

March 19, 1957

T. D. SEGE ET AL
MICROWAVE OUTPUT WINDOW

2,786,185

Filed June 11, 1952

Fig. 1.

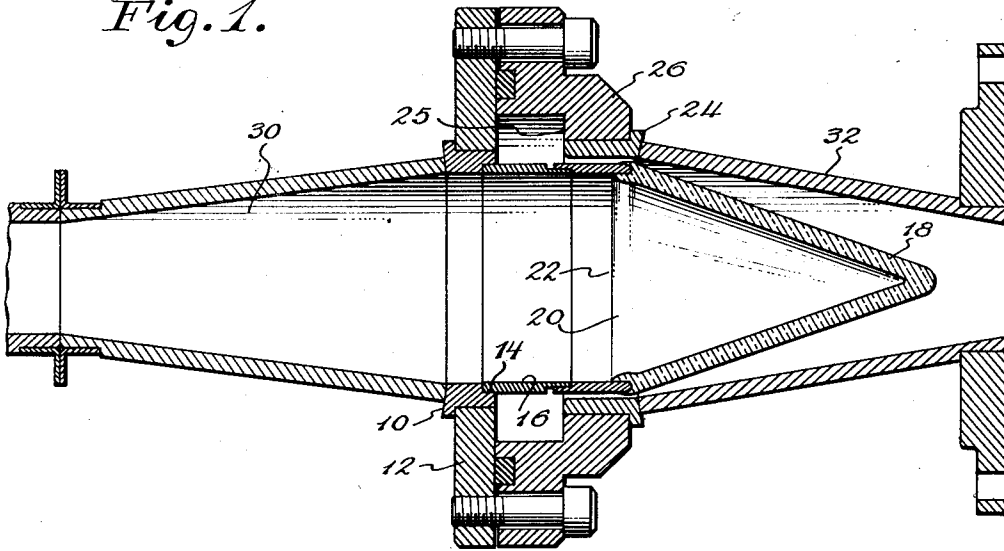
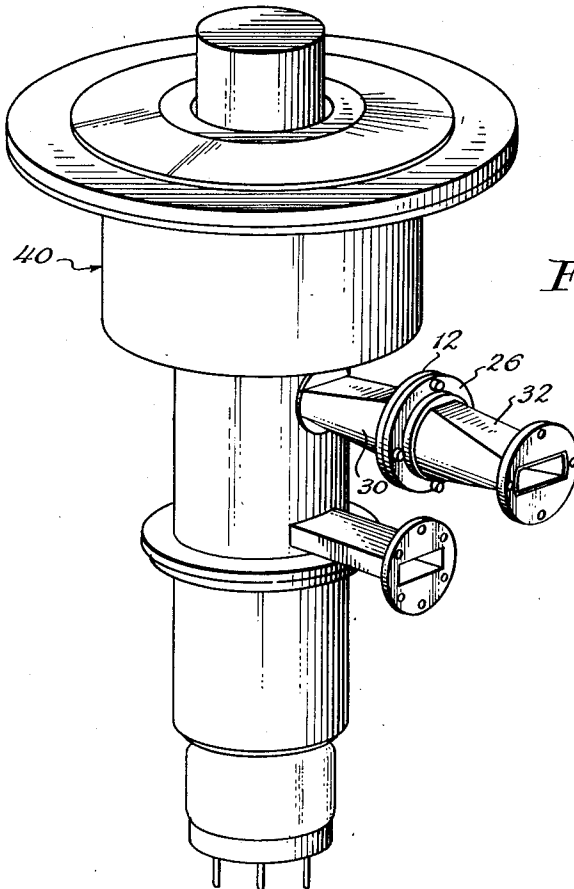


Fig. 2.

INVENTORS
WARREN D. MCBEE
THOMAS D. SEGE
BY
Paul B. Hunter
ATTORNEY

1

2,786,185

MICROWAVE OUTPUT WINDOW

Thomas D. Sege, Roslyn, and Warren D. McBee, Levittown, N. Y., assignors to Sperry Rand Corporation, a corporation of Delaware

Application June 11, 1952, Serial No. 292,896

13 Claims. (Cl. 333—98)

This invention relates to output windows for evacuated ultra high frequency electron discharge devices and the like, and, more particularly, is concerned with a vacuum or pressure sealing means which efficiently transmits ultra high frequency electromagnetic energy.

One limitation in the design of high power klystrons and magnetrons has been the need for an output window which is capable of efficiently transmitting ultra high frequency electromagnetic energy. Such a window should not appreciably affect or be affected by the transmitted energy, and yet must have sufficient mechanical strength to provide an effective permanent seal between the evacuated interior of the electron discharge device and a coupled pressurized transmission line.

