

[54] CAST CONDENSER BUSHING

[75] Inventors: Jame F. Quirk, Penn Hills; Paul W. Martincic, Sharpsville; Kevin F. Friedrich, Sharon, all of Pa.

[73] Assignee: Westinghouse Electric Corporation, Pittsburgh, Pa.

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[51] Int. Cl. H01b 17/28
[58] Field of Search 174/73 R, 73 SC,
174/142, 143; 29/631; 264/262

[56] References Cited

UNITED STATES PATENTS

2,303,283 11/1942 Kirkwood et al. 174/143
3,513,253 5/1970 Woods 174/143

FOREIGN PATENTS OR APPLICATIONS

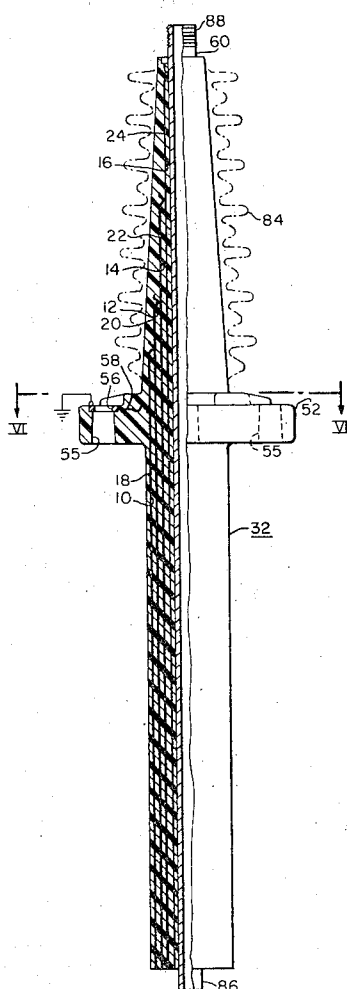
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Primary Examiner—Laramie E. Askin
Attorney—A. T. Stratton et al.

[57] ABSTRACT

A condenser bushing assembly, and method of manufacturing same, having a generally cylindrical body portion formed of cast solid insulation, a central conductor in the body portion, and one or more concentric conductive condenser elements, radially spaced from the central conductor, disposed in the body portion. The required capacitive relationship of the conductive condenser elements is provided by metallic coatings arranged in a predetermined pattern on predetermined portions of tubular members of polycarbonate. The tubular members of polycarbonate are positioned in a mold and the insulation which forms the body portion is cast around the polycarbonate tubular members. The material used to cast the cylindrical body portion chemically attacks the polycarbonate of the tubular members during the casting operation and causes the polycarbonate to soften and amalgamate with the material of the body portion to eliminate all interfaces between the material of the body portion of the bushing and the material of the tubular members carrying the conductive elements of the condenser system.

