

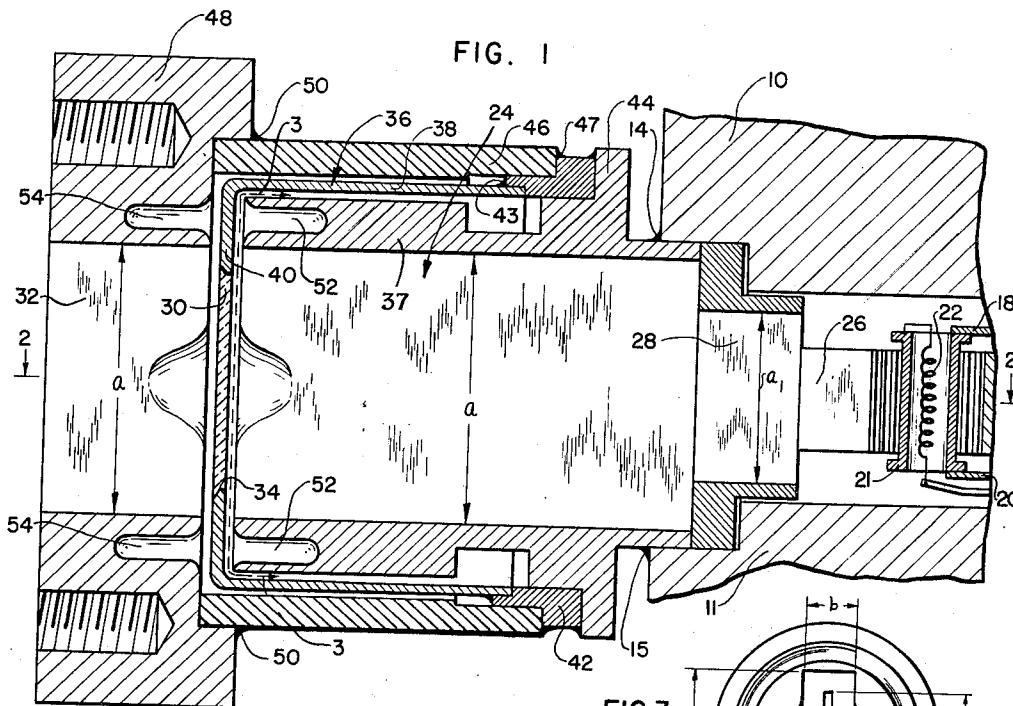
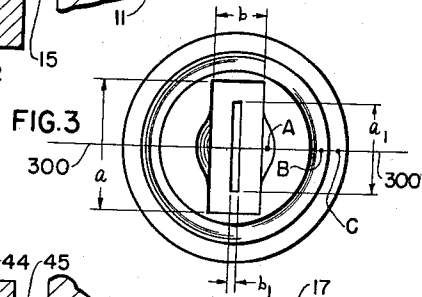
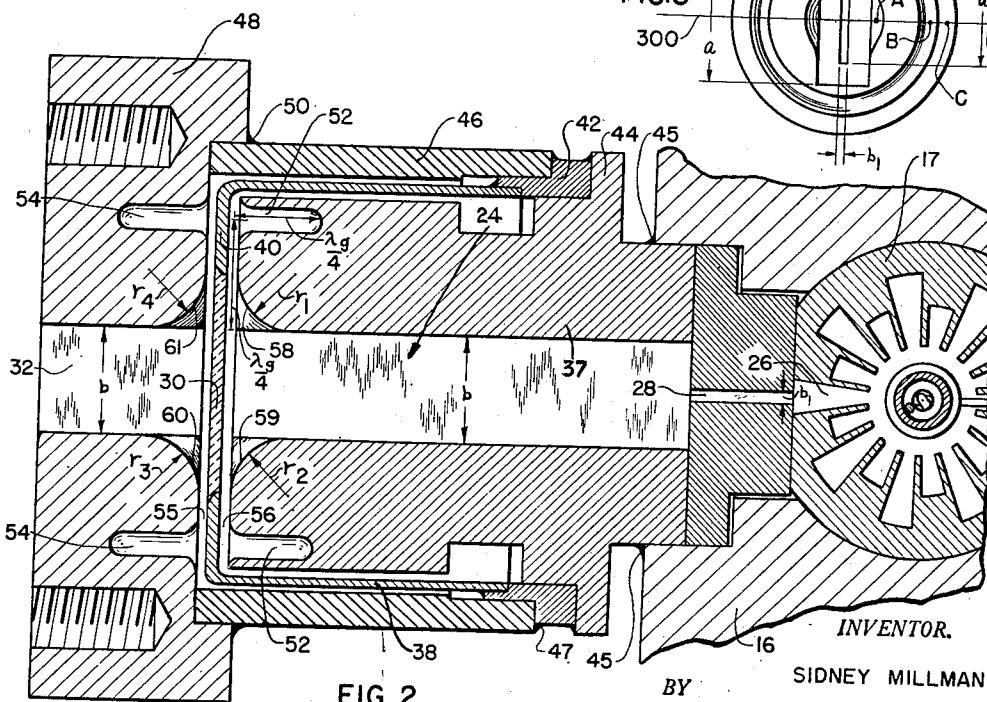
Oct. 23, 1956

