

July 26, 1932.

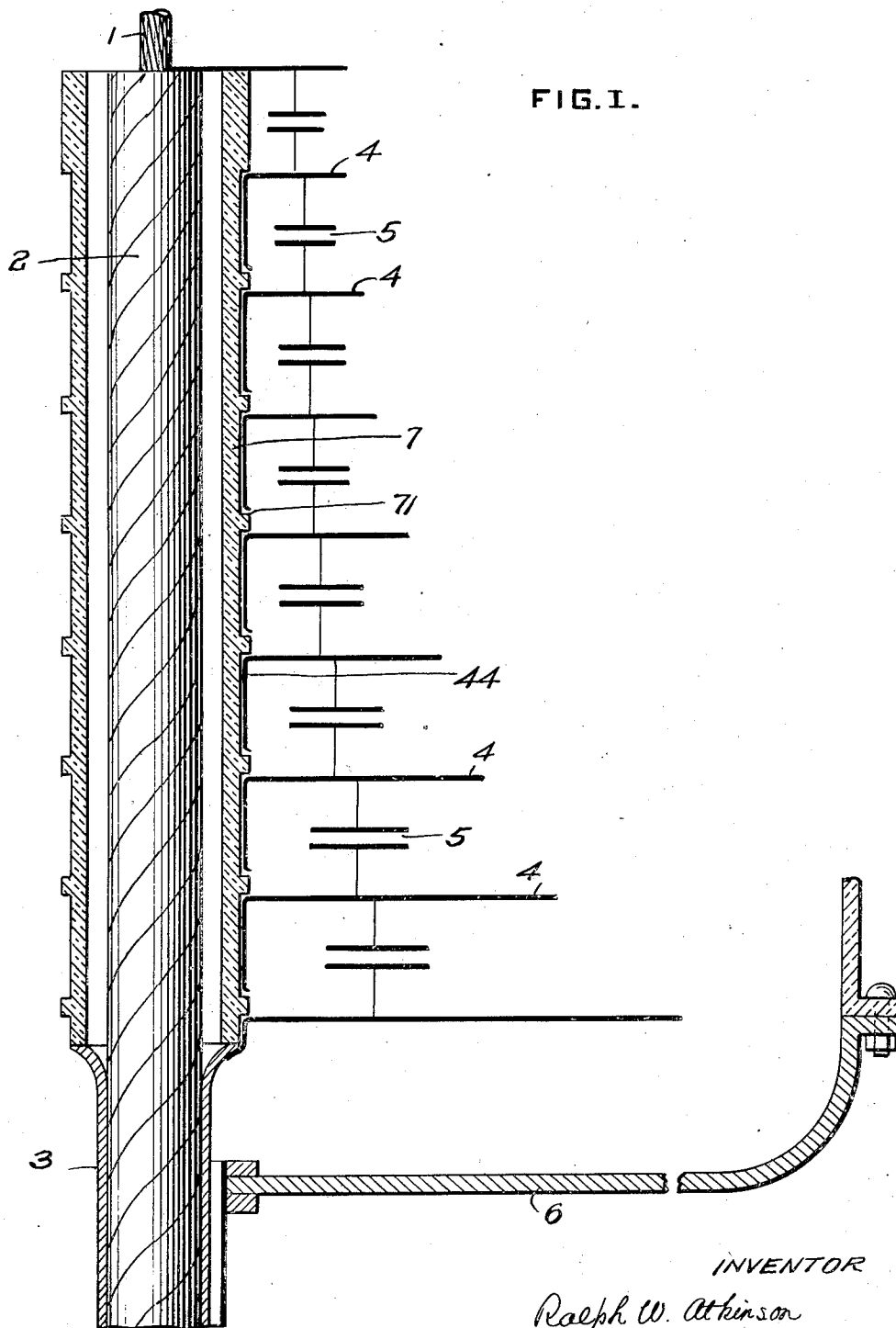
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1,868,962

HIGH VOLTAGE BUSHING

Filed July 1, 1926

4 Sheets-Sheet 1



WITNESSES

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July 26, 1932.

