Sept. 20, 1960 G. W. LAPP 2,953,629

PORCELAIN CONDENSER BUSHING

Filed Nov. 7, 1957 3 Sheets-Sheet 1

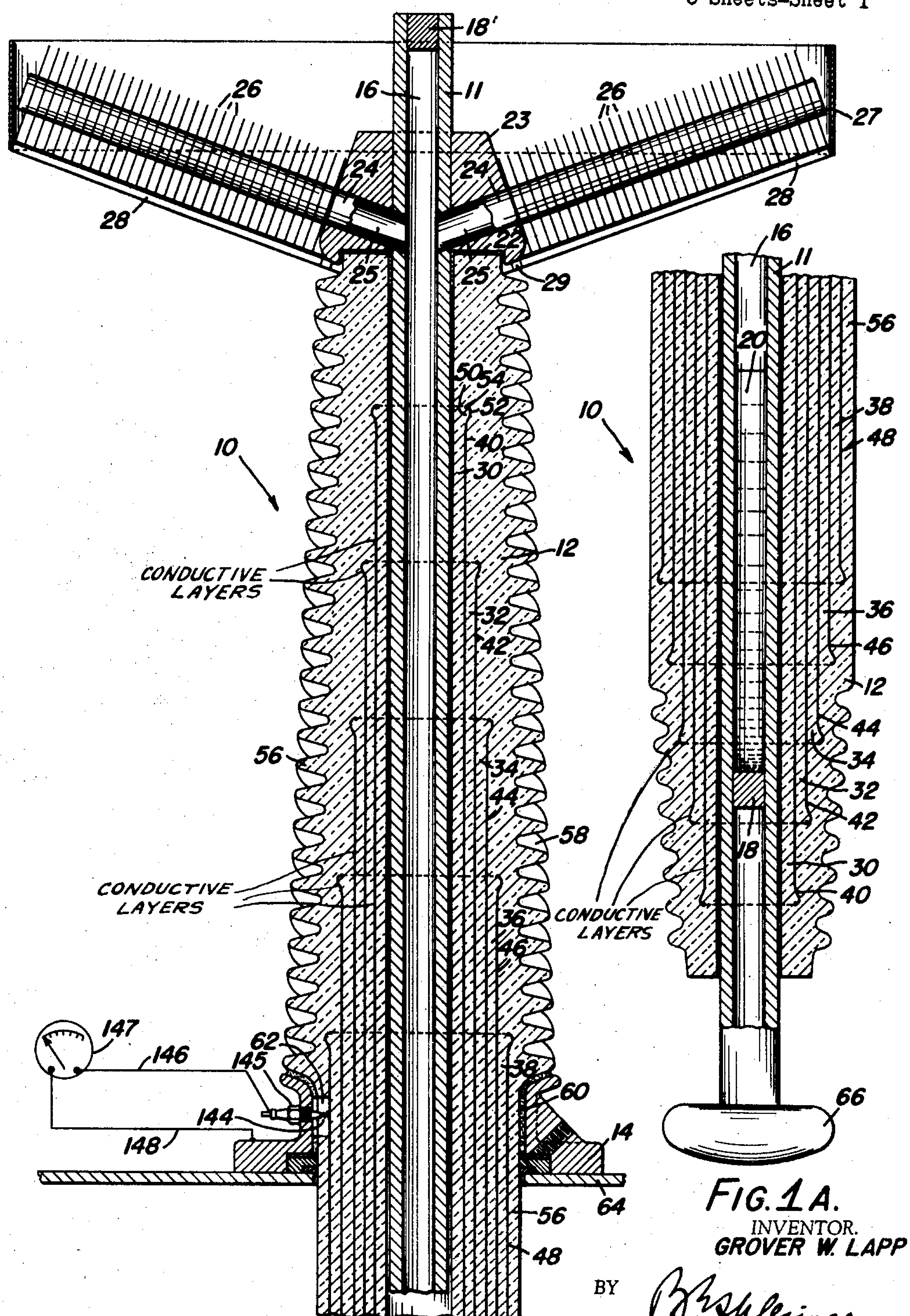

FIG. 1.

FIG. 1 A.

