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Carpenter

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[54] TWO-WIRE PREIONIZER FOR SURGE VOLTAGE ARRESTERS

[72] Inventor: **Thomas J. Carpenter**, Pittsfield, Mass.

[73] Assignee: **General Electric Company**

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[52] **U.S. Cl.** **315/36**, 317/70

[51] **Int. Cl.** **H01t 1/00**

[58] **Field of Search** 315/36; 317/70

Primary Examiner—Roy Lake
Assistant Examiner—Darwin R. Hostetter
Attorney—Francis X. Doyle, Vale P. Myles, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman

[57] **ABSTRACT**

A preionizer for a surge voltage arrester, such as a lightening arrester, is formed by twisting the ends of a pair of wires, at least one of which is insulated except at its end, together so that the exposed ends of the wires form an ionizing gap that is essentially as long as the thickness of insulation between the two wires. After the ionizing gap is formed, an epoxy bead is used to encapsulate the twisted portion of the preionizer in order to maintain the desired gap spacing. The epoxy bead may also be utilized to position the ionizing gap adjacent a main gap or a trigger gap that is to have its sparkover level stabilized by the preionizing action of the twisted-wire preionizer of the invention.

11 Claims, 4 Drawing Figures

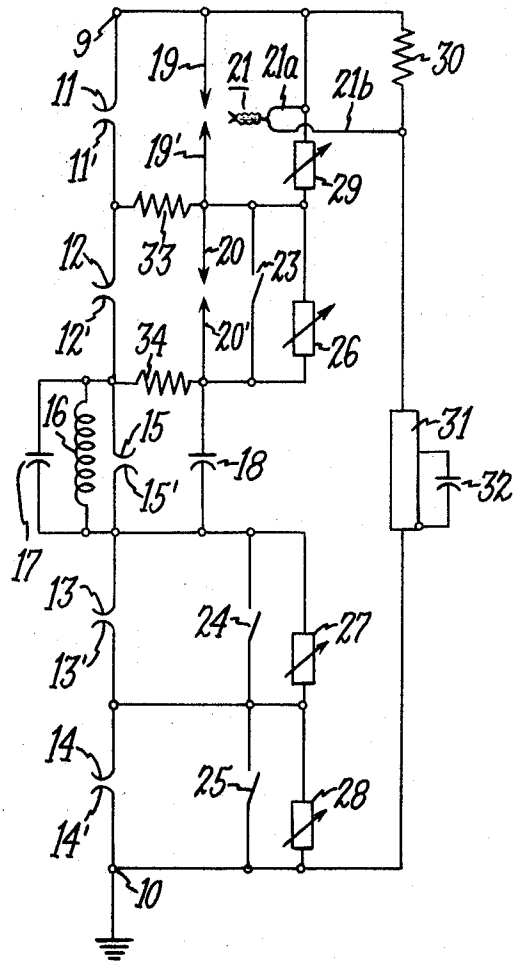


Fig. 1.

