Feb. 23, 1954 E. G. LINDER 2,670,462

SPONGE GLASS SEAL FOR WAVE GUIDES

Filed May 28, 1949

Fig. 1.

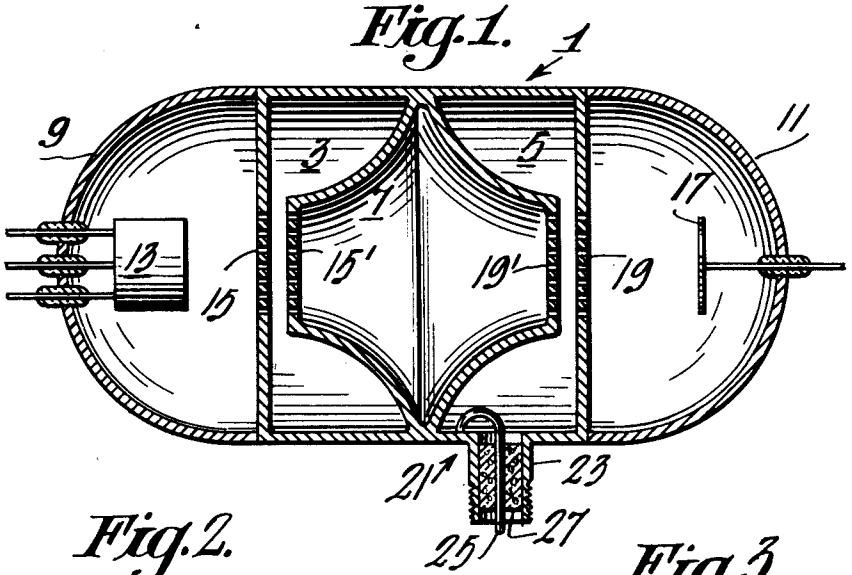


Fig. 2.

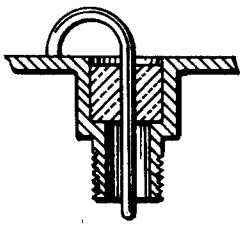


Fig. 3.

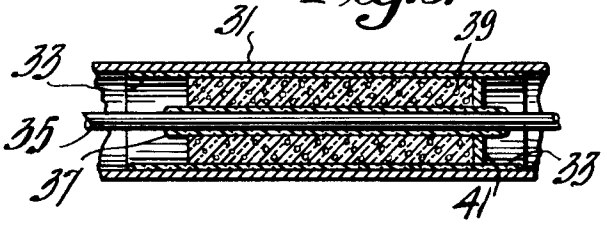


Fig. 4.

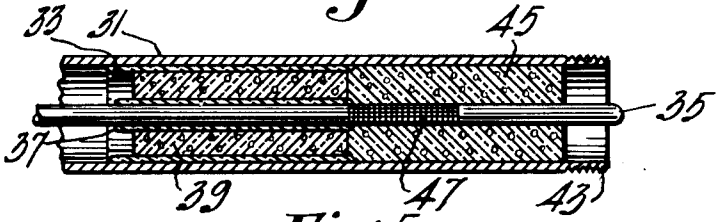


Fig. 5.

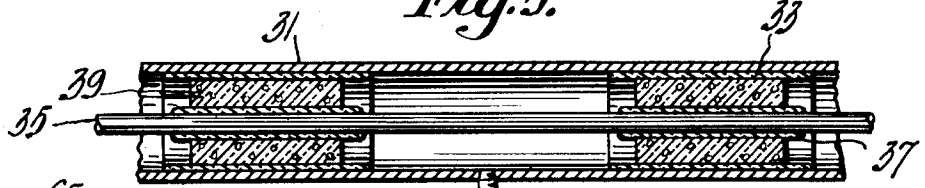
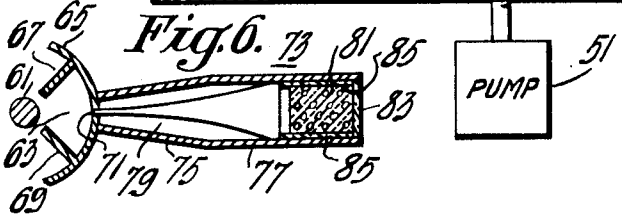


Fig. 6.



