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Ozawa et al.

[11] **3,849,590**

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[54] **GAS FILLED ELECTRICAL BUSHING WITH CONCENTRIC INTERMEDIATE ELECTRODES**

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[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan

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[52] **U.S. Cl.** .... **174/31 R,** 174/143

[51] **Int. Cl.** **H01b 17/28**

[58] **Field of Search** .... 174/28, 30, 31 R, 73 R, 174/140 R, 141 R, 141 C, 142, 143, 150

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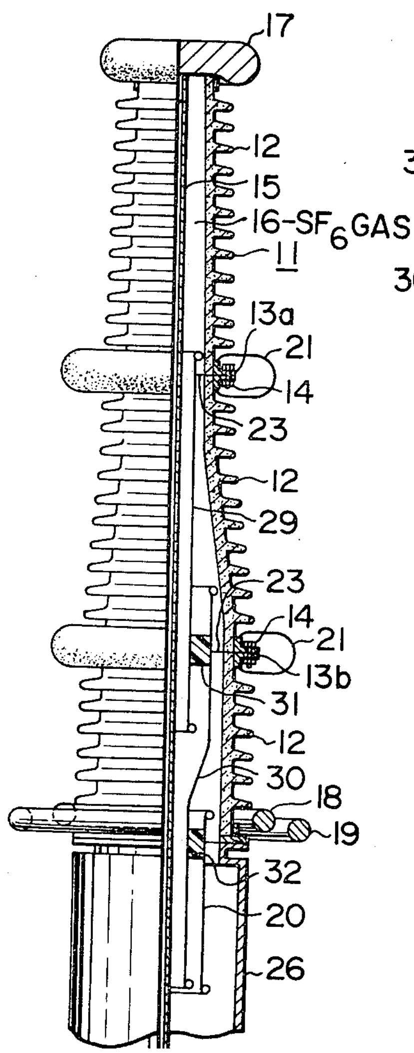
Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

A bushing is disclosed which comprises an insulator including a plurality of stacked insulator units, a plurality of splicers for hermetically connecting the insulator units to each other, SF_6 gas introduced into the insulator, a central conductor disposed at the center of the insulator to form a current path and at least a cylindrical intermediate electrode concentric with the central conductor and electrically connected to the splicers. Provision of the intermediate electrode causes divisions of the electric potential of the central conductor to be applied to the splicers, thus enabling proper control of the potential on the surface of the insulator.

13 Claims, 5 Drawing Figures



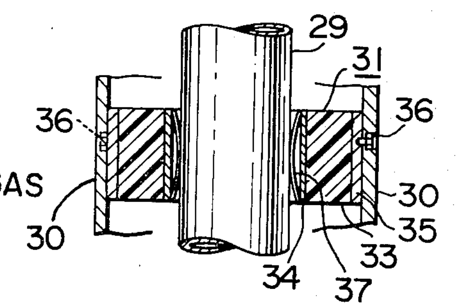
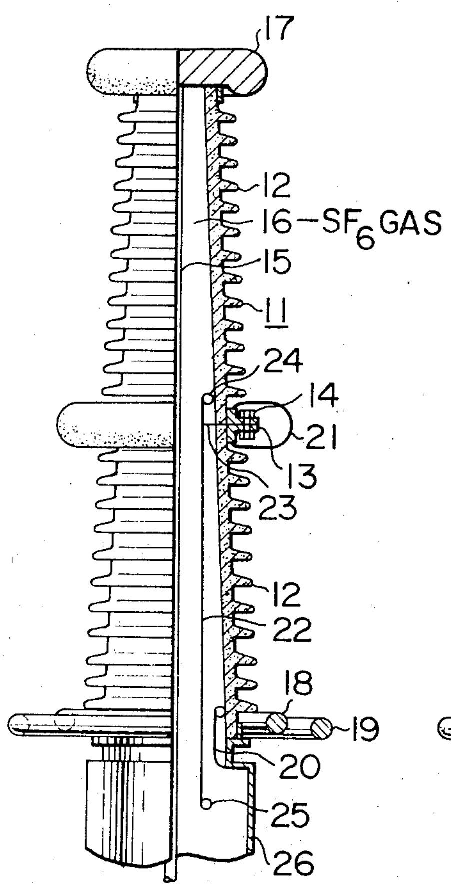


