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CONTROLLED AND SHIELDED SHRINKAGE VOIDS

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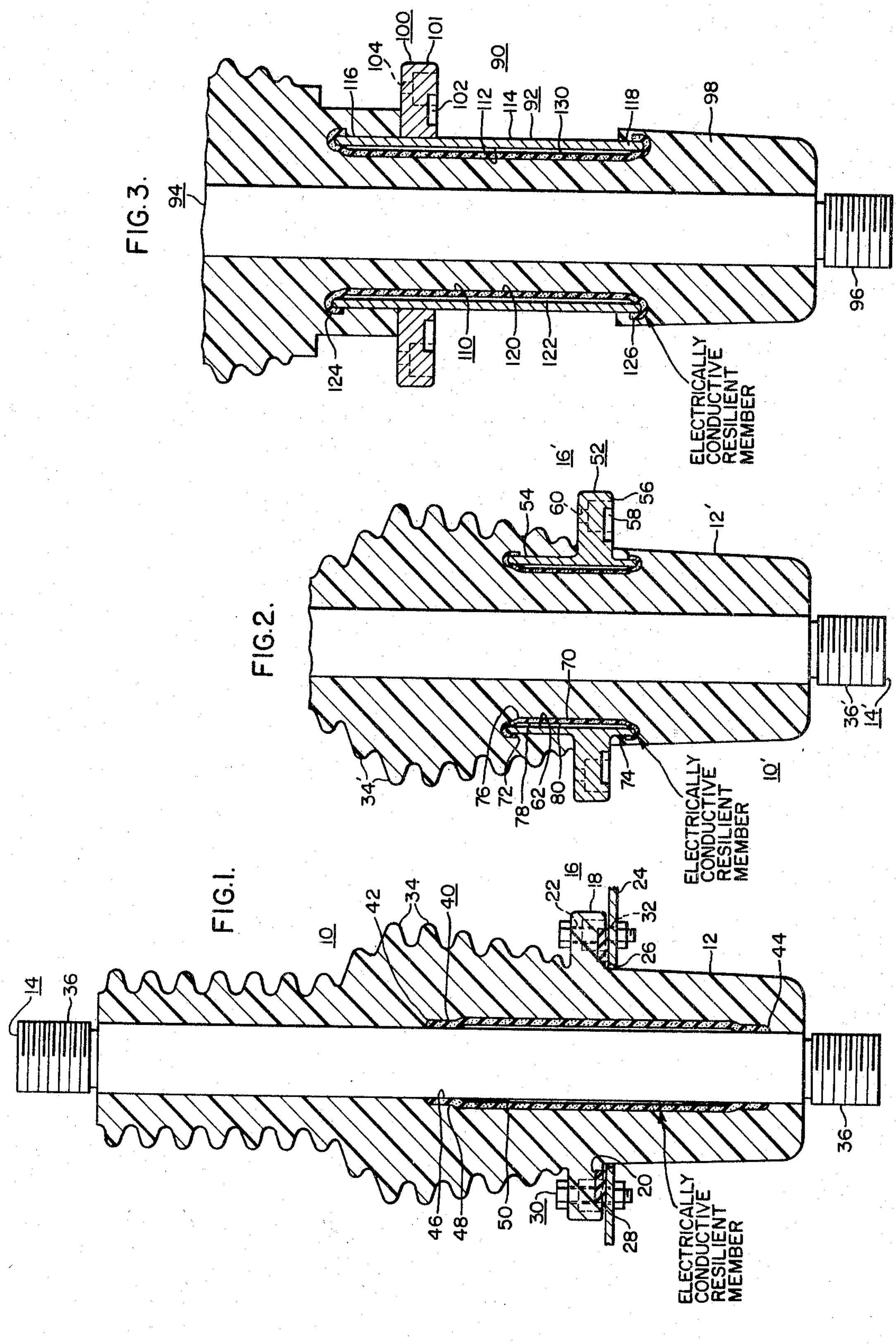

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CAST ELECTRICAL BUSHING CONSTRUCTION HAVING CONTROLLED AND SHIELDED SHRINKAGE VOIDS

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This invention relates in general to bushing assemblies for electrical apparatus, and more particularly to electrical bushing assemblies formed of a castable resinous insulating material.