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PORCELAIN CONDENSER BUSHING

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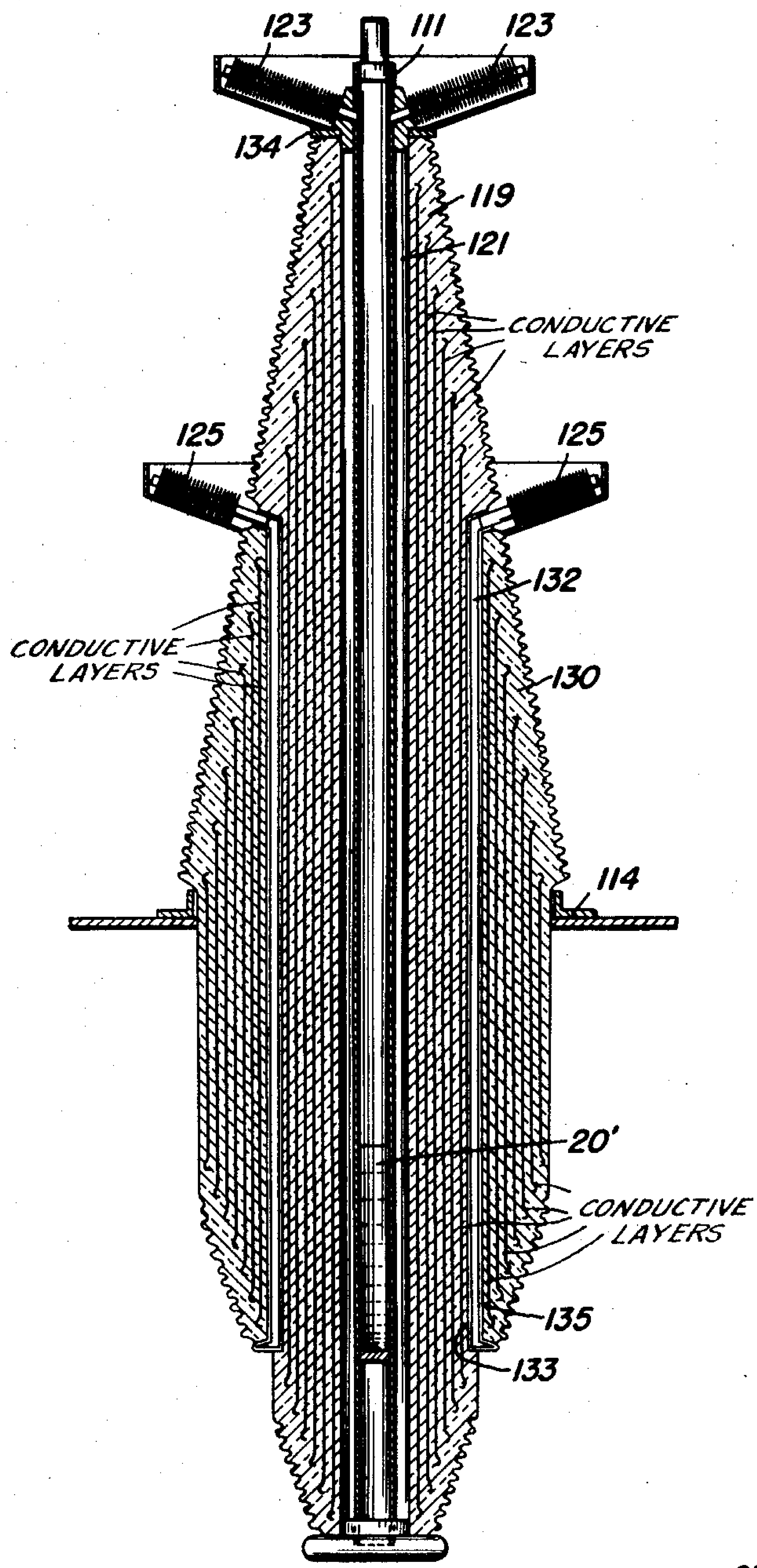

FIG. 3.