FIG. 1


17
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16—SF6 GAS
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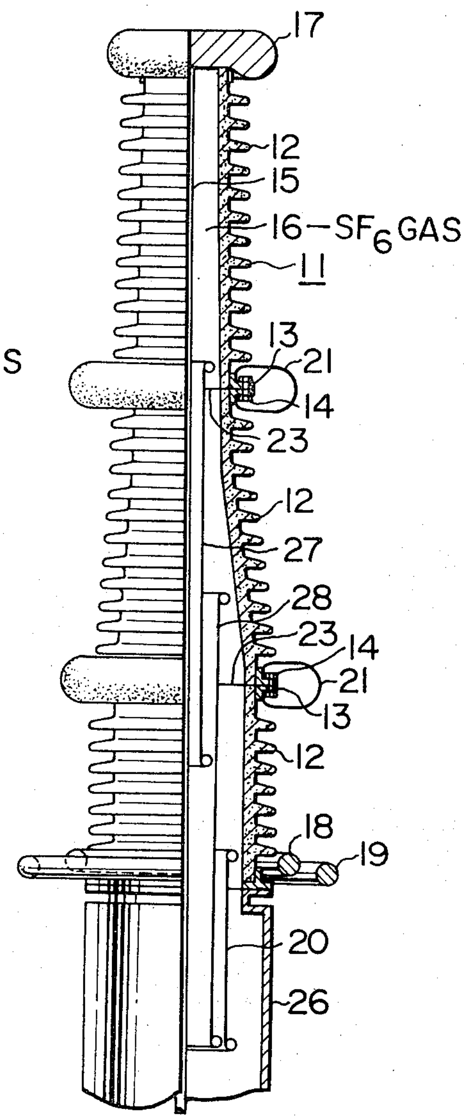
FIG. 2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16—SF6 GAS
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FIG. 3

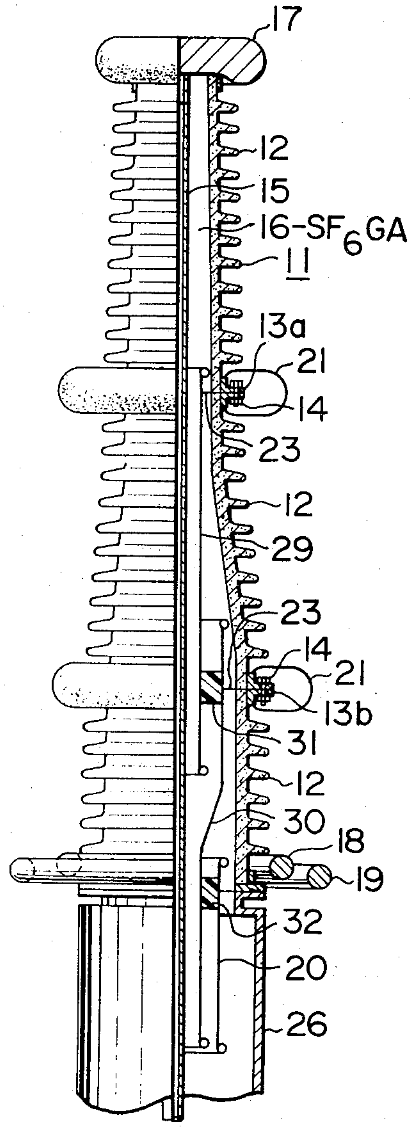


FIG. 5

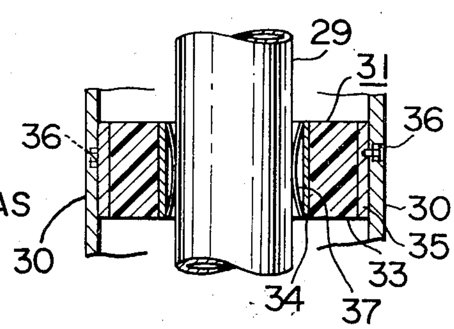
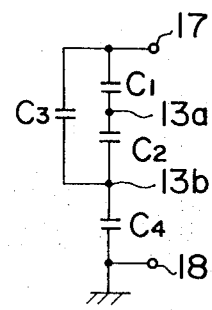


FIG. 4



GAS FILLED ELECTRICAL BUSHING WITH CONCENTRIC INTERMEDIATE ELECTRODES

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to a bushing for a superhigh voltage circuit comprising an insulator, such as porcelain, including a plurality of insulator units laid one on another.