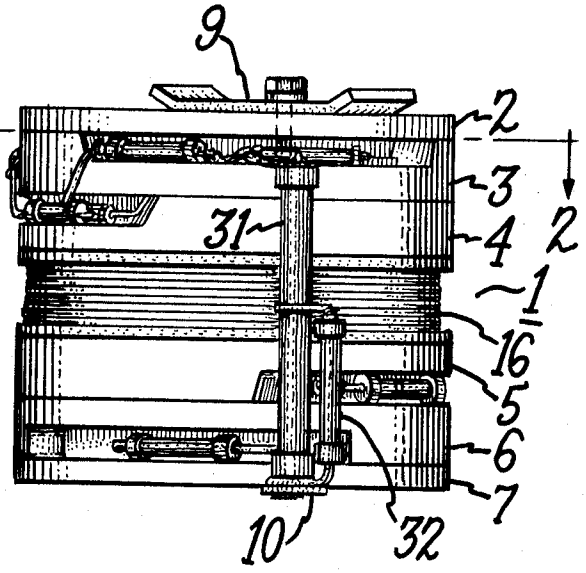
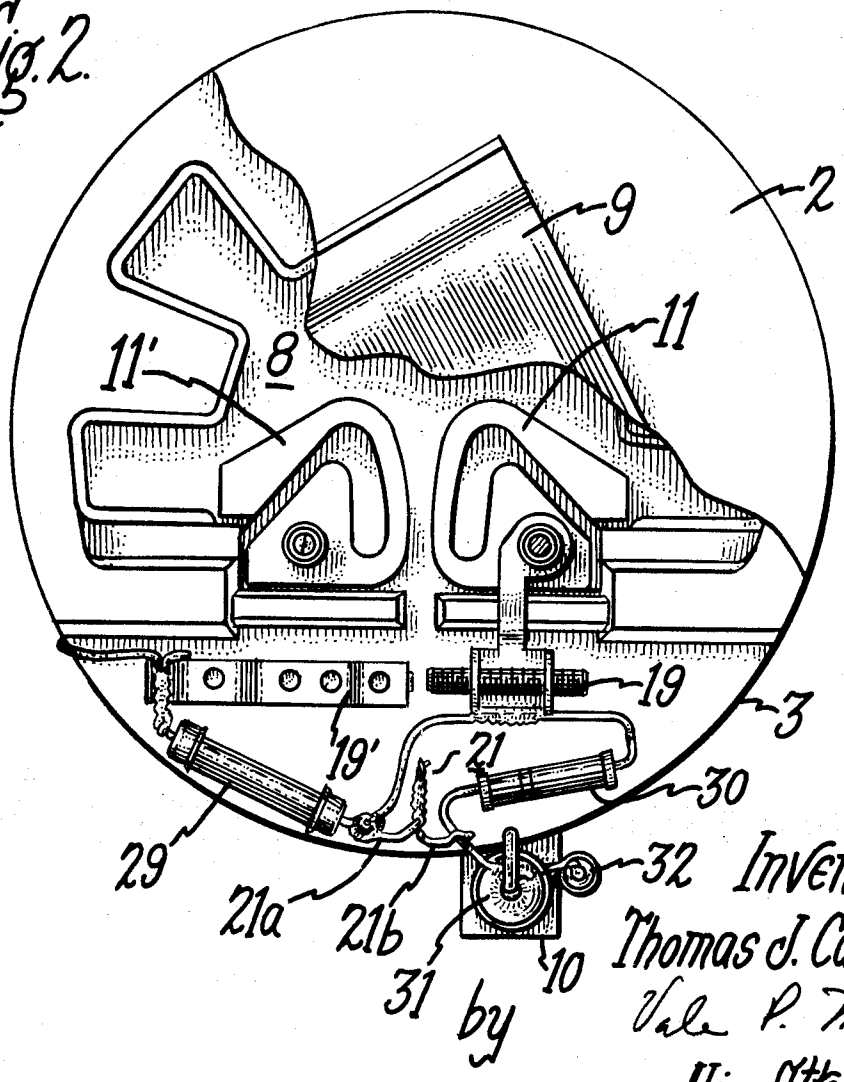


Fig. 2.



Inventor,
Thomas J. Carpenter,
by Vale P. Myles
His Attorney.

Fig. 3.