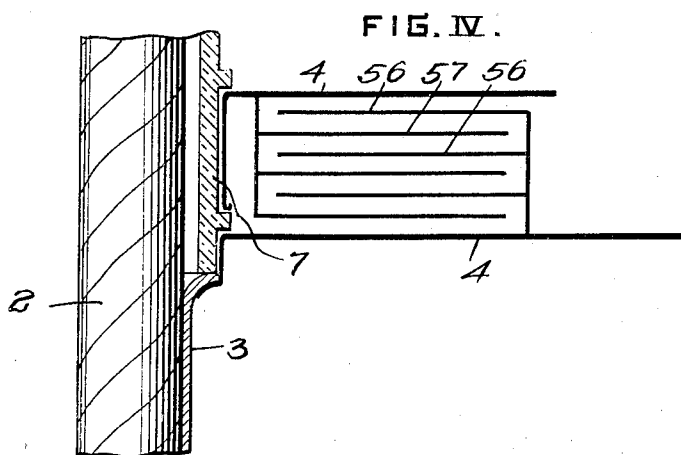
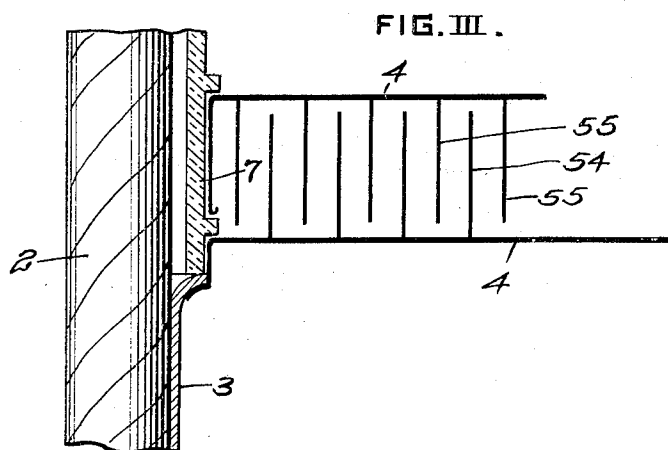
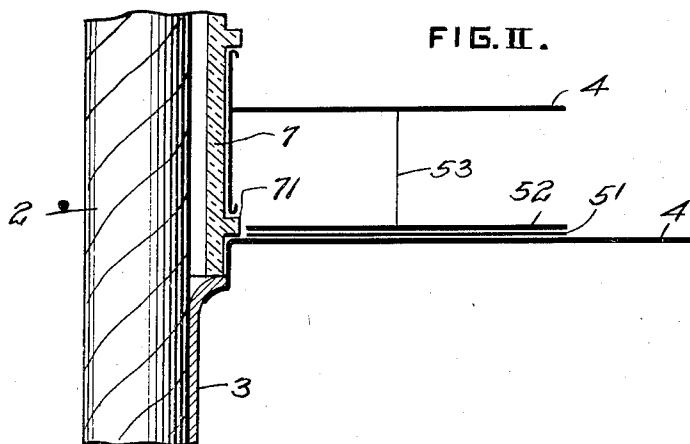
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4 Sheets-Sheet 2



WITNESSES

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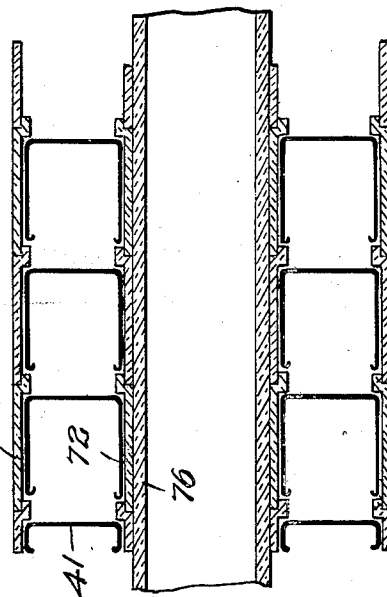
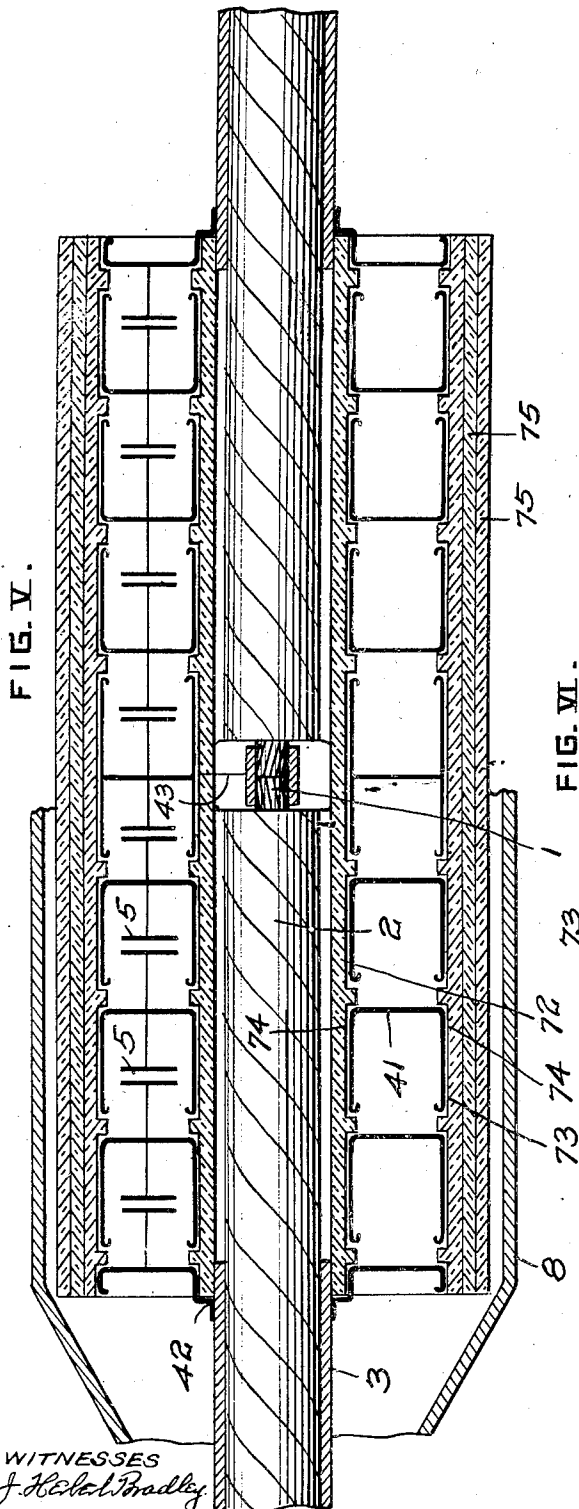
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4 Sheets-Sheet 3



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FIG. VII.