2. DESCRIPTION OF THE PRIOR ART

The recent sharp increase in demand for electric power has promoted installations of transmission lines for large electric power, which is so high in voltage that some of them carry electric power of even **500** KV.

The transformers, circuit breakers, and current transformers used in such a superhigh voltage circuit require to be provided with a very large bushing because of the extremely high voltage.

On the other hand, in order to provide for the insulation of electric equipment of such superhigh voltage, it is common practice to use SF_6 gas or the like very high in dielectric strength. So, a gas bushing having its insulator filled with SF_6 gas is in general use, which forms a current path to the gas circuit breaker having a tank containing a breaking section which in turn contains SF_6 gas.

The conventional gas bushing is such that SF_6 gas is filled in an insulator comprising a single insulator unit having a central conductor provided therethrough. In the bushing of such a construction, electric field is concentrated in the lower portion of the insulator. In spite of the fact that a shield ring is attached to the outside of the insulator to maintain the electric field at the lower portion of the insulator at an appropriate level, it cannot be so maintained under the superhigh voltage unless the diameter of the insulator be sharply increased. It is also necessary to lengthen the creeping distance of the surface of the insulator, that is, to increase the length of the insulator, when such a superhigh voltage is involved. When the transmission line is required to carry the superhigh voltage of 500 KV, for instance, each insulator must be 8 m or more in length. The manufacture of a single insulator capable of accomodating such a superhigh voltage requires an extremely large manufacturing plant because of the large diameter and length of the insulator, resulting in an uneconomically high production cost.

In an attempt to overcome the above-mentioned disadvantages, a method was suggested in which a plurality of short insulator units manufactured in advance and stacked were joined together by a bonding agent to produce an insulator having the appearance of an insulator comprising a single insulator unit. From the standpoint of earthquake proofness, pressure of SF_6 gas, electromagnetic force and other mechanical strengths, however, the use of the insulator thus bonded as a bushing for superhigh voltage has its own limitation.

Another development which was made in an effort to obviate the disadvantages is an insulator comprising a plurality of short stacked insulator units joined hermetically by means of splicers. This insulator, however, has the shortcoming of an increased capacitance between the splicers and the central conductor and distribution of electric field inferior to that of an insulator comprising a single insulator unit, thus posing the problem of an insufficient insulating capacity.

SUMMARY OF THE INVENTION

It is accordingly an object of the invention to provide a low-cost bushing having a superior insulating capacity.

Another object of the invention is to provide a bushing having proper distribution of electric potential over the surface of the insulator.

Still another object of the invention is to provide a bushing of which the diameter of the base of the insulator is capable of being reduced.

A further object of the invention is to provide a bushing having means for successfully supporting the intermediate electrode provided for the purpose of maintaining proper distribution of electric potential over the surface of the insulator.

The bushing according to the present invention comprising an insulator including a plurality of stacked insulator units, a plurality of splicers for hermetically connecting the insulator units to each other, SF_6 gas introduced into the insulator, a central conductor disposed at the center of the insulator to form a current path and a cylindrical intermediate electrode concentric with the central conductor and electrically connected to the splicers, is characterized in that the provision of the intermediate electrodes causes divisions of the electric potential of the central conductor to be applied to the splicers, thus maintaining proper distribution of electric potential over the surface of the insulator for an improved insulating capacity of the insulator.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a partial sectional view of an embodiment of the invention.

FIG. **2** is a partial sectional view of another embodiment of the invention.

FIG. **3** is a partial sectional view of still another embodiment of the invention.