7 Claims, 11 Drawing Figures



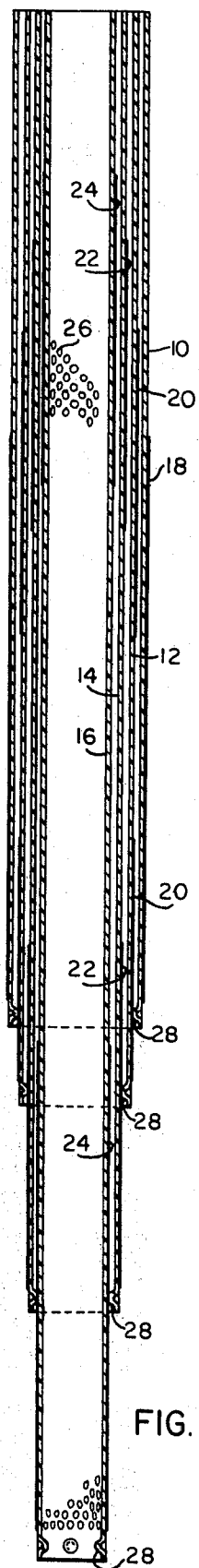


FIG. 1

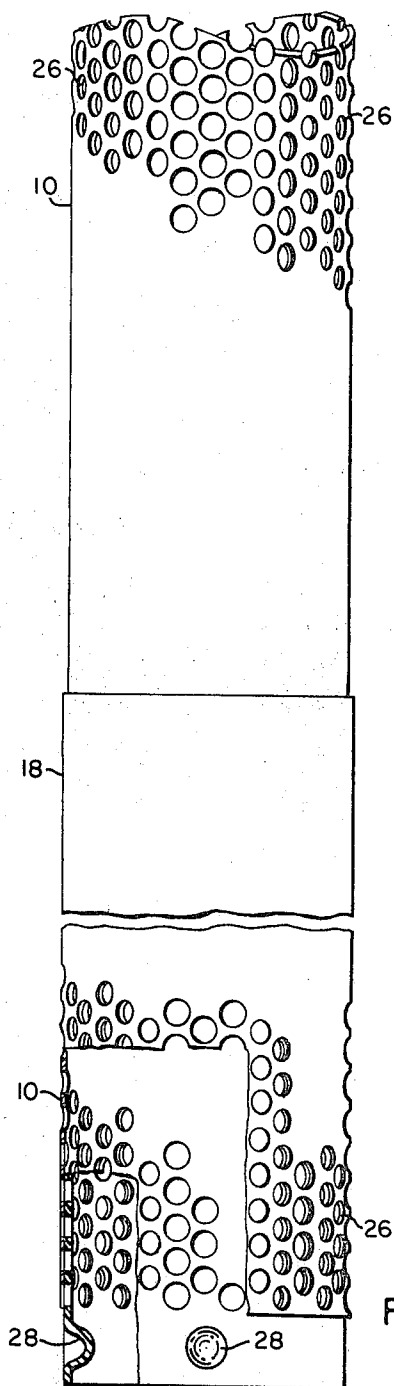
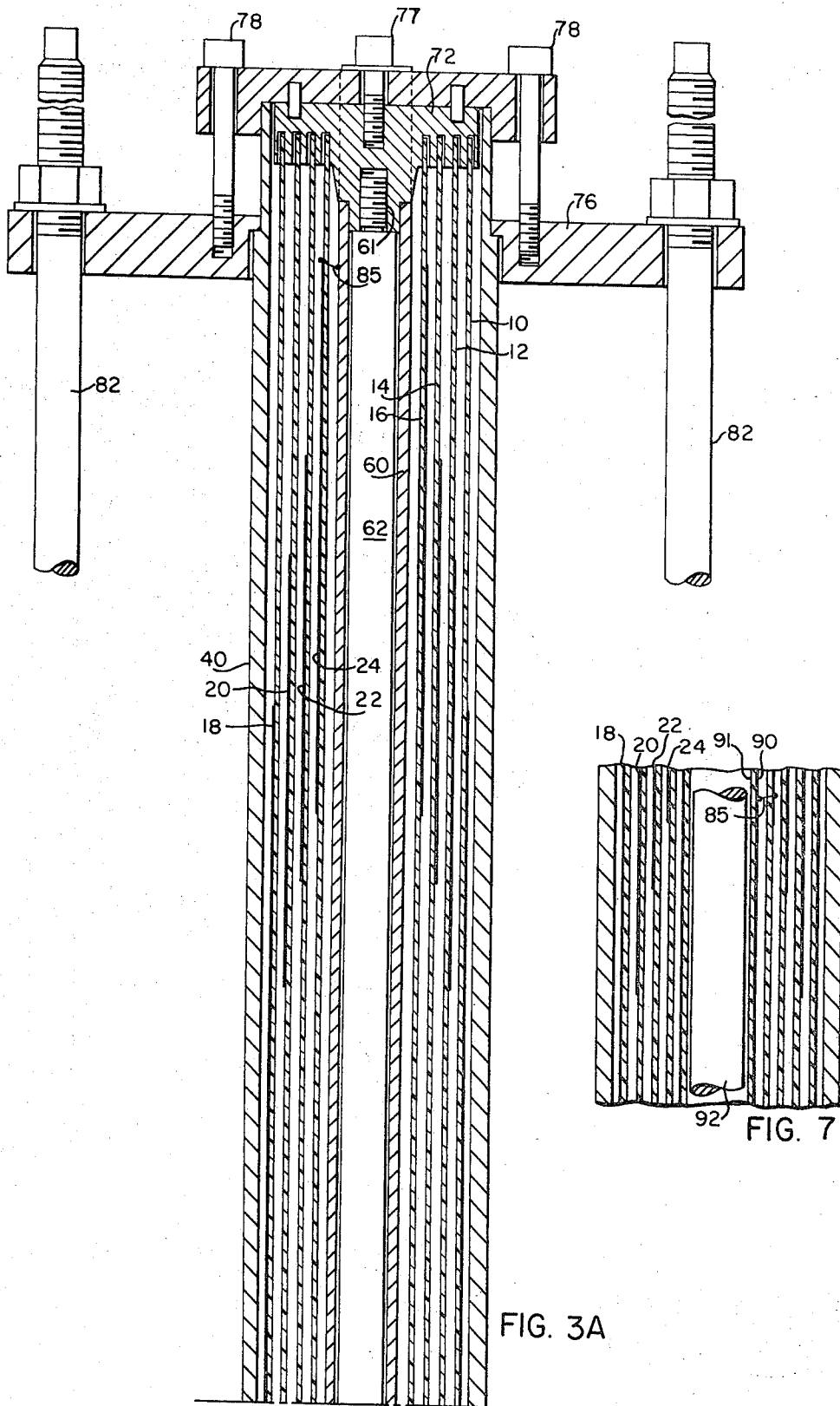