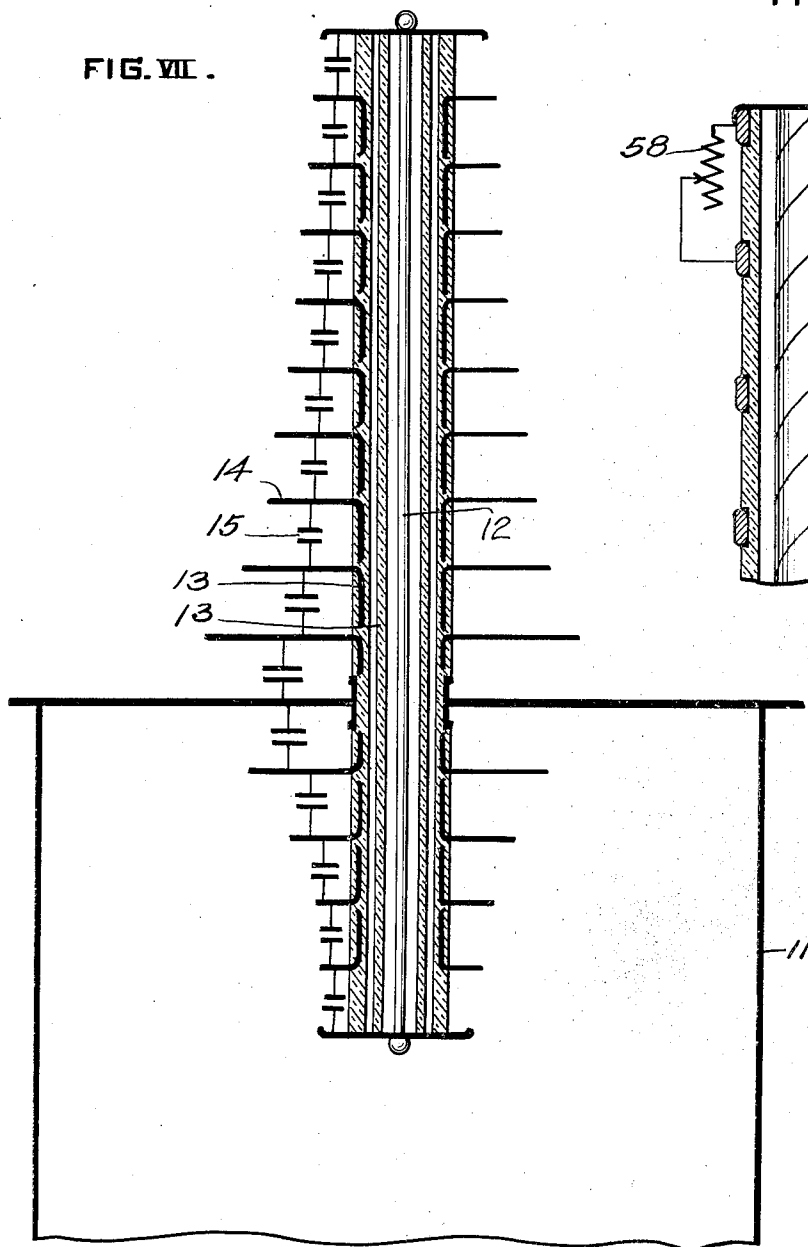
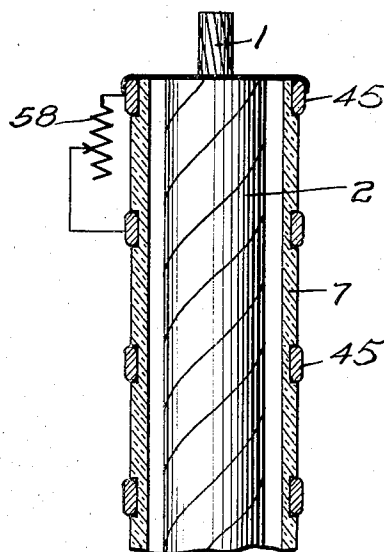


FIG. VIII.



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HIGH VOLTAGE BUSHING

Application filed July 1, 1926. Serial No. 119,898.

My invention relates to electrical installations, and particularly to improvements in high-voltage bushings. The object in view is the prevention of the concentration of stress and of the resulting flash-over or failure of insulation, where a conductor carrying current of high voltage emerges from a metal-surrounded orifice.

In the accompanying drawings Fig. I shows my invention applied to a cable end prepared for union with an aerial. In this figure the cable end itself is shown in elevation (the sheath, however, in section) and the means in which my invention resides are shown diagrammatically, and in section. Figs. II, III and IV are diagrammatic illustrations of particular forms which the condenser in which my invention centers, may assume. Figs. V and VII are views corresponding to Fig. I and showing the invention applied in the structure of a cable joint (Fig. V) and in the structure of a transformer (Fig. VII). Fig. VI is a fragmentary view, corresponding to Fig. V, and illustrating a refinement in structure, over and above the showing of Fig. V. Fig. VIII is a fragmentary view, corresponding to Fig. I, with modification of specific structure, and indicating a wider adaptability of the invention. Referring first particularly to Fig. I the cable end there shown will be recognized to be prepared for union with an aerial conductor. The cable conductor is indicated at 1. The envelope of machine-laid insulation 2 and the cable sheath 3 have been cut away to successively greater distances from the end, leaving the conductor itself exposed sufficiently for the making of electrical union.