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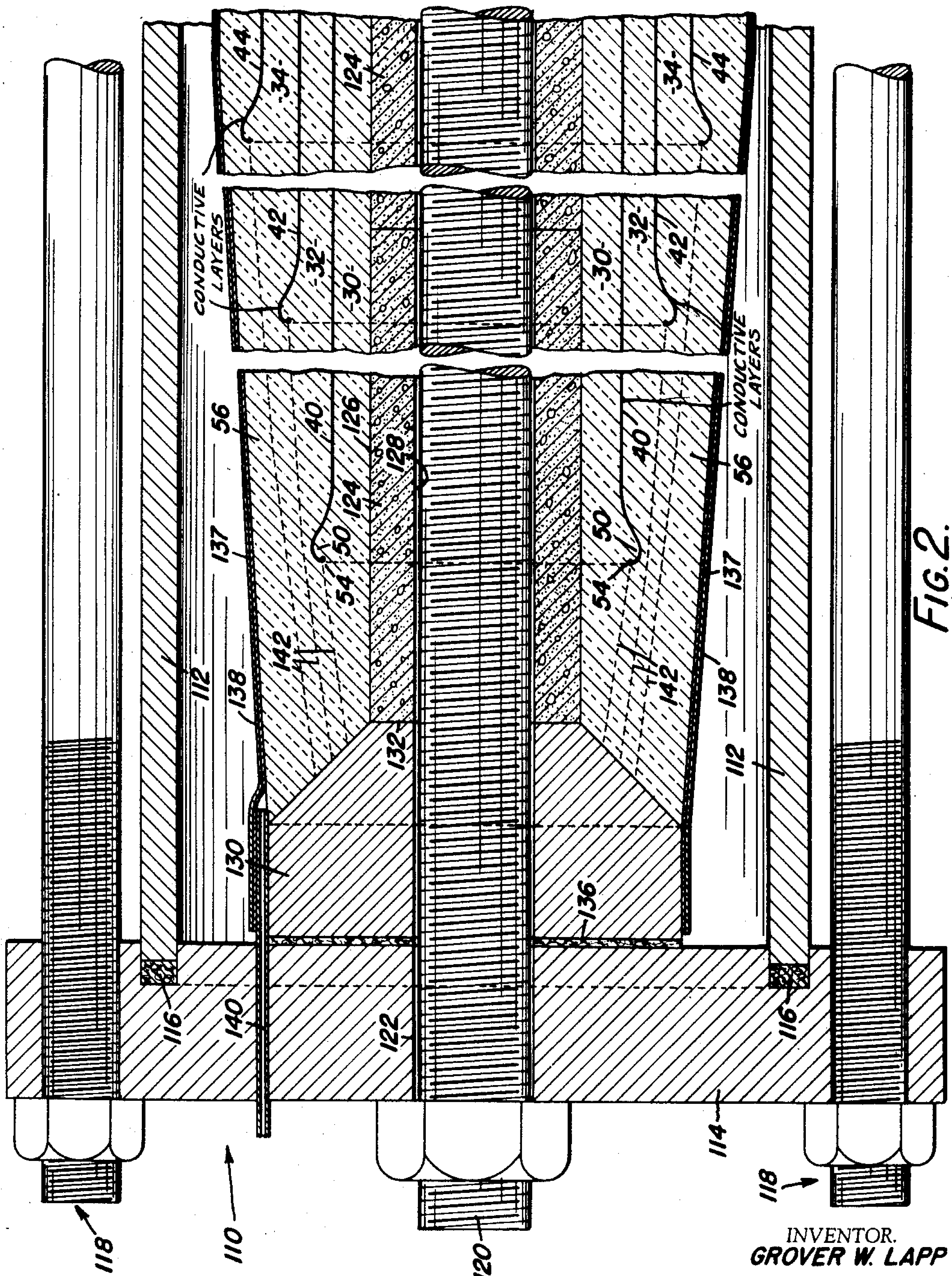

FIG. 2.

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PORCELAIN CONDENSER BUSHING

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5 Claims. (Cl. 174—143)

This invention relates to electrical insulator bushings for high voltage use, and more particularly to procelain condenser bushings such as are used in leading high voltage terminals from oil-immersed switches or transformer windings out through the tank into the air high enough to prevent flashover.

The usual insulating bushing comprises a center conducting member, an insulating structure concentric of the conductor, and a metal grounding sleeve by means of which the bushing is maintained in position with respect to the tank. Where used with oil-immersed electrical equipment, the portion of the bushing, which projects inside the tank or enclosure, is usually either wholly or partially immersed in oil.

In bushings of this type, the internal dielectric stress between the central conductor and the grounded tank is distributed by means of equal capacitances in series. Usually, the capacitances are in the form of concentric conductive tubes which are of decreasing length from the central conductor outwardly, and the outermost tube is grounded. The conductor tubes are spaced apart by dielectric layers whose thicknesses vary to obtain a desired constant dielectric relationship. The lengths of the conductive tubes can be graded in a series of equal steps to correspond with the potential gradients of the external path along the upper and lower surfaces of the bushing. The purpose of this construction is to produce condenser layers of equal capacitance to distribute the voltage in approximately equal steps from the center conducting member carrying the high potential current to the outside grounding sleeve at ground potential that supports the bushing on the transformer cover.

Two basic problems have to be met to achieve a satisfactory condenser bushing. The first is to produce stable dielectric layers between the conductive layers. The second is to make the flashover path resistant to flashover under wet and dusty atmospheric conditions as well as in dry, clear weather.

A conventional way of making an insulating bushing has been by winding up paper sheet interlaid with thin conductive foil. In such a conventional bushing, electrical discharges from the sharp edges at the ends of the conductive layers of foil at the ends of the foil tend to creep along the joints between adjacent paper sheets. Because of the type of construction used there is no opportunity to modify the shape to reduce concentration at the edges of the foil. Accordingly, this type of construction can carry only a very low voltage per mil of thickness of the dielectric layer. Moreover, because bushings of this laminar type are usually immersed in oil, the life of these bushings is limited since oil and paper are notoriously susceptible to progressive deterioration. Other organic insulating materials contain carbon and, when exposed to leakage currents or flashover arcs, tend to "track" or establish conductive carbonized paths, and finally to reduce the flashover voltage.

One object of the invention is to provide a sturdy, simplified condenser bushing having excellent and stable distribution of internal dielectric stress, free from progressive deterioration, and capable of carrying high voltage per mil of thickness of the dielectric material.

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Another object of the invention is to provide a condenser bushing of high quality, capable of utilization at high efficiency with both low and high voltages and without the requirement for oil immersion.

