Oct. 21, 1947. H. O. STOELTING 2,429,533

EXPULSION TYPE ARRESTER

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Fig. 1

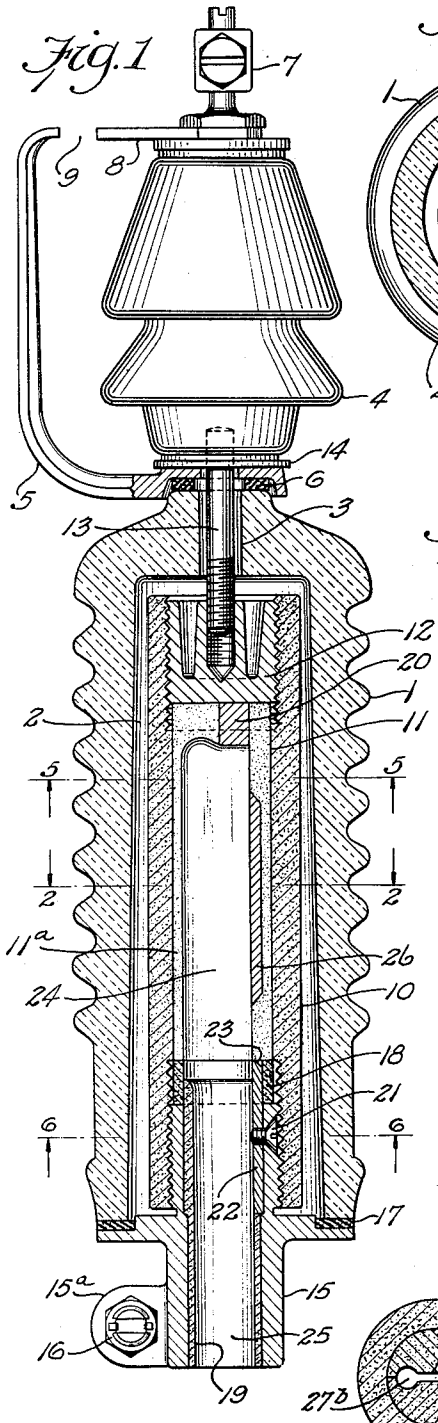


Fig. 2

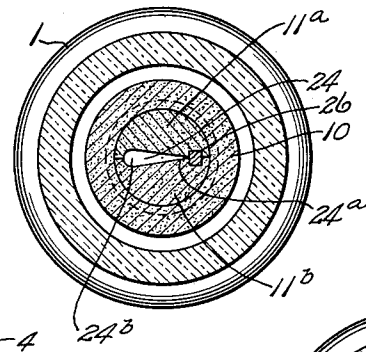


Fig. 3

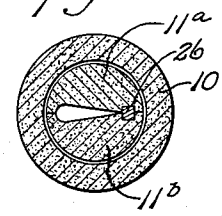


Fig. 4

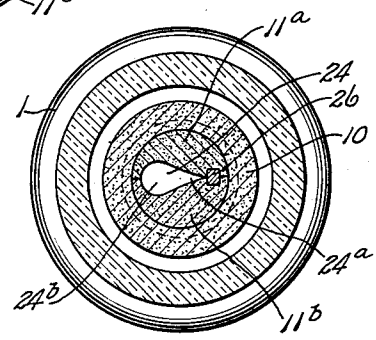


Fig. 5

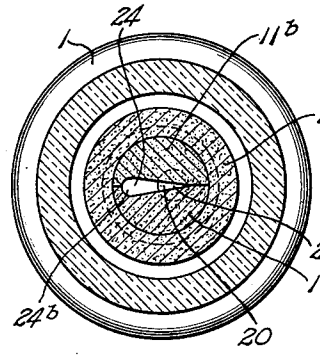


Fig. 6.

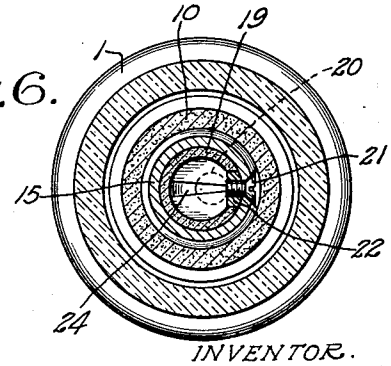
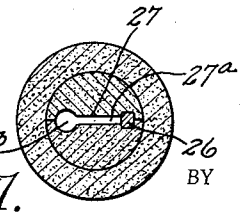


Fig. 7.