When a cable so prepared has been connected to an aerial and when the assembly is in service, electrical tension is set up between the conductor at the point where it emerges from the envelope of machine-laid insulation, over the surface of the body of machine-laid insulation, to the cut-away end of the cable sheath. The voltage of the conductor, it will be understood, will be that imposed by the source of electric energy; the cable sheath is grounded, and its voltage is accordingly zero. This tension, when it becomes great enough,

may result in flash-over or in break-down of insulation; and it is when dealing with high-tension installations that this tension becomes a matter of practical concern.

It has been found that in such an installation there is concentration of stress at the cut-away end of the sheath, and means hitherto have been devised for spreading and distributing the stress. Referring to Fig. I of the drawings, it has been found that if a succession of thin wide metal rings 4 be provided, encircling the enveloped conductor and extending radially with respect to the cable axis, and placed at intervals along the structure, between the cut-away end of the sheath and the cut-away end of the envelope of machine-laid insulation, the stress otherwise concentrated at the end of the sheath will be distributed. And it has been found that if such rings so placed be properly graded in diameter, the total potential difference may be stepped by equal steps from the maximum at the sheath end to zero at the conductor end. To achieve this the ring immediately adjacent the sheath end will be the largest, and the gradient in the decrease of size of ring throughout the series, steepest near the sheath end, will become gentler toward the conductor end. By such provision, manifestly, a given installation may be rendered more effective and able, under practical conditions, to carry current of greater voltage. As the dimensions of the terminal are increased, in accordance with the requirements of higher voltages, other things being equal, the rings must be increased in diameter, for as between succeeding rings there must be sufficient capacity in the desired manner to control the field. When, however, it comes to the conveyance of currents of very high tension, say 100,000 volts and upward, the rings, and particularly of course those adjacent the cut-away end of the cable sheath would have to be made of such huge size that the construction would become practically impossible.

My invention consists in an elaboration of structure such that, in the particular situation under consideration, necessity of great and embarrassing enlargement of these

strain-distributing rings is avoided, and the desired end is gained with rings of reasonable size.

My invention may be accomplished by interposing between adjacent rings of the series an impedance or a series of impedances; and specifically, in the structure of Fig. I, a series of condensers. A condenser so introduced serves the ends otherwise attainable only by enlargement of the rings and as I have said renders enlargement to prohibitive dimensions unnecessary. In Fig. I of the drawings condensers so situated and arranged as to achieve my invention, are diagrammatically indicated at 5.

The condenser may assume any preferred specific form. For instance, in Fig. II I have shown one of the rings 4 to be faced with a layer 51 of suitable dielectric—of varnish-filled cloth, for example—and a plate 52 of metal resting upon the upper surface of the dielectric layer. The plate 52 is made electrically continuous with the next adjacent ring 4 by the wire 53.

In Fig. III I show condenser plates 54 and 55 projecting from the opposite faces of adjacent rings 4 and interdigitated to afford condensing effect, as will be understood by an engineer on a glance at the drawings. Similarly, in Fig. IV, the interdigitated condenser plates 56 and 57 are connected in two series one series to each of the two rings. And in this case the condenser plates extend radially with respect to the cable axis. It will be understood of the structures of Figs. III and IV that the dielectric which occupies the space between the condenser plates may be liquid, solid, or gaseous. For example, it may be air; or it may be insulating compound, applied in liquid condition and contained within a terminal casing; or, again, it may be built up of such solid material as saturated paper or sheets of varnished cambric. A terminal casing is diagrammatically indicated at 6, Fig. I. The rings 4 may conveniently be made perforate, for the passage of liquid insulation.

I preferably provide a structure which may be built in the factory and applied as a unit in field assembly. Such a unit is shown in Fig. I. It includes a rigid sleeve 7 of insulating material (porcelain, for example) of suitable diameter easily applicable to closely encircle the insulation-enveloped cable conductor, as indicated in Fig. I, and of a length suited to the particular conditions of service. In making installation the cable sheath and the envelope of machine-laid insulation are cut away to corresponding intervals.

Upon this sleeve 7 I permanently mount in advance the set of rings 4. The two rings at the ends are so particularly placed that when the structure is applied electrical union may readily be effected between one of them

and the end of the cable sheath and between the other and the bared conductor. This feature is clearly shown in Fig. I.

In service there is electric strain both longitudinally of the structure, and radially between ring and underlying conductor. These stresses, due to the radial field between the conductor and the edges of the rings 4 would, if the rings ended in sharp inner edges, be concentrated at those edges, and they would be greatest at the edges of the rings nearest to the grounded cable sheath 3. This condition would result in ionization and break-down. The break-down might consist in a radial puncture of the dielectric, or it might consist in a longitudinal flash-over. The ionized field would in such case spread from the edge of the ring upon the surface of sleeve 7 and the fields spreading from the edges of successive rings and overlapping might establish a path for longitudinal flash-over from ring to ring. This difficulty I avoid by forming continuous with the ring at its inner edge an extension or zone 44 lying sleeve-like, longitudinally upon sleeve 7. By such a provision I fix the potential, not of a line merely or of a narrow belt, but of a broad belt or surface, which in its breadth may be made to approximate the interval between successive rings. Preferably the extent of the sleeve like extensions 44 is between one-fifth and nine-tenths of the interval between successive rings 4. It will be recognized that where the aggregate extent of the zones or extensions 44 covers more than half of the insulation the zones form a substantially continuous electrostatic shield around the insulation. In accomplishing this result, of having successive broad belts upon the surface of sleeve 7 brought to the required potential, it is necessary to make provision that these successive belts be suitably insulated one from another. A practical carrying out of the ideas here indicated appears in the drawings. The rings 4 (41, 14) are provided, as I have said, with sleeve-like extensions 44, and these, recurved at their edges lie within circumferential grooves 71 formed to receive them in the outer surface of sleeve 7.