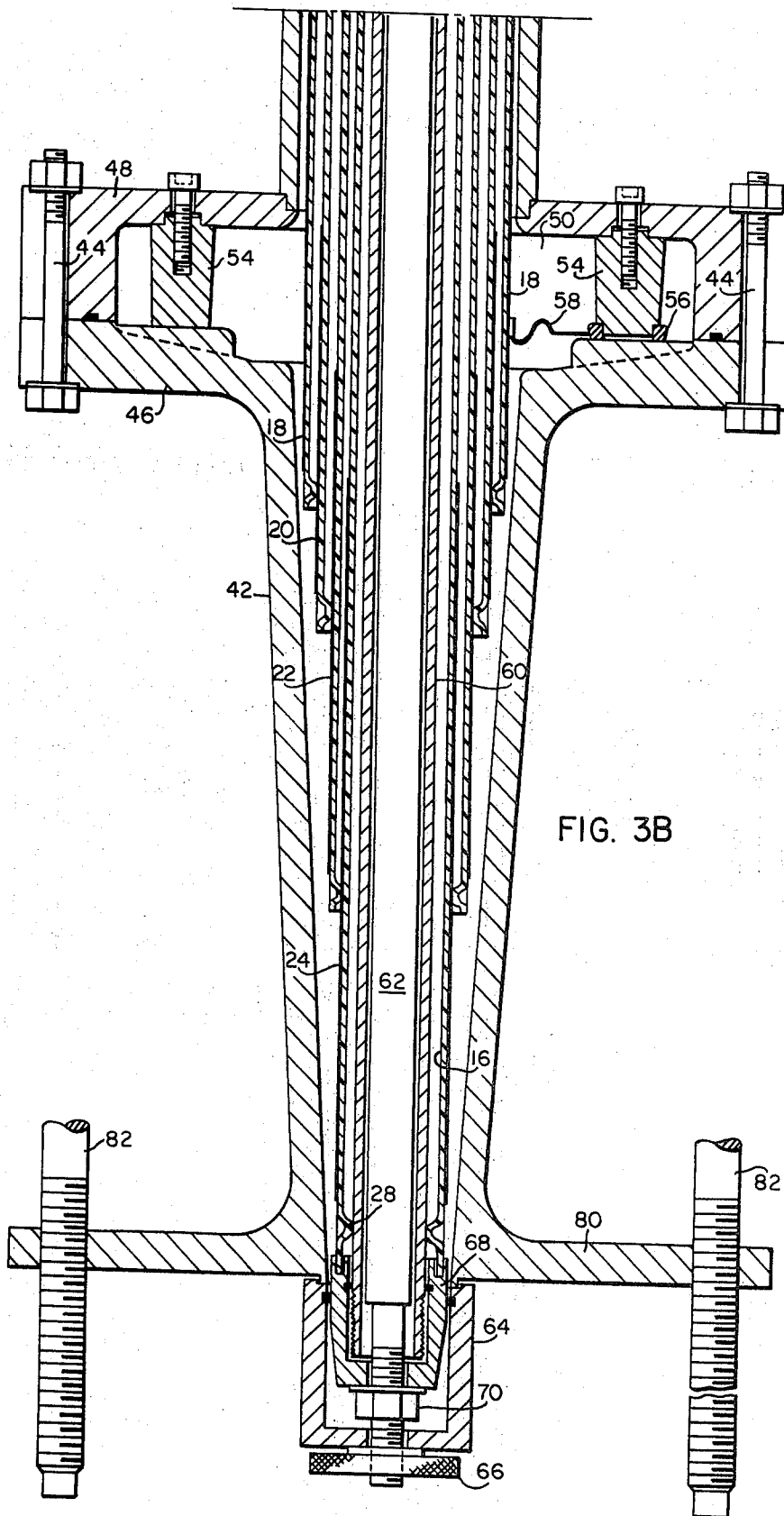
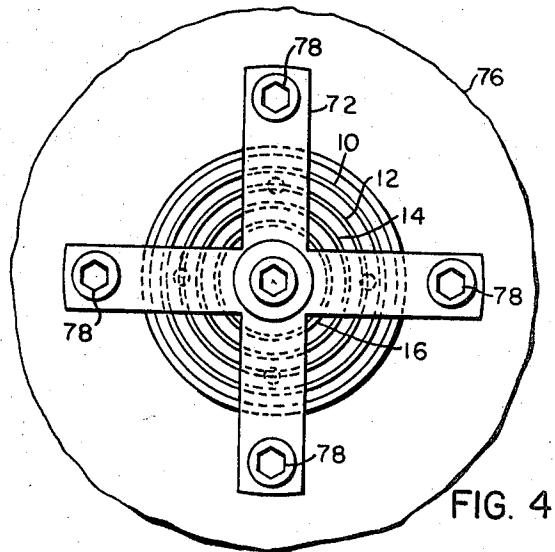
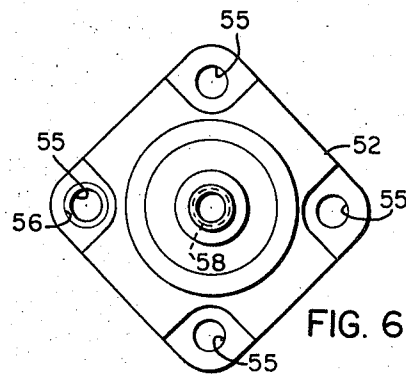
