Nov. 29, 1966 B. VURAL 3,289,122

BOMBARDMENT-FREE MICROWAVE WAVEGUIDE WINDOW

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Fig. 1.
PRIOR ART

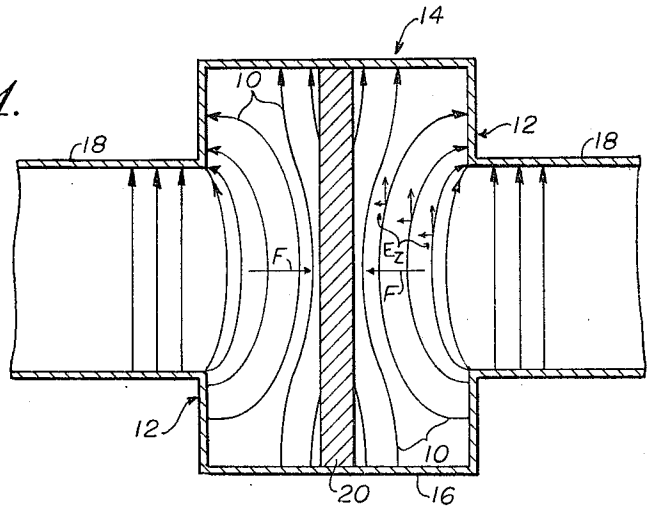


Fig. 2.

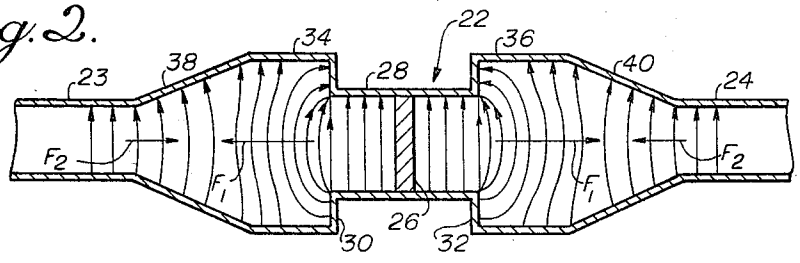
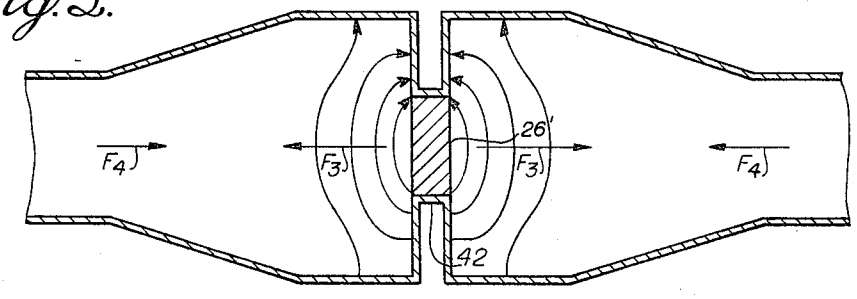


Fig. 3.



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Fig. 4.

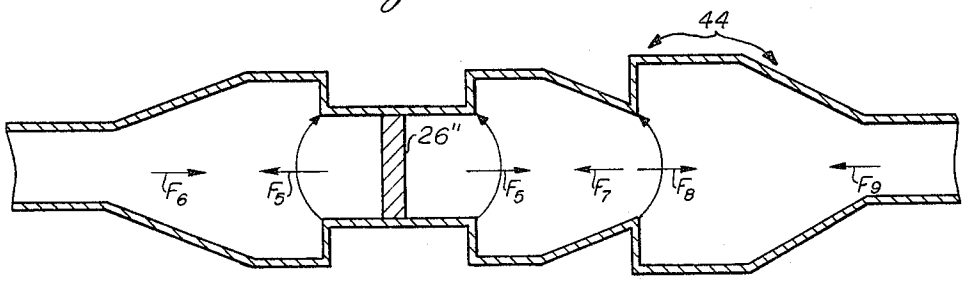
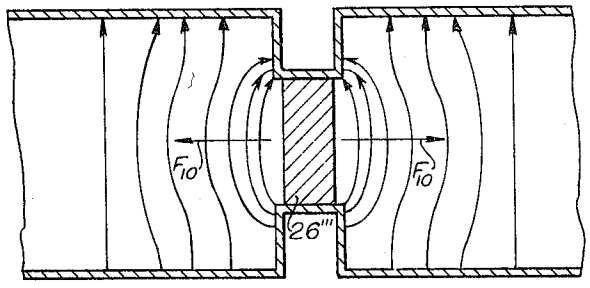