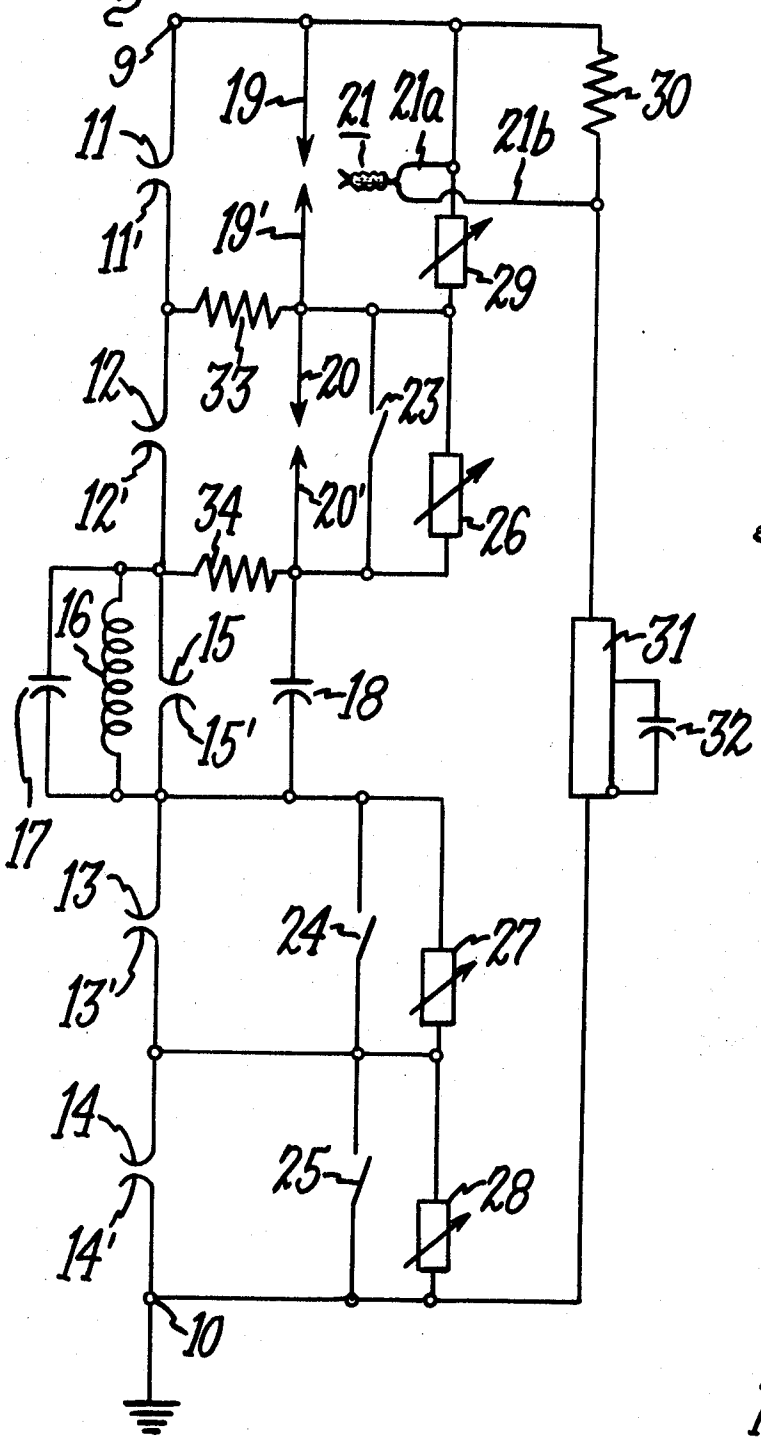
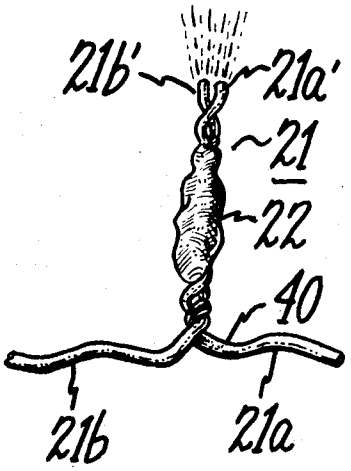


Fig. 4.



Inventor,
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His Attorney.

TWO-WIRE PREIONIZER FOR SURGE VOLTAGE ARRESTERS

It has become common practice in the field of surge voltage arresters, such as lightning arresters, to utilize preionizing means to assure consistent sparkover of the main discharge gaps of the arrester within a relatively narrow range of voltages. In fact, prior to the present invention, numerous attempts have been made to develop preionizer devices that will afford this desirable function inexpensively and reliably. In general, such prior art preionizers have performed satisfactorily, but due to the limited space available in arresters, it would be advantageous to develop a smaller preionizer than is now commercially available for ionizing arresters. Also, it is particularly desirable to develop a preionizer having a sparkover voltage much lower than the 2 to 3 kilovolt range that is conventional for present day lightning arrester preionizers. Such a lower sparkover rating would serve to stabilize the discharge characteristics of an arrester when a fast wave front surge voltage is applied to its terminals, because it would amply preionize the main discharge gaps before the surge voltage increased to their rated sparkover level, thus, they would consistently sparkover at this level.