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SPONGE GLASS SEAL FOR WAVE GUIDES

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13 Claims. (Cl. 333—96)

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This invention relates to improvements in electro-magnetic permeable structures in transmission systems such as conductor-spacing bushings and gas-tight bushings for coaxial lines and R. F. windows for wave guide systems.

More particularly it relates to improvements in such bushings and windows whereby the impedance discontinuities which they produce are substantially negligible.

It is well known that there is wide usage in the electrical arts, and in particular in those involving the use of coaxial lines, wave guides, and ultra high frequency transmission systems operating in vacuo or under pressure, to employ bushings and windows made of good quality insulating material such as glass which will not cause excessive losses and which, when necessary, will be capable of being bonded to the inner and outer conductors of a coaxial line or to the walls of a wave guide or cavity resonator to form a gas-tight seal.

Sometimes where a gas-tight seal is not required, a center conductor of a coaxial system is supported on a quarter-wave-length stub which at an exact frequency will act as an excellent insulator and which, due to its being made of metal, is structurally very strong. Of course this will not be of any use where the support must also act as a gas seal. Moreover this type of center conductor support is not suitable for a system operating over a wide band of frequencies. Hence, bushings of non-conductive materials are much more commonly used. However, even this type of center conductor support (and/or inter-conductor seal) is not satisfactory when the transmission system is to be utilized for a wide band of frequencies. This is because of the fact that in the prior art a good insulator of a type suitable for forming a seal usually has had a high dielectric constant and therefore has produced a serious discontinuity in the transmission system. Though the effects of the discontinuity could be minimized by locating the bushing at a position where a voltage null will occur for a particular frequency, it could not be so located if the system were required to operate over a wide band. Obviously this is equally true of a dielectric window.

Thus, it has been quite usual for vitreous bushing-seals and windows to cause reflections in transmission systems using them. In the case of bushings various expedients have been tried to circumvent this difficulty. For example, one or both of the conductors of a coaxial fixture have been under-cut for a section thereof where

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a glass bushing was to be located so that the characteristic impedance of that section would be equal to that of other sections in which the only dielectric was air with its much lower dielectric constant.

In practice the use of under-cutting has proven very unsatisfactory. The required amount of under-cutting has usually been determined by the use of formulae which actually are correct only for long lines. In deriving these formulae, end-effects have been disregarded and the assumption made that over most of a coaxial line the electric field is radial. For a long line this is justified because of the fact that the fringing fields which exist at its ends will only affect the radial field configuration for relatively small distances back from the ends. However, a section which is under-cut to receive a bead is so short that end effects are felt over most of its length. Thus, calculations made on the basis of available formulae yield inaccurate results. Moreover, it has been found that where the amount of under-cutting is determined empirically, in order to correct for the inaccuracies of these formulae, the results obtained are correct only for a narrow frequency band, i. e., the bead causes impedance discontinuities if the system is made to operate on either side of that band. An added disadvantage is that this type of construction is expensive as it requires special machine operations in forming one or both of the conductors as well as the use of heavy materials to permit these machine operations. While this expense may be tolerated if it is incurred only for the fixtures and connectors of a system, it assumes serious proportions where this construction is used for long transmission line runs also required in the system. Moreover, this type of construction does not lend itself to use in long lines.

Sometimes the expedient is practiced of using solid dielectric over the whole length of a system to maintain the spacing between the inner and outer conductors while at the same time avoiding repeated transitions between insulators having different dielectric constants. Not only is this wasteful of material but usually it results in a far more lossy line than one which is air insulated for much of its length.

In the case of dielectric windows the expedients practiced were to include an iris built into the device employing the window (such as a magnetron) and to use very thin windows. The first of these has the disadvantage of operating satisfactorily over only a limited band and the second has the disadvantage of poor mechanical

strength. In some broad band magnetrons it has been the practice to make the windows of mica since this material is elastic and therefore, unlike thin glass, it can yield to atmospheric pressure without fracturing.