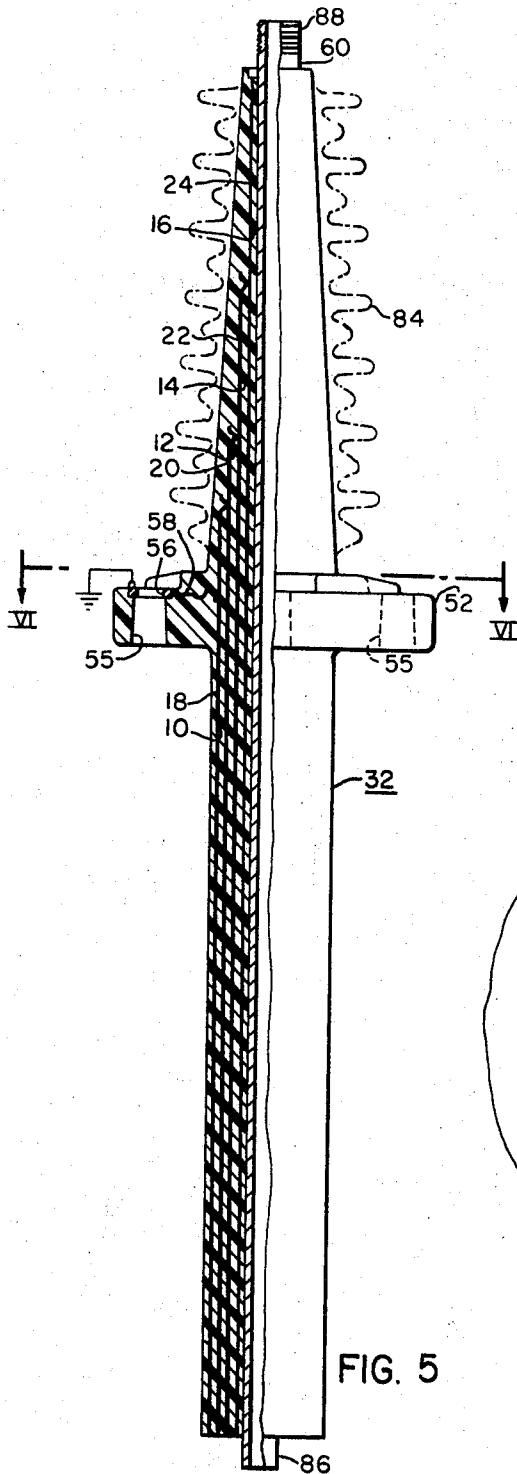
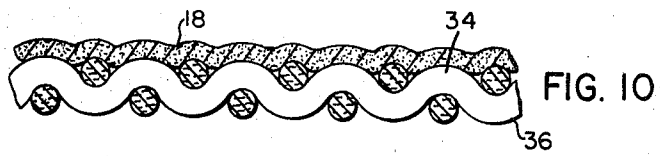
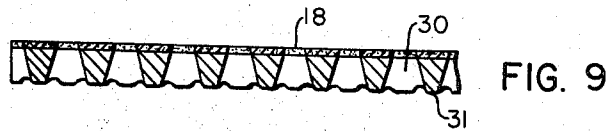
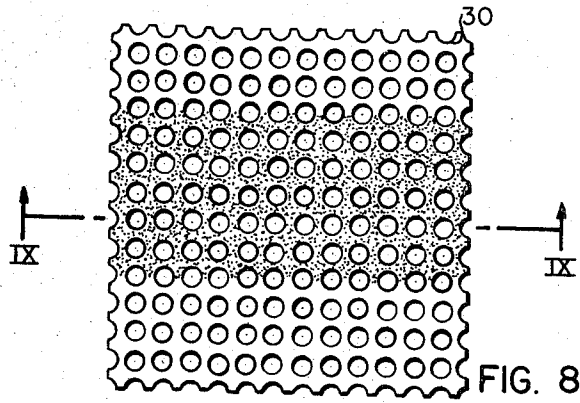