Even with my invention added, the rings of the set may be graded in diameter, as Fig. I shows them to be; it will, however, be understood that, my invention being present, the actual dimensions of the rings may be kept small, within limits otherwise impossible, successfully to attain the degree of security required. The necessary grading effect will be achieved by correctly proportioning the capacities, as between the successive pairs of rings. This will be recognized by the engineer. I shall presently return to this matter of the shape and extent of the rings.

If the specific structure of Fig. I be em-

ployed, with its sleeve 7, the narrow space intervening between the otherwise exposed surface of the envelope of machine-laid insulation 2 and the surface of the bore of the sleeve 7 will be filled with dielectric, ordinarily insulating compound applied in liquid condition, and ordinarily, though not necessarily, the compound will be one which remains liquid.

Fig. V shows the invention applied in the construction of a cable joint. In this case as in the case of a terminal a condition of tension exists between the bared end 1 of the conductor and the cut-away end 3 of the cable sheath. The interval between the cut-away ends of the cable sheath is bridged by a structure which consists of two concentrically arranged rigid sleeves 72 and 73 of insulating material, with a series of annular plates 41 of metal extending radially with respect to the cable axis and transversely across the annular space between the sleeves. The inner sleeve is of such interior diameter as snugly to fit over the sheathed cable; the sleeves may be suitably grooved as at 74 to receive the edges of the rings 41; the end rings of the series will at the time of assembly be brought into electrical union with the ends of the cable sheath. This may be done in any convenient way; for instance, by particularly shaping the inner edges of the end rings, as indicated at 42; and the mid-ring of the series will be electrically united with the union of the cable conductors 1, as indicated at 43. Between the successive pairs of rings 41 condensers 5 are arranged. Externally of sleeve 73 the structure will ordinarily be further strengthened electrically by insulating tubes 75 (two such are shown in the drawings) immediately surrounding sleeve 73. The whole may be enclosed in a casing 8, and all the spaces within this casing may be flushed with insulating compound applied in liquid condition. The plates 41 may be made perforate for the free passage of such insulating compound.

As a matter of practice, it will be found convenient to form sleeves 72 and 73 in a series of short sections, each section corresponding in length to the space interval between successive rings, and to make assembly of the sections in the factory or in the field. Carrying further this idea of sectional construction, Fig. VI shows the assembly of sleeves 72 and 73 with the rings 41 to be sectional, and the sections brought together by stringing them upon an inner rigid tube 76.

Similarly as in the cases described of a terminal and of a joint, the invention is applicable to make safe against breakdown any other insulating bushing within which a conductor is carried through a metallic orifice; the bushing of a transformer, or of a switch.

In Fig. VII I show a transformer. The cas-

ing of the transformer is of metal, and is indicated at 11. Within this casing are the coils of the transformer (not shown) and from them the high-tension lead 12 extends. The lead 12 passes through an orifice in the casing. At its passage through the casing wall the lead 12 is surrounded with a body of insulation, adapted to afford high radial dielectric strength. Such a body of insulation may take the form of a plurality of concentrically arranged cylinders 13, 13 of insulating material. The inner cylinders 13 will ordinarily in the completed structure be surrounded and the spaces between the cylinders filled with liquid insulation. Similarly as such structures as those already described are protected against breakdown, such a structure as that shown in Fig. VII may be protected by a succession of rings of graded diameter, and (to avoid the necessity of undue enlargement of such rings) by condenser units 15, interposed between successive rings 14. Thus a terminal adequate to exacting conditions of service, small in size and inexpensive, may be produced.

Since the series of rings within the transformer casing 11 is in this case assumed to be submerged in oil, while the series outside is disposed in air, the relative dimensions of the two series are shown to be different. This difference in dimensions will, however, be understood to be incidental to the conditions of service indicated. And in case the invention were applied to a wall bushing, where conditions on the two sides of the wall were alike, the structure in which the invention centers would on the two sides of the wall advantageously be symmetrical in dimensions.

It will be recognized that in each of the three cases described, there is present, first, a conductor upon which when the apparatus is in service, high tension is imposed,—the conductors 1 of the terminal (Fig. I) and of the joint (Fig. V), and the lead 12 of the transformer (Fig. VII). Second, the conductor is in each case surrounded by a wall of insulating material,—the envelopes 2 of machine-laid insulation of terminal and of joint (Figs. I and V) and the cylinder 13 of the transformer (Fig. VII). Third, the conductor with its surrounding insulation extends in each case through a metallic orifice,—the cut-away end of the cable-sheath 3 of the structures of Figs. I and V, and the orifice in the wall of the casing 11 of the transformer of Fig. VII. And in each instance it will be perceived that there is a condition of electric tension existing between the conductor and the metallic body which surrounds the insulation. The conditions are similar, the danger is the same, and the remedial means in which my invention is found are in the several cases the same.