It is an object of the present invention to devise an electro-magnetic permeable structure for use in a high frequency transmission system which will have a dielectric constant of substantially 1 so that, without the use of expedients such as the under-cutting of one or more of the conductors of a coaxial line where it is a coaxial transmission system, the system will have substantially the same characteristic impedance at points where it is insulated with gas, such as air, as at the point where said structure, such as a bushing, a seal, or a window, is employed.

It is a further object of this invention to provide an electro-magnetic permeable structure of the kind set forth above which is in the form of a bushing for a coaxial transmission system and can be bonded to the metallic conductors thereof to produce a gas-tight seal.

It is a further object of the present invention to devise a transmission system which is primarily insulated by gas, such as air, but also utilizes bushing seals, of the kind to be described hereinafter, in an arrangement whereby the system may be pressurized sufficiently to raise the dielectric constant of the gas to the value, only slightly higher than 1, of said bushings, whereby the system will be substantially free of any reflective discontinuities.

It is a further object of the present invention to devise a coaxial line connector including a bushing-seal which is an electro-magnetic permeable device of the kind set forth above and which is embodied in an arrangement for protecting the seal from damage during coupling and uncoupling of the connector.

It is a further object of this invention to devise a dielectric window having good dielectric and structural strength, and a dielectric constant close to unity whereby it will not produce any appreciable impedance discontinuity in a gas insulated wave guide system over a wide band of operating frequencies.

Other objects, features and advantages of this invention will be apparent to those skilled in the art from the following description of several illustrative embodiments of the invention and from the drawing in which:

Fig. 1 represents the evacuated envelope of a known electron discharge device of the velocity-modulatd beam type to show the use of a gas-tight insulating bushing-seal according to the present invention for the output connector thereof;

Fig. 2 shows one type of prior art for the output connector of a device such as that represented in Fig. 1;

Figs. 3, 4 and 5 illustrate further embodiments of the present invention; and

Fig. 6 illustrates an embodiment of the present invention in which the electro-magnetic permeable structure is an R. F. window for a magnetron.

Fig. 1 shows a velocity modulated inductive output discharge device 1 of a kind now well known in the art. It comprises an input or buncher cavity 3 and an output cavity 5. These cavities are mechanically connected together in a known manner to enclose between them a drift-space 7 through which a beam of electrons passes from the input cavity 3 to the output cavity 5. To complete the vacuum enclosure for the discharge device 1 there are two dome-like closures 9, 11 which are respectively joined to the cavities 3 and 5 so that together these four elements 3, 5, 9, 11 enclose an evacuated space. Supported within closure 9 is a conventional gun structure 13 for producing a beam of electrons and directing it into the drift-space 7 through a pair of parallel grids 15, 15^1 of the input cavity 3. A collector electrode 17 is positioned within the closure 11 to receive the beam after it has passed out of the drift space 7 through a pair of grids 19, 19^1 of the output cavity 5. All of the structure thus far described is entirely in accordance with usual and known practice and for this reason the device 1 will not be described herein in any further detail.

An output coupling 21 includes an inductive loop 22 which is positioned within the output cavity 5 in a region of large magnitude radio frequency magnetic field. A portion of the coupling 21, which is located outside of the discharge device 1, constitutes a coaxial line connector including a cylindrical outer conductor 23, an inner conductor 25 and a bushing-seal 27. The connector shown in Fig. 1 illustrates the fact that neither conductor of a bushed element of a coaxial transmission system according to the present invention needs to be under-cut in order to attain for the element the same characteristic impedance as that of air-insulated portions of the system. This is made possible by making the bushing-seal 27 of sponge-glass formed with a small enough ratio of glass to air, not less than .01 and not greater than .1, to cause its dielectric constant to be close to unity. I have ascertained that despite the cellular structure of this material, bushings which are made of it in lengths not much greater than those of ordinary glass beads may be bonded to the conductors to form a seal capable of preserving a hard vacuum or holding considerable gas pressure.

Fig. 2 illustrates a conventional type of construction for the output connector of a device as in Fig. 1 in which a solid glass bead is employed in combination with under-cutting of the conductors.