S. MILLMAN

2,768,327

WAVE GUIDE OUTPUT CIRCUIT FOR A MAGNETRON

Filed March 11, 1946



INVENTOR.

SIDNEY MILLMAN

BY

William D. Hall.
ATTORNEY

2,768,327

WAVE GUIDE OUTPUT CIRCUIT FOR A MAGNETRON

Sidney Millman, Brooklyn, N. Y., assignor to the United States of America as represented by the Secretary of War

Application March 11, 1946, Serial No. 653,514

24 Claims. (Cl. 315—39)

This invention relates to ultra-high frequency generators of multicavity magnetron type in which ultra-high frequency oscillations are generated by a number of resonators set into oscillations by high velocity electrons moving along curvilinear or orbital paths, these paths being followed by the electrons because of the joint action of the static and R. F. electromagnetic fields. More particularly the invention relates to wave guide output circuits for the magnetrons, and wave guide coupling structure suitable for coupling an evacuated wave guide to a wave guide open to atmospheric pressure.

It is an object of this invention to provide an efficient coupling connection between a magnetron and a wave guide.

An additional object of this invention is to provide a window for a wave guide, which makes it possible to connect an evacuated wave guide to a wave guide open to atmospheric pressure.

It has been customary in the past to connect the anode of a multiresonator magnetron to an output circuit by means of a concentric line-to-wave guide connection, one of the resonating cavities of the magnetron being coupled to the concentric line by bending the inner conductor into a loop and inserting the loop into one of the end spaces of the magnetron so that the loop surrounds the R. F. field produced by the resonator.

The concentric line output circuit performs fairly well when connected to magnetrons generating waves in the order of 10-7 centimeters or higher; however, with the advent of the Rising Sun magnetron (for the description of this Rising Sun magnetron, reference is made to my application for patent Serial No. 651,317, filed March 1, 1946) which made it possible, in the extreme cases, to decrease the lengths of the generated waves to several millimeters and still maintain high power outputs, the use of the concentric line output circuits becomes, for all practical purposes, an impossibility. Besides drastically lowering the overall efficiency of the circuit, it presents additional difficulties, such as sparking in the coaxial line-to-wave guide matching sections. Therefore, in the high power-high frequency regions, it becomes necessary to eliminate the coaxial line between the magnetron and the wave guide altogether provided better means are found to connect the magnetrons to the antennas. The invention discloses a direct magnetron-to-wave-guide connection which has several advantages over the previously used output circuits, namely, it greatly reduces the R. F. losses in the output circuit; it reduces the sparking difficulties by eliminating the troublesome coaxial line-to-wave guide matching sections or couplers; it simplifies the construction of the output circuit, and enables one to construct more reproducible output circuits. It also makes the design of the output circuit electrically simple, and thus simplifies alteration of the output circuit when output requirements change. The output circuit of the type disclosed in this specification, because of the simplicity of its design, is also particularly suitable when used with experimental tubes since it facilitates the study

of the effect of the output circuit on the magnetrons operating not only in the desired mode but also when the magnetrons are troubled by competing modes.

The magnetron-to-wave guide connection is accomplished by interposing a quarter-wave-length transformer between one of the resonating cavities of the magnetron and the wave guide, the dimensions of the transformer being proportioned so that it serves as an impedance matching device which transforms the high impedance of a conventional wave guide to a low impedance at the magnetron cavity. A section of this wave guide, having rectangular cross section, and under vacuum, is connected to the high impedance side of the transformer, the outer end of this section terminating in an air-tight window. Two R. F. chokes are provided for the electrical contact between the window and the adjoining guides. This geometry permits the mechanical and electrical joining of the evacuated section of the wave guide to the continuation of the same wave guide in air with the introduction of only negligible reflection and R. F. losses.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawings in which:

Figure 1 is a vertical section view of the magnetron and its output coupling taken along the axis of the magnetron;

Figure 2 is a cross-sectional view of the magnetron and its output coupling, the plane of cross section being perpendicular to the axis of the magnetron;

Figure 3 is an end view of a guide and transformer taken along line 3—3 illustrated in Fig. 1.