In Fig. VIII, in place of radially extend-

ing rings, I show a succession of rings 45, having no appreciable radial extent, but extending longitudinally and spaced at intervals upon the sleeve 7 which carries them.

5 It will be perceived that all of that benefit and effect which in the structure shown in Fig. I is gained by the radial extent of the rings and by the gradation in such radial extent, may be gained in the actual and relative proportioning of the successive condensers 5, and accordingly it will be perceived
10 that the structure of Fig. I (and of the other figures, as well) may be modified; simple rings may take the place of radially extending rings, and the strain-distributing effect
15 may be gained by a proper proportioning of the condensers themselves in their essential structure.

Fig. VIII serves further to indicate the
20 wider implications of and adaptability and applicability of my invention. In the description up to this point, and in the illustrations presented in Figs. I-VII, use for the transmission of alternating currents is a matter of implication. And, as the art stands at
25 the present day, high-tension transmission is transmission of alternating currents. But direct-current transmission is a matter not to be overlooked. Furthermore, in the testing
30 of installations made for alternating-current use, direct currents are commonly employed, so that a terminal designed for alternating-current use may properly be so constructed as to carry safely direct currents as
35 well. Also, in the case of a cable intended for direct-current use, there would be occasion to provide against transient voltages which might be present, and which would require the use of condensers, in the same way as would
40 be requisite for alternating-current use. That is, an installation intended primarily either for direct-current use or for alternating-current use may properly be so constructed as to be able to take care of both. Precisely
45 as between successive rings 4 (Fig. I) or 41 (Fig. V) condensers 5 may be interposed, so (as particularly indicated in Fig. VIII) between successive rings 45, impedances of other form and, specifically, resistors 58 may be interposed; and precisely as
50 rings such as shown at 45 (Fig. VIII) may be employed with condensers 5 between, so radially extending rings such as shown at 4 (Fig. I) and at 41 (Fig. V) may be employed with impedances of other form between.
55 Condensers so situated serve with the effect already described when the conductor is carrying alternating current; resistors similarly situated serve with like effect, in case the conductor is carrying a direct current. Either condensers or resistor elements may be used, or both types of elements may be used between the same pair of a series of
60 rings 45. The condenser or resistor element, or both, manifestly, may be introduced be-

tween any two of a series of rings 45, and herein lies the possibility of further adaptability in making minute adjustment in strain distribution.

Having explained the alternative employment of condenser and resistor elements, and having explained that practically it is desirable to provide security both with respect to alternating and with respect to direct currents, it remains only to say that the element introduced between rings is essentially an impedance, and preferably an impedance such as is termed in the art "capacity"; it may be an element which combines in itself the characteristics both of condenser and of resistor. The possibility of providing such an element will be immediately manifest to the engineer. By way of suggestion, I would
70 remark here that any condenser in service is liable to a certain amount of leakage, and to a sufficient extent for my present purposes the quantity of condenser leakage is controllable, so as to render that structure which when
75 subject to alternating current conditions is serviceable as a condenser, serviceable also, when subjected to direct current conditions, as a resistor.

I shall in certain of the claims define as one element of my invention an impedance and by that term I mean to include both
80 condenser and resistor and an element serving vicariously as condenser and resistor.

It will be observed of the rings 45 of Fig. VIII that they are the counterparts of the extensions 44 of the rings 4 (41, 14) of the other figures, and that in each case these members constitute a series of conducting surfaces, arranged at approximately uniform intervals longitudinally of the insulated conductor. These conducting surfaces are insulated each from the others, and a succession of condensers (or, by way of alternative, a succession of resistors) is provided, and each condenser (or resistor) is arranged
10 with one terminal connected to one of two of the series of conducting surfaces and with the other terminal connected to the other of such two surfaces. The condensers (or resistors) of the succession are so adjusted in magnitude that the potential distribution
11 along the surface of the insulated conductor from the exposed end to the cut-away end of the cable sheath is substantially uniform.

These conducting surfaces 45, 44 are superposed directly upon and are carried by solid insulation. The electrical strength of the assembly is increased by submergence in oil. With such an arrangement higher dielectric strength is obtained than could be obtained if the strains set up adjacent the metal surfaces were set up in bodies of free oil, rather than in the solid body of insulation 7.

I claim as my invention:

1. In a high-voltage cable installation the combination of an insulated and sheathed
130

electrical conductor from which an end portion of the sheath has been removed, and means for distributing and directing the electrostatic lines of force adjacent the unsheathed cable end to prevent breakdown when the cable is under electrical stress comprising a series of radial-stress limiting elements arranged along the unsheathed cable end and presenting a longitudinally discontinuous cylindrical surface co-axial with the electrical conductor, and a series of potential-grading impedance units arranged longitudinally along the cable end and connected between the successive radial-stress limiting elements in electrical continuity from the conductor at high potential through units of uniformly decreasing potential to the cable sheath at low potential.