An appreciation of the present state of the art in preionizers for surge voltage arresters may be gained by examining some fairly recent U.S. patents that disclose and claim particular preionizer structures. For example, U.S. Pat. No. 2,805,355-Snell, Jr., which issued Sept. 3, 1957; U.S. Pat. No. 2,922,914-Carpenter et al, which issued Jan. 26, 1960; and U.S. Pat. No. 3,504,226 - Stetson, which issued Mar. 31, 1970 all disclose and claim preionizer devices that are intended to improve the reliability of surge voltage arrester sparkover characteristics while at the same time constituting efforts to economize on space utilization within an arrester housing and attempting to reduce the costs of manufacture and installation of preionizer devices. All three of these patents are assigned to the assignee of the present invention.

It is apparent from a study of the prior art in the field of preionizing devices that an optimum preionizer must incorporate several basic characteristics. First of all, it must be capable of operating reliably and consistently through an extended number of ionizing operations. It should be easy to calibrate accurately and it should be resistant to mechanical shock and jarring forces, so that it does not lose its calibration during normal shipping and operating handling. In addition, a suitable preionizer for a lightning arrester sparkgap assembly must be small enough to be fitted into the arrester housing without requiring the provision of extra space to house the preionizer. Moreover, it is desirable to have a preionizer that is inexpensive to manufacture and assemble in operating position so that the provision of a preionizing function does not unduly increase the overall cost of the surge voltage device in which it is utilized. Finally, it is desirable to provide a preionizer having a sparkover rating substantially lower than 1,000 volts, so that it can be used to enhance the response time of a main discharge gap with which it is utilized.

Accordingly, it is an object of the present invention to provide a preionizer for a surge voltage arrester which overcomes the disadvantages itemized above of prior art preionizers, as well as affording the characteristics of a more nearly optimum preionizer.

More specifically, it is an object of the present invention to provide a preionizer that is inexpensive to manufacture and assemble in operating position, while at the same time being easy to accurately calibrate.

A further object of the invention is to provide a preionizer that is rugged in construction so that it can withstand normal shocks and vibrations without varying the calibration of its ionizing gap.

Yet another object of the invention is to provide a preionizer that is simple to manufacture and relatively small so that it can be assembled within the normally space-limited confines of a lightning arrester housing without requiring any special provision for added space to accommodate the preionizer.

A still further object of the invention is to provide a preionizer that has a sparkover voltage of less than 1,000 volts.

In one preferred form of the invention, a lightning arrester sparkgap assembly is provided with a preionizer that is formed by twisting a pair of thin, insulated copper wires together, then removing the insulation from the ends of the wires that are maintained in proximity by their twisted configuration so that an ionizing gap is thus formed between the exposed ends of the wire. The length of the ionizing gap is substantially equal to the combined thickness of the layers of insulation on the wires, thus, since the thickness of such insulating coatings is normally carefully controlled, the calibration of the preionizer is inexpensively and accurately attained. In order to maintain the desired spacing of the ionizing gap, a bead of epoxy resin is placed over the twisted portion of the wires to encapsulate them. Consequently, when the epoxy hardens, it preserves the calibration of the ionizing gap through all shocks and vibration normally encountered during use of the sparkgap assembly in a lightning arrester. The preionizer thus formed may be shunt-connected with a pair of main electrodes forming a discharge sparkgap of the assembly, or it may be shunt connected across a trigger sparkgap for such a main discharge gap of an arrester. In either application, the preionizer serves to maintain the sparkover voltage of the main discharge sparkgap within a narrow range of voltages so that the operating characteristics of the arrester are desirably consistent.

Additional objects and advantages of the invention will become apparent from the description of it that follows. The particular features of the invention that I believe to be novel are set forth in the claims appended at the end of the description of the invention given below. However, both the structural features and the desirable applications of my invention may best be understood by a reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a side elevational view of a sparkgap assembly for a surge voltage arrester which incorporates a preionizer constructed pursuant to the present invention.

FIG. 2 is a top plan view taken along the plane 2—2 of FIG. 1 showing a pair of main electrodes that form a discharge gap, a pair of trigger gap electrodes and a preionizer, all of which are connected electrically in parallel pursuant to one embodiment of my invention.

FIG. 3 is a schematic circuit diagram of the circuit elements contained in the sparkgap assembly illustrated in FIG. 1 of the drawing.

FIG. 4 is an enlarged perspective view of the preionizer illustrated in FIG. 2, which is constructed pursuant to the invention.

