

[54] **CAST CONDENSER BUSHING**

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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
317/258, 260

[56] **References Cited**

UNITED STATES PATENTS

2,301,882	11/1942	Kappeler.....	174/143
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3,513,253	5/1970	Woods.....	174/143

FOREIGN PATENTS OR APPLICATIONS

695,313	9/1964	Canada.....	174/143
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991,546	5/1965	Great Britain	174/143

Primary Examiner—Laramie E. Askin

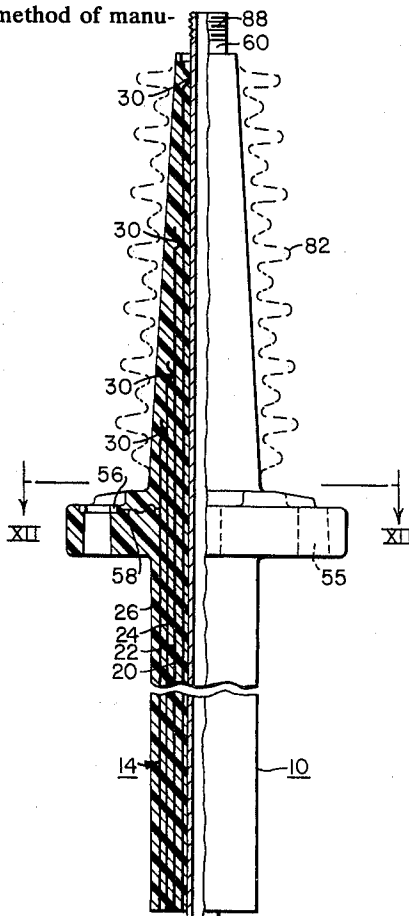
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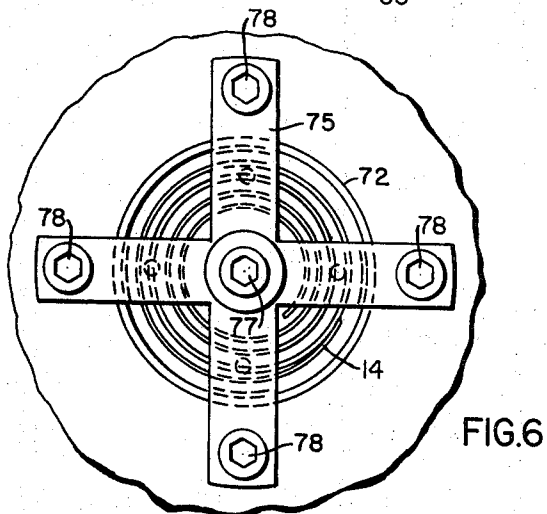
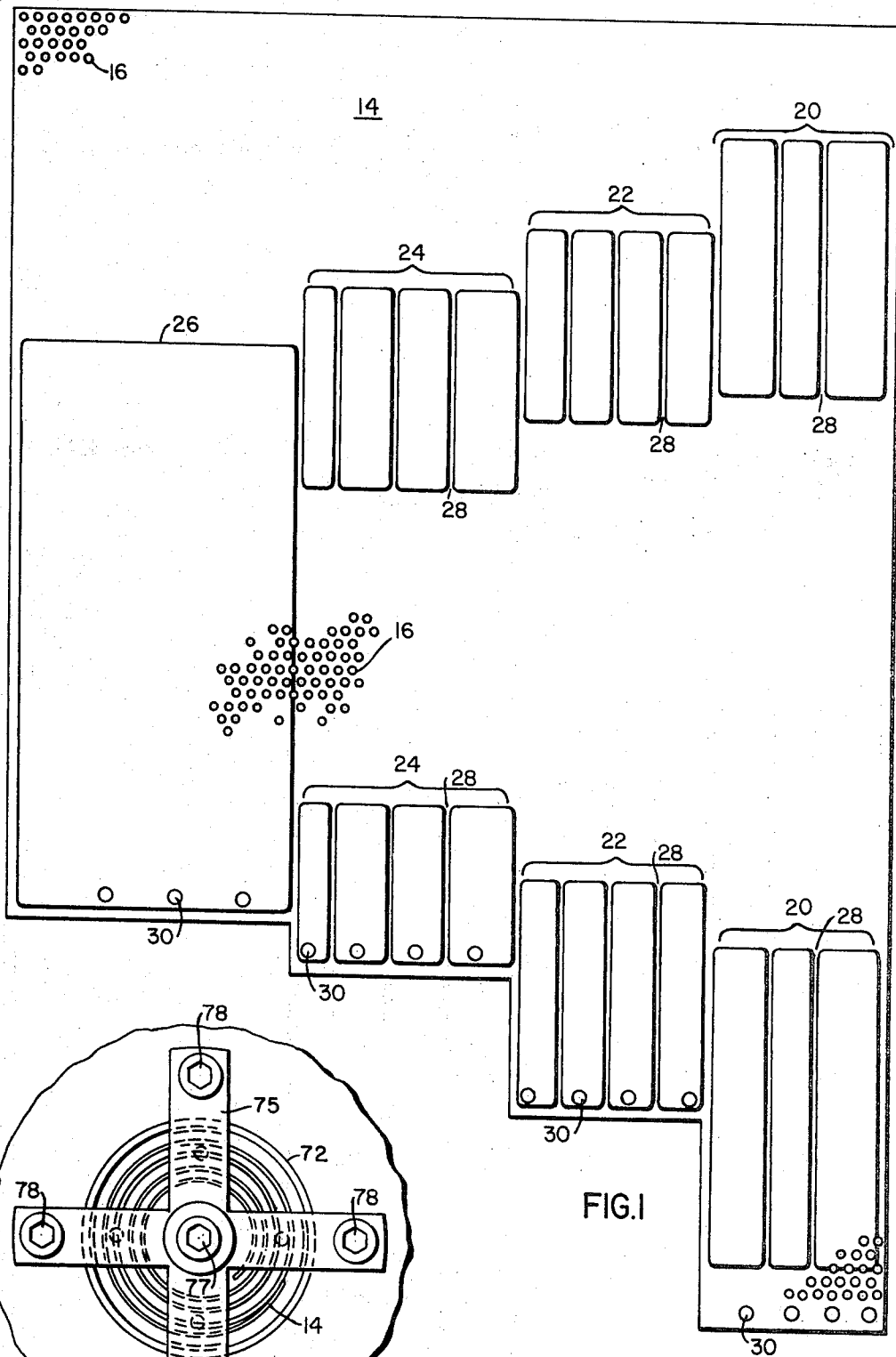
[57] **ABSTRACT**