Another object of the present invention is to provide an improved condenser bushing of simplified, substantially monolithic, ceramic structure.

Still another object of the invention is to provide an improved porcelain condenser bushing having a self-cooling feature.

Other objects of the invention will become apparent to those skilled in the art from the following detailed description of the invention.

To meet the external problem of making the outside flashover path resistant to flashover regardless of weather conditions I make my bushings with an outer shell of fired ceramic material and use corrugations on this outer shell. Preferably helical corrugations of a drainage type are used to cause rain water to flow in and out over the surface of the bushing while rain water is coursing around the bushing in continuous helical paths. This type and form of corrugations make it possible to use small corrugations having long creepage distance.

To meet the internal problem of obtaining a stable dielectric between the conductive layers of the bushing I embed the conductive layers between successive layers of ceramic dielectric.

Two separate embodiments of the invention are illustrated in the drawings. In one embodiment of the invention, the condenser bushing has a center conducting member, a novel vitrified, substantially monolithic conducting and insulating structure concentrically and symmetrically arranged around the conductor, and a grounding sleeve adapted to secure the bushing in position on a grounded tank casing. The novel insulating structure comprises a plurality of unified layers of clay concentric with the center conducting member, each layer of clay being separated, for the major portion of its length, from the overlying layer of clay by a conductive glaze. The concentric cylindrical or tubular layers formed by the conductive glaze are of different lengths, arranged in a graded series of decreasing lengths radially outward from the center conducting member. Each end of each conductive layer is flared or bulged slightly outwardly, then inwardly, to avoid a high concentration of flux at the ends of the conductive layer. The inwardly turned tips of the flared ends provide a less pointed emission of grading flux through the vitrified clay or porcelain to the exterior of the bushing and the outside flashover path. The outer bushing layer is of clay forming a sheath around the bushing, except for one small spot inside the flange to bring out the current through a meter, as is usual, for the purpose of measuring capacitance or charging current and power factor.

At the ends of the bushing, the clay layers overlap without intervening conductive layers, so that the vitrified clay with the intervening conductive layers is unified and integrally united, so that an extremely strong structure is obtained in which the conductive layers are permanently enclosed and are completely weather-proofed.

To carry away the heat from the central conductor and to minimize temperature differences through the bushing, the central conductor is made self-cooling. For this purpose it is made tubular, is completely plugged at both ends, and contains water or other suitable liquid under reduced pressure. Radially-finned heat-dissipating tubes are connected to this central tubular conductor at its upper end to radiate therefrom; and these finned tubes are sealed at their outer ends, and an arc guard ring is attached around their outer ends. A drainage channel is attached below each finned tube to conduct rain water collected by this top assembly and carry it down over the bushing. The central tubular conductor and connected radial finned tubes form a tightly sealed unit which functions to cool the central conductor. When the central conductor tube cools to ambient temperature, the vapor pressure inside the tube falls to correspond to that temperature. If the temperature rises the water in the tube boils; vapor rises up in the tube and into the radial heat-dissipating tubes where it is condensed; and the condensate drips back to the warmer bottom of the central conductor tube to be vaporized again. In this way, heat is conveyed from the conductor and dissipated into air by the condenser. The larger the condenser the more nearly will the temperature of the tubular central conductor inside the bushing approach the ambient temperature of the air above the bushing. With this structure the central conductor can get rid of its heat, and serve to cool the inside layers of dielectric instead of heating them.

When extremely high voltages are to be carried, the bushing is made in two concentric sections, each having a group of layers of dielectric alternating with conducting glaze. Each section corresponds in structure generally to the form of bushing already described. The central conductor is inserted in the bore of the inner section and is provided with heat exchange means such as described. Between the two sections there is an annular clearance, and a concentric double walled tube is located in the annular clearance. Water or other liquid is sealed in this double-walled tube under reduced pressure, and this tube is interconnected with external heat exchange means, such as, for example, radially finned tubes and a guard ring, so that heat will be dissipated from the double-walled tube and the outer section of the bushing in the same general manner as from the central conducting tube of the inner section of the bushing.

The features of the invention will be best understood by consideration of the following description, with reference to the drawings, in which:

Figs. 1 and 1A, taken together, show an axial section of an improved condenser bushing made according to one embodiment of this invention;

Fig. 2 is a section of apparatus for manufacturing the condenser bushing shown in Fig. 1; and

Fig. 3 is an axial section of a modified form of condenser bushing made according to the invention for carrying high voltage loads.

Referring now in detail to the drawings, and first to the embodiment shown in Figs. 1 and 1A, the condenser bushing **10** comprises a central tubular conductor **11**, an insulating assembly **12** arranged concentrically around the central conductor but slightly spaced radially therefrom, and a short metal grounding sleeve **14** mounted around the insulating assembly about midway the length thereof.