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Fig. 9

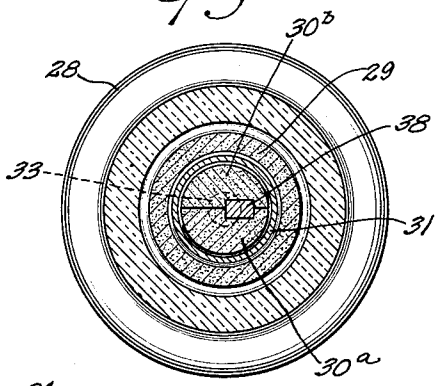


Fig. 8

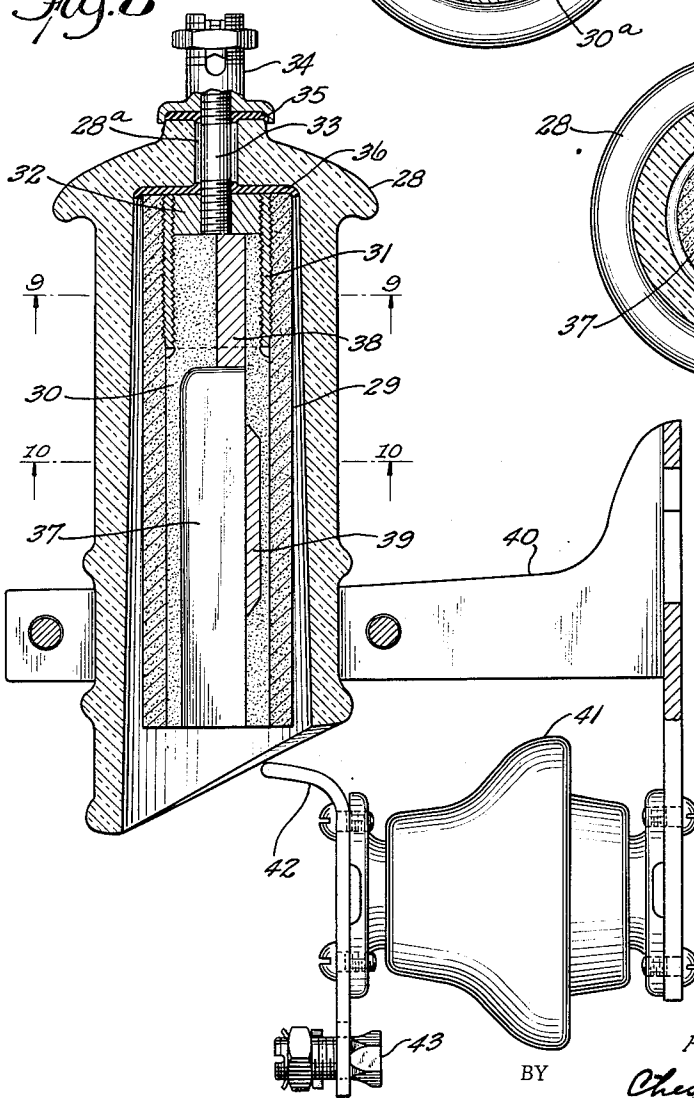
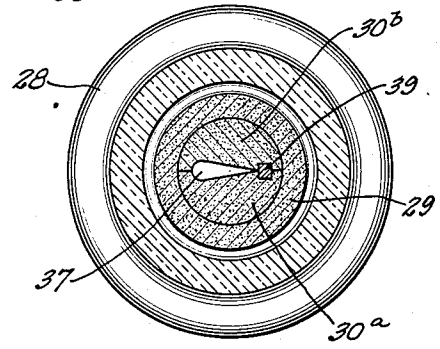


Fig. 10



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EXPULSION TYPE ARRESTER

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Application March 20, 1943, Serial No. 479,898

12 Claims. (Cl. 175—30)

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This invention relates to lightning arresters of the expulsion type designed for use on electric power distribution systems.

In areas where severe electrical storms are common it is economically necessary to provide protection for power and distribution transformers, and sometimes other line equipment; and this is accomplished through the agency of devices known, broadly, as lightning arresters—which devices provide relatively low impedance paths to ground for high potential surges and thus, in part, divert those destructive surges away from the protected equipment.

Where the maximum available power current, as distinguished from surge current, is exceedingly small, an ordinary spark-gap connected between line and ground will afford an adequate drainage path for lightning surges and provide all the protection that is needed; but that condition is one which seldom, if ever, actually obtains so far as electric power distribution is concerned, although it commonly obtains on communication lines.

Power current at commercial voltages is incapable of initiating an arc across a gap of the size ordinarily employed in a power type lightning arrester, but it will operate to maintain an arc across such a gap after the arc has been initiated by a lightning stroke; and for that reason it is necessary to provide, as an auxiliary to the spark-gap, some means which will function either to prevent continuance of the arc or quickly to extinguish the arc after the initiating surge has subsided. Otherwise the continuing arc would cause an outage by blowing a fuse or causing a circuit breaker to open—which means, of course, a service interruption.

There are a number of known feasible methods of extinguishing arcs, but, so far as I am aware, there are only two kinds of arc-extinguishing means which have proved practicable enough to be put into extensive use as adjuncts of lightning arresters of the spark-gap type. One of these is the so-called valve element consisting most often of a compact mass of granular silicon carbide, which is connected in series with the spark-gap and has the property of presenting relatively low impedance to high potential surges and relatively high impedance to power current at commercial voltages; and the other is the so-called expulsion tube which functions by virtue of its capacity to discharge arc-extinguishing gas or vapor when acted upon by an arc—which gas or vapor serves to scavenge or otherwise neutralize the arc path and thereby prevent reformation of

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the arc after the same has passed through zero phase. The present invention is concerned only with arresters of the last-mentioned variety.

The valve type arrester has in the past been considered more suitable than the expulsion type because of its greater life expectancy; but the latter is considerably cheaper and has for that reason been extensively employed on rural distribution lines where initial costs had to be kept at a minimum and where occasional outages were more tolerable than is the case with respect to lines serving thickly populated and industrial communities.

The conventional expulsion type arrester heretofore widely employed on rural lines is exemplified by U. S. Letters Patent No. 2,050,397, granted to Julius J. Torok, August 11, 1936, and consists of a round bore tube made either of horn fiber or "Bakelite" lined with horn fiber and having a pair of spaced gap electrodes at least one of which is within the bore of the tube, while the other electrode is at or near the open lower end of the tube so that the initiating spark and subsequent arc occur principally or entirely within the bore of the tube.

Expulsion type arresters are employed only on alternating current lines where the current and voltage pass through zero phase every half-cycle, and their operation is dependent upon the arc path within the tube bore being rendered incapable of supporting re-establishment of the arc after the power current has passed zero phase following the passage of an arc-initiating surge; and horn fiber is employed because when subjected to the heat of an arc it will emit un-ionized gas or vapor which is capable of being efficiently utilized to extinguish the arc. But to be effective the gas or vapor must be evolved very rapidly and in volume adequate to deionize the arc path or, at least, to so disperse the ions or break up the continuity or density of ionization that the arc will not re-strike when the power current again becomes ascendant.

There being a diversity of respectable opinion as to why the evolution of gas or vapor is effective to extinguish an arc, I shall refrain from expressing myself too positively on this controversial question; but it seems probable that the conductive ions or particles are swept out of the arc path by the rapidly moving evolved gas or vapor. Whatever the fact may be, the point is not vital here as it does not affect the adequacy of my disclosure or the ability of those skilled in the art to comprehend my invention and put the same into practice.

