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HIGH-VOLTAGE ELECTRICAL INSULATING BUSHING

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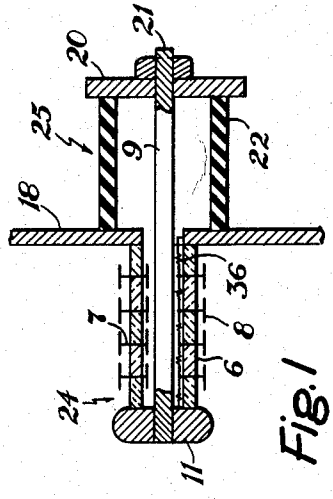



Fig. 1

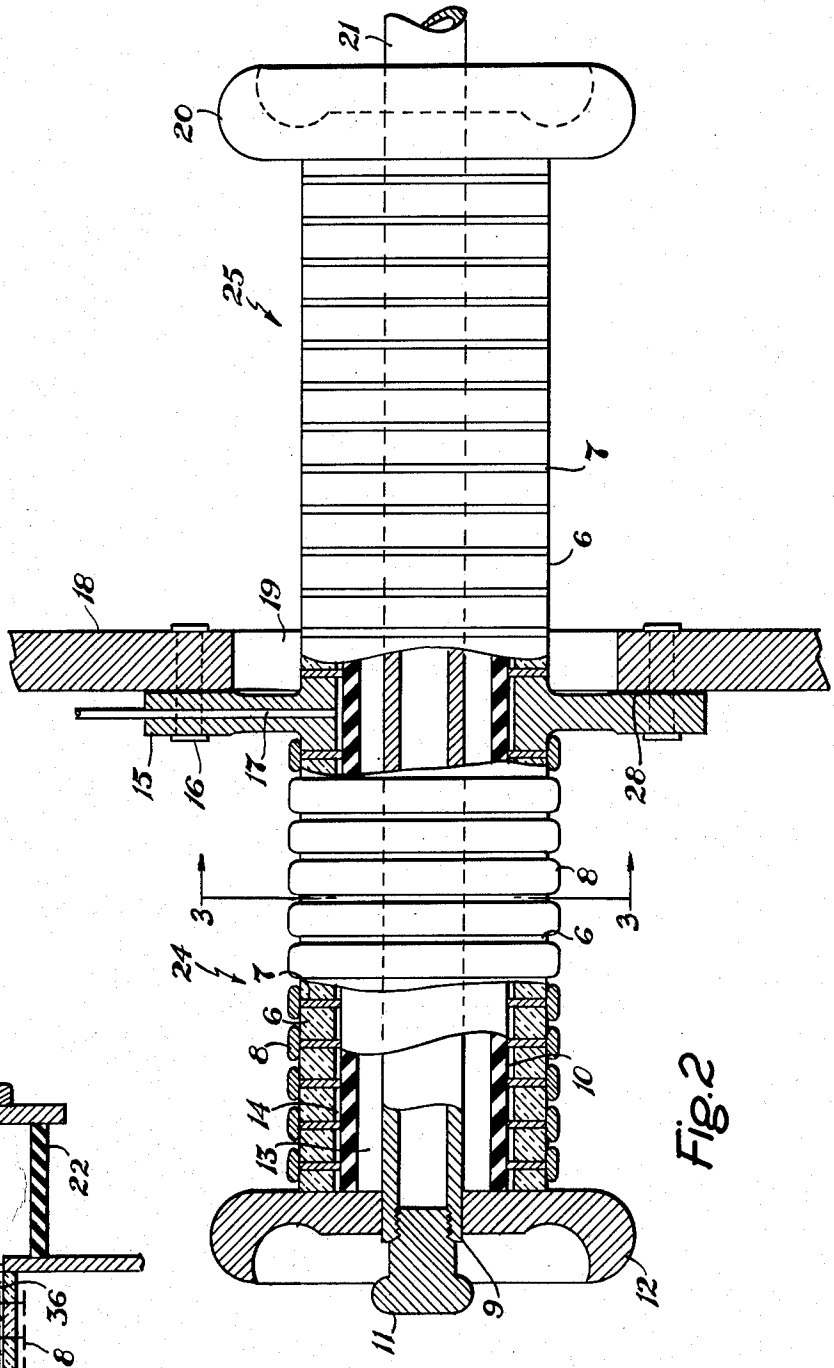



Fig. 2

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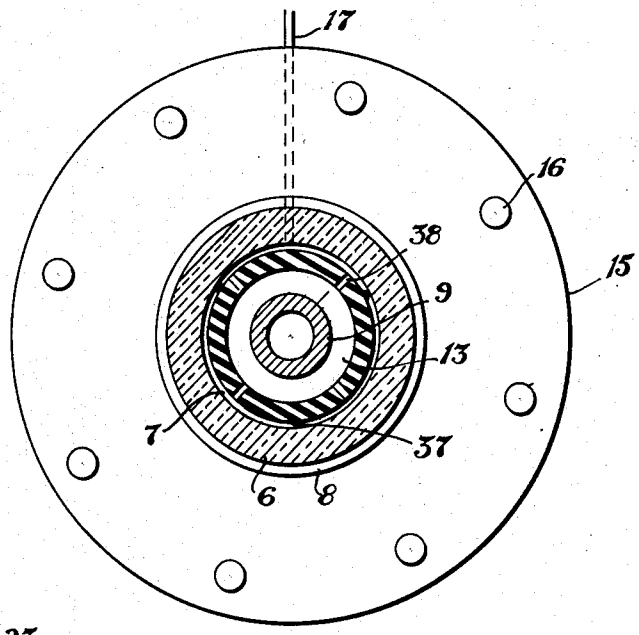



