

July 13, 1965

R. G. LOCK

3,195,010

MAGNETRON DEVICE WITH OUTPUT COUPLING

Filed Oct. 9, 1962

2 Sheets-Sheet 1

FIG. 1.

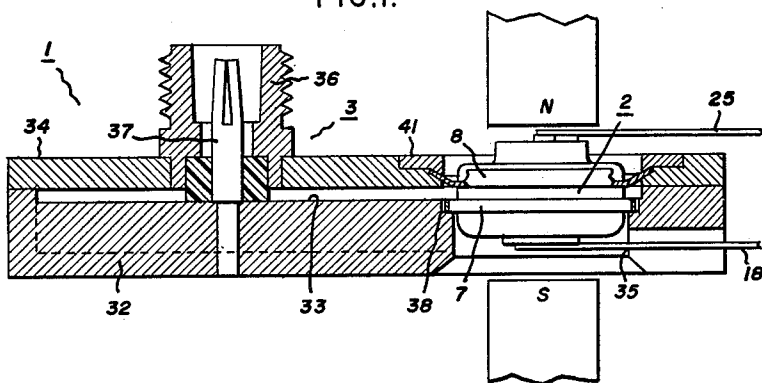


FIG. 2.

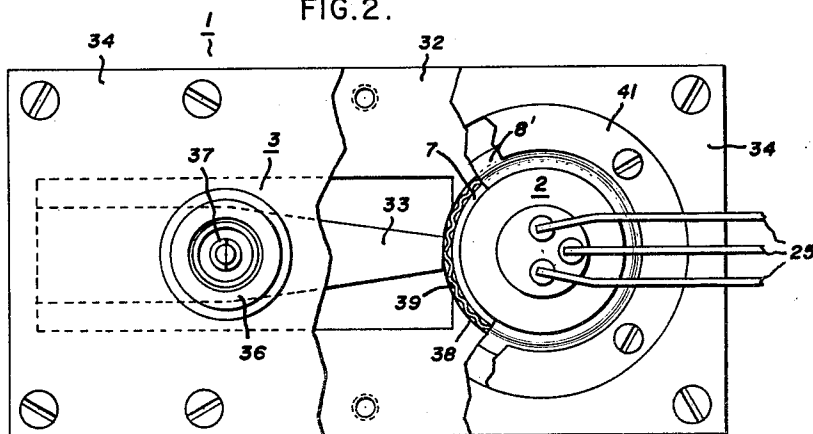
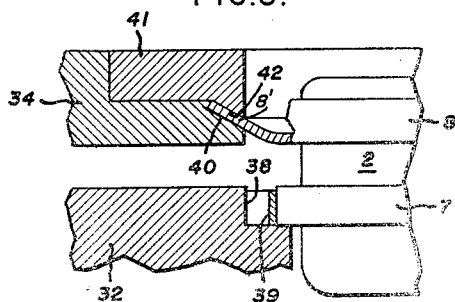


FIG. 5.