Various output windows have heretofore been proposed in the prior art. One such window which has gained general acceptance because of its simplicity and strength consists of a resonant aperture in a metallic plate positioned in a wave guide, the aperture being filled with a flat sheet of dielectric, such as glass, to provide a seal. In this type of resonant window, however, the relatively short breakdown path and the storage of energy in the resonant structure limits the peak energy level at which breakdown occurs. Furthermore, concentration of the electric field in the glass and the small cooling surface of the window cause excessive heating under c-w operation.

Some improvement in the average and peak power capacities of the resonant window has been effected by making the glass portion dome-shaped to increase the discharge path length and increase the cooling area. While the resonant type window has the advantage that it gives rise to very little reflection at the resonant frequency, the resonant window is inherently frequency sensitive and is not suitable for operation over any extended frequency band. Both the flat window and the dome-shaped window introduce appreciable susceptibility causing a high VSWR unless the window is combined with an aperture to provide a resonant structure at the operating frequency.

Broad band type windows using very thin mica sheets extending across the interior of the wave guide transmission line have been used. In addition to having a limited peak power capacity, mica is difficult to seal and is mechanically weak, and so has been used only in special tubes.

It is the general object of this invention to avoid and overcome the foregoing and other difficulties of and objections to known prior art practices by the provision of an improved output window for sealing the transmission line from an electron discharge device which is practical to fabricate and rugged in construction.

Another object of this invention is the provision of an output window which has a low VSWR over a wide operating frequency band.

Another object of this invention is to provide a vacuum seal in the output transmission line of an electron dis-

2

charge device which is capable of withstanding high peak power without breaking down.

Another object of this invention is to provide a high power vacuum-sealed window for a wave guide transmission system.

Another object of this invention is to provide a high power vacuum seal for a rectangular wave guide transmission system by the employment of an output window disposed in a circular wave guide section, the circular wave guide section being disposed intermediate and coupled to said transmission system.

These and other objects of the invention which will become apparent as the description proceeds are achieved by the provision of a non-resonant window for a circular wave guide which includes a thin-walled, hollow, conical member of dielectric material, such as glass or other ceramic material. The conical member has a length substantially greater than the diameter of its base edge. Means for securing the conical member to the circular wave guide is provided which secures the conical member in sealed relationship around its base edge with the wave guide. The circular wave guide is coupled into a rectangular wave guide system by a pair of rectangular-to-circular wave guide transition sections at each end thereof.

For a better understanding of the invention, reference should be had to the accompanying drawing, wherein:

Figure 1 is a longitudinal section of a preferred embodiment of the present invention; and

Figure 2 is a perspective view of the assembly of Fig. 1 used as an output window of a wave guide output klystron tube.

In the drawing, the number 10 indicates a section of circular wave guide which has secured thereto around its outer periphery an annular flanged member 12. The section of wave guide is counterbored, as indicated at 14, to provide a shoulder against which a cylindrical sleeve 16 is seated. The sleeve 16 is brazed in position to the circular wave guide section 10 to provide a pressure seal therebetween.

The window assembly further includes a member 18 in the form of a hollow thin-walled cone of dielectric material. The conical member 18 in one form of the invention is made of a glass having a low loss factor for electromagnetic energy in the ultra high frequency range, but may be made from other suitable ceramic dielectric materials. The glass has the advantage that it is easier to work with and seal. However, other ceramic dielectric materials, such as alumina, have the advantage that they can operate at a higher temperature than glass, and thus are best suited to transmitting a larger average power.

The conical shape of the member 18 is important in achieving the low reflection, high power handling characteristics of the window. Particularly, it has been found that the cone should be at least one-half wavelength long at the operating frequency, and preferably should be even longer to obtain minimum reflection of energy from the window. In the previously mentioned flat resonant window, and also to a slightly lesser extent in the dome-shaped window, voltage breakdown occurs at relatively low peak power because the dielectric material of the window extends transversely in one plane across a substantial portion of the wave guide. However, in the conical window of the present invention, it will be appreciated that there is no one transverse plane in which the dielectric of the window provides a substantial portion of the electric field path between opposite faces of the wave guide. In the middle of the wave guide, where the electric field is maximum, the transverse electric field passes through only two thicknesses of the dielectric window material, whereas in either the dome-shaped or

flat type windows, the transverse electric field in the middle of the guide passes through the dielectric a distance substantially equal to the diameter of the window. The long taper of the present window, in addition, minimizes reflection and avoids the bandwidth limitation of the usual resonant-type output window structure.