High voltage electrical bushing assemblies for bringing electrical leads through the casing of the electrical apparatus have for many years been of the condenser type, utilizing layered cellulosic insulation having electrically conductive shielding members strategically disposed in spaced relation therein, in order to more uniformly distribute electrical stresses along the length of the bushing. This condenser-like structure is disposed within a weatherproof porcelain housing. The condenser type terminal bushing assembly has performed very well, but it does possess disadvantages, such as the inherent fragile nature of porcelain, the surface arc heating of the porcelain which causes cracks therein, the high cost of the porcelain, and the relatively costly manufacturing procedure required to form the condenser portion of the bushing. Thus, it would be desirable to eliminate the multiple layer condenser structure of high voltage electrical bushing assemblies, as well as eliminate the fragile porcelain weather enclosure, if this may be accomplished without sacrifices in the cost and reliability.

One approach to electrical bushing assemblies which eliminates the cellulosic layer insulation-shield construction and porcelain weather housing, is to cast the bushing from a mixture of castable resinous material and filler. This has many advantages, both from the manufacturing and cost viewpoint, as it merely requires pouring the liquid resinous mixture into a suitable mold which has preplaced therein the various metallic inserts, such as the axially disposed electrical conductor. Functionally, however, cast high voltage electrical bushings present a structure fraught with many technical problems. For example, the resinous mixture must be completely non-tracking, it must be weather resistant, it must be thermal-crack resistant, and the mixture should have a coefficient of thermal expansion which closely matches that of the metallic inserts therein, such as the axially disposed electrical conductor, the electrical shielding means incorporated therein, and any metallic insert whose purpose is to provide mounting means for cooperation with the casing or tank of the electrical apparatus the bushing assembly is to be associated with. Unfortunately, means which provide certain of the desired characteristics often deleteriously affect other equally important characteristics of the bushing. For example, the filler or fillers which are added to the resinous material, and which are selected to match the coefficient of thermal expansion of metallic inserts in the cast body portion of the bushing, may not be completely non-tracking. Further, the filler selected to provide non-tracking characteristics may provide a poor match for the thermal coëfficient of expansion of the metallic insert. Increasing the flexibility of the resin system in an effort to compensate for differences in thermal expansion does not solve these problems, as the cast body member becomes too weak at elevated temperatures, which causes splitting or cracking of the cast structure. Also, it is essential that the cast body member have sufficient strength and rigidity to support the electrical lead which

will be attached to one end of its axially disposed electrical conductor.

Accordingly, it is an object of the invention to provide a new and improved cast terminal bushing structure for electrical apparatus.

Another object of the invention is to provide a new and improved cast terminal bushing structure for electrical apparatus which is completely non-tracking, weather resistant, thermal-crack resistant, and which is not deleteriously affected by different coefficients of thermal expansion of the casting material and metallic inserts therein.

Briefly, the invention accomplishes the above-cited objects by providing a cast terminal bushing structure which does not require the coefficient of thermal expansion of the casting material to match the coefficient of expansion of metallic inserts disposed in the casting. Thus, the resinous casting material and filler may be selected for their electrical characteristics and other essential characteristics, without compromise.

Specifically, the invention teaches cast bushing structures in which cracks or shrinkage voids in the cast structure, due to different coefficients of thermal expansion of the casting material and the metallic inserts therein, are directed to a predetermined location which is rendered substantially stress-free by shielding, and which does not deleteriously affect the mechanical strength of the bushing assembly. The shielding means is in the form of an electrically conductive resilient tubular member which may have continuous walls, or formed of lapped layers of a suitable tape. The shielding means performs the functions of distributing the electrical stress along the length of the bushing and preventing concentrations of electrical stress upon any metallic inserts in the cast structure and/or upon the associated casing of the electrical apparatus the bushing is to be used with, directing any shrinkage voids in the casting to a predetermined location, and shielding this location to prevent formation of the corona in the voids.