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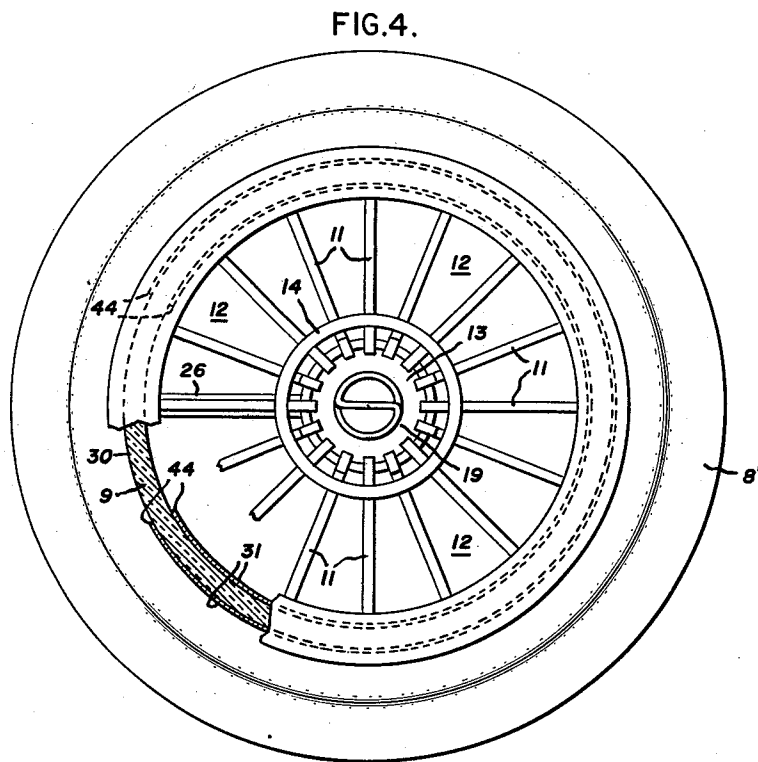
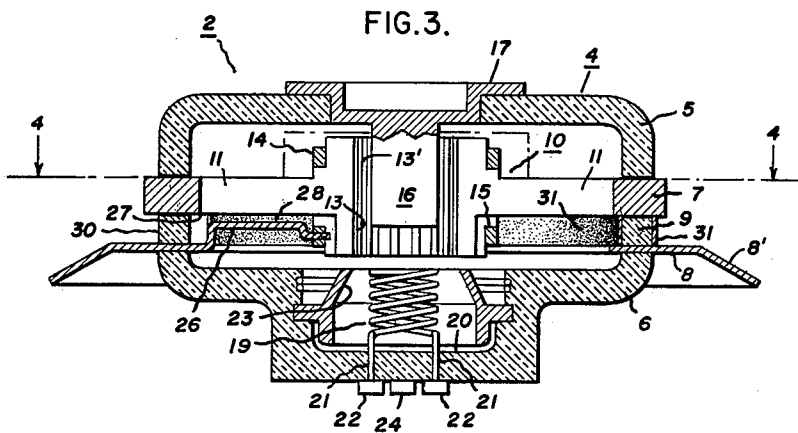
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MAGNETRON DEVICE WITH OUTPUT COUPLING

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13 Claims. (Cl. 315—39.53)

My invention relates to radio frequency apparatus and pertains more particularly to an improved radio frequency voltage tunable magnetron and improved (R.F.) output circuitry therefor.

Heretofore, voltage tunable magnetrons have generally been of the interdigital types disclosed and claimed, for example, in U.S. Patents Nos. 2,810,096 of P. H. Peters, Jr., et al. and 2,930,933 of G. J. Griffin et al., both assigned to the same assignee as the present invention. These tubes have generally been employed in so-called voltage tunable magnetron packages consisting of three principal subassemblies, namely, (1) the tube which contains electrodes including an interdigital anode structure, (2) the radio frequency or R.F. output circuitry including an external cavity resonator coupled to the anode structure, and (3) a magnet providing an operating field extending coaxially through the tube. By constructing tubes for such packages including vacuum brazed ceramic-to-metal butt seals it has been possible to make small, simply constructed, inexpensive tubes adapted for satisfactory performance even at high temperatures and under conditions of severe shock and vibration. Additionally, the mentioned package construction enables precise adjustment of the magnetic field alignment relative to the tube axis while the tube is being operated. Further, a particular type of tube can be adapted for various applications merely by modifying the other two subassemblies of the package. Thus, the just-described type of structure is particularly attractive for a number of applications. However, as the desired operating frequency of such a package increases the wavelength approaches the dimensions of the tube. Then it becomes desirable to include the entire resonator structure within the tube envelope. When the entire resonator is included in a relatively small tube a major problem is encountered in providing an output arrangement effective for coupling R.F. energy from the anode resonator to an external transmission line. Additionally, it is generally desirable to retain the ceramic and metal butt-sealed tube envelope construction and, therefore, the R.F. coupling to the external line must be satisfactorily effected without adversely affecting the seals, as by imposing undue mechanical strains on the mentioned seals.