In order to realize enough gas or vapor evolution to extinguish the arc—where the power current is of relatively low amperage, as on rural lines—it is necessary to make the bore diameter of a conventional round-bore expulsion tube quite small. Commonly this is made about $\frac{5}{32}$ inch. And in order effectively to shield the transformer or other protected equipment, the total spark-gap span must be such as to prevent the building up of hazardous potentials before a sparkover will occur. This means that for installations where expulsion type arresters are most commonly employed the spark-gap is necessarily quite short.

With a small tube bore of the order indicated above there are two primary factors tending to shorten inordinately the life of the tube. One of these is the probability of the tube rupturing due to excessively high internal gas pressure generated in response to a heavy surge; and the other factor is rapid erosion of the fiber and consequent enlargement of the bore. If the tube ruptures, as often happens, its life is, of course, ended; and, in any event, after a relatively small amount of erosion has occurred the tube is no longer capable of extinguishing low current arcs. This is because a low current arc does not generate enough temperature to evolve gas from the enlarged bore surface at a rapid enough rate to cause adequate dispersion or scavenging of the ions or conductive particles to prevent re-establishment of the arc—the temperature being too much decreased by virtue of the enlarged space. And another factor tending to aggravate the above-described adverse conditions is that the spark-gap must, as previously stated, be quite short, wherefore only a small length of fiber surface within the tube is in sufficiently intimate contact with the arc. This means that the area of fiber from which gas is evolved copiously is unavoidably small in a conventional round bore tube designed for operation on rural lines and, incidentally, that the increase of bore diameter due to erosion is greatly accelerated by comparison with the rate of increase of bore diameter which would inherently obtain if the spark-gap length within the bore could be materially increased.

As a result of the foregoing factors, a conventional round-bore expulsion type arrester is quite deficient as concerns life expectancy; this deficiency being particularly pronounced where by reason of relatively small power currents the caliber of the tube must be small; and this is especially true where violent electrical storms are fairly frequent.

A conventional round-bore expulsion tube designed for use where power currents are invariably large and where, in consequence, the bore can be proportionately large, would not be nearly as deficient as the same type of tube having a small bore; but the fact is that expulsion type arresters have rarely been used on high power lines—it having been the general practice to install valve type arresters on those lines.

The primary desiderata in the design of any lightning arrester are: (1) low sparkover voltage, (2) long life, and (3) high surge capacity. Low sparkover voltage is of cardinal importance in that an arrester, to be effective, must always be capable of going into action before impressed surge potential can build up to a magnitude which would imperil the protected apparatus. Long life is important for economic and other obvious reasons; and high surge capacity is vital because

upon it depends the ability of the arrester to resist impairment and destruction, as an operative device, by heavy electircal surges.

The principal object underlying the present invention is to devise an expulsion type arrester having all the previously-recited characteristics—namely, low sparkover, long life, and high surge capacity. Otherwise stated, one object is to achieve a short sparkover distance without sacrifice of life-expectancy or surge capacity. Another object is to achieve long life-expectancy—by which I mean the ability to withstand a very large number of operations before being eroded beyond the point of operativeness. And a third object is to ensure that the arrester expulsion tube will not be ruptured by any surge at all likely to be encountered. It will be noted that in using the term "long life" I refer more specifically to the ability to continue operation notwithstanding erosion, and not to the capacity to withstand disruption—which latter property I designate as "surge capacity." Of course, surge capacity is in the broader sense a factor in life-expectancy; but it plays no part in the gradual wearing out of an arrester and has no known influence as respects the normal life span.

A further object of my invention is to device an expulsion type arrester which, while meeting the above-specified requirements, can be manufactured cheaply enough to meet the competition of other lightning arresters having comparable merits.

From what has been said before, it will be seen that there are two antagonistic factors affecting the determination of bore diameter in the design of round bore expulsion tubes—especially where the power current to be dealt with is comparatively low. One of these factors, namely, surge capacity, demands a large bore in order that the pressure generated within the tube by a heavy surge may not be great enough to burst the tube; but the other factor, namely, ability to extinguish low current arcs, demands a small bore. The present invention reconciles or contributes substantially to a reconciliation of these two opposing factors by providing a bore configuration which results in extinguishment of low current arcs while at the same time presenting a cross-sectional area which is large enough to prevent development of destructive pressures in response to such heavy surges as are at all likely to be experienced.

But the improved bore configuration, which I shall describe and discuss a little later, is not, standing by itself, an operative improvement. On the contrary, in order to be effective it must be combined with a particular disposition of spark-gap electrodes, so that the initiating spark and subsequent power current arc will follow more or less predetermined paths—all in accordance with principles which will be expounded hereinafter.

There are within the contemplation of this invention a large number of tube bore configurations which I look upon as in the nature of equivalents; and anyone skilled in the art, after reading the present specification, will recognize the impracticability of showing all the possible modifications which are obviously operative; but the specific configuration which I prefer—mainly because of manufacturing simplicity—is what I call "sectorial." More especially, it is acutely sectorial. That is to say, the preferred bore configuration has the form of a sector of a circle, or approximately so; and the angle of the sector is

quite acute. Thus, one portion (at least) of the bore configuration, that is to say the apex portion, is narrowly constricted in width whereas that portion of the bore configuration which is remote from the apex is considerably distended—comparatively speaking. With such a bore configuration, it will become apparent that there is presented an expulsion chamber which is constricted along one portion and distended along another but adjacent portion—this being of the essence of my invention, regardless of the specific bore configuration.

By disposing the spark-gap electrodes so that the shortest space path therebetween is exclusively or principally along the constricted portion of the tube bore, the power current arc which follows the initiating spark is caused inherently to favor the constricted portion of the bore—since that comprises the shortest path. Apparently for the same reason that a small round bore is more effective as an arc extinguisher than a large round bore—when the power current is low—the constricted portion of my sectorial or equivalent bore is most effective when the arc is weak. But it so happens, fortunately, in the operation of my improved arrestor, that while the arc current is well above zero phase, the arc is diverted laterally out of the constricted portion of the bore into the more distended portion, and recedes to the constricted portion as the amperage approaches a successive zero phase of its cycle.