The central conductor **11** is an elongated tube having a bore **16** closed in liquid-tight fashion adjacent each end thereof by plugs **18** and **18'**, respectively. A body of water or other liquid **20** is confined within the bore **16** under reduced pressure. The insulating assembly **12** is shorter in length than the tubular conductor **11**; and the conductor **11** protrudes both at top and bottom beyond the insulating assembly. The insulating assembly may be spaced slightly radially from the tubular conductor; and a snug, leak-proof, flanged collar **22** is mounted on top of the insulating assembly **12** around the central conductor **11**, to keep rain water out of the annular space between the central conductor and the insulating assembly.

A plurality of heat exchange tubes **24** are radially disposed around the upper end of the central conductor **11** and are secured at their inner ends in the central conductor **11** and in the cap member or flange ring **23**. The flange

ring **23** is generally conical in shape and seats on the collar **22**, extending at its bottom around the flange of the collar. It surrounds the conductor **11** near the upper end of the conductor and may be made of a conductive material. Each tube **24** has its bore **25** connected at its inner end with the bore of the central conductor and is closed at its other end. Each tube **24** is provided along its length with radial fins **26**. A trough **28** is mounted below each tube **24** to provide a drainage channel to conduct rain water which may accumulate on and drip from each finned tube toward the central conductor **11**. An arc guard ring **27** is attached around the outer ends of the tubes **24**.

The insulating core or assembly **12** comprises a plurality of concentrically disposed layers **30**, **32**, **34**, **36** and **38**, respectively, of clay, with which are bonded, as a wholly monolithic structure, interposed concentric conductive layers **40**, **42**, **44**, **46** and **48**, formed as coatings of conductive glaze on the underlying clay layers. Thus, a conductive glaze layer **40** is interposed between the innermost clay layer **30**, and the adjacent, concentric clay layer **32**. A second, shorter tubular conductive glaze layer **42** is disposed between the second clay layer **32** and the third concentric clay layer **34**, and so forth. Each successive conductive glaze layer, progressing from the central conductor **11** outwardly, is of less length than the next inner conductive layer, so that the lengths are graded in a series of preferably equal steps.

The clay layers **30**, **32**, **35**, **36** and **38** are formed to extend over the entire length of the insulating assembly, and for purposes of illustration only, their boundaries **142** are indicated in Fig. 2. In the vitrified insulating assembly, the several clay layers are fused into a monolithic whole, so that the boundary lines **142** are indistinguishable.

The whole is enclosed in a thick, outer coating of clay **56** having preferably helical drainage corrugations **58** on the outer periphery thereof. The whole insulating assembly is, of course, baked to vitrify it. The drain channels **28** are disposed to discharge any rain water onto the upper end or ends of the helical corrugations.

The portion of each clay layer underlying the extremity of each tubular conductive glaze layer is formed with an outward flare **50**, so that the conductive glaze layer is correspondingly contoured, providing a belled or flared end **52**. Each conductive glaze layer terminates at a part of the flared end **52** that is directed inwardly and is formed at its end with a bead ring **54** formed in a corresponding groove in the clay layer.

The metal grounding sleeve **14** is disposed centrally of the bushing **10** around the outer layer of vitrified clay **56**. The grounding sleeve **14** is secured by cement **60** or other means on the bushing. An aperture **62** is provided in the clay layer **56** inside the flange of the grounding sleeve **14** to permit a plug or probe **145** to be mounted on the flange to bring out current from the outermost conductive layer **48** through the line **146** to a meter **147**, and back to the sleeve **14** through the line **148**, as is usual, to measure capacitance or charging current and power factor.

In a typical installation, the ground sleeve **14** is adapted to be supported on and in electrical contact with a grounded tank casing **64**, in which case the lower portion of the bushing is adapted to be submerged in oil.

A bottom terminal **66**, of metallic conducting material, is mounted on the lower end of the central conductor **11** in electrical contact with it. This terminal may be connected in conventional manner with the oil-immersed switch or other electrical equipment with which the bushing is to be used. The portion of the bushing above the grounding sleeve **14** is adapted to be exposed to the atmosphere, and the upper exposed end of the central conductor **11** is adapted to be connected with an external electrical circuit.

One method of manufacturing the condenser bushing of the present invention is described in detail in my copending application, Serial No. 695,058, filed November 7, 1957. For convenience, a brief description of a method of manufacture of the bushing is described here.

A typical apparatus for use in the manufacture of the bushing is illustrated in Fig. 2.

This apparatus includes a cylinder **110** formed by an elongated tubular pipe **112** interposed between a pair of end plates **114**, with a sealing gasket **116** interposed and compressed between each end of the pipe and each end plate **114**. The end plates are drawn together by any convenient means, such as, for example, a plurality of nuts and bolts indicated generally by the numeral **118**.