FIG. 2









CAST CONDENSER BUSHING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to condenser bushing assemblies for electrical apparatus and more particularly to condenser bushing assemblies having a body portion formed of cast solid resin with the conductor elements of the condenser system cast into the body portion during the process of casting the body portion.

2. Description of the Prior Art

A condenser type bushing including a central conductor having a body portion cast therein with a condenser system comprising a predetermined arrangement of conductive elements located in the body portion of the bushing has been provided in the prior art in several ways.

The U.S. Pat. No. 3,394,455 describes one way of providing a cast resin condenser bushing having a predetermined arrangement of conductive elements positioned in the cast body portion of the bushing. This patent describes and claims what is known in the art as a two-part casting system for providing a condenser bushing having a cast resin body portion disposed about a central conductor, with a predetermined arrangement of conductive condenser elements located in the body portion. The teaching of this patent is to provide a first cast body portion having a configuration to receive cylindrical metallic condenser elements. The first predetermined body portion is first cast to the desired shape, then the cylindrical condenser elements are placed on the first body portion and then the second cast resin body portion is cast over the condenser conductive elements. This patent provides a very satisfactory condenser bushing; however, the resulting condenser bushing is expensive because of the two casting process which requires casting of the first body portion and demolding this portion, then placing the cylindrical elements in position, replacing the bushing in the mold, casting the second body portion, and then de-molding. This elaborate process is time consuming and requires much labor which runs up the cost of the condenser bushing. Although this process provides a very satisfactory bushing it has been found that when the process is extended to higher ranges of bushings; that is, 34 1/2 kilovolts and above, it is difficult to absolutely eliminate all interface surfaces between the condenser conductive elements and the cast portions of the body portion. Any interfaces not eliminated will trap air which will induce the start of corona at high voltages. This corona will cause objectionable radio interference which will require rejection of the bushing.

The prior art also discloses in U.S. Pat. No. 3,513,253 a method of providing a condenser bushing comprising a central conductor having a resin body portion cast thereabout with conductive condenser elements cast into the body portion and radially spaced from the central conductor. This patent teaches a single casting operation for casting a condenser bushing comprising a central stud having a cast body portion thereabout with condenser conductive elements cast into the cast body portion. In this patent the condenser system is provided by providing predetermined conductive areas on a plurality of concentric mesh cylinders. The mesh cylinders are cast into the body portion of the bushing in a single casting operation. The teachings of U.S. Pat. No. 3,513,253 provide a satisfactory

condenser bushing with a single casting operation. The bushing provided by this patent are very satisfactory for certain voltage ranges; however, it is very difficult to eliminate all of the interfaces between the strands of the mesh cylinders and the cast body portion of the condenser bushing. This is because all connection between the mesh cylinders and the resin system is accomplished by surface adhesion. There is no amalgamation of the resin system and the mesh cylinders. If the interface spaces between the mesh cylinders, especially that portion having the condenser elements thereon, and the cast resin body portion of the condenser are not eliminated, air will be trapped and will induce the start of corona at high voltages.

It is one of the main objects of this invention to provide a condenser bushing comprising a cast resin body portion, cast about a central conductor, and having a condenser system comprising a plurality of concentrically arranged, conductive condenser elements radially spaced about the central conductor. It is also an object of this invention to provide means for supporting the radially spaced concentric condenser elements in the mold in such manner that when the central body portion of the condenser bushing is cast, all interfaces which might trap air are eliminated. This is accomplished by providing concentric, radially spaced, polycarbonate cylinders for supporting the conductive condenser elements in the mold during the casting operation. During the casting operation the resin used to cast the body portion of the condenser bushing chemically attacks the polycarbonate material and causes the polycarbonate material supporting the condenser conductive elements to soften and amalgamate with the resin used to cast the main body portion of the condenser bushing and thereby eliminate all interfaces between the main body portion of the condenser bushing and the polycarbonate members supporting the conductive condenser element.

SUMMARY OF THE INVENTION

Briefly the present invention is a new and improved electrical bushing of the condenser type, and method for manufacturing the same, wherein the body portion of the bushing is formed from a castable resin system, such as castable epoxy resin. The conductive condenser elements are provided on tubular members having predetermined inside diameters, with the tubular members being formed from polycarbonate material. Each tubular member has a conductive coating applied to predetermined areas thereof, such as by painting, silk screening, or spraying the tubes with conductive inks, molten conductive material, or the like, while the tube is suitably masked. The method of applying the conductive coatings is not critical, and, if desired, conductive foil or sheet may be applied directly to the polycarbonate material. In some instances conductive resins may be used to provide the conductive elements. The tubular members have sufficient lengths to cooperate with holding and locating fixtures within the casting mold. The central conductor or stud and the tubular members are disposed within a mold with the tubular members concentric and radially spaced with respect to the central conductor or stud. The tubular members are held in proper position in the mold by spacers positioned between the tubular members and special fixtures in the mold. The mold is then filled with a suitable liquid resinous insulation system, such as epoxy resin,

under vacuum. The resin insulation system is such that it chemically attacks the polycarbonate material of the cylindrical members and causes the polycarbonate to soften and amalgamate with the material of the body portion of the bushing. As the polycarbonate material softens, the polycarbonate material amalgamates with the resin of the body portion of the bushing and eliminates all interfaces between the resin insulation system of the body portion and the conductive condenser elements which might exist to trap air which would cause corona. This softening of the polycarbonate material and amalgamation of the polycarbonate material with the resin insulation system provides void free bonding of the resin system to the polycarbonate member. After the resin insulation system has solidified, the bushing is removed from the mold and the ends of the bushing are properly trimmed and dressed for attaching desired terminal connectors to each end of a central conductor or stud of the bushing.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention described herein will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is a sectional view showing the concentric arrangement of the polycarbonate cylindrical members which support the conductive elements of the condenser system;