Referring now to Figs. 1 and 2, they disclose two sectional views of a Rising Sun magnetron and of a wave guide output circuit. The magnetron is mounted between permanent magnets (not illustrated), the faces of the magnets engaging soft iron pole-pieces 10 and 11 which are silver-soldered at corners 14 and 15 to a copper magnetron shell 16. The anode-cathode structure of the magnetron is mounted between the pole-pieces in spaced relationship with respect to the pole-pieces. A Rising Sun anode 17 is held fixedly by shell 16, the shell being sufficiently high to provide two end spaces above and below the cathode-anode assembly. While the invention is illustrated with the Rising Sun anode, it is applicable to any other type of anode, such as hole-and-slot, vane type, etc. For a more detailed description of the Rising Sun anode, reference is made to my previously mentioned application for patent on "Magnetron," Serial No. 651,317. The cathode structure illustrated in the figures is of the radial type, two conductors 18 and 20, being used for supporting the cathode cylinder 21 in central position with respect to the anode. The cathode is of usual indirect heater type, a coil 22 being inserted in the hollow portion of the cathode cylinder 21. For a more detailed description of the remaining cathode structure, reference is made to my previously identified application. It does not form a part of this invention, and therefore is not illustrated in any of the figures. A rectangular wave guide output circuit 24 is connected to one of the large resonating cavities, cavity 26, of the anode through an impedance transformer 28. The guide has a rectangular cross section, as illustrated in Fig. 3, with its narrower dimension designated by *b* and its wider dimension by *a*. The outer end of the guide is provided with a circular glass window 30, the purpose of which will be described later.

As mentioned previously, transformer 28 serves as an impedance matching device which connects the high impedance of the wave guide 24 to the low impedance of the magnetron cavity 26. The required input impedance at the output cavity is of the order of .01 of the

3 impedance of the guide. The actual value of this impedance ratio depends on the required stability of the operating magnetron (External Q) and on the detailed construction of the magnetron oscillating circuit, i. e., on the number of resonators and on the particular geometry of the resonating cavities. The transformer is a substantially quarter-wave section of a narrow rectangular wave guide, the dimensions of this transformer being adjusted to provide the proper loading for the magnetrons.

Let the characteristic impedance of guide 24 be denoted by Z_0 and that of the transformer by Z_t , then, if this guide, which is terminated with a matched load, is attached to the magnetron, and if the window does not reflect, the input impedance, Z , presented to the output cavity of the magnetron, is given by

$$Z = \frac{(Z_t)^2}{Z_0} \quad (1)$$

This can be expressed in terms of the dimensions of guide 24 (a , b) and of the transformer sections (a' , b') by the relation

$$Z = \frac{a}{(a')^2} \cdot \frac{(b')^2}{b} \cdot \frac{\sqrt{1 - \left(\frac{\lambda_0}{2a}\right)^2}}{1 - \left(\frac{\lambda_0}{2a'}\right)^2} \quad (2)$$

in units of 377 ohms, where λ_0 is the free space wave length.

If a , b , and a' are kept constant, as is frequently the case when experimenting with the proper loading for a given magnetron, the impedance Z is directly proportional to the square of the narrow dimension of the transformer. Thus, having measured the loading for a tube with a selected transformer dimension, it is a simple matter to determine the proper dimension for any desired loading.

The actual physical length of the quarter-wave transformer should be somewhat less than

$$\frac{\lambda_g}{4}$$

where λ_g is the wave length of the signal in the guide, if one desires pure resistive load at the output cavity of the magnetrons, in order to cancel the effect of the shunt susceptances accompanying the abrupt change in the transmission line characteristics at the transformer boundaries. The transformer terminates in the rectangular wave guide 24, the a and b dimensions of which, indicated in Fig. 3, are adjusted in accordance with the following relationship:

$$\frac{\lambda_0}{2} < a < \lambda_0 \quad (3)$$

$$0 < b < \frac{\lambda_0}{2} \quad (4)$$

where λ_0 is the wave length in air of the magnetron. The above mentioned dimensions of the guide are for TE_{0,1} mode of propagation in the rectangular guide 24.