Fig. 5.



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United States Patent Office 3,289,122 Patented Nov. 29, 1966

3,289,122
BOMBARDMENT-FREE MICROWAVE WAVEGUIDE WINDOW

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Filed Mar. 18, 1963, Ser. No. 266,115
3 Claims. (Cl. 333—98)

The invention disclosed herein was made under or in the course of Contract AT(04–3)–363 with the United States Atomic Energy Commission.

The present invention is related generally to waveguide windows and, in particular, to a bombardment-free, microwave waveguide window wherein bombardment of the dielectric window disc by charged particles is reduced to an optimum by the configuration of the electromagnetic field established in the window region.

Vacuum windows present one of the major problems at present in the design of practical high-power microwave tubes and waveguide power transmission systems. In the three-centimeter wavelength region, recent developments in high-power tubes have created a need for output windows which have frequency bandwidths of about 15 percent, and which are capable of transmitting peak power in excess of 10 megawatts and average power in the neighborhood of 10 kilowatts. Such windows are used in the output waveguide of high-power tubes, such as klystrons, to permit the transmission of RF power from the evacuated output cavities of the tubes to a relatively pressurized external circuit, e.g., the accelerator pipe of a traveling-wave linear accelerator.

Most waveguide configurations which attempt to transmit high-energy RF power from one pressure region to another pressure region therein, through a pressure isolating window, have realized dielectric disc failures for various reasons. As one example, particularly manifested in linear accelerator applications, waveguide window discs tend to fail due to minute punctures or pits which seem to start on the accelerator side of the disc and work toward the tube side, especially in cases where the windows are required to transmit very high power signals. Such pitting and subsequent failure of the window discs can be attributed to bombardment of the dielectric disc surface by high energy electrons and ions with consequent charging of the disc surfaces. A related problem is the apparent occurrence of different surface conductivities which may be attributable to the different secondary and field emission characteristics which, in turn, are due to the differences created in the surface conditions of the window disc caused by the presence of pump oil vapor on one side, but not on the other side, of the window.

It is possible to prevent the occurrence of such different dielectric disc surface conductivities of above mention which occur when the disc is bombarded by ions or electrons, e.g., by increasing the surface conductivity. However, rather than attempt to solve the problems caused by bombardment of the disc, it is preferable to prevent such bombardment and, thus, the associated undesirable effects, and thereby circumvent entirely the problem of window disc failure due to particle bombardment thereof.

Therefore, it is an object of the present invention to provide a waveguide window wherein the bombardment of the dielectric window disc by electrons and ions is substantially reduced.

It is another object of the present invention to provide a waveguide window wherein bombardment of window disc by electrons and ions is substantially reduced by novel application of gradient field forces.

It is yet another object of the present invention to provide a particularly shaped waveguide window for generating gradient field forces wherein particles approaching the window will experience a net acceleration in a direction away from the window disc surfaces.

It is a further object of the present invention to provide a waveguide window having a relatively abrupt transition region near the window disc, wherein the generated electric field lines bow outwardly to create an average field force which acts in a direction away from the disc.

It is still a further object of the present invention to provide a waveguide window wherein charging of the dielectric disc surfaces is circumvented by substantially reducing the bombardment of the disc by high-energy electrons and ions.