Further objects and advantages of the invention will become apparent from the following detailed description, taken in connection with the accompanying drawings, in which:

FIGURE 1 is an elevational view, in section, of a cast electrical bushing constructed according to one embodiment of the invention,

FIG. 2 is an elevational, fragmentary view, in section, of a cast electrical bushing, illustrating another embodiment of the invention, and

FIG. 3 is an elevational, fragmentary view, in section, of a cast electrical bushing, illustrating still another embodiment of the invention.

Referring now to the drawings, and FIGURE 1 in particular, there is shown an elevational view, in section, of an electrical bushing assembly **10**. The bushing assembly **10** includes a substantially cylindrical, elongated body member or portion **12**, formed of a castable electrical insulating material, an axially disposed electrical inductor **14**, and mounting means **16**. In this embodiment of the invention, mounting means **16** includes a projecting shoulder portion **18** which is an integral portion or part of the cast body member **12**. The projecting shoulder portion **18** has an annular undercut or groove **20** disposed therein, and a plurality of openings **22**. The shoulder **18**, the groove **20**, and the openings **22** allow the bushing assembly **10** to be disposed in sealed engagement with the casing **24** of the associated electrical appartus, such as a transformer or circuit breaker. For example, as shown in FIG. 1, the bushing assembly **10** may be disposed perpendicularly through an opening **26** in the casing **24**. A suitable gasket member **28** may be disposed in the annular groove **20**, and the bushing assembly **10** may be fixed relative to the casing 24 by suitable fastening means, such as nut and bolt assemblies 30 disposed through the openings 22 in the shoulder 18 and through corresponding openings 32 disposed about the opening 26 in the casing 24, or by bolts welded to the casing 24. The openings 22 in the shoulder 18 may each include a metallic liner or sleeve (not shown), to provide additional mechanical strength, if desired.

The bushing assembly 10 may be constructed by disposing the electrical conductor 14, which may be formed of copper, aluminum, or any other good electrical conductor, in a fixed central position within a suitable mold (not shown), and by pouring a liquid resinous mixture into the mold. The resinous mixture may then be cured and the mold removed for reuse. As illustrated in FIGURE 1, surface corrugations or weather sheds 34 may be cast integrally with the body member 12, as well as the hereinbefore mentioned shoulder portion 18. The annular groove 20 and openings 22 may be formed in the mold, or they may be machined and drilled subsequent to the curing of the body member 12.

The electrical conductor 14 forms the axial conductor for the bushing assembly 10, and also the terminal stud, having suitable means at each end thereof for electrically connecting the bushing assembly 10 both internally with the associated electrical apparatus, and externally with the associated electrical system. In this instance, the means at each end of electrical conductor 14 is shown in the form of threads 36, but any suitable fastening means may be used.

Thus, the cast type bushing assembly may be relatively easily manufactured, with a substantial cost savings, compared with the prior art porcelain condenser type bushing assembly, and the cast bushing possesses much greater ability to withstand shock and sharp blows, compared with the porcelain bushing. The cast type electrical bushing, however, has certain limitations which must be overcome in order to successfully replace the porcelain condenser type bushing, especially in high voltage applications. For example, if the coefficient of thermal expansion of the resinous material of which the body member is formed, and the coefficient thermal expansion of metallic inserts which are disposed within the body member, are different, cracks or shrinkage voids between the metallic inserts and the cast resinous materials may occur upon curing of the resinous material. Cracks or voids, must be avoided, as air or other gases in a void will ionize when subjected to a potential gradient which exceeds a predetermined magnitude, causing corona which will degrade the surrounding solid electrical insulation and eventually cause the bushing to fail, as well as causing radio interference.