Referring now to FIG. 1 of the drawing, it will be seen that there is shown an overvoltage protective device in the form of a sparkgap assembly 1 of a type that may be used in a lightning arrester in combination with one or more blocks of nonlinear resistance valve material to provide a suitable current limiting discharge path from a line terminal of the arrester to its ground terminal. In general, except for the unique preionizer that will be discussed in detail hereinafter, the primary structural features of the sparkgap assembly 1 may be similar to the sparkgap housing and electrode arrangement disclosed in U.S. Pat. No. 3,504,226-Stetson, which issued on Mar. 31, 1970 and is assigned to the assignee of the present invention. Thus, it will be understood that the sparkgap assembly 1 will normally be used in combination with additional voltage and current regulating means that form a discharge circuit. However, in order to understand the present invention, it is not necessary to describe such additional circuitry, so the following description will be in context of the structure and circuitry embodied in the sparkgap assembly 1 only.

The sparkgap assembly 1 comprises a plurality of insulating plate members 2, 3, 4, 5, 6 and 7 that are formed of a porous insulating material to define five arc-confining chambers between the respective pairs of plates 2–3, 3–4, 4–5, 5–6 and 6–7, in a manner well known in the lightning arrester art. A

portion of one of these chambers **8** is shown in FIG. **2** of the drawings, which is a top plan view taken along the plane **2—2** depicted in FIG. **1**.

Various suitable circuit arrangements might be used to form a current limiting discharge path through the sparkgap assembly **1**; however, for the purpose of explaining the preferred embodiment of the present invention, an exemplary discharge circuit and associated triggering circuits for the sparkgap assembly **1** is shown in schematic form in FIG. **3**. Like reference numerals are used throughout the various different figures of the drawing to designate identical component parts of the invention. Accordingly, the terminals **9** and **10** on the opposite ends of assembly **1** are also identified as terminals **9** and **10** on opposite ends of the circuit illustrated in FIG. **3**. Four pairs of spaced-apart main electrodes **11—11'**, **12—12'**, **13—13'** and **14—14'**, are electrically connected in series with a fifth pair of coil-gap electrodes **15—15'** to form the primary discharge circuit through the sparkgap assembly **1**. An electromagnetic coil **16** is connected in series with the main discharge gaps **11—11'**, through **14—14'**, and in shunt relationship with the coil gap **15—15'** in order to provide an electromotive force for driving arcs formed in the main discharge gaps outward along the horns of their respective horngap electrodes to accelerate clearing and resealing of the assembly **1**, in a well known manner. In addition, the coil **16** is shunted by a pair of capacitors **17** and **18** to afford the desired sequential breakdown of the main discharge gaps which will be described more fully below.

In order to make the sparkgap assembly **1** spark over within a fairly consistent and narrow range of voltages, a trigger circuit arrangement is provided. This trigger circuit arrangement does not form an essential part of the present invention and no claim is made herein to the specific structural features or functional characteristics of the triggering circuit, per se. As shown in FIG. **3**, the means for defining trigger gaps for main discharge gaps **11—11'** and **12—12'** constitute two pairs of trigger gap electrodes **19—19'** and **20—20'** which are electrically connected in series between the terminal **9** and the upper terminal of the capacitor **18**. Pursuant to the present invention, a twisted-wire preionizer **21** comprising a pair of wires **21*a*** and **21*b*** is supported by any suitable supporting means adjacent the trigger gap **19—19'**. In this embodiment of the invention, the inherent resilience of the wires **21*a*** and **21*b*** is used to support the preionizer **21** in this desired operating position, and a bead of air-curable epoxy material **22** (also see FIG. **4**) is used to encapsulate at least part of the twisted-together portions of the wires **21*a*** and **21*b*** so that it holds the respective first ends of these wires in close proximity and at the same time serves as a bonding agent to glue the wires to the insulating plate member **3**. It should be obvious that other bonding agents or glues may be utilized to perform this securing function; however, I have found that epoxy resin is an ideal material to utilize for this purpose. A further description of the detailed structure and operation of the preionizer **21** will be given below, but first the remainder of the circuit depicted in FIG. **3** will be described.