A condenser bushing assembly, and method of manu-

facturing same, having a generally cylindrical body portion formed of cast solid insulation, a central conductor in the body portion, and one or more conductive condenser elements radially spaced from said central conductor. The radially spaced conductive condenser elements are arranged in a spiral configuration and comprise one or more layers of spiral arranged concentrically of each other about the central conductor and radially spaced from each other. The required capacitive relationship of the conductive condenser elements is provided by metallic coatings arranged in a predetermined pattern on predetermined portions of a spiral sheet of polycarbonate. A spiral sheet of polycarbonate comprising a plurality of turns having the conductive condenser elements provided thereon is positioned in a mold and the insulation which forms the body portion of the condenser is cast around the spiral polycarbonate member. The material used to cast the cylindrical body portion chemically attacks the polycarbonate of the spiral member during the casting operation and causes the polycarbonate of the spiral member to soften and amalgamate with the material of the body portion of the condenser to eliminate all interfaces between the material of the body portion of a condenser bushing and the material of the polycarbonate spiral member carrying the conductive elements of the condenser system, and the conductive elements of the condenser system.

6 Claims, 14 Drawing Figures





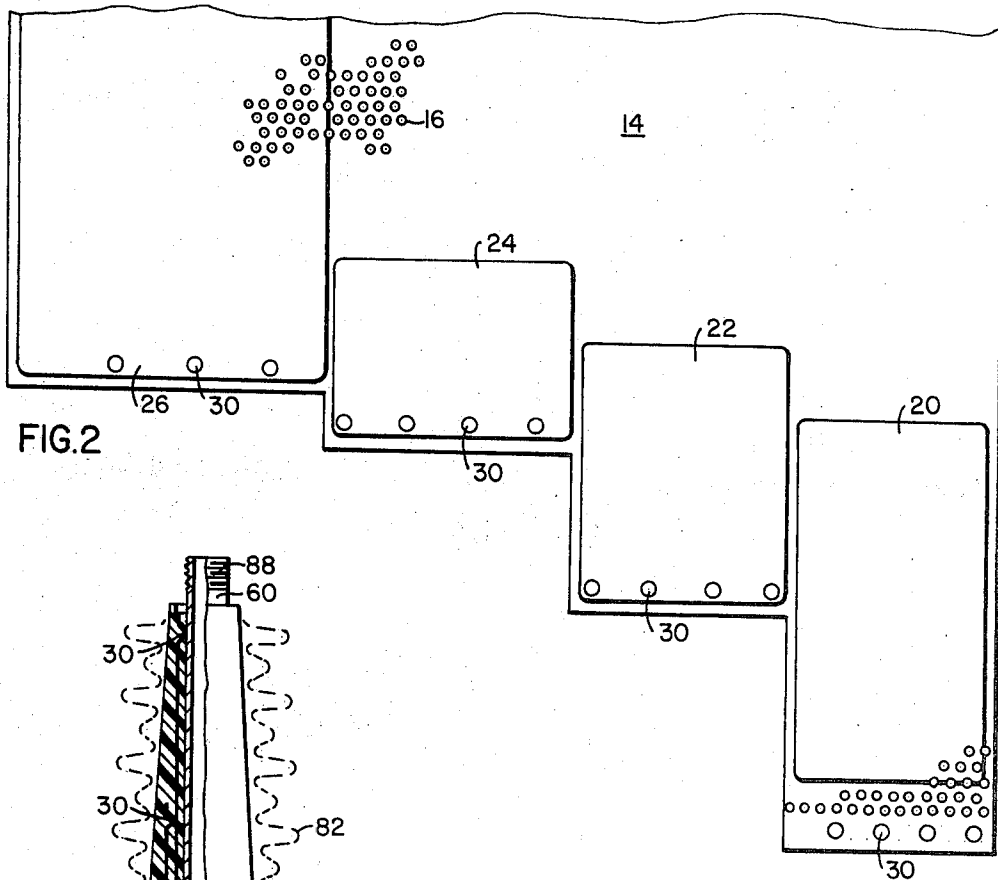


FIG. 2

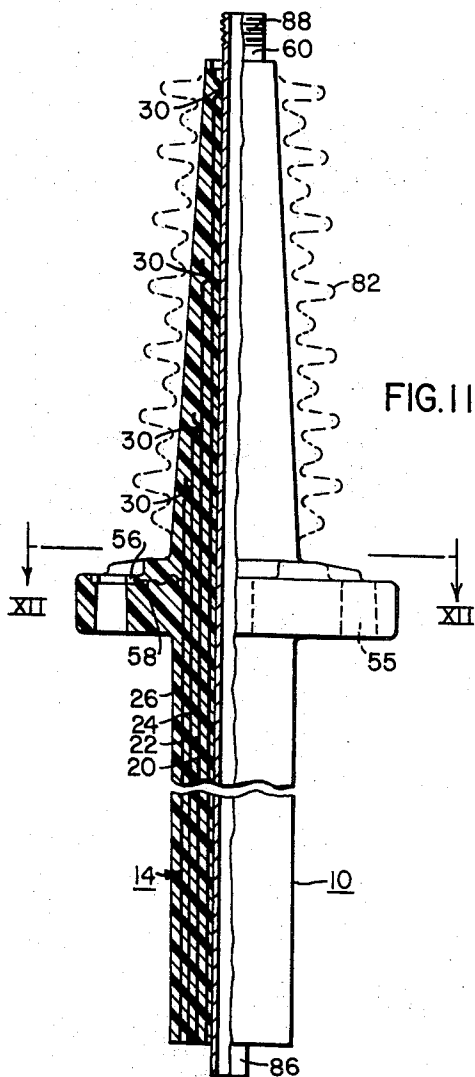


FIG. 11

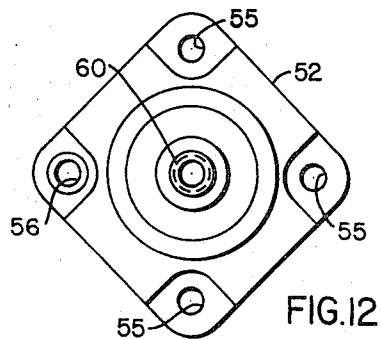
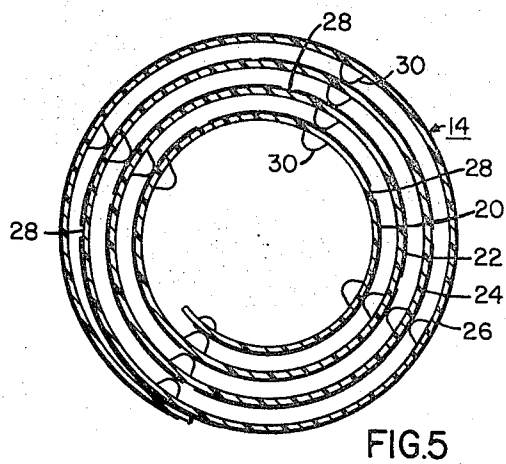
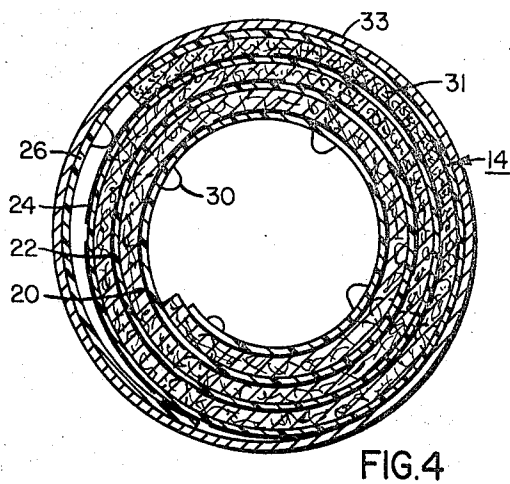
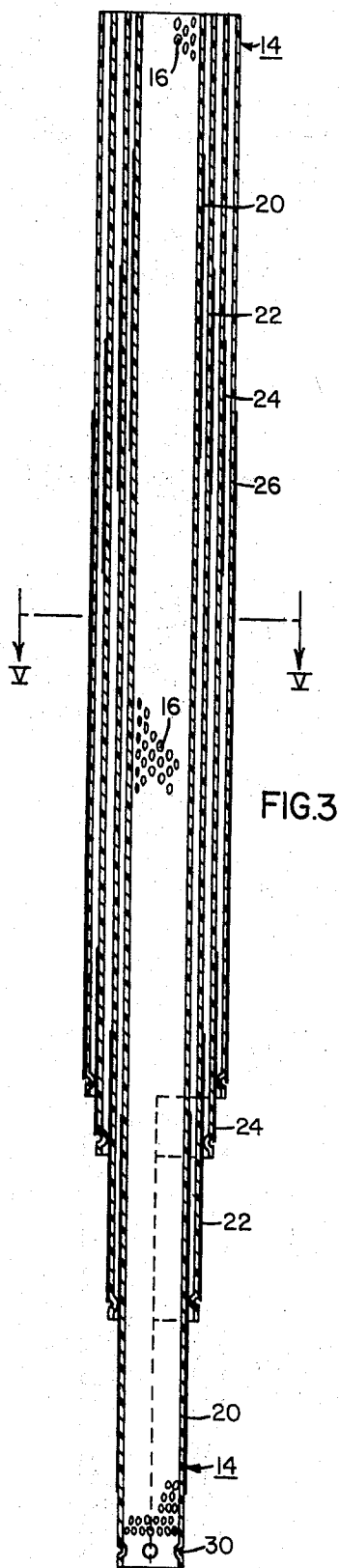
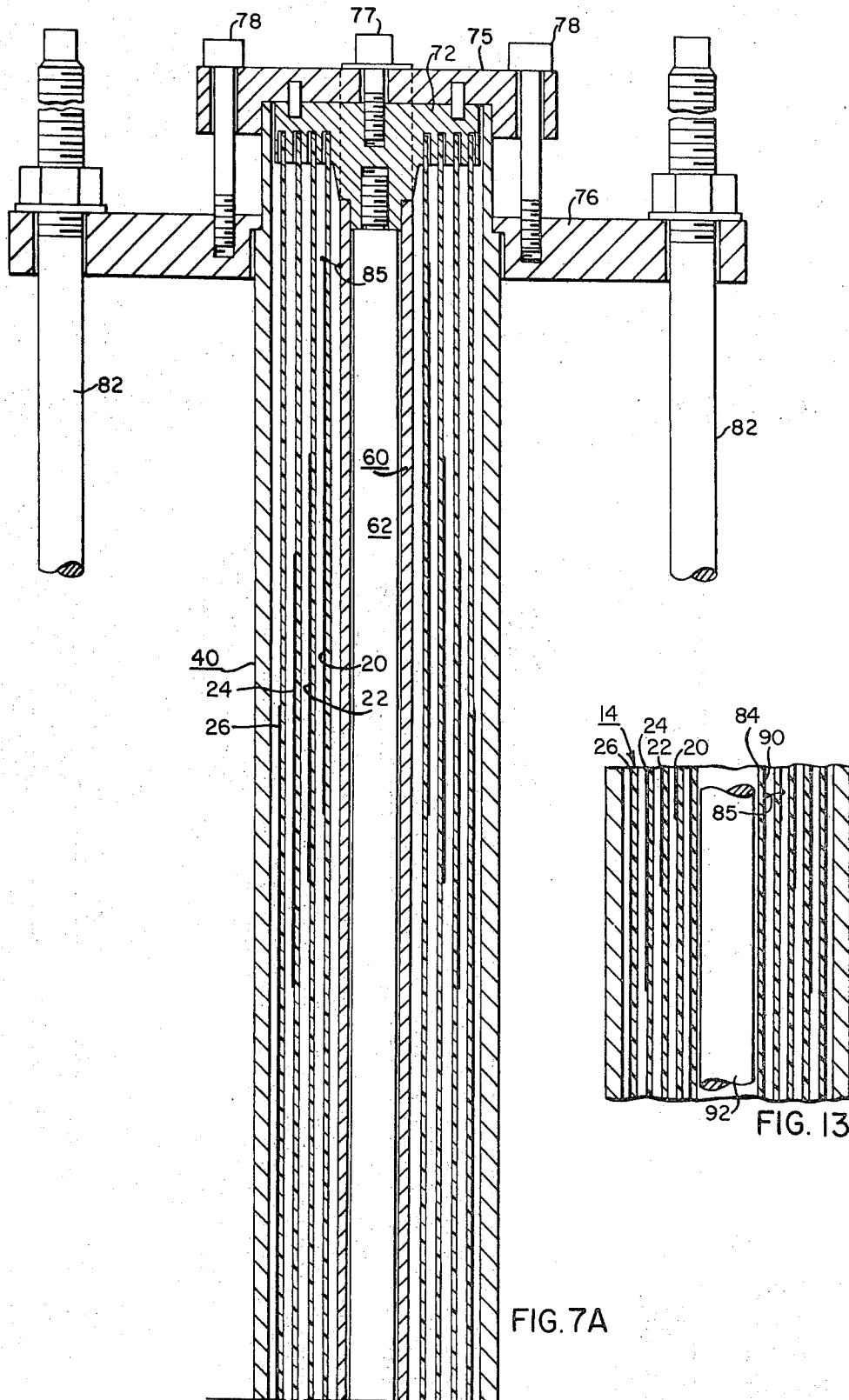
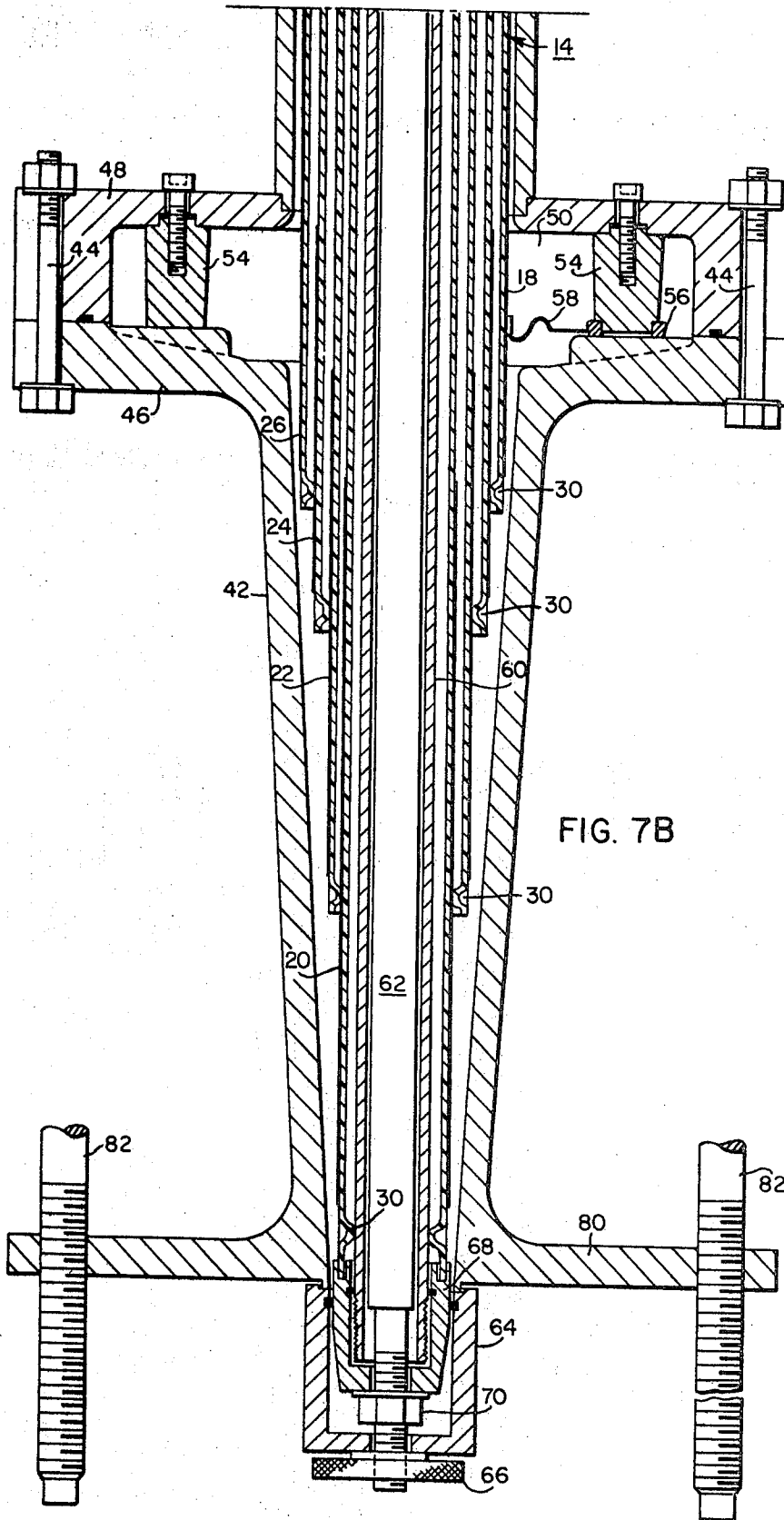
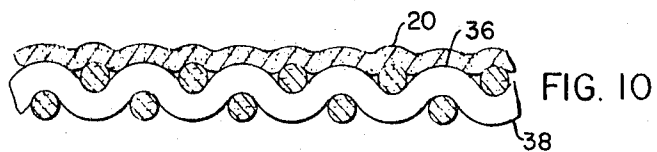
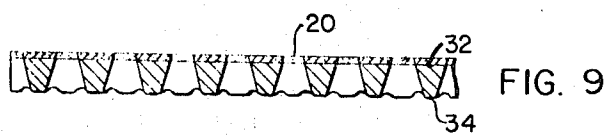
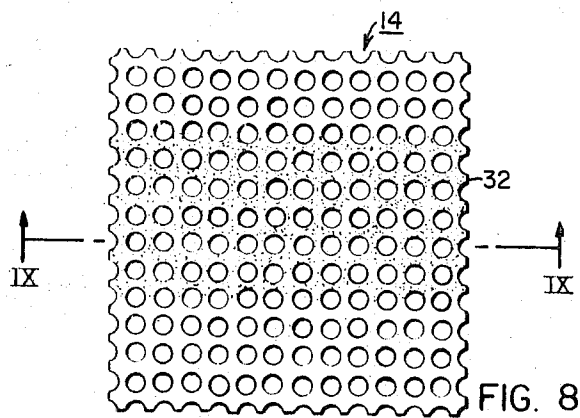