The coefficient of thermal expansion of the cast resinous insulating material may be closely matched to the coefficient of thermal expansion of the metallic inserts therein, such as copper or aluminum, by selecting certain particulated finely divided inorganic fillers, and loading the liquid resinous material with the filler. Unfortunately, other necessary characteristics of the bushing assembly make the fillers which will provide matching coefficients of thermal expansion unsuitable. For example, the cast resinous structure which forms the body portion of the bushing must be completely nontracking. The fillers which provide a good match of the thermal coefficients of expansion of the metallic inserts will not provide completely non-tracking characteristics, and the fillers which will provide the required non-tracking characteristics provide a poor thermal match between the cast resinous mixture and the metallic inserts disposed therein.

The disclosed invention solves this problem by making it unnecessary to have the coefficient of thermal expansion of the resinous material match the coefficient of expansion of the metallic inserts. Thus, the filler or fillers may be selected to provide the desired electrical characteristics and other physical characteristics without compromise. For example, alumina trihydrate ($Al_2O_4 \cdot 3H_2O$) may be used as a filler, which will provide a cast resinous structure having excellent non-tracking characteristics, but which provides a structure which is a poor match of the coefficient of thermal expansion of either copper or aluminum.

Specifically, the embodiment of the invention shown in FIGURE 1 achieves this result by utilizing a resilient tubular member 40, having end portions 42 and 44, and inner and outer surfaces 46 and 48, respectively. Tubular resilient member 40 should have a length and a predetermined electrical resistivity which will enable the member 40 to act as an effective electrical shield. The thickness of the tube wall is not critical. In other words, the resilient member 40 should be partially or semi-conductive. It is not necessary that it be a true semiconductor, i.e., having a voltage dependent resistivity, although it would be suitable. For example, the resilient tubular means 40 may be formed of rubber, filled with the necessary concentration of particulated carbon to provide the desired electrical resistivity. If true semiconductor characteristics are desired, the member 40 may be formed of rubber filled with particulated silicon carbide. A resilient member having an electrical resistivity in the range of 2000 to 100,000 ohms per square has been found to provide suitable results. The resilient member, in addition to being formed of a rubber sleeve, having a continuous wall section, may also be formed of wound, slightly lapped layers of electrically conductive rubber tape.

In this embodiment of the invention, the resilient member 40 has an inner diameter which is substantially the same as the outer diameter of the electrical conductor 14, with the resilient member 40 being telescoped over the electrical conductor in a close fitting manner, or wound around the conductor, if formed of tape, and disposed to provide an electrical shield between the electrical conductor 14 and the tank 24 of the associated electrical apparatus. Thus, the resilient member 40 provides a smooth rounded equipotential surface which will distribute the electrical stress more uniformly across the length of the bushing, and prevent large stress concentration on the edges of the opening 26 in the casing 24.

The resilient member 40 should have at least one of its end portions, 42 or 44, mechanically and electrically connected to the electrical conductor 14. Both end portions 42 and 44 may be connected to the electrical conductor 14, if desired. For example, as shown in FIG. 1, the resilient member 40 may have a length of its inner surface at or near its end portions 42 and 44 mechanically bonded to the electrical conductor 14. A polysulfide rubber adhesive is excellent for the bonding means between the resilient member 40 and the electrical conductor 14, as it bonds equally well to metal and rubber. By rendering the adhesive electrically conductive which is used to mechanically bond the resilient member 40 to the electrical conductor 14, by filling it with a suitable electrically conductive filler, the mechanical bond and electrical connection may be made simultaneously.