The base edge 20 of the conical member 18 is sealed to a cylindrical mounting sleeve 22 which is made of a material having substantially the same coefficient of expansion as the material of the conical member 18. If a glass is used, the conical member 18 and mounting sleeve 22 are secured together by flowing the glass around the edge of the mounting sleeve, as shown in the drawing. If an alumina ceramic window is to be used, a shoulder is provided on the mounting sleeve 22 against which the metalized base edge of the conical member 18 abuts, and the assembly is brazed around the joint to provide a vacuum tight seal.

The assembly of the sleeve 22 and conical member 18 is then secured in position with respect to the circular wave guide section 10 by joining the cylindrical mounting sleeve 22 to the sleeve member 16 in any suitable manner, such as by providing an overlapping joint and by brazing together the overlapping portions to provide a sealed connection therebetween. This construction is employed because the glass-to-metal seal can be made in a sub-assembly operation, and is merely illustrative of the preferred method of fabricating the window.

A second transmission line section 24, having an inner diameter slightly larger than the outer diameter of the mounting sleeve 22, has secured to its outer periphery a flanged member 26 which is bolted or otherwise secured to the flanged member 12. Thus, a complete window assembly is provided including an output and input section of circular wave guide with a conical member of glass establishing a mechanical pressure seal therebetween.

As shown, the sleeves 16 and 22 combine with the circular wave guide section 24 and supporting flange 26 to provide a half-wavelength shorted section of coaxial line extending from the plane of the base edge 20. The coaxial line section thus defined has two quarters wavelength portions of different characteristic impedances, as provided by the step at 25, the higher characteristic impedance section being adjacent the shorted end. The resulting choke configuration provides an effective short circuit between the base edge 20 of the window and the circular wave guide 24. While a coaxial-type choke has been illustrated and described, other well known coupling choke configurations, such as a radial or combination radial and coaxial choke arrangement might be employed.

As illustrated in Fig. 1 of the drawing, the circular wave guide sections 10 and 24 form part of a hollow wave guide transmission line which includes transition sections 30 and 32 for coupling the window into a rectangular wave guide transmission line. The whole window assembly as above described may be utilized as an output window for a rectangular wave guide output klystron, as shown in Fig. 2. Although rectangular wave guides are used almost exclusively in high power high frequency transmitting systems, wave guides of other cross-sectional shapes are equally capable of transmitting electromagnetic waves. The dominant mode of a circular wave guide is a transverse electric mode, designated TE_{11} . The field pattern for this mode in circular wave guide is the pattern that would be obtained from the field configuration of the dominant rectangular wave guide mode, designated TE_{10} , if the rectangular wave guide section were distorted to circular form. Thus, by employing a transition section whose cross-sectional shape gradually tapers from rectangular to circular, a rectangular wave guide operating in the TE_{10} mode will launch TE_{11} waves into circular wave guide. In order to avoid reflection due to the change in wave guide type, it is necessary that both wave guides have the same characteristic impedances. This is assured if both wave guides have the same cutoff wavelength. A rec-

tangular wave guide and a circular wave guide having the same cutoff wavelengths are said to be corresponding wave guides. The dominant mode cutoff wavelength of circular wave guide is 1.71 times the diameter of the guide.

The dominant mode cutoff wavelength of rectangular wave guide is 2.0 times the broad or "a" dimension. Thus, the circular wave guide diameter is 1.17 times the broad or "a" dimension of the corresponding rectangular wave guide. In most rectangular wave guides the ratio of the wide to the narrow dimension is two or greater. Consequently, the circular wave guide diameter is greater than 2.34 times the narrow or "b" dimension of the corresponding rectangular wave guide. The total effective voltage of circular wave guide operating in the dominant mode is applied across a guide diameter, whereas the total effective voltage of rectangular wave guide operating in the dominant mode is applied across its narrow dimension. Thus, for a given transmitted power the electric field strength will be considerably less in circular wave guide than in corresponding rectangular wave guide. Conversely, circular wave guide has greater power handling capacity than corresponding rectangular wave guide. Furthermore, with its greater size the circular wave guide also has lower attenuation than the corresponding rectangular wave guide.