FIG. **4** is a diagram showing an equivalent circuit of the embodiment shown in FIG. **3.**

FIG. **5** is an enlarged sectional view of the insulating spacers shown in FIG. **3.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** showing a partial sectional view of an embodiment of the invention, reference numeral **11** shows an insulator preferably made of porcelain comprising a couple of short insulator units **12** laid one on the other. Connection between the insulator units is effected fastening with a bolt **14** a splicer **13** hermetically fixed on the outside of the insulator units **12,** so that the mechanical strength and hermetic condition of the junction point is secured by the splicer **13.** The insulator **11** contains a central conductor **15** forming a current path at the central portion of the insulator **11.** The inner space of the insulator **11** is filled with SF_6 gas **16** as an insulating medium generally under the pressure of approximately 3 kg/cm^2 to 5 kg/cm^2, the SF_6 gas thus assuring the insulation between the central conductor **15** and the inner wall of the insulator **11.** A top shield **17** provided at the top of the insulator **11** is for alleviating the electric field, while the air shields **18** and **19** are mounted on the lower portion of the insulator **11** also for alleviating the electric field, the grounded inner shield **20** being inserted in the insulator **11.**

An outer shield **21** is mounted on the outside of the splicer **13** at the junction of the insulator unit **12**, and there is in the inner space of the insulator **11** a cylindrical intermediate electrode **22** arranged concentric with the central conductor **15**. This intermediate electrode **22** is interposed between the central conductor **15** and the grounded inner shield **20** in such a manner as to be opposed partially to the central conductor **15** and grounded inner shield **20**. The intermediate electrode **22** is electrically connected to the splicer **13**, and the upper portion of the intermediate electrode **22** is supported by the metal supports **23** extending inward from the junction of the insulator units **12**, so that the intermediate electrode **22** is readily held in place between the central conductor **15** and the grounded inner shield **20**. Shield rings **24** and **25** each having a diameter larger than the thickness of the intermediate electrode **22** are mounted on the ends of the intermediate electrode **22**.

In the bushing constructed as above, the intermediate electrode **22** is arranged in such a position that the electric potential of the central conductor **15** is divided electrostatically by the capacitance between the central conductor **15** and the intermediate electrode **22** and also by the capacitance present between the intermediate electrode **22** and the grounded inner shield **20** or the grounded case **26**, with the result that only approximately 40 percent of the electric potential of the central conductor **15** is applied to the splicer **13** connected through the metal supports **23** to the intermediate electrode **22**, thereby enabling appropriately controlling the distribution of electric potential over the surface of the insulator. Consequently, the electric field in the lower portion of the insulator **11** can be weakened as compared with that of the conventional device. The concentration of electric field, which nevertheless occurs on the shield ring **24** at the upper portion of the intermediate electrode **22**, on the surface of the insulator unit **12** at the upper portion of the splicer **13**, and on the outer shield **21**, is weaker than the concentration of electric field on the lower portion of the insulator which occured in the prior art device.

The alleviation of the electric field intensity of various sections of the device causes the flashover voltage on the atmospheric side and on the SF_6 gas side in the insulator **11** to be increased, so that the capacitance between the intermediate electrode **22** and the central conductor **15** as well as between the intermediate electrode **22** and the earth is increased, thereby preventing a decrease in breakdown voltage which otherwise might occur due to the soiling of the surface of the insulator **11**.

The fact that the insulator **11** comprises a plurality of stacked insulator units **12** joined with the splicer **13** permits the production of the low-cost mechanically strong insulator **11**.

Another embodiment of the invention is shown in FIG. **2**, where like numerals show like or similar component elements as in FIG. **1**.

Referring to FIG. **2**, the insulator **11** comprises a stack of three insulator units **12** the junctions of which have the splicers **13** connected to the intermediate electrodes **27** and **28** respectively arranged concentrically with the central conductor **15**. The intermediate electrodes **27** and **28**, the upper portions of which are supported on the etal supports **23** respectively, are staggered longitudinally, so that the intermediate electrodes **27** and **28** are partially opposed to each other. This arrangement makes it possible to divide the electric potential of the central conductor **15** applied to the intermediate electrodes **27** and **28**, with the result that proper potentials are applied to the splicers **13**, thus weakening the intensity of the electric field on the surface of the insulator **11**.

Still another embodiment of the invention is shown in FIG. **3**, in which like numerals denote like or equivalent component elements as in FIG. **1**. The embodiment under consideration, like the embodiment of FIG. **2**, represents an insulator **11** comprising a stack of three short insulator units. In the embodiment of FIG. **2**, the intermediate electrodes **27** and **28** arranged in the insulator **11** occupy such a space that the inside diameter of the insulator **11**, especially that of the base thereof, is increased, whereby the diameter of the insulator **11** is naturally increased, thereby giving rise to the tendency to deteriorate the breakdown voltage characteristics of the surface of the insulator **11** in the case of the soiling thereof.