Three slab-type preionizers **23**, **24** and **25** are electrically connected in shunt relationship respectively with the trigger gap **20—20'** and the pair of main discharge gaps **13—13'** and **14—14'**. These slab-type preionizers may be of any suitable type construction but in the preferred embodiment of the invention they are constructed pursuant to the teaching in my U.S. Pat. No. 3,223,074, which issued on Dec. 14, 1965 and is assigned to the assignee of the present invention. Each of these slab-type preionizers **23–25** is shunted respectively with one of the non-linear resistors **26**, **27** or **28**, and a fourth non-linear resistor **29** is connected electrically in series between the uppermost terminal **20** of trigger gap **20—20'** and the end terminal **9** on assembly **1**. Finally, a parallel connected grading circuit; comprising a linear resistor **30** connected in series with a non-linear resistor **31**, a portion of which is shunted by capacitor **32**, is provided to bias the preionizer **21**. In order to isolate the trigger circuit including trigger gaps **19—19'** and **20—20'** from the basic discharge gaps **11—11'** and **12—12'**, a pair of isolating resistors **33** and **34** are connected between the triggering circuit and the discharge circuit, as shown in FIG. **3**.

It will be apparent to those skilled in the art that various values of resistance and capacitance can be used for the resistors and capacitors in the circuit illustrated in FIG. **3**. However, by way of example, and without limiting the generality of the present invention, I have found that the following size resistors and capacitors function well in one preferred embodiment of this circuit. Each of the non-linear resistors **26–29** may vary in size, but in the preferred embodiment of the invention, these resistors are substantially the same size and are rated to carry approximately one-tenth milliampere at 2.2 KV. Non-linear resistor **31** is rated to carry approximately one-tenth milliampere at 8.8 KV; linear resistor **30** is 3 megaohms in size and the isolating resistors **33** and **34** are respectively 0.68 megaohms and 0.33 megaohms. Capacitor **32**, which partially shunts non-linear resistor **31**, may vary between 5 and 12 picofarads, but is approximately 6 picofarads in this preferred embodiment of the invention. In like manner, capacitors **17** and **18** can vary substantially in size between approximately 50 to 500 picofarads, but in this preferred embodiment of the invention, capacitor **17** is approximately 50 picofarads and capacitor 18 is 100 picofarads. In addition to these values of resistance and capacitance, it should be understood that each of the main discharge gaps **11—11'** through **14—14'** are separated by approximately 44 mils whereas each of the trigger gaps is substantially smaller, in the range of 25 to 30 mils. In fact, I have found that it is desirable to make the trigger gap **19—19'** slightly smaller than the trigger gap **20—20'**, by about 5 mils, in order to cause it to consistently sparkover first when a surge voltage is applied across the terminals **9–10** of assembly **1**.

Before describing the sequence of breakdown of the sparkgaps in sparkgap assembly **1**, when a surge voltage is impressed across the end terminals **9** and **10**, reference will now be made to FIG. **4** of the drawing to describe in greater detail the unique structure and characteristics of the preionizer **21** of the present invention. The preionizer **21** in the preferred form of the invention comprises a pair of wires that are twisted together adjacent first ends **21*a'*** and **21*b'*** thereof to hold these first ends of the wires in close proximity to one another. One of the wires **21*a*** is covered with an insulating coating **40** that is coextensive with substantially its entire outer surface portion, except for the end **21*a'*** from which this coating has been removed. The other wire **21*b*** is not provided with an insulating coating in this embodiment of the invention. Accordingly, when the wires **21*a*** and **21*b*** are secured together by twisting them in the manner illustrated in FIG. **4**, an ionizing gap is defined between the respective first ends **21*a'*** and **21*b'*** of the wires, and the length of this gap is substantially equal to the thickness of the insulating coating **40** on the wire **21*a***. In the preferred embodiment of the invention, the insulating coating **40** is formed of a suitable standard insulating varnish and is approximately 2 mils in thickness. Therefore, the ionizing gap formed between ends **21*a'*** and **21*b'*** of the wires will sparkover substantially below 1,000 volts and, in fact, I have found that it consistently sparks over in the range of 200 to 300 volts by taking care to assure that the ends **21*a'*** and **21*b'*** are maintained as close together as possible with only the thickness of the insulating coating **40** between them. In order to assure such close spacing of the preionizing gap, a suitable glue or other bonding agent **22** is used to encapsulate the twisted portions of the wires **21*a*** and **21*b*** adjacent the ends thereof that are held in close proximity to form the ionizing gap **21*a'*–21*b'***. As noted above, various materials can be used for this bonding agent **22** but I prefer to use an epoxy resin to form this encapsulating bead.