Fig. 3

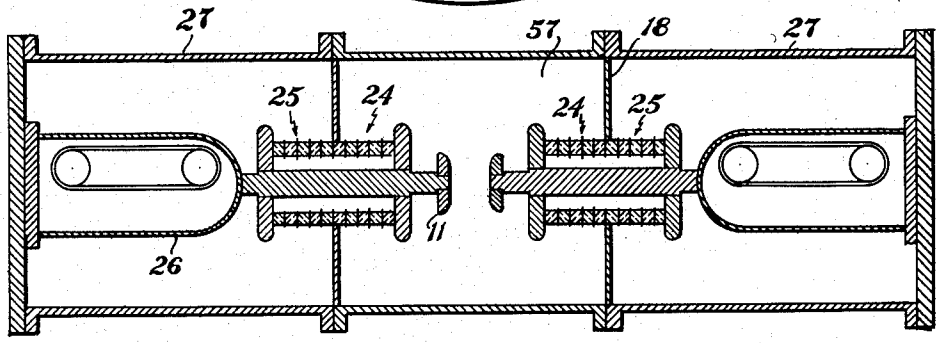



Fig. 4

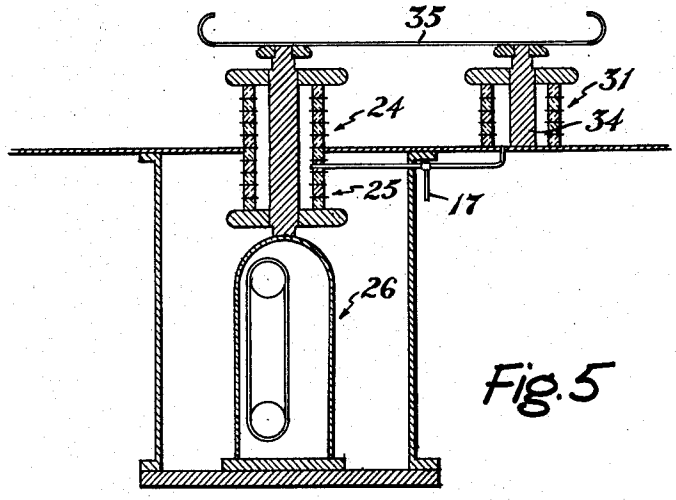



Fig. 5