The resilient member 40 is disposed in the desired location over electrical conductor 14, and its ends mechanically connected thereto prior to the casting of the bushing assembly. Then, when the resinous casting material is introduced into the bushing mold, the resinous casting material will bond itself to the outside surface 48 of the resilient member 40. When the cast resinous material is subsequently cured, the resinous material is free to contract where it is bonded to the resilient member 40, thus creating a circumferential void 50 about the electrical conductor 14 which is completely shielded by the resilient member 40. The free movement of resilient member 40 upon curing of the resinous material, thus relieves the thermal stresses set up within the assembly due to differences in the coefficient of thermal expansion between the cast resinous material and the metallic inserts therein, and confines the void to the predetermined location between the inner surface of the resilient member **40** and the outer surface of the electrical conductor **14**. Since the resilient member **40** is circumferentially bonded to the electrical conductor **14** at one or both of its ends, and since the resilient member **40** is at substantially the same electrical potential as the electrical conductor **14**, there is substantially zero potential gradient in the void **50**, precluding ionization of any air or gas which may be in the void. Thus, the formation of a void in a predetermined desired location is facilitated, with the thermal stresses throughout the bushing assembly being relieved in this area, and the void is shielded to render it innocuous. The resinous casting material and filler may, therefore, be selected for its non-tracking characteristics, its weather resistance, and its thermal-crack resistance, without regard to the resulting coefficient of thermal expansion.

Instead of forming the resilient member **40** from tape, or using a separate one-piece resilient member **40**, and telescoping it over the electrical conductor **14**, and bonding one or both ends of the resilient member **40** to the electrical conductor **14**, similar results may be obtained by applying a circumferential coating of predetermined length of electrically conductive resilient coating means, such as rubber, to the electrical conductor **14**. A suitable mold release material, such as silicone grease, may be applied to a predetermined area of the electrical conductor **14** before being coated with the electrically conductive resilient means, in order to provide a section of the coating which does not bond to the electrical conductor, making it free to move with the subsequently added cast insulating means.

While coating the electrical conductor with electrically conductive resilient means provides a bushing structure which will initiate corona at a lower voltage level than a bushing structure which uses a sleeve type resilient member, the coated conductor type structure easily passes corona and radio interference requirements. For example, an electrical bushing assembly rated 15 kv., similar to that shown in FIGURE 1, was constructed, with the resilient means 40 being applied to the electrical conductor **14** as a circumferential coating of electrically conductive rubber. The bushing was tested for corona and radio interference, after subjecting the bushing to six thermal cycles of −20° C. to 100° C. The results of two tests formed on the bushings are as follows:

Test #1

Voltage (kv.)	Radio interference in microvolts
12.5	0
14 (inception of corona)	[1] 0–10
18	30
45	70
50	50

[1] Fluctuating.

Test #2

Voltage (kv.)	Radio interference (microvolts)
17 (inception of corona)	[1] 8–14
20	20
30	25
40	25
50	[1] 0–10

[1] Fluctuating.

It will be noted that the Radio Interference is well below the maximum allowable 200 microvolts per meter at 15 kv..

The resinous insulating material of which the body member **12** of bushing assembly **10** is formed may be any suitable thermosetting resin. Or, if the softening temperature is high enough, a thermoplastic resin system may even be used. The resinous polymeric epoxides have been found to be excellent in forming bushings of this type, possessing good physical strength, good weather resistant characteristics, relatively low shrinkage upon curing, good adherence to metallic inserts, and excellent resistance to cracking upon thermal cycling. Alumina trihydrate may be utilized as the filler, to obtain the necessary non-tracking characteristics.

A specific example of a resinous casting system which was found to be suitable is as follows:

Material	Parts by weight
Epoxy resin (190–195 epoxide equivalent)	100
Hexahydrophthalic anhydride	80
A product of equimolar mixture of triethylanolamine titanate and trihexylene glycol biborate (see U.S. Patent 2,941,981)	.5
Particulated alumina trihydrate (particle size 10 microns or less)	270
Particulated quartz (80–400 mesh)	150

The quartz in the above example was added to increase the strength of the casting. It will be understood that the above tabulation is merely an example of a suitable resin system which may be used, with the parts by weight being variable over predetermined ranges, and also other resins, curing agents, accelerators, and fillers which will provide the desired results, may be utilized.

The bushing assembly **10** shown in FIGURE 1 is illustrated with the shoulder **18** being an integral part of the cast body portion **12**. However, the same basic structure shown in FIGURE 1, except with the shoulder **16** being formed of a metallic insert embedded in the body member **12** at the time of casting, would be equally suitable.