To obviate this disadvantage, the embodiment of FIG. **3** is so constructed that a cylinder-shaped first intermediate electrode **29** with a substantially uniform diameter and connected to the upper splicer **13***a* is arranged coaxially with the central conductor **15**, while the second intermediate electrode **30** connected to the lower splicer **13***b* has part thereof arranged opposedly to the first intermediate electrode **29**. That part of the second intermediate electrode **30** which is lower than the bottom of the first intermediate electrode **29** is opposed to the central conductor **15** and has a smaller diameter than that part thereof which is opposed to the first intermediate electrode **29**, the part small in diameter of the second intermediate electrode **30** being also opposed to the grounded inner shield **20**.

The distribution of electric potential of the various parts of the bushing constructed as above will be explained with reference to the diagram of an equivalent circuit shown in FIG. **4**. Reference symbol C_1 shows the capacitance between the central conductor **15** and the first intermediate electrode **29**, symbol C_2 that between the first intermediate electrode **29** and the second intermediate electrode **30**, symbol C_3 that between the central conductor **15** and the second intermediate electrode **30** and symbol C_4 that between the second intermediate electrode **30** and the grounded inner shield **20**. That central conductor **15**, the first intermediate electrode **29**, the second intermediate electrode **30** and the grounded inner shield **20** are connected to and maintained at the same electrical potential as the top shield **17**, the upper splicer **13***a*, the lower splicer **13***b* and the air shields **18, 19**, respectively, and therefore, by appropriately selecting the values of capacitances C_1 to C_4, the electric potentials along the surface of each insulator unit **12** can be equalized thereby to weaken the intensity of electric field at various parts of the device.

In the device having the above-mentioned construction, it is apparent from the drawing of FIG. **3** that the diameter of the first intermediate electrode **29** and that of the small-diameter portion of the second intermediate electrode **30** are substantially the same as that of the first intermediate electrode shown in FIG. **2** and the diameter of the first intermediate electrode **29**, respectively, while the diameter of the grounded inner shield **20** is substantially the same as that of the large-diameter portion of the second intermediate electrode 30, so that the diameter of the grounded inner shield 20 can be made smaller than that of the shield 20 included in the device of FIG. 2, thereby making it possible to lessen the inside diameters of the lower portion of the middle insulator unit 12 and that of the lower insulator unit 12. Further, the proximity of the lower portion of the second intermediate electrode 30 to the central conductor 15 results in the same value of capacitance C_3 in spite of a shorter length of the second intermediate electrode 30.

In view of the fact that the first and second intermediate electrodes 29 and 30 have their upper portions supported on the metal supports 23, the considerable length of the intermediate electrodes 29 and 30 of the bushing may cause it to swing laterally in the case of an earthquake. To prevent such a trouble, cylinder-shaped insulating spacers 31 and 32 are interposed between the lower portion of the first intermediate electrode 29 and the second intermediate electrode 30 and between the lower portion of the second intermediate electrode 30 and the grounded inner shield respectively. The diagram of FIG. 5 shows the supporting section of the insulating spacer 31 interposed between the first intermediate electrode 29 and the second intermediate electrode 30. This insulating spacer 31, which comprises a cylinder-shaped injection-molded insulating member 33 and metal rings 34 and 35 fitted inside and outside of the insulating member 33 respectively, is fixed on the second intermediate electrode 30 with a fastening bolt 36. A spring 37 is arranged intermediate the first intermediate electrode 29 and the inner ring 34 to assure electrical connection therebetween. Both the inner ring 34 and the outer ring 35 are formed of metal and thereby prevent the intensity of the electric fields at the fastening bolt 36 and the spring 37 from being increased extraordinarily.

The provision of the insulating spacers 31 and 32 permits the first and second intermediate electrodes 29 and 30 to be supported at their upper and lower portions respectively, thereby eliminating the problem of the lack of resistance to the earthquake. Furthermore, in view of the fact that the dielectric constant of the insulating member 33 of the insulating spacers 31 and 32 is higher than that of the SF_6 gas 16, it is possible to shorten the first and second intermediate electrodes 29 and 30 due to the larger capacitance available in the insulating spacers, whereby the earthquake-resistance of the bushing according to the invention can be improved.