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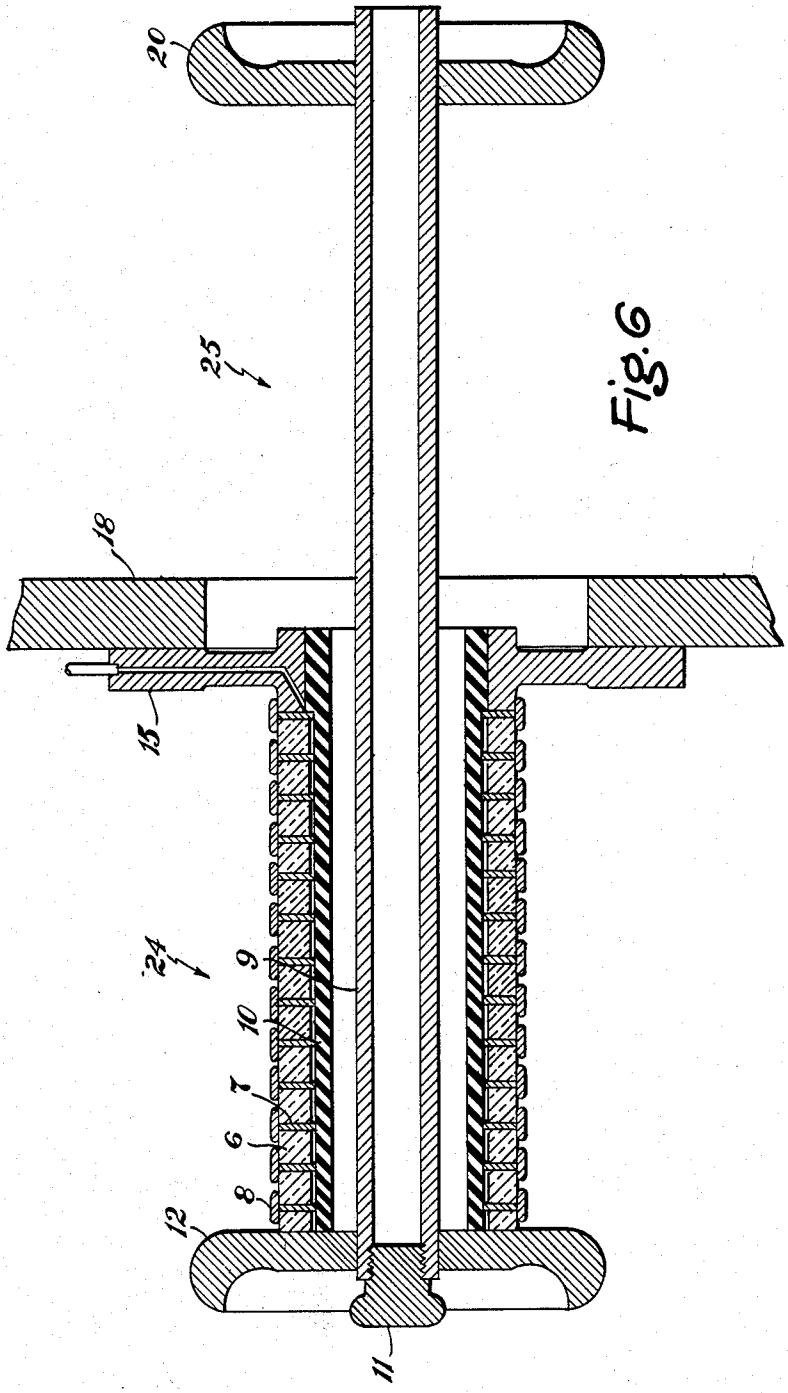
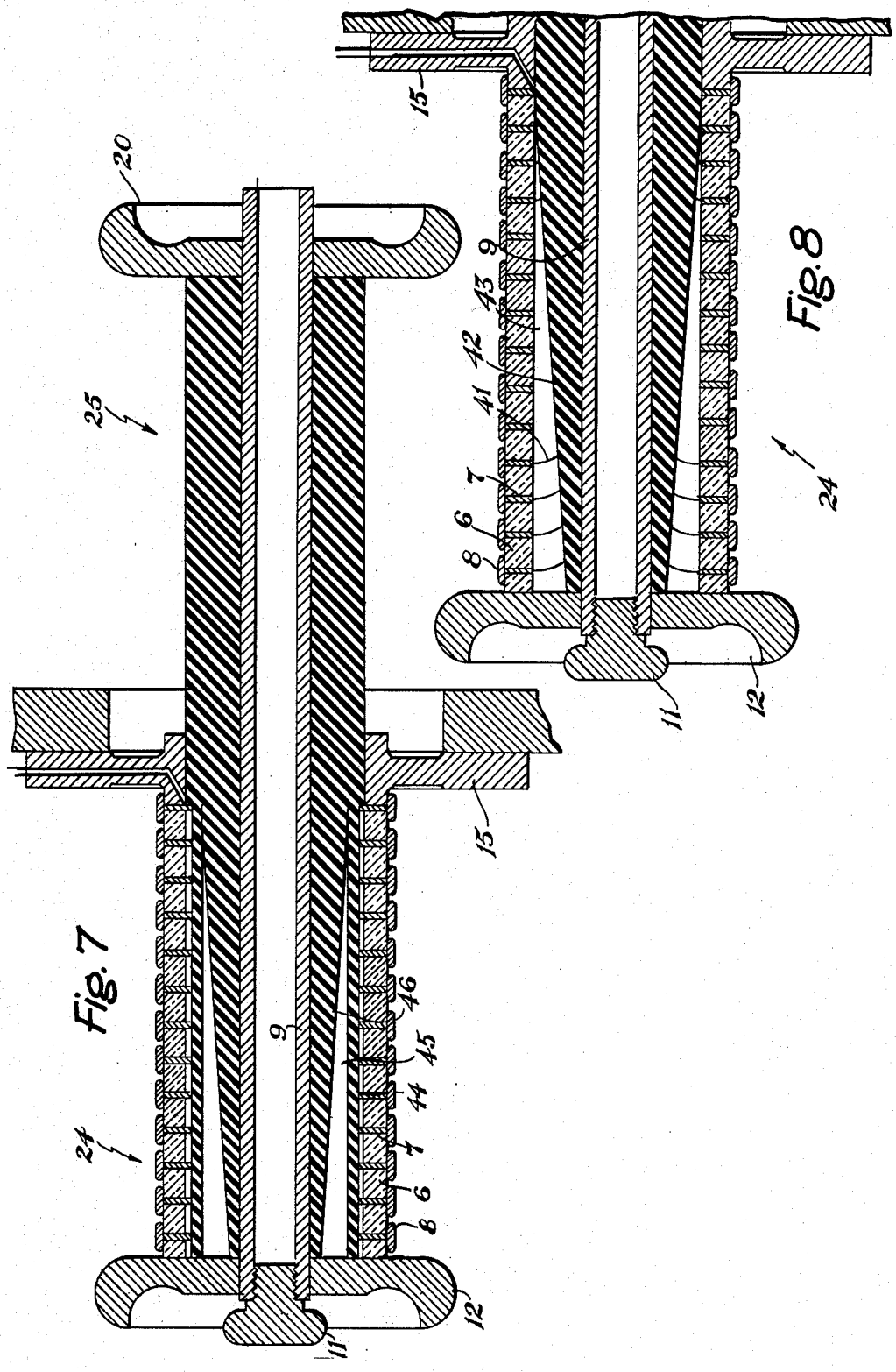



