossible for the electrodes to weld together and short-circuit the arrester.

Failure of the valve element would usually be caused by the passage of very heavy currents, beyond the capacity of the valve element, such as might result from a direct lightning stroke, or from accidental contact of the low-voltage protected circuit with a higher-voltage power line. Such heavy surge currents thus might damage the arrester, making it necessary to replace it, and they might also cause an undesirably, or dangerously, high discharge voltage across the arrester. In order to avoid these effects, in the lightning arrester of the present invention, a second, longer spark gap is provided in parallel with the series-related short spark gap and valve element. In case of a heavy discharge through the arrester, the discharge transfers from the short gap and valve element to the long gap, thus relieving the sensitive short gap and valve element from the heavy discharge current, and protecting them from damage, as well as keeping the voltage across the arrester low. The spacing of the longer gap is great enough so that it is capable, by itself, of interrupting the power current which follows a discharge, although such a gap would have too high a breakdown voltage to protect the circuit if used alone, and the electrodes of the longer gap are of rugged construction, so as not to be substantially damaged even by extremely heavy discharges. In this way, an arrester is provided which meets the exacting requirements outlined above for low-voltage signal-circuit lightning arresters, since the new arrester has a low breakdown voltage and is capable of discharging very heavy currents with a low discharge voltage but cannot become short-circuited under any conditions.

The invention will be more fully understood from the following detailed description, taken in connection with the accompanying drawing, in which:

Figure 1 is a view, partly in side elevation and partly in section, of one form of lightning arrester embodying the invention;

Fig. 2 is a side elevation, with the cover partly in section, of a lightning arrester, showing another embodiment of the invention;

Fig. 3 is a plan view, partly in section on the line III—III of Fig. 2;

Fig. 4 is a longitudinal sectional view on the line IV—IV of Fig. 3; and

Fig. 5 is a perspective view of an electrode element.

One embodiment of the invention is shown in Fig. 1. The lightning arrester shown in this figure is mounted on a base 1 of insulating material, and includes a pair of spaced metal supports 2 mounted on the base 1 by means of rivets 3, or in any other suitable manner. The supports 2 have extending ends which serve as terminals for the device, and their vertical portions have sufficient resilience to hold the arrester elements between them under the necessary pressure. The arrester proper includes a pair of electrodes 4 and 5, and a cylindrical valve block or resistor element 6. The valve block 6 may be made of any suitable resistance material having valve characteristics, that is, a material which has a very high resistance, or is semiconducting, under normal conditions, but which has a relatively low resistance when a high voltage is applied to it. Thus, the block 6 may be made, for example, of granular silicon carbide mixed with a suitable binder, such as sodium silicate, and molded to the desired size and shape and baked. Such valve elements are, of course, well known in the art.

The electrode 5 is a metal disk of substantially the same diameter as the block 6, and is placed in direct contact with the block. The other electrode 4 is generally cup-shaped and, as clearly shown in the drawing, has a plurality of spaced points about its periphery, forming the arc terminals of the electrode. The electrodes 4 and 5 are spaced apart by a ceramic spacer member 7, which is placed within the cup-shaped electrode 4 and bears against the plane electrode 5 to space the tips of the points of the electrode 4 a predetermined distance from the electrode 5, so as to form a short spark gap which will have a sufficiently low breakdown voltage. The spacer 7 perferably has a central projection 12 which engages in an opening in the electrode 5 to center the electrode in the assembly and hold it in position. In the case of an arrester intended for use on railway signal circuits, for example, the spacing of the electrodes 4 and 5 should be such that the breakdown voltage of the gap between them is less than 3,000 volts.

A second pair of electrodes 8 and 9 is also provided. The electrodes 8 and 9 are generally cup-shaped, as clearly shown in the drawing, and enclose the electrodes 4 and 5 and valve block 6. The electrode 8 is placed between the electrode 4 and one of the supports 2, the electrodes being secured to the support in any suitable manner, as by a rivet 10. The other cup-shaped electrode 9 is placed between the valve block 6 and the other support 2, and may be secured to the support 2 by a rivet 11. The elements of the arrester are held together under pressure by the resilient supports 2, the spacer 7 spacing the electrodes 4 and 5 apart as stated above, and the spacer 7 and valve block 6 also spacing the electrodes 8 and 9 apart. It will be seen that a spark gap is formed between the peripheral edges of the electrodes 8 and 9 which is considerably longer than the short gap between the electrodes 4 and 5, and which is in parallel to the series-related short spark gap and valve block 6.