FIG. 2 is a plan view of one polycarbonate cylinder, showing a conductive element of the condenser system thereon;

FIGS. 3A and 3B are elevational views, in section, of a mold in which the bushing is cast, showing the concentric polycarbonate cylinders supporting the condenser conductive elements in position in the mold;

FIG. 4 is a top view of the mold of FIG. 3A showing a special fixture for holding the concentric polycarbonate cylindrical members positioned in the mold;

FIG. 5 is an elevational view, partially in section, showing a completed condenser bushing provided by this invention;

FIG. 6 is a plan view of the mounting flange for the bushing taken along line VI—VI of FIG. 5;

FIG. 7 is a partial sectional view of a modification of the bushing to use a draw-through central conductor;

FIG. 8 is a plan view of an extruded polycarbonate sheet used to provide the cylindrical polycarbonate members for supporting the conductive condenser elements;

FIG. 9 is a view taken along line IX—IX of FIG. 8; and,

FIG. 10 is an edge view of a woven polycarbonate structure which may be used for providing the cylindrical polycarbonate members.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Throughout the description which follows like reference characters refer to like elements in all of the figures of the drawing.

Referring now to the drawings in detail, and FIGS. 1 and 2 in particular, FIG. 2 shows a single cylinder 10 made from a perforated sheet of polycarbonate with a single condenser conductive element 18 thereon, and FIG. 1 is a longitudinal sectional view of the concentric arrangement of a plurality of polycarbonate cylinders

10, 12, 14 and 16 for supporting conductive elements 18, 20, 22 and 24 of the condenser system for an electrical condenser bushing. The cylinders 10, 12, 14 and 16 are made from polycarbonate material. The polycarbonate material is in sheet form and it is perforated as indicated at 26. The polycarbonate cylindrical members 10, 12, 14 and 16 are arranged concentrically and are spaced radially about a central stud which extends through the body of the condenser bushing. The polycarbonate cylinders 10, 12, 14 and 16 are maintained spaced from each other by spacers 28, which are indicated as dimples in the polycarbonate material in FIGS. 1 and 2. However it is understood that any satisfactory spacer may be used for spacing the polycarbonate cylinders from each other, such as insulating buttons or spacer sticks.

Although the polycarbonate material in FIGS. 1 and 2 is indicated as perforated sheet material it is to be understood that solid unperforated polycarbonated sheet material may be used to form the cylindrical members 10, 12, 14, 16, or extruded material such as illustrated in FIGS. 8 and 9, or woven polycarbonate material such as shown in FIG. 10 may be used for forming the cylindrical members 10, 12, 14 and 16. The extruded material illustrated in FIG. 8 is particularly useful, since it is seen that the top surface 30 of the material is flat and provides a good surface for applying the conductive elements, such as 18, of the condenser system, and that the lower surface 31 of the material has a rounded shape which tends to discourage formation of corona on the lower surface of the polycarbonate sheet as shown in FIG. 9. FIG. 10 illustrates a woven material wherein the conductive condenser element, such as 18, may be applied to the top side 34 of the sheet, and all surfaces on the underside 36 of the sheet tend to have a rounded effect which will discourage the formation of corona on the underside of the sheet.

Any of the different variations of polycarbonate sheet; that is, a solid sheet, the perforated sheet as shown in FIGS. 1 and 2, the extruded sheet of FIGS. 8 and 9 or the woven sheet of FIG. 10 will perform satisfactory for providing the cylindrical members for 10, 12, 14 and 16 for supporting the conductive elements of the condenser system 18, 20, 22 and 24. The polycarbonate sheet used to provide the cylindrical members has a thickness from approximately 0.015 inch to approximately 0.030 inch. The coefficient of linear expansion of the polycarbonate used herein ranges from about 66×10^{-6} inches/inch centigrade to approximately $17-40 \times 10^{-6}$ inches/inch centigrade.

The cylindrical members 10, 12, 14 and 16, as shown in FIGS. 1 and 2, are provided by cutting the desired lengths from a polycarbonate sheet, rolling the lengths into cylindrical shape, and sealing the edges of the lengths of material to provide a cylinder. Then the cylinders 10, 12, 14, and 16 are arranged in concentric relationship, as shown in FIG. 1, are placed in an annealing oven and annealed at approximately 150°C for approximately 15 minutes to relieve any locked-in stresses in the cylindrical members 10, 12, 14, 16 due to working of the sheet polycarbonate material. The conducting condenser elements 18, 20, 22 and 24 are formed on the cylindrical polycarbonate members before they are annealed.