Since the section of the guide 24, adjacent to the magnetron, must be under vacuum, it becomes necessary to interpose some suitable gas-tight means for mechanically separating this section from the outgoing section 32 of the same guide, which is exposed to atmospheric pressure. This means must be transparent to the energy propagated along the guide, i. e., the connection should be reflectionless and lossless from an electrical point of view. This is accomplished by means of a glass window 30 and choke joints. Window 30 is of circular shape and is glassed to a beveled seat 34 provided in a cup 36 made of Kovar. The Kovar cup consists of a cylindrical portion 38, and a washer-like portion 40, the longitudinal dimension of the cylindrical portion of the cup being made sufficiently long to absorb all differences in expansion of copper guide section 37 and of the Kovar washer portion 40. This is to prevent cracking of the glass window 30 during the heating and cooling cycles taking place in the

processes of magnetron construction and degassing. The cup is connected to a copper ring 42, which is used for protecting the soldered joint 43 during the cooling cycle, and the inner diameter of the cylindrical portion of the cup is made sufficiently large so as to be in spaced relationship with respect to the outer cylindrical surface of section 24 of the guide. Ring 42 abuts flange 44 of the guide, the inner portion of the ring being brazed to the flange. Section 24 of the guide is also brazed to the shell of the magnetron at a junction 45. A cold rolled steel sleeve 46 is mounted in spaced relationship with respect to the cylindrical portion 38 of cup 36, this sleeve being soldered at 47 to ring 42 on one side and to a coupler 48 made of copper. Coupler 48 comprises the outer section 32 of the guide, this section being exposed to atmospheric pressure. The a - b dimensions of this section are equal to the a - b dimensions of section 24, as illustrated in Figs. 1 and 2. The diameter of the glass window 42 must be selected so that no reflection is produced in the guide. It is preferable to use glass #707 for the window, which produces only a small amount of losses and no reflection of the wave propagated by the guide. The window is given a circular shape rather than the shape of a rectangle for simplifying the construction and for increasing the electrical breakdown strength of the joint. The window of the correct diameter and thickness may be looked upon as a short transmission line of the same characteristic impedance as that of the guide although this would imply that the correct diameter is independent of the thickness of the window. This is not strictly true, because of the existence of end effects. For this reason the window thickness as well as its diameter is usually specified for any wave guide geometry. In general the thinner the window, the larger is the required diameter. The dimensions of the window are determined experimentally in connection with a particular wave guide geometry surrounding the window including such modifications as chamfering the chokes and the width of gap 56, the sought result being the avoidance of the overall reflection from the window region. It is not at all difficult to make windows resulting in a reflection coefficient of 0.05 or less for the entire window region.

The mechanical and electrical joining of the inner section 24 of the wave guide, which is under vacuum, to the outer section 32, which is exposed to atmospheric pressure is accomplished by means of a coupler 48 and two choke joints on both sides of the window and portion 40 of cup 36. Coupler 48 is soldered to sleeve 46 at junction 50, which completes the mechanical connection between the two sections of the wave guide. Both choke joints are provided with circular slots 52 and 54. An air gap 55 is provided between cup 36 and coupler 48, and a similar gap 56 is provided between section 24 of the wave guide and cup 36, as illustrated in the figures. The choke joints of this type are known in the art and need no detailed description. Suffice it to say that the distance from the beginning of the chamfered portion of the wave guide to the center of the choke slot should be approximately equal to

$$\frac{\lambda_g}{4}$$

and the electrical length of the circular choke slot 52 should also be equal to

$$\frac{\lambda_g}{4}$$

When these conditions are satisfied, the impedance looking into the joint from the wave guide will be substantially equal to zero and therefore there will be a positive electrical connection between the outer end of wave guide 24 and the window. The same considerations govern the establishment of positive electrical connections between the outer surface of the window and the coupler, which, as it will be remembered, is also provided with the

5

chamfered portion and circular choke slot 55. Thus the introduction of the window separating the two sections of the wave guide does not introduce any appreciable reflections or losses in the joints.

The purpose of chamfering or of the rounding of the wave guides at 58, 59, 60 and 61 is to eliminate the electrical discontinuities between the rectangular wave guide and the circular window which would otherwise produce such concentration of electrical lines of force at sharp edges as to produce premature breakdown of the guides at lower R. F. levels and at lower powers. The introduction of chamfers is accompanied by an effective insertion of inductances on each side of the window. To balance this effect so that the overall window region retains its non-reflecting properties, it becomes necessary to increase the window diameter. This increase may be looked upon as an insertion of a capacitive reactance at the window region of the right magnitude so as to balance the inductive effect of the scooped out portion of the guide. The increase of the diameter is an added advantage in this design because it serves to improve still further the breakdown properties of this window region because of the increase in the length of the path across the window at the center of the guide. The chamfering of the guide need only be done at the center of the "a" dimension of the guides since the electrical field is strongest at the center of a rectangular guide which transmits radiation in the TE_{0,1} mode and falls off toward the edges according to sinusoidal relationship. Therefore the chamfering may be limited to only the central portion of the guide, as illustrated in Fig. 3. Mechanically this chamfering is easily accomplished by means of a revolving cutting tool positioned at the center of the guide and having the cutting edges shaped as portions of a circumference of a circle, as indicated in Fig. 2 by radii r_1, r_2, r_3, r_4 , which are all equal.