However, the general preference for wave transmission remains with rectangular wave guide since the rectangular cross-section definitely orients the polarization of the wave transmitted in the dominant mode. In circular wave guide, minor irregularities in the wall surface will cause the wave pattern to turn or rotate within the guide, thus rendering less effective the operation of the terminating and coupling devices. Hence, this invention enables the employment of the preferred rectangular wave guide for coupling energy from the output cavity of a source such as a klystron, indicated generally at 40, to a load, and yet permits employment of a dielectric window seal, such as conical member 18, in a corresponding circular wave guide section, where the electric field and consequent probability of breakdown are reduced. The transition section 30 is secured in sealed relation to the output rectangular wave guide of klystron 40, so that the output cavity can be evacuated. The conical window 18 points or extends toward the high pressure side of the system, so that the differential pressure across the window sets up compressive forces, which the glass or other ceramic dielectric material can readily withstand.

By way of example, and to illustrate one suitable window for use in connection with a 2" x 1" rectangular wave guide transmission line system, the following dimensions are given:

Outer diameter of the mounting sleeve—1 $\frac{3}{4}$ ".

Length of the conical member—2.4".

Wall thickness of the conical member (using DG707 glass)—0.085".

A window having the above dimensions has been found to operate over a band width of 4700 to 6400 megacycles with a VSWR of less than 1.5 over the band, with a VSWR of less than 1.1 over a 10% band being possible.

The matching characteristics of the cone are affected somewhat by length and wall thickness. Such a window as described has withstood in test a peak power of the order of 2.2 megawatts in air at atmospheric pressure, with 3 microsecond pulses at 100 pulses per second, without breakdown. As the c-w power capacity would ordinarily be limited to values at which the temperature rise is not excessive, various well known means for cooling may be employed to raise the average power handling capacity of the window.

From the above description, it will be appreciated that the objects of the invention have been achieved by the provision of a window for providing a pressure seal in a transmission line which by its particular conical shape provides not only a structurally rugged and strong window, but one that provides a minimum of reflection and is

5

capable of operating at a peak power greatly exceeding what has heretofore been achieved by any known prior art methods for sealing a wave guide. These results are achieved by tapering the window over a distance of at least one-half wavelength, with best results being obtained by tapering the cone over a distance of one wavelength or more. Actually, a length of about a wavelength has been found to provide a satisfactory balance between maximum efficiency of operation and minimum cost and complexity of construction, a shorter taper length substantially reducing performance and a longer taper length providing weaker and more costly construction.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, 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. A high power vacuum seal coupling for a wave guide transmission line comprising a first section of hollow circular wave guide, a thin cylindrical metallic sleeve secured in sealed relationship to the end of said first section of hollow circular wave guide, said sleeve being substantially a half wavelength long at the operating frequency of the transmission line, a thin-walled hollow conical member of dielectric material, the base edge of said conical member being hermetically sealed to the edge of the sleeve remote from said first section of hollow circular wave guide, the length of the conical member being substantially greater than the diameter of the base, and a second section of hollow circular wave guide of larger internal diameter than said first section, said second section being secured to said first section to provide a continuous transmission line, said second section being concentrically positioned with respect to said sleeve and conical member, the outer surface of the sleeve and the inner concentric surface of said second section of hollow circular wave guide combining to form a half wavelength coaxial line section.

2. A high power vacuum seal coupling for a wave guide transmission line comprising a first section of hollow circular wave guide, thin cylindrical metallic sleeve means secured in sealed relationship to the end of said first section of hollow circular wave guide, a thin-walled hollow conical member of dielectric material, the base edge of said conical member being hermetically sealed to the edge of the sleeve means remote from said first section of hollow circular wave guide, the length of the conical member being substantially greater than the diameter of the base, and a second section of hollow circular wave guide of larger internal diameter than said first section, said second section being secured to said first section to provide a continuous transmission line.

3. In combination, a first section of hollow circular wave guide, a second section of hollow circular wave guide of larger diameter than said first section, means joining adjacent ends of said sections to provide a continuous wave guide, hollow cylindrical means secured to the end of said first section of cylindrical wave guide and projecting into said adjacent second section of circular wave guide in concentric relation thereto, and a hollow conical dielectric member secured in sealed relationship around the base edge thereof to the circular projecting edge of said cylindrical means, the conical member having a length substantially greater than the diameter of the base thereof.

4. In combination, a first section of hollow circular wave guide, a second section of hollow circular wave guide of larger diameter than said first section, means joining adjacent ends of said sections to provide a continuous wave guide, hollow cylindrical means secured to the end of said first section of cylindrical wave guide and projecting into said adjacent second section of circular

6

wave guide in concentric relation thereto and having a circular projecting edge therein, and a hollow conical dielectric member secured in sealed relationship around the base edge thereof to the circular projecting edge of said cylindrical means, the conical member having a length substantially greater than the diameter of the base thereof.