Fig. 6

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# HIGH-VOLTAGE ELECTRICAL INSULATING BUSHING

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This invention relates generally to the development of high potential differences in a high vacuum, and more particularly to a novel electrical insulating bushing adapted to bring a conducting medium through a grounded vacuum chamber wall and therein establish and maintain voltages of the order of a million volts in a vacuum of $10^{-4}$ torr and less.

The problem of establishing a very high voltage in a vacuum may be approached by either generating the voltage within the vacuum chamber or generating the voltage externally of the vacuum chamber and establishing the voltage therein through means of a conductor and an insulating bushing. For various reasons the internal voltage generation technique becomes undesirable as higher voltages and harder vacuums are required. Higher voltages mean larger voltage generating machines and larger volumes to evacuate. Furthermore, maintenance of the voltage generator within the vacuum is a problem and outgassing these large machines is difficult.

The more effective solution, when high voltages and hard vacuums are specified, is that of externally generating the desired voltage. In addition to removing the voltage generating apparatus from the vacuum chamber, such an approach provides a much more flexible system wherein heating of the member which is being maintained at a high potential within the vacuum is permitted. Other advantages are external control of the discharge energy and selective variation of the gap spacing without disturbing the vacuum. However, conventional bushings (corrugated porcelain with grading rings and centrally disposed conductor) when used in such an environment are subject to several limitations. High non-uniform longitudinal electric stress and very high radial stresses at the vacuum wall in addition to test electrode to chamber wall voltage breakdown down the length of the bushing make the bringing of very high potentials into a vacuum chamber by a conventional bushing impractical. Since the relationship of bushing size to breakdown voltage is not necessarily linear, it requires an excessively large bushing to maintain a voltage of greater than 600 kv. While bushings of this type have been developed to support voltages as great as 600 kv. they have in general required a porcelain member at least three feet long and have also resulted in some compromise in the degree of vacuum.