FIG. 2 illustrates another embodiment of the invention, in which the shoulder **18** of the bushing assembly **10** is formed by a metallic insert **52** embedded into the cast body portion **12**, with like components in FIGS. 1 and 2 being indicated with like reference numerals, with the addition of prime mark in FIG. 2. As hereinbefore stated, when a metallic insert is used to form part of the mounting means, the construction of FIG. 1 wherein the resilient member **40** is disposed immediately adjacent the electrical conductor **40** may still be used. FIG. 2 illustrates another arrangement which also may be used when the flange or shoulder **18** is metallic.

More specifically, FIG. 2 illustrates a bushing assembly **10'** having a metallic insert **52**, formed of aluminum, or other suitable material, and having a generally cylindrical portion **54** which is embedded in the cast resinous material of which the body member **12'** is formed. Although the cylindrical portion **54** is shown completely embedded within the cast body portion **12**, it is only necessary that a predetermined length adjacent each of its ends be embedded within the cast body structure. The metallic insert **52** has a shoulder portion **56** which forms part of the mounting means **16'** for mounting the bushing assembly **10'** in position on the associated electrical apparatus. The shoulder portion **56** includes an annular groove **58** for receiving the gasket member **28** shown in FIG. 1, and it also includes a plurality of openings **60** for receiving fastening means, such as the nut and bolt assemblies **30** shown in FIG. 1.

The integral cylindrical portion **54** of the metallic insert **52** is formed to have a smooth cylindrical inner surface **62**, and a length sufficient to act as an electrical shield, distributing electrical stress along the bushing length, and preventing stress concentrations on the shoulder portion **56** and the associated casing of the electrical apparatus on which the bushing assembly **10'** is to be disposed. As illustrated, the inner surface **62** of the cylindrical portion **54** is disposed in spaced, concentric relation with electrical conductor **14'**.

In order to allow a castable resin system to be used for the cast body postion **12'** which does not have to closely match the coefficient of thermal expansion of metallic inserts therein, such as the mounting means insert **52**, and the electrical conductor insert **14**, a tubular resilient member **70**, similar in electrical characteristics to the resilient member **40** shown in FIG. 1 and hereinbefore described, is disposed immediately adjacent the inner surface **62** of cylindrical portion **54**. Resilient member **70** has end portions **72** and **74**, and inner and outer surfaces **76** and **78**, respectively, and is formed with its outer diameter being substantially the same as the inner diameter of the cylindrical surface **62** of cylindrical portion **54**. As illustrated in FIG. 2, the length of the resilient member **70** may exceed the length of the cylindrical portion **54**, allowing each end to overlap and fit over the ends of the cylindrical portion **54**. The end portions **72** and **74** of resilient member **70** are mechanically and electrically connected to the cylindrical portion **54**, which may be performed in the same manner hereinbefore described when discussing the mechanical and electrical connection of resilient member **40** to the electrical conductor **14** in connection with FIG. 1.

As hereinbefore described relative to the resilient member **40** in FIG. 1, instead of resilient member **70** being a separate tubular structure, it may be in the form of electrically conductive tape, or it may be applied to the desired surfaces of cylindrical portion **54** in the form of a coating, with mold release material being applied to the portion of the surface **62** where the coating should not adhere to the surface.

When forming the bushing assembly **10'** shown in FIG. 2, the electrical conductor **14'** and metallic insert **52** are disposed in fixed position within a bushing mold, and a liquid resinous insulation system is introduced into the mold to form the cast body portion **12'** to the bushing assembly. The resinous insulating material will thus be bonded to the inner diameter of the resilient means **70**, and as the resinous insulating material is cured, stresses produced by different coefficients of thermal expansion between the cast resinous insulating material and metallic inserts therein are relieved at the "weakest" point, i.e., at the resilient member **70**. The resinous insulating material, being bonded to the inner diameter of resilient member **70**, is free to pull away from the metallic insert **52**, producing a circumferential void or space **80** between the outer diameter of the resilient member **70** and the inner diameter **62** of cylindrical portion **54**. Since the resilient member **70** is electrically and mechanically connected to the metallic insert **52**, the circumferential void is completely surrounded by substantially equipotential surfaces, thus shielding the void and any air or gas therein from potential gradients which may cause ionization.