It is possible to bond the sponge-glass bushing 27 to each of the conductors 23 and 25 by heating the conductor until the part of the bushing adjacent to it flows onto it and to do this without causing the entire bushing to collapse into a small solid mass of glass. This is possible, despite the very small volume of actual glass in the bushing, because of the fact that both the glass and the air spaces formed within its sponge-like structure have very low thermal conductivity.

However, there is described below a method of reducing any possibility of melting the entire bushing in bonding it to the conductors. This method can be best understood by reference to Fig. 3. As shown therein an outer conductor 31 of a coaxial line has a thin film 33 of low melting point glass fused to its inner surface in the region thereof where a sponge glass bushing-seal 39 is to be located. It will be understood that the term "low melting point glass" means a glass having a melting point lower than the melting point of the sponge glass bushing, whereby the film 33 can be fused without melting the sponge glass bushing.

Similarly, an inner conductor 35 of the coaxial line has a thin film 37 of the same kind of low melting point glass fused to its outer surface in the region intended for that seal. To assemble

together the bushing 39 and the two conductors 31, 35, the bushing is placed over the film 37 on the inner conductor 35 and radio frequency heating is induced in the inner conductor. This will not cause heat to be directly generated in either the bushing 39 or the film 37. However, heat induced in the inner conductor 35 will be thermally conducted to the film 37 and to adjacent portions of the glass of the bushing 39 and after a predeterminable length of time will fuse them together and to the conductor. Thereafter the inner conductor 35 and the bushing 39 are inserted into the outer conductor 31 until the bushing is surrounded by the film 33. The outer conductor 31 may be heated directly, as by a gas flame, or by induction until the film 33 flows sufficiently to bond the bushing to the outer conductor.

As is known, the amount of heat which will be absorbed by the bushing 39 during the heating of one of the conductors, 31 or 35, will depend not only upon the conductivity of the material of which the bushing is formed and of the air in its interstices but also upon the period of time over which heat is applied to, or generated in, the conductor. Accordingly, there is an added advantage to be gained in using radio frequency heating, since, as is well known, it is possible by so doing to generate intense heat in an extremely short and predeterminable time. If the heating time is short enough, considerable success may be attained by following the process described above even if the glass films 33 and 37 are formed of the same glass as the bushing rather than of low-melting-point glass. This is partly due to the fact that in practice the film will melt before the bushing is dangerously heated since it is in such intimate contact with the metal in which the heat is generated.

If it is desired to mechanically strengthen the bushing 39, for example, to strengthen one of its ends to protect it against damage from lateral thrusts which may be brought to bear against the end of the inner conductor 35 which extends out of the bushing into free space, a solid glass disc 41 may be dropped into place as shown in Fig. 3 and fused to the bushing 39 and the two conductors by the direct application of heat. Preferably disc 41 should be a low-melting-point glass. Even if the disc 41 is made thin enough so that it will not produce any noticeable discontinuity in the line it will have considerable structural strength due to its being backed up by the bushing 39 in the manner shown herein.

Fig. 4 shows an alternate construction for mechanically strengthening the termination of a coaxial line employing a bushing according to the present invention. In Fig. 4 the sponge-glass bushing 39 is positioned a little distance back from the end 43 of the coaxial line. For this short distance another bushing 45 is used which, while it also has a sponge-like structure (to cause it to have a low-dielectric constant), is different from bushing 39 in that it is made of a more resilient material. Such a material is sponge polystyrene or "styrol." If the bushing 45 is sufficiently long it will ordinarily absorb enough of the energy from any accidental lateral thrusts on the terminal end of the inner conductor 35 to prevent damage to any of the air cells located near the center of the sponge glass bushing 39. However, if it is desired to provide further protection for the bushing 39 a short section 47 of flexible inner conductor may be inserted between the portion of inner conductor 35 which is sealed within the bushing 39 and the portion thereof which is carried within the bushing 45 and extends from it at the end 43. This section 47 may be composed of a bundle of thin wires enclosed in a braided sheath such as the type of sheath used for shielding. The sheath should have the same external diameter as the inner conductor 35.