This phenomenon results, to a very large degree, though not entirely, in confining the erosive action of the arc to the distended portion of the bore, where it has the least effect toward terminating the useful life of the tube. In this way the depth of erosion per operation is reduced because of the larger area acted upon while at the same time the erosive action is largely confined to an area where a given depth of erosion has the least diminutive effect on tube life. Because, as appears to be the case, the arc recedes to the constricted portion of the bore as it approaches zero phase, it is more effectively acted upon by the evolved gas—due, I believe, to the smaller space into which the gas then being evolved is discharged; and to this supposed action I attribute the pronounced efficacy of my improved arrester in extinguishing weak arcs notwithstanding the greatly increased area of the tube bore.

It is within the purview of my invention to employ a single pair of spark-gap electrodes arranged as previously indicated; but by reason of my novel bore configuration I am able to utilize to great advantage an intermediate spark electrode by virture of which the spark-gap within the tube is divided into two spaced portions; which is to say, two spaced spark-gaps in series. If this were done with a conventional round bore tube, nothing would be gained; but in the present case much is gained because the arc which follows the initial spark disregards or, at any rate, appears to disregard the intermediate electrode and passes directly between the two terminal electrodes. This means that the arc could be stretched out enormously, if that were desired, without increasing the sparking distance, and, as a practical matter, it permits lengthening of the arc within the tube to an extent which results in presentation to the arc of a much increased fiber surface area—which, in turn, spells a reduction in depth of erosion per operation. This, then, is one of the factors contributing to long life; the other being the diversion of the arc from the constricted portion of the bore to the distended portion, as previously explained.

Powerful electrical surges are capable of producing enormous internal pressures in expulsion tubes, and there are practical limits to what can be done by way of coping with such disruptive forces, since the cost may easily be prohibitive. Any tube, no matter how rugged, can be ruptured if the surge is heavy enough, and so, as a practical matter, it is necessary to determine more or less arbitrarily upon some surge value to serve as a test standard applicable alike to both valve type and expulsion type arresters. Such a standard has been suggested and rather widely observed, though having no legal status, and it contemplates a surge rising from zero, in five micro-seconds, to 65,000 amperes crest value and then decaying from crest to half value, that is 32,500 amperes, in an additional five micro-seconds. In developing arrester designs pursuant to the present invention, I have utilized test surges conforming to the above-stated proposed standard and also test surges of even greater severity, and I have found that to meet such tests consistently, with an adequate factor of safety, it was almost if not altogether necessary to resort to certain additional improvements which I conceived and tried out contemporaneously with the extended test program which the arresters of this invention have undergone. But I wish it to be understood that the subordinate features I am about to mention are not vital in the sense of being indispensable. They simply are improvements superimposed upon an already operative invention and contributing materially to the ability of my arrester to resist disruption without increasing production costs.

First among the subordinate improvements, although not necessarily the most important, is one which has to do with improving surge capacity and consists in splitting the expulsion tube lengthwise, leaving it free to expand laterally to a very slight extent, so that there results a constricted leakage passageway extending laterally from the tube bore and substantially throughout its length. This permits some of the excess pressure developed within the tube to be relieved—thus decreasing the possibility of disruption—but it does not appear to have any detrimental influence on the ability of the tube to extinguish follow-current arcs of low amperage, nor does it influence adversely the life of the tube.

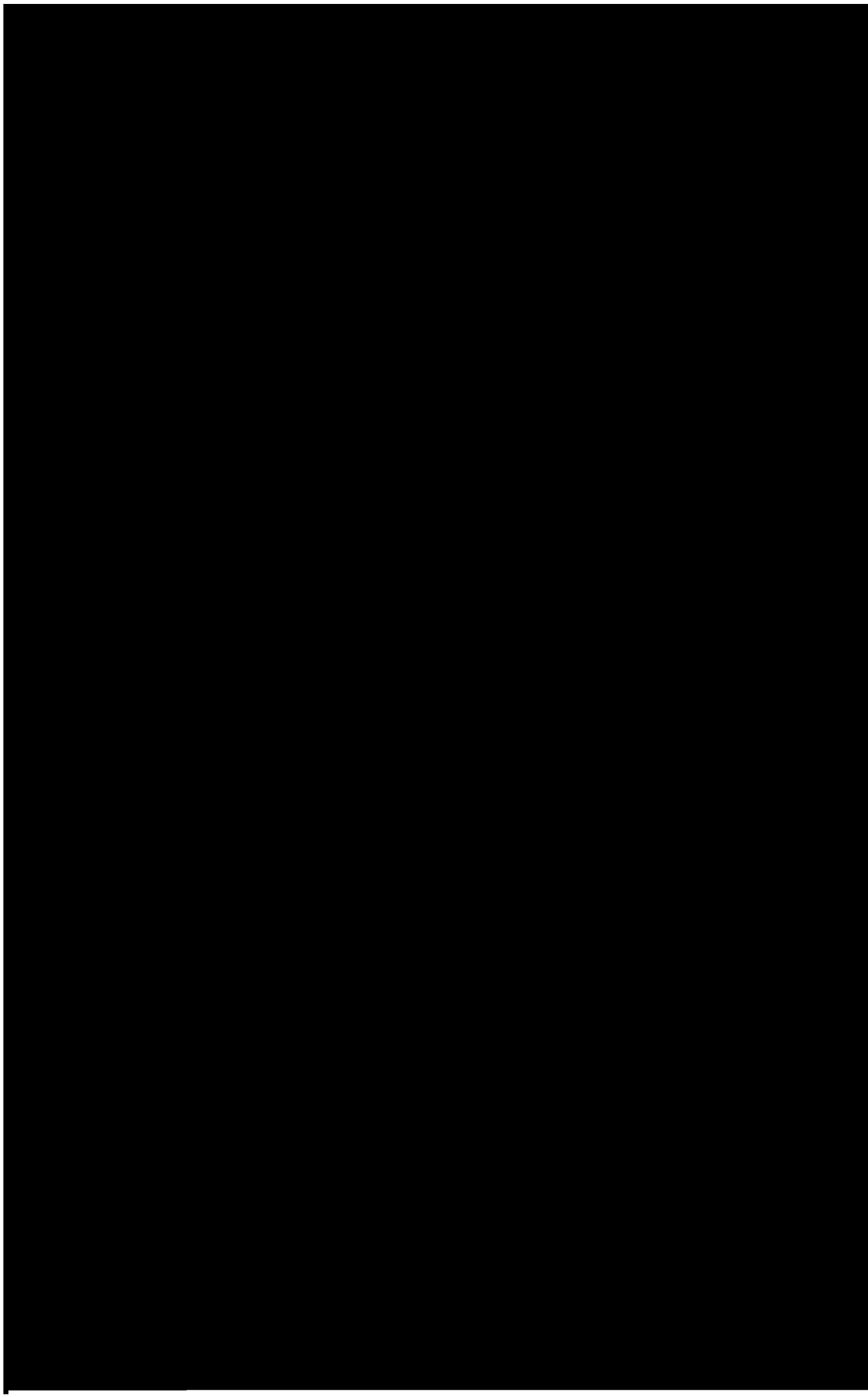
Another subordinate improvement having a similar effect and contributing, accordingly, to improved surge capacity without seeming to influence adversely the effectiveness of the tube, consists in forming the tube bore so that it tapers—increasing in cross-section toward the discharge end. This precaution manifestly diminishes the choking action of the tube and accordingly tends to curtail the pressure build-up within the tube; and it does so without diminishing to any noticeable degree the effectiveness of the tube with respect to extinguishment of low current arcs.