An elongated, completely threaded bolt **120** passes through apertures **122** in the end plates and centrally through the cylinder **110**. A mandrel **124** is mounted around the elongated bolt **120** within the cylinder **110**. The mandrel **124** is preferably sectional and is made from a porous or water-permeable mixture of Portland cement and sand or other filler. The mandrel surface **126** is preferably slightly tapered from one end to the other to facilitate its removal from the completed blank. The mandrel has an open bore **128** through which the threaded bolt **120** passes freely. At each end of the mandrel a metallic end bushing **130** is mounted. Each end bushing has an inner end face **132** coinciding in size with the diameter of the mandrel at that end and engaging the adjacent end of the mandrel, from which the end bushing tapers gradually outward to coincide approximately with the outer diameter of the condenser bushing at that end. A gasket **136** is interposed between the opposed surfaces of each end bushing **130** and each end plate **114**.

In manufacturing a condenser bushing with this apparatus, the mandrel **126** is mounted on the elongated bolt **120**, together with the end bushings **130**. Wet plastic clay is built up in a single layer around the mandrel in excess thickness to form the first dielectric layer **30**. This may be done by casting from clay slip, or by plastering the clay on, or by laying it on by an injection-plugging method in my copending application referred to above.

It is preferred to lay a perfectly air-free layer, but not necessary since any inclusions of air in the clay will be removed in the next step in the process. A rubber sheath, similar to sheath **138**, is placed over, or a rubber ribbon is wound around the layer of wet plastic clay. Care is taken that the sheath or ribbon extends around the end bushings **130**. The sheathed cast is then placed in the cylinder **110**. Hydraulic pressure on the order of 1000 p.s.i. is then applied to the sheath. This pressure forces the sheath tightly against the layer of clay, to cause the clay to be dewatered, compacted, and densified. Water forced out of the clay, passes through the porous mandrel **126**, and escapes in the void space between the threads of the bolt **120** and the bore **128** of the mandrel. The pressure is maintained until water stops dripping, or until the clay is considered sufficiently dewatered and densified. If desired, the pressure may be progressively increased during this step.

When dewatering is completed, the pressure is released and the mandrel and its clay coating are removed from the cylinder **110**. The rubber sheath or rubber ribbon is then removed and the layer of clay is turned in a lathe, preferably in a vertical position to avoid any tendency to sag. The consolidated or compacted clay is then in excellent condition to be precisely turned to size, leaving the portion that is to be given a conductive coating slightly smaller than the ends. The ends of the precisely sized section are flared slightly to give a gradually thickened wall, and the outer tips of the flarred ends can be turned inwardly slightly. This is for the purpose of shaping the clay so that when the conductive layer is deposited on the compacted clay layer, concentrated flux at the ends of the conductive layer will be avoided, and there will be less pointed emission of the grading flux through the porcelain to the outside flashover path of the finished bushing. The clay is turned precisely to the particular length, diameter, and flared end shape desired.

After the clay layer has been machined to the precise shape desired, the ends of the clay layer, which are beyond the contour portion can be taped to mask them; and a conductive glaze **40** of metallic oxides is then applied, having flared ends **50** and small beads **54** in the end grooves of the clay layer **30**. The glaze must be refractory so that it will not fuse to a pre-vitrified layer. It must remain permeable to the exit of gases and must be free of constituents such as copper, that tend to migrate into the clay during firing.

After the conductive glaze coating has set so that it will not wash, a second clay layer **32** is applied. The clay layer is then wrapped again in the rubber sheath **138** or in a rubber ribbon, which is extended around the end bushings **130**, and the assembly is placed in the cylinder **110** and pressure is again applied. The cast is thus dewatered by hydraulic pressure. Then the whole is removed from the pressure tank **110**, and unsheathed, and the newly-applied clay layer is turned to the thickness and contour desired, and another conductive coating **42** is applied, which is shorter and of larger diameter than coating **40**.

This sequence of operations is repeated until the final conductive glaze coating **48** has been applied. In this way, successive layers of dielectric and conductive coatings are built up. The final or outside cover layer of porcelain body is then applied as a final thick coating of clay around the conductive coating **48**, one small spot being left inside the flange **23** to bring out the current from the ground sleeve **11** through a meter for the purpose of measuring capacitance, or charging current and power factor. The outermost layer may be wound in a porous layer of glass wool or tape **137**, which in turn is covered by the rubber sheath **138**. A pipe or metallic tubing **140**, that extends through the end plate **114**, is provided to drain off water from the pressure tank.

During successive dewatering steps, the pressure applied to the sheath **138** is programmed so that dewatering of the final thick outer layer **56** is accomplished at the highest pressure. This has the desirable result that the successive clay layers **30**, **32**, **34**, etc. and the intermediate glazed coatings **40**, **42** **44**, etc. are compacted about the mandrel, and formed as a substantially monolithic whole. At the ends of the successive clay layers, where conductive glaze is not interposed between them, their boundaries, indicated in the drawing by the dotted lines **142**, are not distinguishable.

When the dewatering and densification steps on the outer layer **56** have been completed, the rubber sheath and the porous layer are removed; and the insulating assembly blank is placed in a lathe and turned to form the helicoidal corrugations **58** in the outermost clay layer **56**. If convenient, the blank may be left on the porous mandrel **126** while turning on the lathe.