There currently exists, then, in the field of physics research, the need for a compact electrical insulating bushing adapted to bring very high voltages through the grounded wall of a vacuum chamber. It is desirable that such a bushing support voltages in the order of a million volts while occupying minimum possible space and that it reliably withstand the severe electrical and mechanical stresses that continuous experimental voltages subject it to.

Accordingly, it is a principal object of our invention to provide a new and improved high voltage electrical insulating bushing.

It is another object of our invention to provide an electrical insulating bushing adapted to bring very high voltages through the ground plane of a vacuum chamber housing and to establish and maintain within the vacuum chamber potential differences in the order of a million volts and greater.



Still another object of our invention is to provide an electrical insulating bushing of the class described having a unique structure adapted to break a large insulating surface into several controlled discrete surfaces in series whereby the maximum potential gradient at the surface thereof is materially reduced as compared to other constructions.

To accomplish these and other objects, we propose an electrical insulating bushing comprising a contiguous series of annular members arranged to form a cylindrical bushing having end plates adapted to position a conductive member concentrically therein. The annular members are alternately of insulating and conducting material and the members of conducting material are serially connected through resistor means whereby a uniform potential gradient is established along the bushing surface. The end plates further provide a hermetically sealed bushing interior wherein is maintained a pressurized insulating gas.

In order that all of the structural features for obtaining the objects of this invention may be readily understood, reference is made to the following detailed description taken in conjunction with the accompanying drawings in which the same reference numerals are given to like elements throughout and wherein:

FIGURE 1 is a sectional view of an electrical insulating bushing as comprehended by our invention;

FIGURE 2 is a longitudinal, partially cut away view, of one specific embodiment of our invention;

FIGURE 3 is a section through FIGURE 2 at 3—3;

FIGURE 4 illustrates test apparatus utilizing electrical insulating bushings as comprehended by our invention;

FIGURE 5 illustrates another application of our invention;

FIGURE 6 is a sectional view of an alternate embodiment of our invention;

FIGURE 7 is a sectional view of another alternate embodiment of our invention; and

FIGURE 8 is a sectional view of still another alternate embodiment of our invention.

Referring now to FIGURE 1, there are illustrated the essential elements of an electrical insulating bushing as comprehended by our invention. A high potential is applied at **21** to conductor **9** which conductor passes through vacuum chamber wall **18** and is connected directly to terminal **11**. Terminal **11** is supported within the vacuum chamber by structure **24** which comprises annular insulating members **6** and metal ring members **7**. Field shaping rings **8** are provided in juxtaposition to metal ring members **7** and serve the two-fold purpose of protecting insulating member **6** from direct charged particle bombardment and relieving the stress at the metal ring and insulating member interfaces. Resistors **36** are arranged in series relationship between metal ring members **7** and are adapted to permit a current leak therethrough sufficient to establish a uniform voltage gradient between said ring members **7**. That portion of the bushing **25** that is external to the vacuum chamber may comprise simply a cylindrical insulating member **22** and end plate **20**. Commonly said external portion **25** resides in an insulating fluid such as pressurized $N_2+CO_2$ wherein voltage breakdown is much easier to control, thereby making an extension of the uniform voltage gradient structure unnecessary. Finally, since extreme electrical stress occurs in the region where conductor **9** passes through the ground plane (that is, through vacuum chamber wall **18**) it is necessary that the interior of the bushing be hermetically sealed and filled with a pressurized insulating gas such as $SF_6$.

A more specific embodiment of our invention that has proved to be particularly effective is illustrated by FIGURES 2 and 3 and will hereinafter be described in detail

with reference thereto. A metal flange member 15 is provided to secure the subject bushing in a vacuum tight manner through aperture 19 in vacuum chamber wall 18. A plurality of bolts 16 together with vacuum seal 28 insure maintenance of the vacuum. Aluminum rings 7 and annular glass members 6 are alternately placed in contiguous relationship so as to extend coaxially on either side of flange member 15. The outer surfaces of glass members 6 and aluminum rings 7 are substantially conterminous and in combination, form cylindrical sections 24 and 25. Cylindrical section 24 has a plurality of field-shaping rings 8 thereon, said field shaping rings being coincident with and contiguous to aluminum rings 7. The inner diameters of aluminum rings 7 are slightly smaller than the inner diameters of glass members 6. A urethane tube 10 is inserted into the bushing in firm contact with aluminum rings 7. In practice this is accomplished by contracting the urethane tube (through cooling or vacuum), inserting it into the bushing, and then allowing it to expand against the protruding aluminum rings. Urethane tube 10 should have a resistivity of $10^{12}$ ohm cm. or less and is the equivalent of series resistors 36 in FIGURE 1. In the present illustrative example, the bushing described is designed to sustain voltages in the order of from 720 kv. to a million volts and the urethane tube has a resistance value adapted to pass a current of $1\mu$ amp or more. The electrical characteristics in any given instance will, of course, depend upon the parameters involved, and the resistance will be determined as that required to maintain a uniform voltage gradient between successive segments of the bushing.