FIG. 12









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 conducting 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 discloses and 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, then the second cast resin body portion is cast over the 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, demolding this portion, then placing the cylindrical elements in position, replacing the bushing in the mold, casting the second body portion, and then demolding. 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, 34½ kilovolts and above, it is difficult to absolutely eliminate all interface surfaces between the conductive condenser elements in the cast portions of the body portion. Any interfaces not eliminated will entrap 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 cast condenser bushing. 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 non-conducting mesh cylinders. The mesh cylinders are cast into the body portion of the bushing in a single casting operation. The bushings provided by the teaching of this patent are also very satisfactory in some voltage ranges, however, it is difficult to absolutely eliminate all of the interfaces between the strands of the mesh cylinder and the cast body portion

of the condenser bushing. This is because all connection between the mesh and the resin system is accomplished by surface adhesive only. There is no amalgamation of the resin system and the mesh cylinder. If all interfaces between the mesh cylinders, especially that portion having the condenser elements thereon and the cast resin body portion of the condenser bushing are not eliminated, air will be trapped and will induce the start of corona at high voltages. Another object to the teachings made according to U.S. Pat. No. 3,513,253 is that each bushing rating requires a different size mesh cylinder and this runs up the cost of the bushings, since the mesh cylinders must be woven.

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 spirally arranged conductive elements radially spaced about the central conductor. It is also an object of this invention to provide means for supporting the radially spaced spirally arranged 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 a spiral of polycarbonate material comprising a plurality of concentrically arranged layers radially spaced from each other for supporting the 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 of the spiral 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 spiral member, and the conductive condenser elements.

SUMMARY OF THE INVENTION

Briefly the present invention is a new and improved electrical bushing of the condenser type and methods for manufacturing the same, wherein the body portion of the bushing is formed from a castable resin system such as a castable epoxy resin. The conductive condenser elements are provided on a spiral sheet of polycarbonate comprising a plurality of turns or material radially spaced from each other. Each turn of the spiral polycarbonate sheet has a conductive coating applied to predetermined areas thereof, such as by painting, silk screening, or spraying the polycarbonate sheet with molten conductive material, or the like, while the sheet is suitably masked to provide the desired configuration of conductive elements on the sheet. The method of applying the conductive coatings to the polycarbonate sheet 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 on the polycarbonate sheet. The polycarbonate spiral member has sufficient length to cooperate with holding and locating fixtures within the casting mold.

The conductive central conductor or stud and the polycarbonate sheet having the conductive condenser elements thereon are disposed within a mold with the polycarbonate sheet concentrically spaced about the central conductor. The polycarbonate spiral is held in

proper position in the mold by spacers between the turns of the spiral polycarbonate member and special fixtures in the mold. The mold is then filled with a suitable liquid resinous insulation system, such as an epoxy resin system, under vacuum. The resin insulation system is such that it chemically attacks the polycarbonate material of the spiral member and causes the polycarbonate of the spiral member 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 induce 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 formed for attaching the desired terminal connectors to each end of the 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 plan view of a polycarbonate sheet used for supporting the conducting condenser elements, illustrating one arrangement of the conductive condenser elements;

FIG. 2 is a plan view of a polycarbonate sheet showing a second arrangement of the conductive condenser elements on the polycarbonate sheet;

FIG. 3 is a longitudinal sectional view showing the polycarbonate sheet after it has been rolled into a spiral, with the conductive condenser elements provided thereon;

FIG. 4 is a cross-sectional view showing the polycarbonate sheet rolled into a spiral comprising a plurality of concentric turns with a spacer member located between the concentric turns;

FIG. 5 is a cross-sectional view taken along line V—V of FIG. 3;

FIG. 6 is a top view of the mold showing a special fixture for holding the spiral polycarbonate member positioned in the mold;

FIGS. 7A and 7B are an elevational view, in section, of a mold in which the bushing is cast, showing the spiral polycarbonate member supporting the conductive elements of the condenser system in position in the mold;

FIG. 8 is a plan view of an extruded polycarbonate sheet which may be used to provide the spiral polycarbonate member;

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

FIG. 10 is an edge view of a woven polycarbonate sheet which may be used to provide the spiral polycarbonate member;

FIG. 11 is an elevational view, partially in section, showing the completed condenser bushing;

FIG. 12 is a view taken along line XII—XII of FIG. 11, showing the flange for mounting the bushing on electrical apparatus; and,

FIG. 13 is a partial sectional view showing a second embodiment for the central conductor member of the bushing.