It has been previously mentioned that the distance A—B should be

$$\frac{\lambda_g}{2}$$

and it can be seen on the end view of the slotted flange (Fig. 3) that this distance is measured at the center of the wave guide, i. e., along the center line 300 illustrated in Fig. 3. Since the field is strongest at the center of the rectangular wave guide with TE_{0,1} mode propagation and falls off rapidly toward the edges, it is only necessary that the distance from the wave guide to slot 52 be exactly

$$\frac{\lambda_g}{4}$$

for the center portion of the wave guide. What has been started concerning the first choke joint is equally applicable to the second choke joint on the left side of the window and as a consequence the distance from the wave guide to slot 54 should be exactly

$$\frac{\lambda_g}{4}$$

only for the center portion of the wave guide in order to establish positive electrical connections between the window and the outer portion of the wave guide.

In describing cup 36 it has been stated that the longitudinal dimension of the cylindrical portion 38 of the cup is made sufficiently long to absorb all differences in expansion of copper guide 37 and of the Kovar washer 40 to prevent cracking of the glass window 30 during the heating and cooling cycles taking place in the process of construction and especially degassing of the magnetron. This longitudinal dimension, and especially the inner diameter of the cylindrical portion 38 of the cup, has also some electrical significance, namely, the impedance of the region between the inner surface of the cup and the wave guide (B—C region in Fig. 3) should be sufficiently

6

low so as to prevent any significant electrical influence of this region on the choke joint. This can be accomplished by making this region in the order of

$$\frac{\lambda_g}{2}$$

The dimensions of this region from an electrical point of view are not critical and all that is necessary is to avoid dimensioning of this region so it would approach the electrical length equal to

$$\frac{\lambda_g}{4}$$

In describing the material suitable for making window 30, it has been stated that glass #707 is especially suitable for this purpose because it produces only small losses and no reflection of the wave propagated by the guide. It should be understood however that the invention is not limited to this particular material, and any other suitable material transparent to ultra-high frequency propagation of the waves may be used for accomplishing the sought results.

From the description of the electrical and mechanical joint between the degassed section of the wave guide and the section exposed to atmospheric pressure, it follows that the function performed by the cylindrical portion 38 of the cup is primarily of the mechanical nature, the cylindrical walls of this cup acting as a spring for absorbing the differences between the expansion of the copper wave guide section 37 and the Kovar cup equipped with the glass window 30. While this shape of the gas seal performs its function well, it is to be understood that the gas seal may be given many other possible mechanical configurations for successfully performing the same function, which is to protect glass window 30 from cracking. For example, the cylindrical portion 38 of the cup may be eliminated altogether and the washer portion 40 provided with several circular corrugations; the outer rim of the corrugated washer may then be connected to the steel sleeve 46 by brazing the two together along the circular junction formed by these two elements. In the construction of this type, the corrugated portions of ring 40 would absorb all the differences in expansion between the gas seal 30 and 40, and steel ring 46. An additional modification of the expansion joint would be to reduce the thickness of the Kovar element 40 along a circle so that the differential expansion between the copper elements and the Kovar element 40 and glass 30 would be restricted in the main to the constricted portion of member 40, thus preventing cracking of joint 34 between the window and the Kovar element. The expansion joints of this type are known in the mechanical art and therefore need no further description or enumeration.

The disclosed invention thus solves several important electrical problems in the ultra-high frequency field. It enables one to connect the resonant cavities of an ultra-high frequency magnetron to the wave guide through a coupling transformer, this type of connection being more efficient than the concentric line connections used in the past. Moreover the disclosed output circuit is capable of handling the power levels which are many times higher than the power levels which can be transmitted over the concentric line circuit. This is especially true for the wave length region which is shorter than 10–7 centimeters. The invention also discloses substantially lossless and reflectionless coupling joint between an evacuated and degassed guide and a guide open to atmospheric pressure, this joint being so constructed that it can also withstand effectively atmospheric pressure and the expansions and contractions during the manufacturing process of the magnetron. The invention thus made it possible to transmit to antennas high power generated by the Rising Sun magnetrons, which had been impossible to accomplish with the previously used and known concentric line output circuits.

While the invention has been described with reference to several particular embodiments, it will be understood that various modifications of the apparatus shown may be made within the scope of the following claims.

I claim:

1. An ultra-high frequency circuit including a multicavity magnetron, an impedance matching transformer coupled to a cavity of said magnetron, and a rectangular outgoing wave guide connected to said transformer, said transformer being a section of a rectangular wave guide of uniform cross-section opening on one side into said cavity, and on the other side into said outgoing wave guide the smaller dimension of the transformer wave guide being less than the smaller dimension of the outgoing wave guide.