In the operation of this device, when an over-

voltage such as a lightning surge occurs, the short gap between the electrodes 4 and 5 breaks down at a low enough voltage to protect the circuit to which the arrester is connected, and the surge is discharged through the valve block 6 and the short gap. If the discharge current is relatively low, the surge is discharged to ground in this way, and after passage of the surge, the current which tends to flow through the arrester to ground is limited by the increased resistance of the valve block 6 to such a small magnitude that it is readily interrupted by the short gap, thus restoring the arrester to its normal insulating condition. If, however, the discharge current through the arrester is relatively high, the longer gap between the electrodes 8 and 9 will spark over, and the discharge is transferred to the longer gap. This effect appears to occur because a heavy discharge current produces such profuse ionization of the air in the short gap that the space between the electrodes 8 and 9 becomes sufficiently ionized to cause breakdown in the long gap at a much lower voltage than would otherwise be required. Thus, the heavy discharge is transferred to the longer gap, which has heavy, rugged electrodes which are capable of withstanding the heavy discharge current without substantial damage. When the surge has passed, the power follow current is interrupted because of the relatively long spacing of the longer gap.

Thus, a low-voltage arrester is provided which has very good protective characteristics, since the short gap has a low enough breakdown voltage to provide a good margin of protection, while the longer gap is capable of discharging heavy surge currents without damage, although such a gap would have too high a breakdown voltage to be used by itself for protection of a low-voltage circuit. The discharge characteristics of this type of arrester are very good since the discharge voltage across the arrester is relatively low, even for very heavy currents, so that the protected apparatus is not subjected to a high voltage during the discharge. In case the valve block 6 should fail, or become punctured, so that a discharge across the short gap would not be interrupted, or if for any other reason the short gap continues to discharge, the point or points of the electrode 4, which are involved in the discharge, will burn back until the gap is lengthened sufficiently to interrupt the discharge. Thus, there is no possibility of the arrester bridging, or becoming short-circuited, under any conditions, since the effect of a continued discharge is to lengthen the gap until it is interrupted. Even if this should occur, however, the circuit is not left without protection, since normally only one or two points of the electrode 4 are involved in a particular discharge, and after they have burned back and interrupted the discharge, the remaining points are still intact, and the arrester is still operative to protect the circuit until it can be replaced. Thus, the new arrester fully meets the exacting requirements outlined above for arresters for railway signal circuits and similar applications.

Another embodiment of the invention is shown in Figs. 2 through 5. The arrester shown in these figures has a base 15, which is molded of any suitable insulating material. The base 15 is generally rectangular in outline and has two slots 16 and 17 extending vertically through it. Between the slots there is provided a transverse recess 13. The arrester elements themselves include a metal

electrode member 19 which extends upwardly through the slot 16 and is secured to the base 15 by means of a rivet 20. The electrode 19 has an extending end 21 which serves as a terminal for the device. A valve block 22 and a metal electrode member 23 are placed in the recess 18. The valve block 22 is made of a resistance material having valve characteristics, and may be similar to the block 6 described above in connection with Fig. 1, except that it is preferably rectangular in shape. The electrode 23 is also rectangular and of the same size as the block 22, and it is placed in direct contact with one side of the block 22, as shown. The electrode 23 has a portion 24 bent at right angles to the electrode so as to extend into close spaced relation to the end of the electrode 19, as clearly shown in Figs. 2 and 4, and the portion 24 of the electrode 23 terminates in a plurality of substantially parallel points 25, which form the arc terminals of the electrode.

A third metal electrode member 26 extends through the slot 17 of the base 15, and is secured to the base by a rivet 27. One end of the electrode 26 extends outwardly from the base to form a terminal 28. The other end of the electrode 26 extends up past the block 22 and electrode 23, and is bent over at right angles. The end portion 29 of the electrode 26 is bent down toward the upper end of the electrode 19, so that a relatively long spark gap is formed between the electrode portion 29 and the end of the electrode 19. The electrode 26 has oppositely extending spring elements 30 and 31 struck up from it, which bear against the block 22 to hold the block 22 and electrode 23 firmly in contact and in place in the recess 18, and also to effect electrical connection between the terminal 28 and the block 22. An angular insulating spacer 32 is placed between the block 22 and the upper part of the electrode 26 to space the electrode from the block and to prevent accidental discharges between the upper part of the electrode 26 and the block 22 or electrode 23. The complete arrester is enclosed by a cover 33 of sheet metal, or other suitable material, which fits over the upper part of the base 15 and is retained in position by indented portions 34 which engage in recesses 35 in the sides of the base 15.