After the cylindrical members 10, 12, 14, 16 have been prepared and the conductive condenser elements 18, 20, 22 and 24 formed thereon and the cylindrical

members have been annealed and positioned concentrically as indicated in FIG. 1, then the assembly illustrated in FIG. 1 is placed in a two part mold which is illustrated by FIGS. 3A and 3B.

The mold provided by the apparatus shown in FIGS. 3A and 3B comprises an upper part 40 and a lower part 42. The two parts 40 and 42 of the mold are held in assembled arrangement by bolts 44 which extend through flange elements 46 and 48 of the mold provided by the two parts 40 and 42. A cavity 50 is provided between the flange elements 46 and 48 for providing a mounting flange 52 on the bushing. Inserts 54 are also provided in the cavity 50 for providing holes for mounting the bushing. Insert 56 is also provided around one of the holes for providing a ground connection to the outer metallic element 18 of the condenser system. The outer metallic condenser element 18 is connected to the grounding element 56 by means of a conductor 58.

The assembly of cylindrical polycarbonate elements having the metallic condenser elements formed thereon, as shown in FIGS. 1 and 2, is placed in the mold comprising the parts 40 and 42 with a hollow central conducting stud 60 located centrally of the assembly of cylindrical elements. A central clamping rod 62 extends through the hollow cylindrical conducting stud 60 and is clamped at its lower end by means of a clamping arrangement comprising a clamp 64 and a nut 66. The concentric polycarbonate cylinders are placed in the mold around the central conductor 60. The lower end of the inner polycarbonate member 16 is held in proper position by means of a special fixture 68 and a nut 70. The upper ends of the polycarbonate members 10, 12, 14 and 16 are held in proper position at the upper end of the mold by means of a special slotted fixture 72. The slotted fixture 72 is attached to the clamping rod 62 by means of a threaded bolt 77 and threads 61 on the end of the clamping rod 62. A top view of the slotted fixture 72 is shown in FIG. 4. The slotted fixture 72 is attached to a member 76 by four bolts 78. The member 76 is clamped to a bottom member 80 of the mold by means of three tie rods 82.

After the central conductor 60 and the cylindrical polycarbonate cylinders 10, 12, 14 and 16 have been positioned in the mold comprising the two halves 40 and 42 and the mold has been tightened by means of the tie bolts 82, the mold is placed in a vacuum chamber which is sealed and evacuated to a predetermined low pressure such as 1 to 4 millimeters of mercury. The vacuum chamber is heated to approximately the pouring temperature of the casting resin system which is usually in the range of 80° to 110°C such as 105°C $\pm$ 5° for the specific resin formulation used in this invention. The mold and its inserts are held at this elevated temperature in the vacuum chamber for a predetermined period of time which is sufficient to insure that all moisture and air have been removed from the mold and the cylindrical members 10, 12, 14 and 16. The resin system, which is an epoxy resin system, is mixed in a mixing tank at an elevated temperature, which is dependent upon the resin system used, such as 105°C $\pm$ 5°. At this temperature the resin mixture is fluid and will flow readily. The resin is poured into the top of the mold between the space between the arms of the special fixture 72, as shown in FIG. 4. The resin is poured into the mold until the mold is completely filled with fluid resin. The vacuum chamber is then brought back to atmospheric pressure and the mold is removed and

placed in a suitable oven to gel the resin. A typical gel cycle for the epoxy resin used herein is about two hours at a temperature of 100° to 120°C. After the resin system has gelled, the cast bushing may be removed from the mold by removing the clamping bolts 82 and separating the two parts of the mold at the flange provided by the members 46 and 48. The bushing produced by this process is as shown at 32 in FIG. 5, but without the shed 84. The shed 84 is provided by another process and then attached to the bushing 32.

The bushing 32 in FIG. 5 is shown in the position in which it would normally be mounted on electrical apparatus. It is emphasized that in the mold provided by the parts 40 and 42, the bushing is cast in the upside down position, from the position shown in FIG. 5. After the bushing 32 has been removed from the mold, the ends of the bushing may be trimmed to make accessible portions 86 and 88 of the central conductor member 60 for attaching terminals thereto.

The process just described in connection with FIGS. 3A and 3B, and the bushing 32 shown in FIG. 5, shows a hollow cylindrical conductor 60 cast into the body portion of the bushing 32. However, if desired, the rigid central conductor 60 may be eliminated and a polycarbonate cylinder 91 coated with a thin conducting element 90 such as the material of the conducting elements 18, 20, 22 and 24 may be provided on the cylinder 91 as indicated in FIG. 7. With this arrangement a separate central current carrying conductor 92 would be provided when the bushing is installed on electrical apparatus. This type of bushing is referred to in the art as a draw-through type bushing, since the central conductor 92 may be drawn through the central opening when the bushing is installed on apparatus.