Referring to the drawings in detail, and FIG. 1 in particular, this figure shows a polycarbonate sheet 14 having perforations 16 therein. Although only a few perforations 16 are shown, it is to be understood that the entire sheet 14 is perforated. The polycarbonate sheet 14 has provided thereon conductive elements 20, 22, 24 and 26. The polycarbonate sheet 14 is wound into a spiral form so that the conductive element 20 provides substantially a complete turn in the first or the smallest diameter layer of the spiral, the conductive element 22 provides a substantially complete turn in the second layer of the spiral, and the element 24 provides a substantially complete turn in the third layer of the spiral, and the element 26 provides a complete unbroken turn of conducting material in the outer or largest diameter layer of the spiral. It is observed that the elements 20, 22 and 24 are provided with breaks in the conductive material, as indicated by the reference character 28. The purpose of the breaks 28 in the conductor material is to cause more even distribution of the voltage stress in the resin between the layers of the spiral having the conductive elements 20, 22 and 24 thereon. It is observed that the conductive element 26 has no breaks therein and comprises a complete conductive turn in the outermost or largest turn of the spiral. The sheet 14 is provided with a plurality of dimples or button spacers 30 for maintaining the layers of the polycarbonate spirals properly separated from each other when the sheet 14 is rolled into spiral form.

FIG. 2 discloses another arrangement of the conducting elements on the polycarbonate sheet 14. The polycarbonate sheet of FIG. 2 is identical in all respects to the polycarbonate sheet of FIG. 1 and includes perforations 16 and spacing elements 30. The only difference between FIG. 1 and FIG. 2 is that in FIG. 2 the condenser conducting elements 20, 22 and 24 are provided to provide a continuous conducting surface for each entire turn of the spiral and having no breaks therein, such as the breaks 28 provided in the embodiment shown in FIG. 1. In the embodiment shown in FIG. 2, the conductive condenser elements 22, 24 and 26 provide a continuous turn of conducting surface for each continuous turn of the spiral polycarbonate member. Although the polycarbonate material in FIGS. 1 and 2 is indicated as perforated sheet material, it is to be understood that solid unperforated polycarbonate sheet material may be used to form the spiral support member for the condenser conductor elements 20, 22, 24 and 26, or an extruded sheet material such as indicated in FIGS. 8 and 9, or woven polycarbonate materials such as shown in FIG. 10. The extruded material illustrated in FIGS. 8 and 9 is particularly useful since it is seen that the top surface 32 of the material is flat and provides a good surface for applying the conductive elements such as 20 of the condenser system, and the lower surface 34 of the material has a round 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 elements, such as 20, may be applied to the top side 36 of the sheet and all surfaces on

the underside 38 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, a 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 satisfactorily for supporting the conductive condenser elements 20, 22, 24 and 26. The polycarbonate sheet used to provide the spiral member 14 has a thickness of from approximately 0.015 inches to approximately 0.030 inches. The coefficient of linear thermal expansion of the polycarbonate used herein ranges from about 66×10^{-6} inches per inch centigrade to approximately $17-40 \times 10^{-6}$ inches per inch centigrade.

After the conducting elements of the condenser system 20, 22, 24 and 26 have been laid out on the polycarbonate sheet 14, the polycarbonate sheet is cut to proper size and the spacing elements 30 are provided on the lower end of the sheet 14. These spacing elements 30 may be dimples formed into the sheet or insulating buttons cemented to the sheet or spacer blocks or sticks attached to the sheet 14. After the sheet 14, with the condenser elements attached, has been laid out and the sheet 14 has been cut to size, a spacing element 31, such as a blanket of fiberglass or nitrile rubber is placed on the sheet 14. Then the sheet 14 is rolled into a spiral form as indicated in FIG. 4. The sheet 14 is held in this form by means of a cylinder 33 and placed in an annealing oven which is maintained at approximately 150°C for approximately 15 minutes to relieve locked in stresses set up in the spiral member 14 by rolling it into spiral form. The spiral member is then removed from the annealing oven and the cylinder 33 and spacer blanket 31 are removed. After the spacer blanket 31 has been removed, the polycarbonate spiral member 14 is illustrated in cross section in FIG. 5. As seen from FIG. 5, the spacer elements 30 maintain the layers of the polycarbonate sheet 14 in fixed spaced relationship to each other.

After the sheet 14 having the conductive condenser elements 20, 22, 24 and 26 provided thereon has been rolled into the spiral form and annealed as indicated in FIG. 5, then the polycarbonate spiral 14 is placed in a two part mold which is illustrated by FIGS. 7A and 7B. The two part mold 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 55 for mounting the bushing. Insert 56 is also provided around one of the holes 55 for providing a ground connection to the outer metallic element 26 of the condenser system. The outer metallic condenser element 26 is connected to the grounding element 26 by means of a conductor 58.