Referring now to the drawings which accompany this specification:

Fig. 1 is a longitudinal sectional view of an expulsion type arrester and depicts one of the preferred embodiments of this invention;

Fig. 2 is a cross-sectional view taken at 2—2 of Fig. 1;

Fig. 3 is a cross-sectional view corresponding to Fig. 2 (except for omission of the porcelain housing) and illustrating a modified construction



an examination of that figure it will be seen that the configuration is slot-like—being approximately sectorial—and is narrowly constricted along one edge portion and considerably distended along the opposite edge portion. The narrowly constricted edge portion is identified by reference numeral 24*a* whereas the distended portion of the slot is identified by reference numeral 24*b*. It is not important that the configuration of the slot be geometrically sectorial, as shown, but it is important that the slot be narrowly constricted in one portion and somewhat distended along an adjacent portion. I find that the approximately sectorial form shown works well, but, obviously, there are many possible deviations, within the scope of this invention, from what can be called geometrically sectorial. Therefore, when I use the term "sectorial" in this specification I wish it to be understood in a broad general sense, in keeping with the underlying principles of the invention, and not in a restricted geometrical sense.

It is also to be noted that the cross-sectional configuration of passageway 24 approximates that of an isosceles triangle wherein the included angle at the apex is acute.

The two half-portions 11*a* and 11*b* are also appropriately slotted to receive and secure, jointly, a third electrode 26 which will be known as the intermediate electrode. This is an elongate strip of metal of square cross-section, beveled at its two ends, as shown in Fig. 1, and disposed immediately adjacent the apex edge of passageway 24, as clearly depicted in Fig. 2—being spaced from both the upper electrode 20 and the lower electrode 23 to form two spaced spark-gaps within the expulsion chamber.

It is to be particularly observed that all three electrodes, 20, 23, and 26, respectively, are located immediately adjacent the narrowly constricted portion of passageway 24—which disposition is a material feature of the invention.

In the structure of Fig. 1 it may be assumed that the expulsion tube 11 is a tight fit in tube 10—the device being satisfactorily operative when that condition obtains. But I have found experimentally that the surge capacity of the arrester can be substantially improved by mounting the expulsion tube somewhat loosely in tube 10 so that the two half-portions can separate a little. It appears that by so doing the evolved gas is allowed more space in which to expand and therefore does not attain such a high peak pressure—for which reason the device is capable of handling a considerably heavier surge without bursting and without added reinforcement. In Fig. 3 the expulsion tube is shown mounted in tube 10 with a small clearance between. The clearance on each side should preferably be between .007 and .015 inch, but is not very critical.

When there is impressed across the terminals of the arrester a surge of sufficient potential to cause it to operate, a spark occurs at gap 9 and simultaneously at two spaced gaps within the expulsion tube. These latter are the gap between upper electrode 20 and the upper end of intermediate electrode 26, and the gap between the lower end of the intermediate electrode and the upper end of lower electrode 22. Manifestly, these two last-mentioned gaps can be spaced as far apart as desired without increasing the total sparking distance. Immediately following the initial spark-over, the arc which follows—including, I believe, both surge and follow current—

proceeds to ignore the intermediate electrode and passes directly between the upper and lower electrodes while at the same time being deflected out of the narrowly constricted apex portion 24*a* of passageway 24 and into and along the distended portion 24*b*. That this is true is evidenced by the fact that the distended portion 24*b* is eroded to a much greater extent than the narrowly constricted portion 24*a*; and the converse would be true if the arc were distributed uniformly throughout the cross-sectional area of the passageway. Thereafter, according to my theory, when the surge has subsided and the follow current is approaching a zero phase of its cycle, the arc moves back into the narrowly constricted portion 24*a*. It does this, in my opinion, because it prefers the shortest path, and the deflecting force which previously caused its diversion from the shortest path is no longer sufficient to maintain the diversion. It has not been possible to prove with certainty that the waning arc does in fact return to the apex portion of the passageway as a prelude to extinguishment, but reasoning from the known behavior of conventional round-bore expulsion tubes I have not been able otherwise to explain how it comes to pass that my expulsion tube, having a comparatively large area bore, is able to extinguish low current arcs following low current surges, whereas such arcs could not be extinguished with round bore tubes of comparable cross-sectional bore area.