2. In an electrical installation the combination of a conductor, a cylindrical sleeve of insulation surrounding the conductor, and means for distributing stress longitudinally of said sleeve, such means consisting of a succession of broad belts encircling, and spaced longitudinally along said sleeve and forming with the conductor the immediately opposed plates of a condenser, and additional condensers connected electrically to said belts and across the spaces established by such belts, the widths of the belts and the spaces therebetween being so proportioned that when a difference of potential exists between the conductor and a point on the exterior of the sleeve, substantially all lines of force originating on the conductor within said sleeve terminate either on the said belts or on the electrodes of the said additional condensers, and the said additional condensers being so adjusted as to provide substantially uniform variation in potential along the surface of the sleeve.

3. In an electrical installation a cylindrical sleeve of insulation surrounding a conductor and means for distributing stress longitudinally of said sleeve, such means consisting of a succession of broad belts encircling said sleeve and forming with the conductor the immediately opposed plates of a condenser and spaced longitudinally of said sleeve, the belts being provided with outward and transverse extensions, and condensers connected electrically to such extension-equipped belts across the spaces established by such belts, each condenser including plates, one at least of which is other than and additional to such extension.

4. In an electrical installation the combination with an insulated, sheathed electrical conductor from which an end portion of the sheath has been removed, of means for distributing stress, such means including a plurality of belts of conducting material spaced along the unsheathed portion of the conductor insulation, and additional external condenser means connected electrically to said

belts and across the spaces established by such belts, the widths of the belts and the spaces therebetween being so proportioned that when a difference of potential exists between the conductor and the sheath, substantially all lines of force originating along that portion of the conductor from which the sheath has been removed terminate either on the said belts or on the electrodes of the said additional condenser means, and the said additional condenser means being so selected and arranged to fix the relative potentials of the belts in a continuous series, progressing by substantially uniform increments, from the potential of the sheath to the potential of the conductor, thereby distributing the electrical stress with substantial uniformity along the unsheathed insulation of the said conductor.

5. In an electrical installation two cable ends, each cable end including an insulated and sheathed conductor, the insulation and the sheath being cut away to successively greater distances from the conductor ends, means electrically connecting the conductor ends, a casing surrounding the so joined conductor ends and connected to the sheaths of the cable ends, means for preventing breakdown from the conductors to ground, such means including a series of broad belts of conducting material encircling the insulated conductor ends within the casing, each belt spaced at an interval from the next longitudinally along the insulated conductors, and condensers connected electrically to said belts and across the spaces established by such belts, the widths of the belts and the spaces therebetween being so proportioned that when a difference of potential exists between the cable conductors and the cable sheaths, substantially all lines of force originating on the conductors along the portions from which the sheaths have been removed terminate either on the said belts or on the electrodes of the said condensers, and the said condensers being so adjusted as to provide substantially uniform variation in potential along the exposed cable insulation within the casing.

6. In an electrical installation two cable ends, each cable end including an insulated and sheathed conductor, the insulation and the sheath being cut away to successively greater distances from the conductor ends, means electrically connecting the conductor ends, a casing surrounding the so joined conductor ends and connected to the sheaths of the cable ends, means for preventing breakdown from the joined conductors to ground, such means including a sleeve of insulating material surrounding at an interval the unsheathed but insulated conductor ends, and stress-distributing means arranged in such interval, such means including inner and outer belts of conducting material overlying

the outer surface of the cable insulation and underlying the inner surface of the said sleeve, and a plurality of condenser elements associated with and connected electrically to such belts.

7. In a high voltage electrical installation the combination of an electrical conductor, a cylindrical sleeve of insulation surrounding the conductor, a conducting body encircling the sleeve of insulation and spaced from one end thereof to leave a portion of the sleeve exposed, and means for distributing and directing the electrostatic lines of force along the exposed insulation to prevent breakdown when there is a difference of potential between the conductor and the said conducting body comprising a series of radial-stress limiting elements arranged along the exposed insulation and presenting a longitudinally discontinuous cylindrical surface co-axial with the electrical conductor, and a series of potential-grading impedance units arranged longitudinally along the exposed insulation and connected between the successive radial-stress limiting elements in electrical continuity from the conductor at high potential through units of substantially uniformly decreasing potential to the encircling conducting body at low potential.

8. In an electrical installation including a conductor and an encircling wall of insulating material, means for preventing breakdown along the wall and longitudinally of the conductor including a plurality of zones of conducting material arranged in longitudinal succession externally upon the surface of insulating material, the aggregate extent of the said zones being not less than half that of the surface of insulation upon which they are arranged, and a plurality of impedance units connected electrically between said zones for distributing electrical stress longitudinally of said wall of insulating material.

9. In an electrical installation including a conductor surrounded by a protecting wall of insulation, means for preventing breakdown along the wall and longitudinally of the conductor, such means including a plurality of zones of conducting material arranged in longitudinal succession externally upon the surface of said protecting wall and insulated one from another, the aggregate extent of said zones being not less than half that of the surface of the wall along which they are arranged, and a plurality of impedances connected electrically to said zones, each impedance being borne by one of said zones and constituting, together with the zone which bears it, a preformed and integral unit and as such applicable to the said protecting wall in the making of the installation.

10. In an electrical installation including a conductor and an encircling wall of insulating material, means for preventing break-

down along the wall and longitudinally of the conductor including a plurality of zones of conducting material arranged in longitudinal succession along the wall of insulation, the aggregate extent of said zones being not less than half that of the surface of the insulating material along which they are arranged, and a plurality of condensers connected electrically to said zones for distributing electrical stress longitudinally of said wall of insulating material.