Fig. 5 illustrates a section of a coaxial transmission line system employing sponge glass gastight bushing-seals according to the present invention and a means such as a pump 51 for pressurizing the gas, such as air, which insulates the remainder of the system. It is known that it is advantageous to pressurize a transmission system to increase the dielectric strength of the gas insulation thereof and that sometimes an incidental advantage arises in that the air is dried as it is pressurized thus avoiding greatly lowered dielectric strength in damp weather. In addition to all of these advantages there is another which is offered by the embodiment shown in Fig. 5 as a result of the fact that the dielectric constant of the bushing-seals 39 is so close to unity. This is that it is possible to obtain the same characteristic impedance at all points and for all elements of the transmission system since the pressurizing will be adequate to raise the dielectric constant of the gas insulation by the small amount by which it is exceeded at normal pressure by that of the sponge dielectric. By proper selection of the insulating gas it is possible either to control what variations in dielectric constant are brought about by variations in pressure or to eliminate the need for pressurizing. For example, as is known, ammonia gas has a higher dielectric constant than air and the increases in its dielectric constant which occur with increases in pressure are greater than those which occur for corresponding increases in the pressure of air.

Fig. 6 illustrates an embodiment of the present invention as an R. F. window for the output of a plural cavity magnetron. In order to simplify the drawing and to conserve space only that portion of the magnetron is shown which is necessary to indicate the manner in which the window is installed. The cathode for the magnetron is represented at 61. As is known, the cathode of such a magnetron is surrounded by a plurality of radial resonant spaces or cavities. In Fig. 6 only one of these is shown. It is the output cavity for the magnetron and is shown at 63. Cavity 63 is formed within a portion of the curved outside wall 65 of the magnetron, the two vanes 67 and 69 and the circular end closures of the magnetron envelope (not shown). Cut through the curved outside wall of the output cavity 63 there is a narrow slot 71 for coupling energy from the magnetron to a wave guide transmission system. The slot feeds a transitional section of wave guide 73 which includes a tapered portion 75 having its small end connected to the curved wall 65 over the slot 71 and its large end connected to a rectangular portion 77 which over all of its length is of the same cross-sectional dimension as a wave guide system to be fed from the magnetron.

Within the transitional section 73 there is a pair of tapered ramps 79 which serve in a known manner as an impedance transformer. At the output end of the transitional section 73 there is a window 81 made of sponge-glass material which is so formed that the ratio of solid glass to interstitial space is small enough to result in a dielectric constant close to unity. For this reason no appreciable discontinuity will be of-

fered by the window 81 even though it is very thick. In fact, this will be true even if most of the transitional section is solidly filled with this material. If desired a thin surface film 83 of solid glass may be employed to protect the window and to improve the seal. The inside walls of the transitional section 73 carry thin films 85 of solid low-melting-point glass for bonding the window 81 to the section. The reasons for the use of this film are the same as those mentioned above in describing other embodiments of this invention.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. A high frequency transmission system including a conductive metallic structure a portion of which defines a passage positioned in the system to permit the transfer of electromagnetic energy from one part of the system to another through the structure, and an electromagnetic energy permeable sponge glass insulator located in said passage and bonded to said portion in gas-tight relation to seal said passage without preventing said transfer of energy, said insulator being formed to have a sponge-like structure in which the ratio of the volume of solid material to that of interstitial space has a value between .01 and .1 for which the insulator has a dielectric constant close to unity.

2. A high frequency evacuated conductive structure having an aperture therein and glass means permeable to electromagnetic energy sealed across said aperture in gas-tight relation, said means comprising a sponge-glass insulator in which the ratio of the volume of solid glass to that of the interstitial space has a value between .01 and .1 for which the insulator has a dielectric constant close to unity.

3. A section of coaxial transmission line comprising an outer cylindrical conductor, an inner cylindrical conductor, and an insulating bushing for supporting the inner conductor in a coaxial relationship with said outer conductor, the bushing being made of sponge glass in which the ratio of the volume of solid glass to that of interstitial space has a value between .01 and .1 for which the bushing has a dielectric constant close to unity, said sponge glass bushing being bonded to said conductors in gas-tight relation.

4. A section of coaxial transmission line comprising an outer hollow conductor, an inner conductor, an insulating bushing for supporting the inner conductor within said outer conductor, the bushing being made of glass formed to have a sponge-like structure in which the ratio of solid glass to that of interstitial space has a value between .01 and .1 for which the structure has a dielectric constant close to unity, a thin film of solid glass fused to one of the surfaces of the bushing and to a portion of the surface of one of the conductors to bond them together.