The bushing formed by glass members 6 and aluminum rings 7 is terminated by terminal member 20 and by stainless steel grading ring 12. A hollow conducting member 9 is coaxially disposed within the bushing and mechanically secured by terminal member 20 and grading ring 12. Because of the relative pressures involved, there is considerable longitudinal mechanical stress on the bushing. This longitudinal stress is largely counteracted by hollow conducting member 9. The hollow center of conducting member 9 also permits the manipulation of test electrodes and the insertion of a supply of low voltage power for heater coils and the like therethrough. The member 11, which is to be maintained at high potential, is affixed to the vacuum end of conducting member 9 and an input terminal 21 is provided at the external end thereof.

An insulating gas, $SF_6$ for example, is maintained within the bushing at a pressure sufficient to prevent breakdown of the ground plane through gas supply conduit 17. A plurality of small holes 38 and notches 37 have been made in urethane tube 10 and aluminum rings 7 respectively to permit the free passage of said insulating gas to the entire interior of the bushing.

The glass members 6 of the bushing hereinabove described are approximately one inch thick and, in the novel combination disclosed, the metal rings 7 hold approximately 60 kv. between them. A bushing as disclosed then, having twelve glass members would be about twelve inches long and would support 720 kv. This compares favorably with the conventional thirty-six inch porcelain bushing which supports only 600 kv.

There is illustrated in FIGURE 4 an application of our invention whereby a potential difference of 1.5 million volts is sustained in a vacuum of $10^{-4}$ torr and less. Such an arrangement includes two high voltage sources, (1.3 mev. Van de Graaff generators 26 in the present illustration) disposed within pressure chambers 27 adjacent to vacuum chamber 57. Two bushings of the type illustrated by FIGURES 2 and 3 bring 720 kv. potentials through vacuum chamber walls 18 to electrodes 11. As indicated in FIGURE 4 a positive potential is applied to one electrode while a negative potential is applied to the other thereby establishing a potential difference therebetween of approximately a million and a half volts.

Another embodiment of our invention is illustrated by stand off insulator 31 of FIGURE 5. This type of insulator is generally applicable when it is desired to support an elongated member, such as electrode 35, within a vacuum. Although the electric stresses present when a high voltage is brought through a ground plane are not a factor with this type of device, it is still desirable to maintain an insulating fluid such as $SF_6$ within the insulator. However, since the function of the insulating fluid in this instance is merely to prevent the possibility of voltage breakdown within and down the length of the insulator, it may be maintained at a pressure of considerably less than that used when ground plane stresses are involved. The stand off insulator is also subjected to considerable longitudinal mechanical stress and a supporting member 34, of insulating material, may be used to counteract it.

Referring to FIGURES 6, 7 and 8, there are illustrated thereby various other embodiments of our invention.

FIGURE 6 illustrates, in section, an arrangement wherein the insulating gas fluid used in the voltage generating device may also be used to insulate the interior of the bushing. In such an arrangement urethane tube 10 extends only through flange 15 and there is no voltage gradient structure external to the vacuum chamber. The bushing, thus simplified, is more restricted in its application and has less mechanical strength than previously described embodiments, however.

FIGURE 7 illustrates another embodiment of our invention wherein the urethane tube has been replaced with a urethane member comprising tubular segment 44 adapted to establish the correct potential gradient, and portion 46 which portion is separated from tubular segment 44 by an insulating gas filled gap 45 and provides increased insulation and mechanical strength at the ground plane.

Still another embodiment of our invention is illustrated by FIGURE 8 wherein the urethane tube is replaced by conical urethane jacket 42. Aluminum rings 7 are connected to equipotential points along the surface of said urethane jacket by conductive members 41. As in the embodiment of FIGURE 7, gap 43 is filled with insulating gas.