The present invention contemplates the provision of a new and improved voltage tunable magnetron structure including butt-sealed alternate ceramic and metal envelope wall members, a resonant anode structure completely contained in the envelope, and output means for transmitting R.F. energy through a side wall section of the envelope. Additionally, the present invention contemplates a new and improved combination of the just-described improved magnetron and external R.F. transmission means particularly effective in providing satisfactory R.F. energy coupling between the tube and a coaxial line and with minimal mechanical strain on the mentioned seals.

Accordingly, a primary object of my invention is to provide a new and improved magnetron device including new and improved R.F. output means.

Another object of my invention is to provide a new and improved high frequency voltage tunable magnetron.

Another object of my invention is to provide a new and improved voltage tunable magnetron circuit including a

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new and improved voltage tunable magnetron having the entire resonator structure thereof wholly contained in the magnetron envelope.

Another object of my invention is to provide a new and improved magnetron including a butt-sealed ceramic and metal envelope construction, a wholly-contained anode structure and improved means for effecting satisfactory R.F. output coupling from the anode structure without adversely affecting the envelope seals.

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

FIGURE 1 is a sectional view of apparatus constructed according to my invention and showing the external output means in section;

FIGURE 2 is a plan view partially broken away to illustrate certain details of the external coupling means;

FIGURE 3 is an enlarged sectional view of a voltage tunable magnetron constructed according to the present invention;

FIGURE 4 is a sectional view taken along the lines 4—4 in FIGURE 3, looking in the direction of the arrows and partially broken away to illustrate details of the R.F. window construction; and

FIGURE 5 is an enlarged fragmentary sectional view illustrating the manner of mounting the magnetron device in the external coupling means.

In carrying out the objects of my invention I provide a voltage tunable magnetron comprising an envelope including a pair of cup-shaped ceramic end caps, a pair of annular metal terminals and an annular ceramic insulator all arranged in alternate butt-sealed relation with the rim of each end cap sealed to one of the terminals and the annular insulator sealed between the terminals. The magnetron is positioned in external coupling means comprising a ridged rectangular waveguide section with the terminals coupled to the ridge and the opposite waveguide wall. One of the terminals is rigid and the other relatively flexible and these in cooperation with particular mounting means are effective for coupling the tube to the external output means without imposing undue mechanical strains on the mentioned seals. Supported in the envelope by the rigid terminal is a strapped anode structure comprising a plurality of circumferentially spaced radially extending segments defining resonator cavities laterally thereof and a central space and annular conductors interconnecting alternate sets of anode segments to provide strapping of the anode structure. Supported in the central space from one end of the envelope is a non-emissive cathode cooperating with the anode to define an annular interaction space. Axially displaced relative to the non-emissive cathode and supported from the other end of the envelope is an emissive cathode and means for controllably directing electrons axially into the interaction space. Conductively connecting the strapped portion of the anode structure and the flexible terminal is a conductor which cooperates with one of the segments to define an internal R.F. transmission line extending radially toward the insulator between the terminals and coaxial with respect to the waveguide section. The insulator is metalized except for an area defining an R.F. output window aligned with the internal line and the waveguide section.

Referring to FIGURES 1 and 2, there is shown a voltage tunable magnetron circuit generally designated by the numeral 1 and comprising a voltage tunable magnetron tube device 2 and external R.F. output coupling means generally designated 3. Also shown in FIGURE 1 is a magnet including poles designated N and S adapted for providing an operating magnetic field extending generally coaxially through the tube 2.

As best seen in FIGURES 3 and 4, the tube 2 comprises an envelope generally designated 4. The envelope 4 is constructed of a plurality of alternate ceramic and

metal members including upper and lower ceramic end caps 5 and 6, respectively, upper and lower metal terminals 7 and 8, respectively, and an annular ceramic wall insulator 9 interpositioned between the terminals. The just-described members are all butt-sealed together to complete the envelope 4 and the terminals 7 and 8 include externally disposed sections adapted for affording the making of electrical connections to elements in the envelope.