The cylinder-shaped insulating spacers used in the embodiment mentioned above may alternatively be replaced by an insulating spacer in the form of a plurality of rods arranged around the central conductor. The insulating spacers may also be arranged either between the central conductor and the intermediate electrodes or longitudinally along the intermediate electrodes.

It is needless to say that although the abovedescribed embodiments involve two or three stacked insulator units, the invention can also be applied with equal effect to a bushing with four or more insulator units laid one on another.

We claim:

1. A gas filled-bushing comprising an insulator including at least three stacked insulator units, at least two splicer means hermetically joining each of said insulator units, insulating gas inserted in an inner space of said insulator, a control conductor means disposed at the center of said insulator for providing a current path, and at least a pair of cylinder-shaped intermediate electrodes arranged concentrically with said central conductor and electrically connected to said splicer means, said intermediate electrodes having at least a portion thereof opposed to each other, at least one intermediate electrode other than the electrode disposed nearest to said central conductor means including a portion extending below the terminus of the intermediate electrode disposed nearest to said central conductor means, said last-mentioned portion of said intermediate electrode having a diameter smaller than the portion thereof opposed to said intermediate electrode disposed nearest to said central conductor means.

2. A bushing according to claim 1, in which each of said intermediate electrodes is supported on a metal support electrically connected to said splicer means.

3. A bushing according to claim 2, in which each said metal support is fixed on an upper portion of each of said intermediate electrodes.

4. A bushing according to claim 3, in which at least one insulating spacer means is inserted between said intermediate electrodes at the portions thereof which are opposed to each other for maintaining said intermediate electrodes in spaced relationship.

5. A bushing according to claim 4, in which said insulating spacer means comprises a cylinder-shaped insulating member, inner and outer metal rings fitted along the inside and outside peripheries of said insulating member respectively, and a spring member inserted between said inner metal ring and the inner electrode, said outer metal ring being fastened to the outside electrode with a fastening bolt from the side of said outside electrode.

6. A bushing according to claim 5 in which a cylinder-shaped grounded inner shield is provided and disposed to be opposed to said smaller diameter portion of said intermediate electrode, said grounded inner shield being supported on a metal support connected to one of said insulator units.

7. A bushing according to claim 6 wherein at least one insulating spacer means is inserted between said grounded inner shield and said smaller diameter portion of said intermediate electrode for maintaining said grounded shield and said intermediate electrode in spaced relationship.

8. A bushing according to claim 7, in which said spacer means inserted between said grounded inner shield and said smaller diameter portion of said intermediate electrode comprises a cylinder-shaped insulating member, inner and outer metal rings fitted along the inside and outside peripheries of said insulating member respectively, and a spring member inserted between said inner metal ring and said intermediate electrode, said outer metal ring being fastened to said grounded inner shield with a fastening bolt from the side of said grounded inner shield.

9. A bushing according to claim 8, in which the diameter of said grounded inner shield is substantially equal to the diameter of the portion of the intermediate electrode opposed to said intermediate electrode disposed nearest said central conductor means.

10. A bushing according to claim 1, in which at least one insulating spacer means is inserted between said intermediate electrodes at the portions thereof which

are opposed to each other for maintaining said intermediate electrodes in spaced relationship.

11. A bushing according to claim **10,** in which said insulating spacer means comprises a cylinder-shaped insulating member, inner and outer metal rings fitted along the inside and outside peripheries of said insulating member respectively, and a spring member inserted between said inner metal ring and the inner electrode, said outer metal ring being fastened to the outside electrode with a fastening bolt from the side of said outside electrode.

12. A bushing according to claim **11,** in which a cylinder-shaped grounded inner shield is provided and disposed to be opposed to said smaller diameter portion of said intermediate electrode, said grounded inner shield being supported on a metal support connected to one of said insulator units.

13. A bushing according to claim **12,** in which the diameter of said grounded shield is substantially equal to the diameter of the portion of the intermediate electrode opposed to said intermediate electrode disposed nearest said central conductor means.

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