It will be apparent that the operation of this embodiment of the invention is similar to the operation described above in connection with Fig. 1. Thus, when an over-voltage occurs, the short gap between the points 25 of the electrode 23 and the electrode 19 flashes over to discharge the surge. If the discharge current is relatively low, the surge is discharged through the short gap and the valve block 22, and, after passage of the surge, the block 22 increases its resistance and limits the current to such a low value that the short gap can interrupt it. In case of a heavy discharge current, the discharge transfers to the longer gap between the electrode portion 29 and the end of the electrode 19, which are of relatively rugged construction so as to be able to discharge heavy currents without substantial damage. The spacing of this longer gap is great enough so that the follow current is interrupted after passage of the excess voltage. In case of failure of the block 22 under a low surge current, or if for any other reason the discharge continues across the short gap without being either interrupted or transferred to the longer gap, the point or points 25 involved in the discharge burn back until the arc is lengthened and finally interrupted, thus preventing any possibility of bridging or short-circuiting of the arrester.

It should now be apparent that a low-voltage lightning arrester has been provided which has very desirable characteristics for the protection of low-voltage circuits, such as railway signal circuits. Tests have shown that the new arrester is capable of discharging very heavy surge currents, of the order of 100,000 amperes or higher, such as might result from a direct lightning stroke. Such heavy currents can safely be handled because of the provision of the relatively long spark gap in parallel with the series-related short spark gap and valve element. Tests have indicated that in a typical construction embodying the invention, the long, parallel gap sparks over at discharge currents of the order of about 1500 amperes or higher, with a time delay of the order of only three microseconds. The discharge voltage across the arrester during a discharge is very low, since for heavy-current discharges the valve element is by-passed by the parallel spark gap so that the discharge voltage is only the relatively low arc voltage. The long, parallel gap with its rugged electrodes protects the more sensitive elements of the arrester from damage due to heavy discharge currents, and thus permits the arrester to discharge very heavy currents repeatedly without damage and without affecting the protective characteristics. The possibility of the arrester becoming damaged, or of the valve element 22 failing or being punctured, is quite remote, but in case such failure should occur, or if for any other reason a discharge continues in the short gap without being either interrupted or transferred to the long gap, the points of the short gap burn back and interrupt the discharge without any possibility of the arrester becoming short-circuited, while the remaining points of the short gap are still available for subsequent discharges so that the circuit is not left unprotected until the damaged arrester can be replaced.

Thus, a low-voltage lightning arrester is provided which has very desirable characteristics, and which fully meets the exacting requirements of the type of service for which it is intended. Two specific embodiments of the invention have been shown and described for the purpose of illustration, but it will be apparent that various other embodiments are possible, and the invention is not restricted to the particular arrangements shown, but, in its broadest aspects, it includes all equivalent embodiments and modifications which come within the scope of the appended claims.

We claim as our invention:

1. A lightning arrester comprising a first pair of spaced electrodes, one of said electrodes having a substantially plane surface and the other of said electrodes having a plurality of points substantially equally spaced from the first-mentioned electrode to form a first spark gap therebetween, a block of resistance material having valve characteristics disposed in series relation with said first spark gap, and a second pair of spaced electrodes, said second electrodes enclosing the first pair of electrodes and the block of resistance material and forming a second spark gap of greater spacing than the first spark gap in parallel relation to the series-related first spark gap and block.

2. A lightning arrester comprising a first pair of spaced electrodes, one of said electrodes having a substantially plane surface and the other of said electrodes being generally cup-shaped and having a plurality of points about its periphery, spacing

means between said electrodes for spacing them a predetermined distance apart to form a first spark gap, a block of resistance material having valve characteristics disposed in series relation with said first spark gap, and a second pair of opposed, generally cup-shaped electrodes, said first spark gap and said block of resistance material being disposed within said second pair of electrodes and spacing them apart to form a second spark gap of greater spacing than the first spark gap and in parallel relation to the series-related first spark gap and block.