All three spark electrodes, as previously noted, are placed immediately adjacent the apex edge of passageway 24, while fitting 15 is so insulated and disposed that the arc cannot pass directly to said fitting and thus ignore electrode 22. I found in the course of my experiments that if the arrester were so constructed that the arc could flash to fitting 15 or its equivalent at a point in line with the distended portion of the passageway and, therefore, away from the narrowly constricted portion, the arc frequently could not be extinguished under unfavorable conditions—by which conditions I mean a relatively weak surge and weak follow current. This, I think, substantiates my view that the waning arc returns to the narrowly constricted portion of the passageway and is there extinguished, whereas it would not otherwise be extinguished under unfavorable conditions.

In stating the objects of this invention it was said that these included (1) low spark-over, (2) high surge capacity, and (3) long life. Now will follow an explanation as to how those objects are achieved.

Realization of satisfactorily low spark-over value means simply that the combined spark gaps, in series, must be short enough, in toto, so that a spark-over will occur before a surge potential can build up to an injurious magnitude. This is absolutely mandatory since otherwise the arrester would afford no protection. A certain amount of compromise is possible in that the potential build-up can be permitted to reach a value which approaches the break-down resistance of the protected apparatus; but this means that as the break-down resistance of the protected apparatus decreases with the passing of time, the margin of safety diminishes, until at last the surge potential can reach ground via the protected apparatus more easily than through the arrester.

In all prior art expulsion type arresters of which I have any knowledge there is but one spark-gap within the expulsion tube, and the

shorter that gap is made the shorter is the life of the arrester. This follows from the fact that the fiber erosion is localized between the electrodes, and the more restricted the area of fiber acted upon by the arc the greater is the depth of erosion per operation. Consequently, it will be apparent that heretofore there has been a conflict between optimum spark-gap length and life expectancy. In addition, the evolution of arc-extinguishing gas from the fiber is diminished by decreasing the area of fiber intimately exposed to the arc to a greater extent than the gas evolution is increased as a consequence of shortening the arc. Putting this another way, an increase in the surface area of fiber acted upon by the arc will increase the expulsive pressure to a greater extent than said pressure would be diminished as a result of stretching out the arc. Hence, in my new arrester the arc-extinguishing effectiveness is increased as a result of the arc extending all the way from the upper to the lower electrode and vice versa, while at the same time the scouring out or erosion of the fiber is spread over a greater area and is of greatly decreased depth per operation.

Life-expectancy and the ability to extinguish low current arcs are both materially increased by virtue of the intermediate electrode, which results in elongating the arc; but that is not the only contributing factor to increased life-expectancy. In Fig. 4 it is shown that the erosion of the fiber is most pronounced in the distended portion of passageway 24 and that the erosion in the more constricted apex portion is much less pronounced. The ability of the tube to extinguish a low current arc following a light or moderate surge is dependent upon the portion 24*a* remaining narrowly constricted, and, relatively, is but little affected by an increase in the cross-sectional area of the distended portion 24*b*.

I have found it to be of some considerable importance that the upper and lower ends of intermediate electrode 26 and the upper end of lower electrode 22 be beveled, as shown, to sharp edges. This has a clear tendency to confine the sparkover to the interior of the expulsion chamber and prevent it entering the joint between half-portions 11*a* and 11*b*. Contrary to expectations, the sharp edges are not seriously pitted by the spark or arcing current. This is almost certainly due to the fact that the arc ignores the intermediate electrode, after the initial spark, and to the further fact that the arc, for some unknown reason, contacts lower electrode 22 along its exposed surface near its lower end, to the exclusion of the sharpened upper end.

In arrester structures built according to Fig. 1, I have tested and found satisfactory expulsion tubes wherein the cross-sectional area of passageway 24 was ⅞ inch long by $\frac{3}{32}$ inch wide, measured across the distended portion 24*b*; and I have also employed successfully a passageway having the above cross-sectional dimensions at the top end, but tapered widthwise toward the bottom end to a width of $\frac{2}{32}$ inch measured across the distended portion 24*b* at the lower end of the expulsion tube—the cross-sectional length of the opening being constant. None of the above dimensions are to be regarded as critical; but they will serve as a guide to those who are skilled in the design of expulsion type arresters.

The over-all length of the expulsion tube will generally vary in conformity with the rated voltage. For 2400 volt service I make the length of the expulsion tube 3¼ inches; for 4800 volts, 4½ inches; and for 7200 volts 5⅞ inches. The foregoing are standard rural line voltages.

Manifestly, if the angularity of the slot 24 is increased so much that the apex portion 24*a* is no longer narrowly constricted, compared to the distended portion 24*b*, the principles underlying the invention will cease to be operative. I have found that an angularity of 25 degrees is about the maximum at which the device will operate in accordance with this invention and still produce the improved results to a substantial degree. The optimum angle is more nearly of the order of 14 degrees and, in all events, within the range of 10 to 20 degrees. Decreasing the angle too much will have a tendency to decrease the surge capacity somewhat, while at the same time tending to obliterate the distinction between the constricted and distended portions of the slot. An angle of five degrees is about the minimum that can be effectively utilized when the slot is geometrically sectorial or approximately so.

As already remarked, the sectorial cross-sectional formation of passageway 24 is not of the essence of the invention, but is merely one practicable and desirable form. In order to make this point clear, I have illustrated in Fig. 7 an alternative form of slot which may be substituted for the sectorial form. In Fig. 7 the slot is identified by reference numeral 27. The narrowly constricted portion is identified by reference numeral 27*a* and the distended portion by numeral 27*b*. The narrowly constricted portion has parallel sides instead of angularly converging sides.