11. The combination in a high-voltage cable installation of two cable lengths, each cable length comprising an insulated conductor and a surrounding fluid tight sheath, a joint connecting adjacent ends of said cable lengths, said joint including means electrically connecting the conductors of said cable lengths, a casing surrounding said joined cable ends, said casing being joined to the sheaths of said cable lengths, means for preventing electrical breakdown from the conductors to ground including a series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends within said casing, said zones forming a substantially continuous electrostatic shield around the joined cable ends, and impedance means electrically connected to said zones for distributing electrical stress longitudinally of said joint.

12. The combination in a high-voltage cable installation of two cable lengths, each cable length comprising an insulated conductor and a surrounding fluid tight sheath, a joint connecting adjacent ends of said cable lengths, said joint including means electrically connecting the conductors of said cable lengths, a casing surrounding said joined cable ends, said casing being joined to the sheaths of said cable lengths, means for preventing electrical breakdown from the conductors to ground including a series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends within said casing, said zones forming a substantially continuous electrostatic shield around the joined cable ends, and capacitances connected electrically between said zones for distributing electrical stress longitudinally of said joint.

13. The combination in a high-voltage cable installation of two cable lengths, each cable length comprising an insulated conductor and a surrounding fluid tight sheath, a joint connecting adjacent ends of said cable lengths, said joint including means electrically connecting the conductors of said cable lengths, a casing surrounding said joined cable ends, said casing being joined to the sheaths of said cable lengths, means for preventing electrical breakdown from the conductors to ground including a series of conducting zones insulated from each other and arranged in succession along and encircling

the joined cable ends within said casing, said zones forming a substantially continuous electrostatic shield around the joined cable ends, a second series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends, said second series of zones being spaced from said first series radially of the conductors, and a condenser means mounted between said two series of zones and connected electrically to said zones.

14. The combination in a high-voltage cable installation of two cable lengths, each cable length comprising an insulated conductor and a surrounding fluid tight sheath, a joint connecting adjacent ends of said cable lengths, said joint including means electrically connecting the conductors of said cable lengths, a casing surrounding said joined cable ends, said casing being joined to the sheaths of said cable lengths, means for preventing electrical breakdown from the conductors including a series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends within said casing, said zones forming a substantially continuous electrostatic shield around the joined cable ends, a second series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends, said second series of zones being spaced from said first series radially of the conductors, and electrical impedance means mounted between said two series of zones and connected electrically to said zones.

15. The combination in a high-voltage cable installation of two cable lengths, each cable length comprising an insulated conductor and a surrounding fluid tight sheath, a joint connecting adjacent ends of said cable lengths, said joint including means electrically connecting the conductors of said cable lengths, a casing surrounding said joined cable ends, said casing being joined to the sheaths of said cable lengths, means for preventing electrical breakdown from the conductors including a series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends within said casing, said zones forming a substantially continuous electrostatic shield around the joined cable ends, a second series of conducting zones insulated from each other and arranged in succession along and encircling the joined cable ends, said second series of zones being spaced from said first series radially of the conductors, impedance means mounted between said two series of zones and connected electrically to said zones, and insulation surrounding the outer series of conducting zones.

16. The combination in a high-voltage electrical installation of a conductor, an insulating wall encircling said conductor, a con-

ducting member encircling a portion of said insulating wall, means for preventing electrical breakdown along the exposed portion of said insulating wall between said conductor and said conducting member, comprising a plurality of zones of conducting material insulated from each other and arranged in succession along said exposed portion of the insulating wall, said zones forming a substantially continuous electrostatic shield substantially coextensive with said exposed portion of the insulating wall, and independent impedances connected between said zones for establishing the electrical potentials of said zones and distributing electrical stress longitudinally of said insulating wall.

17. The combination in an electrical installation of two conducting members to be insulated from each other, an interposed body of insulation having an exposed surface extending between said conducting members, a plurality of zones of conducting material arranged in succession along said exposed surface between said conducting members, said zones being insulated one from another and of such area that collectively they form a substantially continuous electrostatic shield along said surface, and condenser means electrically connected between said zones for distributing electrical stress longitudinally along said exposed surface to prevent electrical breakdown between said conducting members.

18. The combination in an electrical installation of two conducting members to be insulated from each other, an interposed body of insulation having an exposed surface extending between said conducting members, a plurality of zones of conducting material arranged in succession along said exposed surface between said conducting members, said zones being insulated one from another and of such area that collectively they form a substantially continuous electrostatic shield along said surface, and an independent impedance means electrically connected to said zones to prevent electrical breakdown between said conducting members.

19. The combination in a high-voltage electrical installation of an insulating sleeve, a plurality of zones of conducting material arranged in succession longitudinally along said sleeve, said zones being electrically insulated one from another, the aggregate extent of said zones collectively forming a substantially continuous electrostatic shield along said sleeve, and condenser means connected to said zones for distributing stress longitudinally of said insulating sleeve.

20. The combination in a high-voltage electrical installation of an insulating sleeve, a plurality of zones of conducting material arranged in succession longitudinally along said sleeve, said zones being electrically insu-

lated one from another, the aggregate extent of said zones collectively forming a substantially continuous electrostatic shield along said sleeve, and independent impedance
5 means connected between said zones for distributing stress longitudinally of said insulating sleeve.

In testimony whereof I have hereunto set
10 my hand.

RALPH W. ATKINSON.