It is apparent that many changes could be made in the construction of the device discussed hereinabove and that many apparently different embodiments of the invention could be made without departing from the scope thereof. Accordingly, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for establishing a very high voltage within a vacuum comprising a first high voltage terminal disposed within a vacuum chamber, a second high voltage terminal disposed externally of said vacuum chamber, an electrically conductive conduit connecting said first and second high voltage terminals, a first insulating member disposed within said vacuum chamber and adapted to position said first high voltage terminal a fixed distance from the vacuum chamber wall, said first insulating member consisting of a plurality of annular insulating elements and a plurality of electrically conducting ring shaped elements alternately arranged in contiguous relationship, said annular insulating elements and said conductive ring shaped elements being substantially conterminous and cooperating to form a cylinder that is coaxial with said conduit, a second insulating member disposed externally of said vacuum chamber and adapted to position said second terminal member a fixed distance from the vacuum chamber wall, said second insulating member being cylindrical and in coaxial relationship to said first insulating member, a flange member, a vacuum seal, said flange member and said vacuum seal cooperating to position said first and second insulating members in vacuum tight relationship to said vacuum cham-

ber wall, said first and second insulating members cooperating to hermetically enclose a volume therein, resistance means comprising a tube of insulating material having a resistivity of not more than $10^{12}$ ohm cm. disposed within said first insulating means, said resistance means being in electrical contact with said plurality of electrically conducting ring shaped elements and adapted to provide a uniform voltage gradient therealong, and means for maintaining a pressurized insulating fluid within said enclosed volume.

2. Apparatus as defined in claim 1 wherein said electrically conductive conduit consists of a tubular metal member wherethrough manipulation of said first high voltage terminal can be achieved.

3. Apparatus as defined in claim 1 wherein said resistance means comprises a urethane tube, said urethane tube being in electrical contact with each of said conductive ring shaped elements, and having a resistivity of not more than $10^{12}$ ohm cm.

4. Apparatus as defined in claim 1 wherein said annular insulating elements are fabricated of glass.

5. A high voltage standoff insulator suitable for maintaining high electrical potentials within a vacuum comprising a high voltage terminal, an insulating member adapted to position said terminal a fixed distance from a ground plane, said insulating member consisting of a plurality of annular insulating elements and a plurality of electrically conducting ring shaped elements alternately arranged in contiguous relationship and cooperating with said high voltage terminal to hermetically enclose a volume therein, means for securing said insulating member to said ground plane, resistance means comprising a tube of insulating material having a resistivity of not more than $10^{12}$ ohm cm. disposed within said insulating member, said resistance means being in electrical contact with said plurality of electrically conductive ring shaped elements and adapted to provide a uniform voltage gradient therealong, and means for maintaining a pressurized insulating fluid within said enclosed volume.

6. A high voltage standoff insulator as defined in claim 5 wherein said resistance means comprises a urethane tube.

7. A high voltage standoff insulator as defined in claim 5 wherein said annular insulating elements are fabricated of glass.

8. Apparatus for bringing a very high voltage through an aperture in a vacuum chamber wall comprising a first high voltage terminal disposed within said vacuum chamber, a second high voltage terminal disposed externally of said vacuum chamber, an electrically conductive conduit connecting said first and second high voltage terminals through said aperture, an insulating member disposed within said vacuum chamber and adapted to position said first high voltage terminal a fixed distance from said vacuum chamber wall, said insulating member consisting of a plurality of annular insulating elements and a plurality of electrically conducting ring shaped elements alternately arranged in contiguous relationship, said annular insulating elements and said conductive ring shaped elements being substantially conterminous and cooperating to form a cylinder, said cylinder being substantially coaxial with said conduit, means for positioning said insulating member in vacuum tight relationship with said vacuum chamber wall, means for establishing a uniform voltage gradient along said insulating member, said last recited means including an insulating jacket disposed on said conductive conduit in combination with means for electrically connecting successive ring shaped elements to discrete potential points therealong, said insulating jacket having a resistivity of not more than $10^{12}$ ohm cm. and a geometric configuration adapted to provide free space between itself and said insulating member, said jacket being tapered and having a conic surface, the large end thereof completely filling the space between said conduit and said insulating member and effecting a hermetically sealed closure therebetween in the vicinity of said vacuum chamber wall, and means for maintaining a pressurized insulating fluid within said free space.



9. Apparatus as defined in claim 8 wherein said insulating jacket is fabricated of urethane.

10. Apparatus as defined in claim 8 wherein said annular insulating elements are fabricated of glass.

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