2. An output circuit as defined in claim 1 in which the physical length of said transformer is less than

$$\frac{\lambda_g}{4}$$

where λ_g is the wave length of the energy in said outgoing guide.

3. An ultra-high frequency circuit including a multicavity magnetron, a transformer coupled to one of the cavities of said magnetron, said transformer comprising a substantially quarter-wave section of a wave guide opening directly into the cavity of said magnetron, and a degassed section of an outgoing wave guide connected to the output side of said transformer.

4. An ultra-high frequency circuit including a magnetron, said magnetron having a multicavity anode, a transformer coupled to one of the cavities of said magnetron, said transformer comprising a substantially quarter-wave section of a narrow rectangular wave guide, and a degassed section of a wave guide having a greater width than said narrow wave guide and connected to said transformer, said transformer opening into said cavity on one side and into said wave guide on the other side.

5. An ultra-high frequency circuit as defined in claim 4 in which the ratio of the input impedance of said transformer to its output impedance is in the order of .01.

6. An ultra-high frequency circuit including a multicavity magnetron, a wave guide transformer coupled to one of the cavities of said magnetron, a degassed first section of a wave guide connected to said transformer, a second section of a wave guide electrically and mechanically connected to said first section, said first and second sections having identical propagation characteristics, and a gas-tight seal electrically and mechanically interconnecting said first and second sections of said guide.

7. An ultra-high frequency circuit as defined in claim 6 in which said gas-tight seal includes an electrically transparent window, and choke joints on both sides of said window.

8. A mechanical and electrical connection between two sections of an ultra-high frequency wave guide including a first degassed section of said guide, a second section of said guide, said second section being open to atmospheric pressure, and means mechanically and electrically interconnecting said first and second sections, said means including a cup-shaped member mounted in spaced relationship with respect to the adjacent ends of the first and second sections and cupping the end of one of said sections, a gastight electrical window in the end wall of the cup-shaped member, said electrical window being transparent to the energy propagated along said guide, and wave guide choke joints in said first and second sections of wave guide on either side of said window.

9. A mechanical and electrical connection as defined in claim 8 in which said sections of the wave guide have equal rectangular cross-sections, the walls of said wave guide sections having chamfered surfaces adjacent to said window, for increasing the electrical breakdown characteristics and the electrical transparency of said window.

10. A mechanical and electrical connection between

two sections of an ultra-high frequency wave guide having rectangular cross section, said connection including a first degassed section of said guide, a second section of said guide, said second section being open to atmospheric pressure, and means for mechanically and electrically interconnecting said first and second sections and for maintaining said first section in the degassed state, said means including an electrical window between said sections, choke joints on both sides of said window, the walls of said wave guide being chamfered at the center of the wide dimension of said sections and at the edges of said sections adjacent to said window, the dimensions of said chamfers being proportioned so as to introduce an inductive reactance substantially equal to the capacitive reactance of said window whereby said window, with the aid of said chamfers and said choke joints, constitutes an electrical path for the propagation of the mode of resonances sustained along said guide substantially free of losses and reflections in the region of said window.

11. A combination including a degassed wave guide capable of propagating ultra-high frequency radio energy, a cup-shaped member mounted over one end of said wave guide in spaced relationship with respect to said end, the lip of said cup-shaped member forming a gas-tight joint with the outer side-surface of said guide, and a gas-tight, electrically transparent window in the base of said cup-shaped member, said window being spaced from said guide and aligned with the energy propagating portion of said guide.

12. A combination including a magnetron having a multicavity, multiresonator anode, the resonators and the cavities of said anode generating ultra-high frequency electric and magnetic fields, a first wave guide coupled to one of the resonating cavities of said anode, a second wave guide connected to said first guide whereby said resonating cavity communicates with said second guide through said first guide, said first and second guides being dimensioned to propagate said fields, a cup-shaped member having a cylindrical portion and a washer portion having an opening aligned with the opening of said second guide, said opening in said cup-shaped member being mechanically closed with a member transparent to said fields, the cylindrical portion of said cup being dimensioned so as to be held in spaced relationship with respect to the outer surface of said guide by the edge of said cylindrical portion, said edge making a gas-tight joint with the outer surface of said second guide, and a choke joint between said second wave guide and the washer portion of said cup-shaped member for making the opening in said cup electrically transparent to and substantially free of losses and reflections of the fields propagated along said second guide.

13. A combination as defined in claim 12 in which said first and second wave guides are rectangular wave guides each having two narrow and two wide sides forming two rectangular guides respectively, said choke joint having a choke with the electrical length equal to

$$\frac{\lambda_g}{4}$$

said choke joint also having the electrical length of

$$\frac{\lambda_g}{4}$$

from the center of the edge of said wide side to the center of said choke, and an electrical length in the order of

$$\frac{\lambda_g}{2}$$

beyond said choke, where λ_g is the wave length of the fields propagated along said second guide.