It is seen that the conductive condenser element 18 most remote from the central conductor 60 may be connected to ground potential through the insert 56. The conductive element which is the nearest conductive element to the central stud 60 is electrically connected to the central stud 60, as indicated at 85. The purpose of connecting this inner conductive element 24 to the central stud 60 is to eliminate electrical stress between that portion of the resin body portion of the condenser between the conducting condenser element 24 and the central conductive element, whether the stud 60 of FIG. 5, or the element 90 of FIG. 7. This tends to reduce voltage stress and reduce corona forming at the interface between the central conductive element and the resin of the body portion of the bushing.

The resin systems used to cast the condenser bushing 32 described and claimed herein, and the processes used for casting and curing the bushing, may be the same as those described in the U.S. Pat. No. 3,513,253.

The resin system used to cast body portion of the bushing of this invention has a coefficient of linear expansion of approximately 16×10^{-6} to 20×10^{-6} inches per inch per degree centigrade. The thickness of the cast resin between adjacent conducting elements of the condenser system is approximately 0.200 inch.

It has been well recognized in the resin art that a serious disadvantage to the mixing of polycarbonate with other resins is the limited resistance of polycarbonates to chemicals and ultraviolet light. It was found that epoxy resins chemically attacked the polycarbonate and caused it to soften. This disadvantage was used to advantage in this invention, since it was found that when the polycarbonate softened, it formed a very

good amalgamate with the epoxy, that is, the polycarbonate and the epoxy merged into a single body.

It was found that open mesh polycarbonate seemed to make a better bond with the epoxy than solid sheet. It was concluded that this was because the open mesh material provided more area for the epoxy to attack, than the solid sheet. The opener the mesh the better the amalgamate seemed to be, within limits, it being understood that the mesh must be close enough to properly support the condenser conductive elements during the casting of the bushing.

The process and structure just described herein provides an electrical condenser bushing comprising a body portion cast from an epoxy resin system having a central stud or conductor extending therethrough and having a condenser system comprising a plurality of concentric conducting condenser elements radially spaced concentrically in the body portion from the central conductor or stud; wherein, the condenser elements are positioned by means of a high temperature thermoplastic polycarbonate material which is chemically attacked by the epoxy resin system in the casting operation of the bushing to cause the polycarbonate material to amalgamate and blend with the epoxy resin system to completely eliminate all voids between the epoxy resin system and the conducting condenser elements and thereby eliminate all air spaces which might trap air which will ionize and induce the production of corona and unexceptable radio interference.

The epoxy resin system used to cast the body portion of the bushing 32 has a much different co-efficient of linear expansion than the polycarbonate material used in the cylinders; however, since the epoxy resin comprises so much more mass than the polycarbonate, and since the polycarbonate amalgamates so well with the epoxy, this difference in co-efficients of linear expansion presents no problem. The epoxy system seems to hold the polycarbonate material by brute force to prevent it from changing position due to thermocycling.

Since numerous changes may be made in the above described apparatus and methods of producing the same and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all the matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. An electrical insulating bushing assembly, comprising:
 - a substantially cylindrical body member,
 - said body member being formed of a cast epoxy resin electrical insulating material,
 - an axially extending electrical conductor disposed substantially centrally in said body member,

a plurality of tubular members positioned in spaced concentric relation about said axially extending electrical conductor,

said plurality of tubular members comprising polycarbonate material,

said plurality of tubular members each having a coating of electrically conductive material disposed over a predetermined portion thereof, said plurality of tubular members being embedded in said cylindrical body member,

said epoxy resin electrical insulating material being bonded to said polycarbonate material by reaction with said polycarbonate material to form a uniform structure comprising said epoxy resin electrical insulating material and said polycarbonate material.

2. An electrical insulating bushing assembly, comprising:

a substantially cylindrical body member,

said body member being formed of cast epoxy resin electrical insulating material,

an axially extending electrical conductor disposed substantially centrally in said body member,

at least one polycarbonate member spaced radially from said electrical conductor,

said at least one polycarbonate member having a layer of electrical conductive material disposed over a predetermined portion thereof,

said at least one polycarbonate member being embedded in said cylindrical body member,

said epoxy resin electrical insulating material being bonded to said polycarbonate material by reaction with said polycarbonate material to form a uniform structure comprising said epoxy resin electrical insulating material and said polycarbonate material.

3. The bushing assembly of claim 2; wherein, said polycarbonate member comprises sheet polycarbonate material formed into a tubular member.

4. The bushing assembly of claim 3; wherein, said sheet polycarbonate material has a plurality of holes provided therein.

5. The bushing assembly of claim 2; wherein, said polycarbonate member comprises an extruded mesh of polycarbonate material comprising cross strands with the crossing strands joined integrally with each other and the space between crossing strands providing an open mesh.

6. The bushing assembly of claim 2; wherein, said polycarbonate member comprises an element woven from polycarbonate strands with crossing strands bonded together to form an open mesh.

7. The bushing assembly of claim 2 wherein said polycarbonate material has a different thermal coefficient of expansion than said epoxy resin electrical insulating material.

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