It will be apparent that if an ionizing gap having a slightly larger sparkover voltage is desired a thicker insulating coating (**40**) may be utilized on the wire **21*a***, or both the wire **21*a*** and the wire **21*b*** may be coated with insulation so that the ionizing gap is separated by substantially twice the thickness of the in-

dividual insulating coatings. It will be appreciated that this technique of forming the preionizer **21** results in an inexpensive preionizer that can be quickly manufactured and accurately calibrated simply by twisting the ends **21***a*′ and **21***b*′ of the wires together, then cutting them simultaneously at a point at, or near, the twisted portions thereof. Another advantage of this type of preionizer is that the wires are relatively small and flexible so that it is easy to mount the preionizer **21** in operating position adjacent a trigger gap such as gap **19—19**′ or adjacent a primary discharge gap such as gap **11—11**′ within a lightning arrester sparkgap assembly, without requiring the provision of additional space or sophisticated mounting means to support the preionizer **21**. As shown in FIG. **2**, the wires **21***a* and **21***b* may simply be soldered directly to leads on the resistors **29** and **30** respectively and then the preionizer **21** may be bent into operating position.

In the operation of the invention, the sparkgap assembly **1** is made to reliably and consistently spark over within a narrow range of voltages due to the optimum preionizing effect obtained from the unusually low-voltage sparkover of preionizer **21**. Referring to FIG. **3**, and assuming that a surge voltage is applied across the terminals **9** and **10** of sparkgap assembly **1**, a rapid increase in voltage will occur across the linear resistor **30**, since the non-linear resistor **31** in series with it initially builds a relatively small back voltage. Since the sparkover voltage of preionizer **21** is approximately 300 volts, it breaks down and starts to discharge protons into the trigger gap **19—19**′ to ionize it in the very early stages of a surge voltage rise. Since nonlinear resistors **26–29** and capacitor **18** form a series grading circuit to ground potential at terminal **10**, the rising surge voltage is graded across the substantially equal nonlinear resistors **26–29** and thus causes the trigger gap **19—19**′ to sparkover first, since it is ionized by the preionizer **21** and also is slightly shorter than the trigger gap **20—20**′. The trigger gap **20—20**′ sparks over next in the sequence, since it is substantially shorter than the main discharge gaps **13—13**′ and **14—14**′, and is isolated from the main discharge circuit by resistors **33** and **34**. With trigger gaps **19—19**′ and **20—20**′ sparked over, the full surge voltage is impressed directly across main discharge gaps **13—13**′ and **14—14**′ and causes both of these gaps to break down, either in sequence or simultaneously. After discharge gaps **13—13**′ and **14—14**′ are sparked over, the voltage level on terminal **13** is relatively close to ground potential, therefore, substantially the entire discharge voltage now is distributed across the remaining two discharge gaps **11—11**′ and **12—12**′ in series with capacitor **17**. Accordingly, the remaining two discharge gaps sparkover, then the coil gap **15—15**′ is overvoltaged and forced to sparkover, so that all of the gaps in the main discharge circuit are then conducting to discharge the surge voltage to terminal **10** and thence to ground.