Other objects and advantages will be apparent in the following description and claims considered together with the accompanying drawings, in which:

FIGURE 1 is a cross-sectional view of the RF field configuration in the transition region of a prior-art window having abrupt transitions from circular to rectangular waveguide,

FIGURE 2 is a cross-sectional view of an embodiment of the present invention showing the associated electric field configuration therein,

FIGURE 3 is a cross-sectional view of an alternative embodiment of the present invention and the associated electric field configuration therein,

FIGURE 4 is a cross-sectional view of yet another embodiment of the present invention indicating a portion of the associated electric field configuration,

FIGURE 5 is a cross-sectional view of still another possible embodiment of the present invention and associated electric field configuration.

FIGURE 1 shows the usual RF field configuration (depicted by arrows **10**) in the abrupt transition region **12** of a prior-art waveguide window **14** utilizing as a window disc support a length of circular waveguide **16** which is secured at either end thereof to a length of rectangular waveguide **18** of a waveguide system. As is well known in the art, there exists a mismatch in the circular guide **16**, partailly due to the presence of a dielectric window disc **20** in the configuration of FIGURE 1. Consequently, there will be places in the guide where the electric field strength may be extremely high. As seen in FIGURE 1, the electric field strength converging at the corners of the transition from circular to rectangular waveguide can be very high depending on the curvature of such corners. If the curvature is zero, the electric field intensity would theoretically be infinite at the corners. Obviously, in practice the curvature has a finite value and the field strength is thus also finite.

Thus, due to the spatially non-uniform electromagnetic field caused by the inherent non-uniformity of the TE_{11}-mode and the non-uniformity created by the sharp transition from the circular to rectangular waveguide, there exists an E_z component in the window region, which has its maximum value at the corners of the transition area as shown in FIGURE 1. In estimating the magnitude of the forces acting on the particles within the electromagnetic field in the window region, the time-average forces, F, due to the field gradients are of particular interest.

In a spatially non-uniform RF field there are time-average forces of magnitude proportional to the gradient of $|E|^2$, $(\nabla|E|^2)$, where E is the electric field strength. This force, F, acts in the direction of decreasing electric field and accelerates both positive and negative charges in the same direction. More particularly, the gradient field forces acting on electrons and ions are shown by:

$$F_e = -\tfrac{1}{4} e^2/m\omega^2 \nabla|E|^2$$

$$F_i = -\tfrac{1}{4} q^2/M\omega^2 \nabla|E|^2$$

where:

F_e is the force acting on the electrons,
F_i is the force acting on the ions,
e is the electron charge,
q is the ion charge,
m is the electron mass,
M is the ion mass,
ω is the angular frequency of the signal.

By novel application of these gradient field forces, the bombardment of the window disc by electrons and ions can be substantially reduced to a value much lower than is experienced in prior-art windows. Therefore, in accordance with the concept of the present invention, the manner of applying such gradient field forces is determined by the design of the window disc support configuration.

Referring to FIGURE 2, there is shown an embodiment which applied the gradient field forces generated therein, as set forth by the present invention. More particularly, the bombardment-free microwave window **22** is inserted where desired in a waveguide system and, in particularly, between lengths of rectangular waveguide **23** and **24**. A dielectric window disc **26** is mounted in sealed, transverse relation within a substantial length of circular waveguide **28** of proper dimensions; the waveguide **28** thus acting as a support for the disc **26**. Annular waveguide wall members **30** and **32** are preferably brazed to, and extend generally radially outward from, the circular support waveguide **28** to form an abrupt waveguide transition region at either end thereof. The wall members **30**, **32** are herein secured in perpendicular relation to window disc support waveguide **28**; however, the angle therebetween could be acute or obtuse. Short lengths of circular waveguide **34** and **36** are coaxially affixed to the outer circumference of the radially extending wall members **30** and **32**, respectively. The lengths of waveguide **34** and **36** are connected to the rectangular waveguides **23** and **24**, respectively, by tapered waveguide portions **38** and **40**, respectively. Thus, waveguide wall members **30**, **32** and integral waveguide lengths **34**, **36**, respectively, comprise means for creating an abrupt transition region near the window disc **26**. The dimensions (diameters, widths, etc.) of the components forming the waveguide window **22**, as well as the window disc material and dimensions, are determined by the desired waveguide transmission characteristics; such matter being well known in the art and needing no further explanation herein.