5. A coaxial transmission system comprising an outer hollow conductor, an inner conductor, an insulating bushing for supporting a portion of the inner conductor within said outer conductor near an end thereof, the bushing being made of sponge glass having a dielectric constant close to unity, a second bushing adjacent to said first-mentioned bushing and between it and said end of the outer conductor, the second bushing being made of an insulating material which has, as a solid, a dielectric constant substantially greater than one but is formed into a sponge-like structure sufficiently diffused to have a dielectric constant close to unity, the second bushing being long enough and said insulating material of which it is made being resilient enough to absorb energy from lateral thrusts exerted upon the inner conductor so as to protect the adjacent sponge-glass bushing from damage thereby.

6. A coaxial transmission system comprising an outer hollow conductor, an inner conductor, an insulating bushing for supporting the inner conductor within said outer conductor, the bushing being made of sponge glass having a dielectric constant close to unity, a second bushing adjacent to said first-mentioned bushing, the second bushing being made of an insulating material which has, as a solid, a dielectric constant substantially greater than one but is formed into a sponge-like structure sufficiently diffused to have a dielectric constant close to unity, the second bushing being long enough and said insulating material of which it is made being resilient enough to absorb energy from lateral thrusts exerted upon the inner conductor so as to protect the adjacent sponge-glass bushing from damage thereby, and said inner conductor including a flexible section which is carried within the second bushing as a portion of the inner conductor surrounded thereby and extends between the portion of the inner conductor which is surrounded by the first-mentioned bushing and the remaining portion of the inner conductor which is surrounded by the second bushing.

7. A coaxial transmission system including an outer cylindrical conductor and an inner cylindrical conductor, a first bushing for supporting the inner conductor in a coaxial relationship with the outer conductor, said bushing being composed of sponge glass in which the ratio of the volume of solid glass to that of interstitial space has a value between .01 and .1 for which the bushing has a dielectric constant close to unity and being bounded to the conductors to provide a gas-tight seal at one point in the system, a second bushing similar to the first bushing and bonded between said conductors to form a gas-tight seal at another point in the system and a non-conductive gas occupying the space between said conductors and said bushings at a predetermined pressure at which the gas has a dielectric constant substantially equal to that of said bushings.

8. A coaxial transmission system comprising an outer cylindrical conductor, an inner cylindrical conductor, and an insulating bushing for supporting the inner conductor in a coaxial relationship with said outer conductor, the bushing being made of sponge glass in which the ratio of the volume of solid glass to that of interstitial space has a value between .01 and .1 for which the insulator has a dielectric constant close to unity and being bonded to said conductors in gas-tight relation, and a disc of glass having a central opening to receive the inner conductor and an outer diameter to fit snugly within the inner conductor, said disc having one of its surfaces fused to an end of said bushing and its outer and inner

edges fused respectively to said outer and inner conductors.

9. A high frequency system comprising an evacuated conductive closure which includes a window portion providing an electrical opening to permit the transfer of electro-magnetic energy between the inside and the outside of the closure, the window portion being made of glass formed to have a sponge-like structure in which the ratio of the volume of said material to that of interstitial space has a value between .01 and .1 for which the insulator has a dielectric constant close to unity, the window being bonded around its periphery to the closure in gas-tight relation.

10. A high frequency transmission system including a hollow conductor and glass means permeable to electromagnetic energy sealing said hollow conductor in gas-tight relation, said means comprising a sponge glass insulator in which the ratio of the volume of solid glass to that of the interstitial space has a value between .01 and .1 for which the insulator has a dielectric constant close to unity.

11. A high frequency transmission system according to claim 10, wherein said sealing means includes a thin film of solid glass interposed between and fused to said hollow conductor and said insulator.

12. A section of coaxial transmission line according to claim 3, wherein said sponge glass bushing is bonded directly to said outer and inner conductors.

13. A high frequency transmission system according to claim 10, wherein said sponge glass insulator is bonded directly to said hollow conductor.

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