14. An output lead for an evacuated device operable at ultra high radio frequencies and including a member having a passageway therethrough, a conducting cup-shaped element mounted over one end of said member, the lips

of the cup-shaped element being hermetically sealed to said member and the bottom of said cup-shaped member being closely adjacent the member having said passageway, the inner surface of said cup-shaped element being spaced from the outer surface of said member, said cup-shaped element being provided with an aperture registering with the passageway in said member, and a member permeable to electromagnetic waves hermetically sealed across said aperture.

15. A device for use at ultra high frequencies including a cavity resonator sealed vacuum-tight, said resonator having an aperture in the wall thereof, a coupling device for said resonator and including a hollow member having one end opening into said resonator through said aperture, the other end of said coupling device being sealed vacuum-tight by a conducting closure member permeable to electromagnetic waves, said closure member including a cup-shaped member positioned over the end of said hollow member, the lip of said cup-shaped member being sealed to said hollow member, the inner surface of said cup-shaped member and the outer surface of said hollow member being spaced from each other, said cup-shaped member having an aperture registering with the passageway through said hollow member, and means permeable to electromagnetic waves sealed across the aperture in said cup-shaped member.

16. An electron discharge device including a magnetron assembly comprising a cathode surrounded by an anode assembly, said anode assembly including a plurality of cavity resonators, the wall of said anode assembly having an aperture extending therethrough and opening into one of said cavity resonators, and a coupling device including a hollow member having one end registering with and opening into said one resonator through the aperture in the wall of said anode assembly, and a closure member permeable to electromagnetic waves for sealing the other end of said coupling device, said closure member including a cup-shaped member positioned over the end of said hollow member, the lip of said cup-shaped member being sealed to said hollow member, the inner surface of said cup-shaped member and the outer surface of said hollow member being spaced from each other, said cup-shaped member having an aperture registering with the passageway through said hollow member, and means permeable to electromagnetic waves sealed across the aperture in said cup-shaped member.

17. An apparatus for use at high radio frequencies, including evacuated cavity resonator means, an electron discharge device for exciting said cavity resonator means, said cavity resonator means having an aperture extending through the wall thereof and a coupling device adjacent said cavity resonator means, said coupling device comprising an elongated member provided with a passageway and having one end adjacent said resonator means and registering with said aperture and its end remote from the apertured wall sealed by a closure member permeable to electromagnetic waves, said closure member including a cup-shaped member positioned over the end of said elongated member, the lip of said cup-shaped member being sealed to said elongated member, the inner surface of said cup-shaped member and the outer surface of said elongated member being spaced from each other, said cup-shaped member having an aperture registering with the passageway through said elongated member, and means permeable to electromagnetic waves sealed across the aperture in said cup-shaped member.

18. An output lead for an evacuated device useful at ultra high frequencies and including a wave guide having one end sealed by a closure device comprising a member having a passageway of rectangular transverse section extending therethrough, and a cup-shaped member positioned over said last member, the lip of said cup-shaped member being sealed to said last member, the inner surface of said cup-shaped member being spaced from said

last member, said cup-shaped member having an aperture registering with the passageway through said last member, and means permeable to electromagnetic waves sealed within said aperture, the portion of said cup-shaped member defining said aperture being provided with inwardly beveled edges sealed to said means permeable to electromagnetic waves the end of said last member being provided with a slot extending around said passageway and having a depth equal in electrical length to a quarter wave of the frequency at which said output lead operates.

19. A closure member for a wave guide to be used with an evacuated device useful at ultra high frequencies and including a cylindrical member provided at one end with a flange and having a passageway extending along the axis thereof, said passageway having a rectangularly shaped transverse section, a cup-shaped member positioned over the end of said cylindrical member, the lip of said cup-shaped member being hermetically sealed to said cylindrical member adjacent said flange, said cup-shaped member having an aperture registering with the passageway through said cylindrical member, and means sealed across said aperture permeable to electromagnetic waves, the walls of said cylindrical member and said cup-shaped member spaced apart, the end of said cylindrical member adjacent said aperture having a slot therein circumscribing the passageway through said cylindrical member, said slot having a depth equal to an electrical length of a quarter wavelength of the operating frequency of the evacuated device with which said wave guide is associated.