In Figs. 8–10 inclusive there is depicted a second expulsion type arrester embodying all the previously-discussed novel features of the present invention. The principal differences lie in omission of one of the spark-gaps, omission of the discharge fitting, and mounting of the lower electrode independently of the arrester housing. This design has one advantage, at least, over the structure of Figs. 1–6 in that the bore of the expulsion tube can be more easily inspected for the purpose of ascertaining the extent of erosion and, hence, for determining whether the arrester should be replaced.

In this instance the arrester housing—which is generally made of porcelain—is identified by reference numeral 28. Disposed within the housing is a tubular member 29 of insulating material—preferably fiber—which serves as a retainer for an expulsion tube 30.

The upper end of tubular member 29 is threaded internally to receive a metal sleeve 31 which is internally threaded to engage the externally threaded upper end of the expulsion tube and an externally threaded metal plug 32. The latter is drilled and tapped to engage the lower end of a stud 33 which extends through an aperture 28*a* in the cap of the housing and is threaded into a solderless connector 34. A gasket 35 is inserted between the solderless connector and the top of the housing; and a second gasket 36 is inserted between the under side of the housing cap and the upper end of tube 29. Stud 33 supports all the parts within the housing while at the same time anchoring the solderless connector to the housing. It also functions as a conductive connection between the solderless connector and plug 32.

Expulsion tube 30 is split longitudinally to form two complementary semi-cylindrical half-portions 30*a* and 30*b* respectively, and is milled out internally to form an expulsion chamber 37, the cross-sectional configuration of which is

shown in Fig. 10—being sectorial, as in the previous case. The expulsion chamber constitutes a vertically trending passageway terminating in a discharge port at the lower end of the expulsion tube.

Gripped between the two semi-cylindrical half-portions 30*a* and 30*b* are an upper electrode 38 and an intermediate electrode 39, which are disposed in complementary recesses cut in the two half-portions 30*a* and 30*b*.

The arrester housing is supported by means of a metal bracket 40 which is adapted for attachment to a pole or cross-arm and which also serves as the supporting medium for an insulator 41. To the latter is secured a lower electrode 42, to which is secured a solderless connector 43.

A connection to line is made via connector 34, and the ground connection is made at connector 43.

It will be observed that the upper and lower electrodes 38 and 42 are situated approximately in line with the constricted apex portion of passageway 37 and that the intermediate electrode is disposed immediately adjacent the apex.

The mode of operation is precisely the same as in the case of the previously described arrester. But here there are only two spark-gaps instead of three. The elimination of one spark-gap is made feasible by mounting the lower electrode in well insulated relation to the fiber elements 29 and 30.

What is claimed is:

1. In a lightning arrester of the expulsion type: a tubular retainer member of insulating material, a plug secured to and forming a closure for one end of said member, a conductive discharge fitting secured to the other end of said member, said fitting having a discharge passageway extending therethrough, an expulsion tube within said member and embraced laterally thereby, said expulsion tube being supported endwise between said plug and said discharge fitting, said expulsion tube having a laterally enclosed internal expulsion chamber extending lengthwise thereof and opening at one end into said discharge passageway, the other end of said chamber being closed, the cross-section of said chamber, viewed along planes normal to its length, being an aperture of elongate slot-like configuration, said chamber having a lengthwise extending portion which is narrowly constricted widthwise and another lengthwise extending portion which is considerably distended widthwise, a first electrode exposed to said chamber at the closed end thereof, a second electrode carried by said discharge fitting and exposed to said chamber at the open end thereof, said electrodes being so oriented that the shortest sparking and arcing path therebetween is exclusively within the constricted portion of said chamber, and an elongate third electrode extending lengthwise of said chamber and exposed to said chamber only along the constricted portion thereof, said electrodes being spaced to form, conjointly, a first spark-gap near the closed end of said chamber and a second spark-gap near the open end of said chamber, both said spark-gaps traversing the constricted portion of said chamber to the exclusion of the distended portion, said discharge fitting being insulated to prevent it functioning as an arc electrode.

2. In a lightning arrester of the expulsion type: a tubular retainer member of insulating material, a plug secured to and forming a closure for one end of said member, a conductive discharge fitting secured to the other end of said member, said fitting having a discharge passageway extending therethrough, an expulsion tube within said member and embraced laterally thereby, said expulsion tube being supported endwise between said plug and said discharge fitting and comprising two elongate semi-cylindrical contiguous members composed of material having the capacity to emit effective quantities of arc-extinguishing gas or the like when subjected to high temperature, said expulsion tube having a laterally encolsed expulsion chamber extending lengthwise thereof and opening at one end into said discharge passageway, the other end of said chamber being closed, said chamber being defined by said semi-cylindrical members jointly, the cross-section of said chamber, viewed along planes normal to its length, being an aperture of elongate slot-like configuration, said chamber having a lengthwise extending portion which is narrowly constricted widthwise and another lengthwise extending portion which is considerably distended widthwise, a first electrode secured between said semi-cylindrical members and exposed to said chamber at the closed end thereof, a second electrode carried by said discharge fitting and exposed to said chamber at the open end thereof, said electrodes being so oriented that the shortest sparking and arcing path therebetween is exclusively within the constricted portion of said chamber, and an elongate third electrode extending lengthwise of said chamber and exposed to said chamber only along the constricted portion thereof, said electrodes being spaced to form, conjointly, a first spark-gap near the closed end of said chamber and a second spark-gap near the open end of said chamber, both said spark-gaps traversing the constricted portion of said chamber to the exclusion of the distended portion, said discharge fitting being insulated to prevent it functioning as an arc electrode.