After the mandrel is removed, the clay blank is reamed to a diameter approximately 5% larger than the desired diameter. The bore of the blank is then coated with a conductive glaze, and the blank is fired. During firing, plastic flow completely fuses adjacent clay layers so that a homogeneous, unitary, and monolithic bushing is thus obtained. After firing, the remaining components of the bushing are assembled on the fired core.

This construction provides conductive contoured layers embedded in solid vitrified porcelain, hermetically sealed away from the weather and atmospheric moisture. Such a bushing may be housed in a porcelain, oil-filled housing as usual and will give excellent performance. However, because of the presence of the outer thick corrugated layer of porcelain, the bushing may also be employed as a "dry" type of bushing without oil. Because the bushing is suitable for use as a dry bushing, even at high voltages, troublesome design problems, which would otherwise be encountered, are avoided.

Simplicity of structure is a marked characteristic of this type of bushing. Because of the stability of fused ceramic as compared with organic dielectric material, the structure will have long life without increase in dielectric power factor. Much testing and replacement in service can, therefore, be avoided.

The flared end contour of each conductive layer eliminates hot spots, or points of critical dielectric stress.

As a result of the described method of manufacturing my bushing, when each layer of clay is dewatered under known pressure, and then a conductive layer is applied, followed by another pressure-dewatered layer of clay, there is thorough consolidation of the ceramic granules, no drying shrinkage, and the final firing shrinkage is very much reduced. The residual firing shrinkage can be controlled by programming the successive pressures and the final consolidating pressure to achieve a final solid structure when fired. By eliminating all drying shrinkage and a large part of the firing shrinkage, the residual final shrinkage occurs in the range of early vitrification when the body is hot enough to be safer against cracking because it is somewhat plastic. Since the successive layers are thoroughly compacted, differential shrinkages are largely eliminated and warping is minimized. In this way, roundness and straightness of the tubular forms are improved, and dimensional control is made more exactly predictable.

When the condenser bushing becomes heated in operation, the liquid, which is sealed in the bore of the central conductor, boils under the reduced pressure obtaining. Vapor rises up and condenses in the radially finned tubes **24**, and the condensate returns to the bottom of the conductor **11**, where it again takes on heat. In this way, heat is transferred from the interior of the bushing through the heat exchange tubes **24** to the atmosphere. Moreover, the radially finned heat exchange tubes **24** serve to dissipate electrostatic flux to help grade the flashover path.

For simplicity of illustration and description, the fins **26** of the tubes **24** have been illustrated and described as of uniform size. In order to increase the clearance distance between the surrounding arc guard rings, the finned tubes can be made shorter on the near sides and longer on the outside. Also, other sets of finned tubes can be placed above the first set of tubes.

For bushings of higher voltage ratings, the thickness of wall may exceed the practical thickness for firing ceramic bodies. In this case, the bushing may be manufactured in two or more sections, as illustrated in Fig. 3. This practice is advisable also because of differences in temperature that may exist between the outside and inside layers due to heating and cooling by atmospheric changes on the outside, or due to the sun's heat, or due to heating by dielectric losses and by resistance losses in the central conductor which carries the load current. Differential heating and cooling cause expansion and contraction, resulting in strains in the structure.

The high capacity bushing illustrated in Fig. 3 includes a central tubular conducting member **111** and a first or inner insulating assembly, **119** and a second, or outer insulating assembly **130**. In each assembly, layers of conductive glaze are interposed between layers of clay, as in the first described embodiment of my invention. The central tubular conducting member is cooled as in the first-described embodiment of my invention by radially finned heat exchange tubes **123**. In addition, in the bushing of Fig. 3, a sealed, double walled tube **132** is located in the annular space between the two sections of the bushing. The tube is closed and contains water or other liquid under reduced pressure. A plurality of heat exchange tubes **125** are secured around the bushing to the double walled tube **132**, and the bore of each interconnects at its inner end with the bore of the tube, while the outer end of each is closed. The array of heat dissipating tubes serves not only for cooling the bushing but also to dissipate electrostatic flux to help grade the flashover path. Additional sets of finned tubes can obviously be mounted above the sets illustrated, if desired, to increase the dissipating capacity.

The bore **121** in the inner assembly **119** of the insulating assembly is coated with a conductive glaze (not shown) to avoid corona from the central conductor **111** to the inside wall. Similarly, the exterior surface **133** of the inner section **119**, which is juxtaposed with the double walled tube **132**, and the opposed inner surface **135** of the outer section **130**, are coated with conductive glaze (not shown).

A collar **134** is mounted on top of the inner section **119**, to prevent seepage of rain water into the space **121**. Appropriate gaskets, not shown, are provided between the top of the porcelain of the bushing and the top conductor flange, and also between the inner assembly **119** and the outer assembly **130** where exposed to the weather.