Therefore, in accordance with the present invention, there is provided a relatively abrupt window disc region; that is, a region which varies from a relatively small cross-section at the window disc region, to a relatively larger cross-section. From such larger cross-section, the window then is tapered gradually to substantially the same small cross-section as at the disc region. Therefore (FIGURE 2), the abrupt transistion region provides a large average field force F_1 acting away from the window disc **26**, while the tapered transistion region provides a relatively smaller average field force F_2 acting towards the window disc. That is, since it is necessary to reduce the greater cross-section region of waveguide portions **34** and **36** to the cross-sectional dimensions of the rectangular waveguide without creating time-average forces of a magnitude equal and opposite to those created by the abrupt transistion, gradually tapered sections (portions **38**, **40**) are provided between the abrupt transition regions and the rectangular waveguides.

However, it is possible to construct an embodiment wherein the angle of the taper of the tapered waveguide portions approaches zero. That is (generally in circular waveguide systems), the diameter of the system waveguides equals that of the lengths of waveguide **34** and **36**. In such case, further described below, there is no force F_2 acting in a direction toward the window disc **26**, and the optimum condition of having only a force F_1 acting awayfrom the disc is realized.

In general, particles which enter axially within rectangular waveguide **23** or **24** from a point outside the window **22** are urged toward the window disc **26** by force F_2. However, upon passing the neutral point between force F_1 and F_2 (a point where the opposing fields cancel one another and are thus equal to zero), the particles are acted upon by the relatively larger force F_1 and are forced back away from the window disc region.

Thus, it follows that particles which originate at any point along the force F_1, as shown in the FIGURE 2, or, in essence, at any point outside the corners of the abrupt transistion region, will be forced away from the window disc **26** by force F_1. However, any particles which originate inside the circular waveguide **28** will be unaffected by the force F_1 and will pass through the transverse electric field lines within the waveguide **28** to strike the window disc **26**. Therefore, in the embodiment of FIGURE 2, although particles originating outside the waveguide **28** are prevented from bombarding the window disc **26**, those particles originating inside the waveguide **28** are not necessarily prevented from so doing.

Therefore, referring to FIGURE 3, there is shown an alternative embodiment of the present invention, wherein the length of the window disc support waveguide is reduced to the length of support waveguide **42** equal to the width of the window disc **26'**. Thus, there is, in essence, no region within support waveguide **42** wherein particles originated are not affected by the force F_3. Even particles originating at the corners of the abrupt transition region are forced in a direction away from window disc **26'**, since there is no region near the window disc **26'** surfaces wherein the electric field lines exist parallel to the surfaces. That is, essentially all electric field lines bow outwardly away from the window disc surfaces, thereby creating an average field force F_3 which acts away from the disc.

FIGURE 4 depicts another embodiment of the present invention, wherein a second abrupt transisition-tapered transition configuration **44** is added to one side of the microwave window configuration of FIGURE 2. The region within the second abrupt transition-tapered transition configuration **44** generates an additional force F_8 which acts to further strengthen the effects of the gradient field forces F_5 acting away from the region of dielectric disc **26''**. It is to be understood that several such additional abrupt transition-tapered transition configurations can be added in series to either side of the disclosed embodiments; the addition of such components being determined by the desired waveguide transmission characteristics, i.e., impedance matching, desired frequencies, etc.