3. A lightning arrester comprising a base of insulating material, a first electrode member supported on the base, a second electrode member supported on the base, said second electrode member having a portion extending into close spaced relation to the first electrode member to form a spark gap therewith, a block of resistance material having valve characteristics supported on the base in contact with said second electrode member, and a third electrode member supported in the base in contact with the other side of said block, said third electrode member having a portion extending toward the first electrode member to form a spark gap therewith of greater spacing than the first-mentioned spark gap.

4. A lightning arrester comprising a base of insulating material, a first electrode member supported on the base, a second electrode member supported on the base, said second electrode member having a portion extending into close spaced relation to the first electrode member to form a spark gap therewith, said extending portion of the second electrode member terminating in a plurality of substantially parallel spaced points, a block of resistance material having valve characteristics supported on the base in contact with said second electrode member, and a third electrode member supported on the base in contact with the other side of said block, said third electrode member having a portion which extends past the block and the second electrode member to form a second spark gap with the first electrode member in parallel relation to the series-related first-mentioned spark gap and block, the spacing of said second spark gap being greater than the spacing of the first spark gap.

5. A lightning arrester comprising a base of insulating material, said base having two slots extending therethrough and having a recess between the slots, a first electrode member extending through one of said slots, a second electrode member and a block of resistance material having valve characteristics disposed in said recess, said second electrode member being in contact with one side of said block and having a portion extending into close spaced relation with said first electrode member to form a spark gap therewith, said extending portion of the second electrode member terminating in a plurality of substantially parallel, spaced points, and a third electrode member extending through the other slot in the base, said third electrode member being in electrical contact with the other side of said block and having a portion extending toward the first electrode member to form a second spark gap therewith, the spacing of said second spark gap being greater than the spacing of the first spark gap.

6. A lightning arrester for the protection of low-voltage signal or control circuits, said lightning arrester comprising first and second electrode means spaced apart to form a short spark gap between them, said spark gap having a breakdown voltage less than 3,000 volts and being so short that it is incapable, by itself, in its normal condition, of interrupting a discharge after an excess voltage has passed, a valve-type resistor disposed adjacent said second electrode means and having one side in electrical contact with the second electrode means so as to be in series relation with the spark gap, and a third electrode member disposed in electrical contact with the opposite side of said resistor and extending past the resistor to form a second spark gap with the first electrode means, said second spark gap being relatively long, as compared to the first-mentioned spark gap, and being long enough to be capable, by itself, of interrupting a discharge after an excess voltage has passed, both of said spark gaps having open, unrestricted arc paths, and the second gap being disposed adjacent the first gap so as to be rapidly ionized by a discharge in the first gap.

7. A lightning arrester for the protection of low-voltage signal or control circuits, said lightning arrester comprising first and second electrode means, one of said electrode means having a substantially plane sparking surface and the other of said electrode means having a plurality of substantially parallel points, means for supporting the electrode means with said points spaced from said plane sparking surface to form a short spark gap therebetween, said spark gap having a breakdown voltage less than 3,000 volts and being so short that it is incapable, by itself, in its normal condition, of interrupting a discharge after an excess voltage has passed, a valve-type resistor disposed adjacent said second electrode means and having one side in electrical contact with the second electrode means so as to be in series relation with the spark gap, and a third electrode member disposed in electrical contact with the opposite side of said resistor and extending past the resistor to form a second spark gap with the first electrode means, said second spark gap being relatively long, as compared to the first-mentioned spark gap, and being long enough to be capable, by itself, of interrupting a discharge after an excess voltage has passed, both of said spark gaps having open, unrestricted arc paths, and the second gap being disposed adjacent the first gap so as to be rapidly ionized by a discharge in the first gap.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 20,465	Brach	Aug. 10, 1937
1,510,731	Williams	Oct. 7, 1924
2,297,323	Rees	Sept. 29, 1942
2,330,918	Pittman	Oct. 5, 1943
2,386,720	Schlesinger	Oct. 9, 1945
2,415,945	Gilson	Feb. 18, 1947

FOREIGN PATENTS

Number	Country	Date
516,482	Great Britain	Jan. 3, 1940