The assembly of the spiral polycarbonate member 14 having the metallic condenser elements formed thereon as illustrated in FIG. 3 is placed in the mold comprising the parts 40 and 42 with a central conducting stud 60 located centrally of the assembly comprising the spiral polycarbonate member 14 having the conducting condenser elements 20, 22, 24 and 26 thereon. A central clamping rod 62 extends through

the hollow cylindrical element 60 and is clamped at its lower end by means of the clamping arrangement comprising a clamp 64 and a nut 66. The polycarbonate spiral member 14 is placed in the mold around the central conductor 60. The lower end of the innermost turn of the polycarbonate spiral 14 is held in proper position by means of a special fixture 68 and a nut 70. The upper ends of the concentric turns of the polycarbonate spiral 14 are held in proper position at the upper end of the mold by means of a special slotted fixture 72. A top view of the slotted fixture 72 is shown in FIG. 6 with the turns of the polycarbonate spiral 14 fitted into the slots in the fixture. The slotted fixture 72 is attached to four arms 75 by means of a bolt 77. The slotted fixture 72 is attached to a member 76 by four bolts 78 which extend through holes in the arms 75. 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 spiral polycarbonate member 14 comprising the conductive condenser elements 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 one to four millimeters of mercury. The vacuum chamber is heated to approximately the pouring temperature of the resin system, which is usually in the range of 80° to 110°C, such as $105^\circ\text{C} \pm 5^\circ$ for the specific resin formulation used in this invention. The mold and its inserts are held in this elevated temperature for a predetermined period of time which is sufficient to insure that moisture and air have been removed from the mold and the spiral polycarbonate member 14. 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 $105^\circ \pm 5^\circ$. At this temperature, the resin mixture is fluid and will flow readily. The resin is poured into the top of the mold through the space between the arms of the special fixture 72 as shown in FIG. 6. 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 2 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 10 in FIG. 11, but without the shed 82. The shed 82 is provided by another process and then attached to the bushing 10.

The bushing 10 in FIG. 11 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 10 is cast in the upside down position from the position shown in FIG. 11. After the bushing 10 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 60 for attaching terminals thereto.

The process just described in connection with FIGS. 7A and 7B and the bushing 10 shown in FIG. 11 which was provided thereby shows a hollow cylindrical conductor 60 cast into the body portion of the bushing 10.

However, if desired, the rigid central conductor 60 may be eliminated and a polycarbonate cylinder 84 coated with a thin conducting element 90, such as the material of the conducting elements 20, 22, 24 and 26, may be provided on the cylinder 84 as indicated in FIG. 13. 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 drawthrough 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 26 furthest from the central conductor 60 may be connected to ground potential through the insert 56. The conductive element which is the nearest 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 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 20 and the central conductive element, whether the stud 60 of FIG. 11 of an element 90 of FIG. 13. This tends to reduce voltage stress and reduce corona forming at the inner face between the conductive element and the resin of the body portion of the bushing.

The resin systems used to cast the condenser bushing 10 described and claimed herein, and the process 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 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 turns of the polycarbonate spiral member of the condenser system is approximately 0.200 inches.

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 polycarbonate to chemicals and ultraviolet light. It was found that epoxy resin chemically attacks the polycarbonate and causes it to soften. This advantage of polycarbonate was used to advantage in this invention, since it was found that when the polycarbonate softened, it formed a 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 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 the polycarbonate 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 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 start of corona that could produce unacceptable radio interference.

The epoxy resin system used to cast the body portion of the bushing 10 has a much different coefficient of linear expansion than the polycarbonate material used in the polycarbonate spiral member 14; however, since the epoxy has so much more mass than the polycarbonate and since the polycarbonate amalgamates so well with the epoxy, this difference in coefficients 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 as 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 preformed spiral shaped polycarbonate member having a plurality of radially spaced turns, said turns being spaced from each other to provide a substantial space between adjacent turns where there is no contact between adjacent turns of said polycarbonate member;

a coating of electrical conductive material deposited over a predetermined portion of turns of said preformed spiral shaped polycarbonate member;

an axially extending electrical conductor disposed substantially centrally in said preformed spiral polycarbonate member and spaced from said polycarbonate member;

epoxy resin filling the space between said axially extending electrical conductor and said preformed spiral polycarbonate member and the spaces between adjacent turns of said preformed spiral shaped polycarbonate member, said epoxy resin forming a body member for said bushing;

said preformed spiral shaped polycarbonate member being bonded to said epoxy body member by chemical reaction between said preformed spiral shaped polycarbonate member and said epoxy body member.

2. The bushing assembly of claim 1; wherein, said spiral member comprises a sheet of polycarbonate having a plurality of openings therein.

3. The bushing assembly of claim 1; wherein, said spiral 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.

4. The bushing assembly of claim 1; wherein, said polycarbonate spiral member comprises an element woven from polycarbonate strands bonded together to form an open mesh.

5. The bushing assembly of claim 1; wherein, the electrically conductive material on at least one turn of

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said spiral member is continuous for a complete turn and the electrically conductive material on at least one other turn comprises a plurality of separate and distinct areas.

6. The bushing assembly of claim 1; wherein, the 5

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polycarbonate material has a different coefficient of thermal expansion than the coefficient of thermal expansion of the epoxy resin.

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