FIGURE 5 shows a modification of the above embodiments, wherein the angle of convergence of the tapered portion thereof approaches zero. That is, there is no tapered waveguide portion. Thus, since there is, in essence, only an abrupt transition region in this construction, it follows that there is created only an average field force F_{10} acting in a direction away from the window disc **26'''**, and all particles are forced in a direction away from the disc **26'''**.

While the invention has been disclosed with respect to several embodiments thereof, it will be apparent to those skilled in the art that numerous variations and modifications may be made within the spirit and scope of the invention. For example, the window construction, as well as the waveguide system, could be of rectangular configuration, of or circular configuration. Also, under particular internal pressure conditions, it is possible to utilize the present invention only on one side of the window disc to thus protect from bombardment only one side thereof. Further, it is to be understood that the abrupt transition of previous description does not have to be of 90° design, but could define an angle greater or smaller than 90°, e.g.,

70°, etc. Thus, it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. A waveguide window for use within a rectangular waveguide system wherein bombardment of a wave-permeable window disc by ions and electrons is substantially reduced comprising a length of circular support waveguide, said wave-permeable window disc being supported in sealed transverse relation within said length of circular support waveguide at the midpoint therein, an annular waveguide wall extending generally radially outward from the ends of said circular support waveguide, a circular wave-guide wall member coaxially secured in sealed relation to the outer circumference of said annular waveguide wall, wherein the outside diameter of said circular waveguide wall member is approximately twice the diameter of the circular support waveguide, said annular waveguide wall and circular waveguide wall member defining an abrupt transition region having an electromagnetic field configuration with a time-average force acting in a direction away from said window disc, a length of tapered waveguide secured at its large end to said circular waveguide wall member and at its small end to the rectangular waveguide of the waveguide system in sealed coaxial relation thereto, said tapered waveguides thereby inherently having an electromagnetic field configuration with a time-average force acting in a direction towards the window disc but counterposed by a force created by the abrupt transition region which is greater than that of the tapered region, resultingly causing particles approaching the waveguide window to experience a net acceleration in a direction away from the window disc.

2. A waveguide system comprising adjacent waveguide sections under differential pressures, a wave-permeable window between the adjacent waveguide sections to maintain the differential pressures, the cross-sectional area of said wave-permeable window being significantly more than the cross-sectional area of the adjacent waveguide section, a length of support waveguide, said wave-permeable window being supported in sealed transverse relation within said length of support waveguide, a waveguide wall extending transversely outward from an end of said support waveguide, a waveguide wall member secured in sealed relation to the outer periphery of said waveguide wall, said waveguide wall and waveguide wall member defining an abrupt transition region having an electromagnetic field configuration with a time-average force acting in a direction away from said window, a length of tapered waveguide secured at its large end to said waveguide wall member and at its small end to one of said adjacent waveguide sections of said waveguide system in sealed relation thereto, said tapered waveguide thereby inherently having an electromagnetic field configuration with a time-average force acting in a direction toward the window, but counterposed by a force created by the abrupt transition region which is greater than that of the tapered region, resultingly causing particles approaching said wave-permeable window to experience a net acceleration in a direction away from the window.

3. A waveguide window according to claim 2, further including a second waveguide wall extending transversely outward from the small end of said length of tapered waveguide and in sealed relation thereto, a second waveguide wall member secured in sealed relation to the outer circumference of said second waveguide wall, said second wall and second wall member defining a second abrupt transition region having an electromagnetic field configuration with a time-average force acting in a direction away from said second wall, a second length of tapered waveguide secured at its large end to said second waveguide wall member, and at its small end to one of said sections of waveguide of the waveguide system in sealed relation thereto, said second tapered waveguide resulting in an electromagnetic field having a time-average force acting in a direction toward said second wall, but counterposed by a force created by the second abrupt transition region of said second wall and second wall member which is greater than that of the tapered region of said second tapered waveguide, resultingly strengthening the acceleration of particles away from said wave-permeable window.

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