In FIG. 2, the cylindrical portion **54** is an integral portion of the metallic insert **52**, which forms the shoulder of the mounting means **16'**. The cylindrical portion **54** may also be in the form of a separate cylindrical member, disposed in spaced concentric relation with the electrical conductor **14'**. FIG. 3 is an elevational, fragmentary view, in section, of a bushing assembly **90** which illustrates an embodiment of the invention which uses a separate metallic cylindrical shielding member **92**.

More specifically, bushing assembly **90** includes a centrally disposed metallic insert **94**, which forms the electrical conductor of the bushing assembly **90**, and which includes means, such as threads **96** for connecting the electrical conductor **94** with the electrical apparatus and with the associated electrical system, a body portion **98** formed of a cast resinous electrical insulating system, as hereinbefore described relative to body portion **12** of bushing assembly **10** shown in FIG. 1, mounting means **100**, which includes a shoulder portion **101** having an annular groove **102** for receiving gasket means, and a plurality of openings **104** for receiving fastening means, a metallic cylindrical insert **92**, and resilient means **110**.

As illustrated in FIG. 3, mounting means **100** may be a metallic insert, formed of aluminum, or other suitable metal, or it may be an integral portion of the cast body member **90**, similar to the mounting means **16** shown in FIG. 1.

The metallic cylindrical insert **92**, which may be formed of copper, aluminum, or other suitable electrical conductor, has inner and outer surfaces **112** and **114**, respectively, and end portions **116** and **118**. The metallic cylindrical insert **92** is disposed in spaced, concentric relation with the electrical conductor **94**, and it has a length sufficient to shield the casing of the associated electrical apparatus, and the mounting means **100**, if the latter is metallic. As shown in FIG. 3, only a predetermined length of the end portions **116** and **118** is embedded within the cast insulating material of which the body portion **98** is formed, but it may be completely embedded therein if desired. If the mounting means **100** is metallic, the outer surface **114** of the metallic cylindrical insert **92** may be disposed immediately adjacent to and contacting the surface of the inner diameter of the mounting means **100**, if desired.

The metallic cylindrical insert **92** forms an electrical shield, which more uniformly distributes electrical potential along the length of the bushing assembly **90**, and provides a smooth rounded equipotential surface which prevents electrical stress from concentrating on the associated casing, and also from concentrating on sharp edges of the mounting means **100**, if the mounting means **100** is metallic.

In order to eliminate the necessity of providing cast resin insulating material for the body portion **98** which closely matches the coefficient of thermal expansion of the metallic inserts, such as the electrical conductor **94**, the metallic cylindrical member **92**, and the mounting means **100**, and thus allow the use of completely non-tracking filler for the resin system, a cylindrical resilient member **110**, similar to the resilient member **40** shown in FIG. 1, is utilized. Cylindrical member **110**, which has a predetermined electrical resistivity, has inner and outer surfaces **120** and **122**, respectively, and end portions **124** and **126**. The diameter of the outer surface **122** of resilient member **110** is substantially the same as the diameter of the inner surface **112** of metallic cylindrical member **92**. The length of the resilient member **110** may be slightly longer than the length of the metallic cylindrical member **92**, such that the end portions **124** and **126** of resilient member **110** may be folded over the ends of the metallic cylindrical member **92**. The end portions **124** and **126** of resilient member **110** are mechanically and electrically connected to the metallic cylindrical member **92**, as hereinbefore described relative to resilient members **40** and **70** in FIGS. 1 and 2, respectively. Also, as pointed out relative to FIGS. 1 and 2, the resilient member **110** may be applied in this embodiment of the invention, in the form of a coating, with mold release material being used to prevent bonding of the outer surface of the resilient member to the inner surface of the tubular metallic member, where bonding is not desired, or it may be applied in tape form.