20. An apparatus for use at high radio frequencies, including evacuated cavity resonator means, means supplying an electron discharge for exciting said cavity resonator means, said resonator means having an aperture extending through the wall thereof and coupling device for said cavity resonator means and having a passageway opening into said cavity resonator means through said aperture, a closure member for said coupling device and including a cylindrical member provided at one end with a flange and having a passageway extending along the axis thereof, said passageway having a rectangularly shaped transverse section, a cup-shaped member positioned over the end of said cylindrical member, the lip of said cup-shaped member being hermetically sealed to said cylindrical member adjacent said flange, said cup-shaped member having an aperture registering with the passageway through said cylindrical member, and means sealed across said last aperture permeable to electromagnetic waves, the walls of said cylindrical member and said cup-shaped member being spaced apart, and the end of said cylindrical member adjacent said last aperture having a slot therein circumscribing the passageway through said cylindrical member.

21. An apparatus for use at high radio frequencies, including evacuated cavity resonator means, means for exciting said cavity resonator means, said cavity resonator means having an aperture extending through the wall thereof, an output lead for said cavity resonator means including a wave guide having one end sealed to said cavity resonator means adjacent said aperture and having its other end sealed by a closure device comprising a member having a passageway of rectangular transverse section extending therethrough, and a cup-shaped member positioned over said last member, the lip of said cup-shaped member being sealed to said last member, the inner surface of said cup-shaped member being spaced from said last member, said cup-shaped member having an aperture registering with the passageway through said last member, and means permeable to electromagnetic waves sealed within said last aperture, the portion of said cup-shaped member defining said last aperture being provided with inwardly beveled edges sealed to said means permeable to electromagnetic waves, said end of the last member adjacent said last aperture being provided with

a slot extending around said passageway and having a depth equal in electrical length to a quarter wave of the operating frequency of said cavity resonator means.

22. An electron discharge device including a magnetron assembly comprising a cathode surrounded by an anode assembly, said anode assembly including a plurality of cavity resonators, the wall of said anode assembly having an aperture extending therethrough and opening into one of said cavity resonators, and a coupling device having a passageway registering with the aperture in the wall of said anode assembly, a closure member for said coupling device and including a cylindrical member provided at one end with a flange and having a passageway extending along the axis thereof and opening into the passageway in said coupling device, a cup-shaped member positioned over the end of said cylindrical member, the lip of said cup-shaped member being hermetically sealed cylindrical member adjacent said flange, said cup-shaped member having an aperture registering with the passageway through said cylindrical member, and means sealed across said last aperture permeable to electromagnetic waves, the walls of said cylindrical member and said cup-shaped member being spaced apart, the end of said cylindrical member adjacent said last aperture having a slot therein circumscribing the passageway through said cylindrical member, said slot having a depth equal to an electrical length of a quarter wavelength of the operating frequency of the electron discharge device.

23. A device for use at ultra high frequencies including a cavity resonator sealed vacuum-tight, means for exciting said cavity resonator, said cavity resonator having an aperture in the wall thereof, a coupling device for said cavity resonator and including a hollow member having one end communicating with said resonator through said aperture, a closure device for said hollow member and including a cylindrical member provided at one end with a flange and having a passageway extending along the axis thereof, said passageway having a rectangularly shaped transverse section, a cup-shaped mem-

ber positioned over the end of said cylindrical member, the lip of said cup-shaped member being hermetically sealed to said cylindrical member adjacent said flange, said cup-shaped member having an aperture registering with the passageway through said cylindrical member, and means sealed across said last aperture permeable to electromagnetic waves, the walls of said cylindrical member and said cup-shaped member being spaced apart, said last aperture being provided with inwardly beveled edges sealed to said means permeable to electromagnetic waves.

24. An apparatus for use at high radio frequencies, including a cavity resonator, means for providing an electron discharge for exciting said resonator, said resonator having an aperture extending through a wall thereof, and a wave guide adjacent said resonator and having an aperture opening into the aperture in said resonator, said wave guide comprising an elongated hollow tubular member having its end remote from the apertured wall sealed by a closure member permeable to electromagnetic waves, said wave guide having a rectangular shaped transverse section and being oriented with respect to said cavity resonator so that $H_{0,1}$ type electromagnetic waves are developed within the wave guide.

References Cited in the file of this patent

UNITED STATES PATENTS

2,200,023	Dallenbach	May 7, 1940
2,247,077	Blewett et al.	June 24, 1941
2,372,193	Fisk	Mar. 27, 1945
2,401,425	Hershberger	June 4, 1946
2,404,086	Okress et al.	July 16, 1946
2,407,069	Fiske	Sept. 3, 1946
2,409,913	Tonks	Oct. 22, 1946
2,412,446	De Walt	Dec. 10, 1946
2,421,912	Spooner	June 10, 1947
2,489,131	Hegbar	Nov. 22, 1949
2,585,084	Brown	Feb. 12, 1952