3. In a lightning arrester of the expulsion type: a tubular retainer member of insulating material, an expulsion tube within said retainer member and co-axial therewith, said tube comprising two complementary semi-cylindrical portions composed of material having the capacity to emit effective quantities of arc-extinguishing gas or the like when subjected to high temperature, said semi-cylindrical portions being grooved complementatively to form, conjointly, an elongate expulsion chamber of slot-like cross-section, said chamber trending lengthwise of said tube and being closed at one end and open at the other, a sleeve encircling one end of said tube and threaded thereto, said sleeve being also threaded to one end of said retainer member, a nut threaded into said sleeve, a housing of insulating material enclosing said retainer member except at one end, a stud extending through the closed end of said housing and engaging said nut within said housing, a connector threaded to the outer end of said stud, a first electrode interconnecting said stud with the interior of said chamber at the closed end thereof, supporting structure for said housing, an insulator carried by said supporting structure, a second electrode carried by said insulator and disposed exteriorly of said chamber and near the open end thereof in arcing relation to said first electrode, and an elongate third electrode situated intermediately of said first and second electrodes in spaced relation to each, said third electrode extending lengthwise of said chamber and exposed thereto only along one edge thereof.

4. In a lightning arrester, an expulsion tube

closed at one end and open at the other, the full length of the bore of said tube having an elongated cross-sectional delineation including an apex at one end of the elongation and a relatively wide base portion at the other end, an electrode at each end of said bore and an electrode intermediate the ends of said bore, said electrodes being disposed at the apex end of said elongation to the exclusion of substantially the remaining portion of said elongation, said arrester being characterized in its operation by spark-over between successive electrodes and by arcing between the end electrodes to the virtual exclusion of the intermediate electrode as an element of the arcing path.

5. In a lightning arrester, an expulsion tube closed at one end and open at the other, the full length of the bore of said tube having an elongated cross-sectional configuration which approximates that of an isosceles triangle wherein the included angle at the apex is more than ten degrees and less than twenty degrees, an electrode at each end of said bore and an electrode intermediate the ends of said bore, said electrodes being disposed at the apex end of said elongation to the exclusion of substantially the remaining portion of said elongation, said arrester being characterized in its operation by spark-over between successive electrodes and by arcing between the end electrodes to the virtual exclusion of the intermediate electrode as an element of the arcing path.

6. In a lightning arrester of the expulsion type: two complementary members composed of material having the capacity to emit effective quantities of arc-extinguishing gas or the like when subjected to high temperature, said members having complementative elongate grooves, defining, conjointly, a laterally enclosed passageway constituting an expulsion chamber which is open at one end and closed at the other, the transverse cross section of said passageway including an apex at one side of the elongate grooves and a relatively wide base portion at the other side, an electrode at each end of said passageway and an electrode intermediate the ends of said passageway, said electrodes being disposed at the apex side of said elongate grooves to the exclusion of substantially the remaining portion of said elongate grooves, said arrester being characterized in its operation by spark-over between successive electrodes and by arcing between the end electrodes to the virtual exclusion of the intermediate electrode as an element of the arcing path.

7. In a lightning arrester of the expulsion type: two complementary members composed of material having the capacity to emit effective quantities of arc-extinguishing gas or the like when subjected to high temperature, said members having complementative elongate grooves, defining, conjointly, a laterally enclosed passageway constituting an expulsion chamber which is open at one end and closed at the other, the transverse cross section of said passageway including an apex at one side of the elongate grooves and a relatively wide base portion at the other side, retainer means embracing said members for holding said members together against internal pressure, an electrode at each end of said passageway and an electrode intermediate the ends of said passageway, said electrodes being disposed at the apex side of said elongate grooves to the exclusion of substantially the remaining portion of said elongate grooves, said arrester being characterized in its operation by spark-over between successive electrodes and by arcing between the end electrodes to the virtual exclusion of the intermediate electrode as an element of the arcing path.

8. In a lightning arrester, an expulsion tube closed at one end and open at the other, the full length of the bore of said tube having an elongated cross-sectional delineation including an apex at one end of the elongation and a relatively wide base portion at the other end, an electrode at each end of said bore, said electrodes being disposed at the apex end of said elongation to the exclusion of substantially the remaining portion of said elongation.

9. In a lightning arrester of the expulsion type: two complementary members composed of material having the capacity to emit effective quantities of arc-extinguishing gas or the like when subjected to high temperature, said members having complementative elongate grooves, defining, conjointly, a laterally enclosed passageway constituting an expulsion chamber which is open at one end and closed at the other, the cross section of said passageway including an apex at one side of the elongate grooves and a relatively wide base portion at the other end, an electrode at each side of said passageway, said electrodes being disposed at the apex side of said elongate grooves to the exclusion of substantially the remaining portion of said elongate grooves.

10. In a lightning arrester of the expulsion type: means defining a laterally enclosed elongate expulsion chamber, said chamber being closed at one end and open at the other end to provide a discharge port, the transverse cross section of said chamber being an aperture of elongate slot-like configuration, said chamber being narrowly constricted widthwise, substantially throughout its length, at one portion of its cross-sectional area, and considerably distended widthwise, substantially through its length, at an adjacent portion of its cross-sectional area, and a plurality of electrodes spaced apart in series and disposed lengthwise of said chamber in the constricted portion thereof to the exclusion of substantially the remaining portion of said chamber, said arrester being characterized in its operation by spark-over between successive electrodes and by arcing between the end electrodes to the virtual exclusion of the intermediate electrodes as elements of the arcing path.

11. A lightning arrester comprising an insulating tube, an electrode in one end of said tube, said tube having an expulsion chamber extending from said electrode to the other end thereof and open at said other end for the expulsion of gases in said chamber, and a second electrode exteriorly of said chamber at said other end of said tube in unobstructing relation thereto, said chamber having an elongated cross-sectional delineation including an apex at one end of the elongation and a relatively wide base portion at the other end, said electrodes being disposed along the apex end of said chamber to the exclusion of substantially the remaining portion of said elongation.

12. In a lightning arrester, an expulsion tube closed at one end and open at the other, the full length of the bore of said tube having an elongated cross-sectional delineation including an apex at one end of the elongation and a relatively wide base portion at the other end, spaced electrodes disposed at the apex end of said elongation to the exclusion of substantially the remain-

ing portion of said elongation, a first arc path between said electrodes, and a second arc path between said electrodes, said first arc path being in the apex portion of said bore, said second arc path being in the wide portion of said bore, both said paths being confined laterally within said bore.

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