When forming bushing assembly **90**, the electrical conductor **94**, metallic cylindrical member **92**, with resilient means **110** disposed adjacent its inner diameter and having its ends mechanically and electrically connected thereto, and mounting means **100**, if metallic, are all disposed in a predetermined fixed concentric relation in a suitable mold for the electrical bushing. The liquid resinous insulating material may then be introduced into the mold, with the resinous insulating material bonding itself to the metallic inserts and to the inner diameter **120** of resilient member **110**. When the resinous insulating system is cured, stresses produced by the different coefficients of thermal expansion of the metallic inserts and of the resinous insulating system, are relieved by the movement of resilient member **110** away from the inner diameter **112** of metallic cylindrical member **92**, which produces a circumferential shrinkage void **130**.

The shrinkage void **130** is completely shielded on all sides by the electrically conductive resilient member **110**, and the metallic cylindrical member **92**, as they are mechanically and electrically connected, and are thus at substantially the same electrical potential. Thus, any air in the void **130** will not be subjected to a potential gradient which is sufficient to cause ionization, and the void **130**, occurring in a controlled location, does not mechanically weaken the bushing assembly **90**.

Two electrical bushing assemblies were constructed according to the teachings of FIG. 3, with resilient member **110** being omitted on one of the bushings. The body portion **98** was constructed of an epoxy resin system, with alumina trihydrate filler. The resin system thus had excellent non-tracking characteristics, but was a poor match for the thermal coefficient of expansion of the metallic inserts, which in this instance were copper for the electrical conductor **94**, and aluminum for the cylindrical member **92** and mounting means **100**. The electrical bushing assembly formed without the electrically conductive resilient member cracked upon curing, and on test intense corona started in the void at a voltage level between 2 and 3 kv. This bushing was placed on test at a voltage level of 15 kv. while being subjected to a controlled high humidity, with failure occurring due to corona degradation after 17 days.

The bushing formed according to the teachings of FIG. 3, including the resilient member **110**, was placed on test, with the voltage on the electrical conductor being raised to 39 kv. before corona started, which produced a reading of 2 microvolts per meter. Upon dropping the voltage, corona extinction occurred at 32 kv. This bushing was given three tests at 50 kv., with a reading of 12 microvolts per meter being recorded in the first test, and a reading of 4 microvolts per meter being recorded in the final two tests. This bushing was then given an extensive outdoor test at 28.8 kv. without failure or presence of corona.

In summary, there has been disclosed a new and improved cast resinous bushing assembly which allows the use of fillers for the resin system which provides the necessary electrical characteristics, without compromise. The necessity of matching the coefficient of thermal expansion of the resin system with that of the metallic inserts therein has been eliminated, by controlling the location of the cure shrinkage voids, forcing them to occur in an electrically shielded area, and an area in which the mechanical strength of the bushing assembly is unaffected.

Since numerous changes may be made in the above-described apparatus and different embodiments of the

invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sence.

We claim as our invention:

1. An electrical bushing assembly comprising
a substantially cylindrical body member having first and second ends,
said body member being formed of a castable electrical insulating material,
an axially extending electrical conductor disposed in said body member, a tubular metallic member having an inner axially continuous surface and end portions, at least the end portions of said tubular metallic member being disposed at least partially within said body member and being at least partially bonded thereto, the inner surface of said tubular metallic member being disposed in spaced coaxial relation with said axially extending electrical conductor,
and electrical shielding means comprising a tubular resilient member having first and second ends, inner and outer surfaces, and a predetermined electrical conductivity, said shielding means being disposed with its outer surface immediately adjacent the inner surface of said tubular metallic member, the inner surface of said shielding means being bonded to the castable electrical insulating material of said body member, at least one of the ends of said shielding means being mechanically and electrically connected to said tubular metallic member.

2. The electrical bushing assembly of claim **1** wherein said tubular metallic member also provides means for securing said body member in predetermined fixed relation with the casing of electrical apparatus.

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LARAMIE E. ASKIN, *Primary Examiner.*