5. In combination, a first section of hollow circular wave guide, a second section of hollow circular wave guide of larger diameter than said first section, means joining adjacent ends of said sections to provide a continuous wave guide, a hollow conical member of dielectric material having a length substantially greater than the diameter of the base thereof, and means securing said conical member in sealed relation across the end of said first section of circular wave guide, the conical member projecting into the adjacent second section of circular wave guide.

6. A non-resonant window for a circular wave guide, said window comprising a thin-walled hollow conical member of dielectric material having a length substantially greater than the diameter of the base edge thereof, and means for securing the conical member to the circular wave guide, said means providing a completely sealed connection between the base edge of the conical member and the wave guide, the inner diameter of the circular wave guide being substantially equal to the diameter of the base edge of the conical member.

7. In combination, a thermionic vacuum tube having a hollow pipe wave guide output section, and a hollow conical member of dielectric material secured in sealed relation across the output end of said wave guide output section, the tapered member extending in a direction away from the tube, said conical member providing a low loss window for permanently sealing said tube.

8. A non-resonant window for a circular wave guide, said window comprising a thin-walled hollow conical member of dielectric material having a length of at least a half-wavelength at the operating frequency of the wave guide, and means for securing the conical member to the circular wave guide, said means providing a completely sealed connection between the base edge of the conical member and the wave guide, the inner diameter of the circular wave guide being substantially equal to the diameter of the base edge of the conical member.

9. In a klystron having a rectangular wave guide output section, a non-resonant output window comprising a rectangular-to-circular wave guide transition section, the rectangular end of the transition section being secured in sealed relationship to the rectangular wave guide output section of the klystron, and a hollow conical member of dielectric material, the base edge of said member being secured in sealed relationship to the circular end of the transition section, said conical member having a length substantially greater than the diameter of the base.

10. A vacuum seal for a rectangular wave guide transmission system comprising in combination, a pair of rectangular-to-circular wave guide transition sections, a circular wave guide section, said circular wave guide section being secured in sealed relationship at one end thereof to the circular end of one of the transition sections, said circular wave guide section being connected at the other end thereof to the circular end of the other of the transition sections, and a dielectric window member extending across said circular wave guide section and secured in sealed relationship thereto.

11. A vacuum seal for a rectangular wave guide transmission system comprising a rectangular-to-circular wave guide transition section, and a hollow conical member of dielectric material, the base edge of said member being secured in sealed relationship to the circular end of the transition section.

12. A non-resonant window for a rectangular wave guide transmission system comprising in combination, a pair of rectangular-to-circular wave guide transition sec-

7

tions, a circular wave guide section, said circular wave guide section being secured in sealed relationship at one end thereof to the circular end of one of the transition sections, said circular wave guide section being connected at the other end thereof to the circular end of the other of the transition sections, and a hollow conical member of dielectric material, the base edge of said conical member being secured in sealed relationship to the inner surface of the circular wave guide section, said member having a length substantially greater than the diameter of the base.

13. In combination, a first section of hollow circular wave guide, a second section of hollow circular wave guide of larger diameter than the said first section, means joining adjacent ends of said sections, hollow cylindrical means secured to the end of said first section of circular wave guide and projecting into said second section of circular wave guide in concentric relation thereto and having a circular projecting edge therein, a hollow conical dielectric member secured in sealed relationship around the base edge thereof to the circular projected edge of said cylindrical means, and a pair of circular-to-rectangular wave guide transition sections, said first transition section being secured at the circular end thereof in sealed relation to the end of said first circular wave

8

guide section, said second transition section being connected at the circular end thereof to the end of said second circular wave guide section.

5

References Cited in the file of this patent

UNITED STATES PATENTS

1,912,794	Peterson	June 6, 1933
2,375,223	Hansen	May 8, 1945
2,454,337	Okress	Nov. 23, 1948
2,458,579	Feldman	Jan. 11, 1949
2,489,131	Hegbar	Nov. 22, 1949
2,504,494	Bull	Apr. 18, 1950
2,506,627	Barford	May 9, 1950
2,610,249	Fiske	Sept. 9, 1952
2,637,776	Edson	May 5, 1953
2,658,147	Bainbridge	Nov. 3, 1953
2,706,275	Clark	Apr. 12, 1955

FOREIGN PATENTS

20	592,401	Great Britain	Sept. 17, 1947
----	---------	---------------	----------------

OTHER REFERENCES

Practical Analysis of Ultra High Frequency, Meagher and Markley, 1943, RCA Service Publication. Copy in Div. 69 (page 5 relied on).

25