A grounding sleeve **114** is mounted on a smooth portion of the outer section **130** of the insulating assembly.

The operation of this multi-sectional condenser bushing is similar to that of the bushing previously described. The heat exchange means provided between the two sections eliminates any difference in temperature that may exist between the two sections and thus prevents differential expansion or contraction which would result in strains in the structure.

Each section is separately made by the general process previously described, and the sections and other components of the bushing are assembled to complete the final structure shown.

While the invention has been described in connection with specific embodiments thereof, then, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. An electrical insulator bushing having a central bore and comprising alternating layers of ceramic insulating and of electrically conductive material, said insulating layers extending at their ends beyond the conductive layers, said conductive layers comprising conductive films deposited on the respectively subjacent insulating layers and arranged concentrically of each other in a graded series in which the films are of progressively decreasing lengths outwardly from said bore, the corresponding ends of successive films being displaced progressively axially of said bore, each film comprising a layer of metallic oxide, each end of each film being convex and being directed radially inwardly of said member, said films being mutually spaced and electrically insulated from each other by said interposed layers of insulating material, and an outer layer of ceramic insulating material surrounding and encasing said alternating layers, the extended end portions of said ceramic insulating layers being integrally united together and to the outer layer of ceramic insulating material to form a substantially monolithic structure, the exterior surface of said member comprising alternating lands and grooves extending around the periphery of said member.

2. An electrical insulator bushing comprising a central conductor rod having a bore sealed at each end thereof, heat exchange fluid confined within said bore, radially finned tubes mounted radially around said rod adjacent the top of said bushing and centrally bored with the bores thereof interconnecting with the bore of said rod, an insulating and condenser assembly concentrically mounted on said rod, and a grounding sleeve mounted concentrically around the insulating and condenser assembly, said insulating and condenser assembly compris-

ing alternating layers of ceramic insulating and of electrically conductive material, said insulating layers extending at their ends beyond said conductive layers and being integrally united at their ends to form a substantially monolithic structure, said conductive layers comprising a series of concentric, substantially tubular conductive members and being arranged according to a decreasing progression of length outwardly from said rod, said conductive members being mutually spaced and electrically insulated from each other by the said interposed layers of ceramic insulating material.

3. An electrical insulator bushing comprising a central conductor rod, an insulating and condenser assembly concentrically mounted on said conductor rod, and a grounding sleeve mounted concentrically around said insulating and condenser assembly, said insulating and condenser assembly comprising at least two concentric sections, each section having a central bore and comprising alternating layers of insulating and electrically conductive material, the insulating layers extending at their ends beyond the conductive layers and being integrally united at their ends to form a substantially monolithic structure, said conductive layers comprising a series of substantially tubular conductive members concentrically disposed relative to said central conductor rod and having areas which are arranged in a decreasing progression outwardly from said rod, said conductive members being mutually spaced and electrically insulated from each other by the interposed layers of insulating material.

4. An electrical bushing comprising a central conductor tube, an insulating and condenser assembly concentrically mounted on said tube, and a grounding sleeve concentrically mounted around said insulating and condenser assembly, said insulating and condenser assembly comprising at least two concentric sections, each section having a central bore and comprising alternating layers of insulating and electrically conductive material, a closed chamber disposed in the annular space between each pair of concentric sections, liquid under reduced pressure confined in each chamber and in said central conductor tube, finned tubes communicating at their inner ends with said central conductor tube and secured to said tube and mounted above said insulating and condenser assembly and being closed at their outer ends, and other finned tubes communicating with each closed chamber between concentric sections and also being closed at their outer ends.

5. An electrical bushing adapted for use in a high voltage circuit and comprising a central conductor tube through which courrent is adapted to pass, an insulating and condenser assembly concentric of said tube, and a grounding sleeve mounted concentrically around said insulating and condenser assembly and adapted to be at ground potential, said insulating and condenser assembly including at least two concentric sections, each section having a bore, said conductor tube extending through the bore of the inner section, and each section comprising alternating layers of insulating and conductive material, the insulating layers extending at their ends beyond the conductive layers, said conductive layers comprising substantially tubular electrically conductive films arranged concentrically of said tube in a series in which the films are of progressively decreasing areas outwardly from said tube, each end of each film being displaced from the corresponding end of the next subjacent film axially of the bushing toward said grounding sleeve and each end of each film being flared outwardly through a convex path and terminating along a slope of said path directed radially inward toward said conductor tube, each film comprising a metallic oxide, said films being mutually spaced and electrically insulated by the interposed layers of insulating material, an outer layer of insulating material encasing said alternating layers, the extended ends of said alternating layers of insulating material being united together and united with the outer layer of insulating material to form a monolithic structure for each section, said outer layer of each section being helically corrugated over at least a portion of its length, heat exchange means for said conductor tube, and heat exchange means interposed between each pair of concentric sections of said insulating and conductive assembly, the outermost of said conductive films in the outer section being electrically connected to said grounding sleeve.

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