Although the preionizer **21** of the invention has been described in the environment of a triggering circuit, such as that shown in FIG. **3**, it will be appreciated that this preionizer may be used directly in combination with a main discharge gap, such as the gap **11—11**′ of the circuit in FIG. **3**. In such an application, the main discharge gap **11—11**′ need not be ionized directly by a trigger gap, such as gap **19—19**′ which may be removed from the circuit depicted in FIG. **3** in such an embodiment of the invention. However, it will be understood by those skilled in the art that in such an application of the invention the primary discharge gap **11—11**′ would not be as completely ionized by the radiation of photons directly from the ionizing gap **21***a*′–**21***b*′ of preionizer **21** as would be the case if it is ionized by the much larger sparkover current of a trigger gap such as gap **19—19**′. It will also be apparent that a low-voltage preionizer may be formed pursuant to the teaching of the present invention by providing some suitable securing means other than the twisted portions of wires **21***a* and **21***b* to hold the ends **21***a*′ and **21***b*′ of these wires in proximity to form an ionizing gap between them. For example, wires **21***a* and **21***b* might be placed in abutting relationship and encapsulated by a suitable bonding agent such as the above-mentioned bead of epoxy resin. However, the preferred twisted-wire embodiment of the invention is inexpensive and results in a desirably rugged and consistently calibrated preionizer being formed. Other advantages and modifications of the invention will be apparent to those skilled in the art from the foregoing description and illustrations of it. Accordingly, it is my intention to encompass within the scope of the appended claims all such equivalent embodiments of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An overvoltage protective device comprising a pair of spaced main electrodes, mounting means for supporting said main electrodes in a predetermined spaced-apart relationship thereby to define a surge voltage discharge sparkgap between the main electrodes, a preionizer for ionizing said discharge sparkgap, means for supporting said preionizer adjacent the discharge sparkgap in operating relationship thereto, said preionizer comprising two electrically conductive wires, at least one of said wires having an insulating coating on the outer surface thereof, said wires being twisted together adjacent a first one of the respective ends thereof thereby to hold said first ends of the wires in close proximity to one another, the first ends of said wires that are held in close proximity to one another being uninsulated and separated by said insulating coating so that an ionizing gap is formed therebetween, and electric circuit means for electrically connecting said two wires in series with said ionizing gap and for connecting the ionizing gap in parallel circuit relationship with said discharge sparkgap, whereby an overvoltage applied to said circuit means causes said ionizing gap to sparkover and preionize said discharge sparkgap to facilitate its sparkover and resultant discharge of the overvoltage.

2. An overvoltage protective device as defined in claim **1** wherein the length of said ionizing gap is substantially equal to the thickness of the insulating coating on said insulated wire.

3. An overvoltage protective device as defined in claim **2** wherein the sparkover voltage of said ionizing gap is in the range between 200 and 1,000 volts.

4. An overvoltage protective device as defined in claim **3** wherein the thickness of said insulating coating is in the range of 1 to 5 mils.

5. An overvoltage protective device as defined in claim **1** wherein both of said wires have insulating coatings thereon, said coatings each being less than 5 mils in thickness over substantially their entire surface areas.

6. An overvoltage protective device as defined in claim **5** wherein said mounting means for said main electrodes includes wall members of a sparkgap assembly in which the electrodes are mounted to define a discharge sparkgap, and wherein said means for supporting the preionizer adjacent the discharge sparkgap includes a bead of glue that substantially encases the twisted portion of the twisted wires and is bonded to the insulating housing of said sparkgap assembly.

7. An overvoltage protective device as defined in claim **6** wherein said glue comprises an epoxy resin.

8. An overvoltage protective device as defined in claim **5** wherein the uninsulated ends of the pair of twisted wires are exposed only at the terminal ends of the wires, the insulation coatings on said wires being coextensive with the remaining outside diameters of the wires.

9. A sparkgap assembly as defined in claim **2** wherein said twisted wires are less than 30 mils in diameter and the insulation coating on the outer surface of said insulated wire is less than 3 mils in thickness.

10. An overvoltage protective device as defined in claim **2** including a resistor electrically connected in shunt relationship with said ionizing gap.

11. An overvoltage protective device comprising a pair of main electrodes, mounting means for supporting said main electrodes in a predetermined spaced-apart relationship thereby to define a surge voltage discharge sparkgap between the main electrodes, means defining a trigger gap for ionizing

said discharge sparkgap, second mounting means for supporting said trigger gap adjacent the discharge sparkgap in operating relationship thereto, a preionizer for ionizing said trigger gap, means for supporting said preionizer in operating relationship adjacent said trigger gap, said preionizer comprising two electrically conductive wires, at least one of said wires having an insulating coating on the outer surface thereof, said wires being twisted together adjacent a first one of the respective ends thereof thereby to hold said first ends of the wires in close proximity to one another, the first ends of said wires that are held in close proximity to one another being uninsulated so that an ionizing gap is formed therebetween, and electric circuit means for electrically connecting said two wires in series with said ionizing gap and for connecting the ionizing gap in parallel circuit relationship with said trigger gap and said discharge sparkgap, whereby an overvoltage applied to said circuit means causes said ionizing gap to radiate photons into the trigger gap to ionize it and lower its sparkover resistance thereby causing it to sparkover and preionize the discharge sparkgap so it sparks over consistently within a relatively narrow range of voltages applied to said circuit means.

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