More specifically, the rim of the upper end cap 5 is butt-sealed to a planar surface on the annular terminal 7. Spaced annular terminals 7 and 8 are each butt-sealed to opposed planar transverse surfaces on the insulator 9 and the rim of the lower end cap 6 is butt-sealed to a transverse planar surface on the terminal 8 opposite the insulator 9. The upper terminal 7 in FIGURE 3 is of a substantially rigid construction in comparison with the terminal 8 and supports within the envelope an anode structure generally designated 10. The anode structure 10 comprises a plurality of circumferentially spaced radially extending segments, or anode vanes, 11 which define a plurality of cavity resonators 12 and a central space 13. The inward tips of the segments 11 are generally T-shaped (FIG. 3) and strapping means in the form of upper and lower annular electrically conductive straps or rings 14 and 15, respectively, are provided for conductively interconnecting alternate sets of segments in a well-known manner and for the well-known purpose of mode separation.

In the central opening or chamber 13 defined by the anode segments 11 there is disposed a cylindrical non-emissive, or cold, cathode post 16 which cooperates with the anode structure 10 in defining an annular interaction space 13'. Post 16 protrudes into the space 13 and is sealed into and supported by upper end cap 5. The outer end of the post 16 includes a contact surface 17 to which a D.C. lead 18 can be attached in the manner illustrated in FIGURE 1 wherein magnetron 1 is shown in an inverted position relative to the illustration of FIGURE 3. By means of lead 18 a predetermined desirable operating potential can be applied to the non-emissive cathode.

An emissive cathode 19 is located in the envelope in axially displaced relation with respect to cold cathode 16 and interaction space 13'. Specifically, emitter 19 in one form comprises a helically formed filamentary emitter positioned in a recess 20 formed in the inner surface of lower end cap 6. Emitter 19 includes leads 21 extending in spaced hermetically sealed relation through end cap 6 and electrically connected to contact buttons 22 bonded to the outer surface of end cap 6. Cooperating with emitter 19 is a frusto-conical control electrode 23 adapted for controllably directing electrons from emitter 19 axially into interaction space 13'. Control electrode 23 is suitably secured in end cap 6 and is connected by an electrically conductive lead (not shown) to a contact button 24 also bonded to the outer end surface of the end cap 6. As seen in FIGURE 1, several D.C. leads 25 are provided for connecting the emitter and control electrode in appropriate D.C. circuitry, whereby the arrangement is adapted for controlled voltage tuned operation in the same manner as those disclosed in the above-noted prior patents.

However, the structure disclosed in the mentioned prior patents include externally located resonators. That is, the interdigital anode structures disclosed have a shunt capacitive effect on the R.F. circuits and external cavity structures are required to provide the necessary compensating inductive effect. The present invention differs in that it provides a voltage tunable magnetron containing the complete resonator structure, including both capacitance and inductance elements, in the envelope thereof. More specifically, and as described above, in the present device annular terminal 7 (FIG. 3) supports in the tube envelope the anode structure 10 which includes the cir-

cumferentially spaced cavity resonators 12. As also described above, alternate sets of the anode vanes or segments 11 defining the cavities 12 are electrically conductively interconnected by annular straps or rings 14 and 15 located on opposite sides of the anode structure. As best seen in FIGURE 3, one of the strapping rings 15 is included in an R.F. power output coupling arrangement which includes a radially electrically conductive tab 26 projecting from the inner edge of the lower terminal 8.

More specifically, lower annular terminal 8 is relatively thin in comparison with the comparable dimensions of terminal 7 and has formed, as an integral projection thereof, a radially inwardly extending coupling tab 26 which is electrically conductively connected to strapping ring 15 on the lower side of the anode structure, as viewed in FIGURE 3. Additionally, tab 26 extends parallel with and in predetermined close spaced relation to a lower edge surface 27 on one of the anode segments 11. Thus, tab 26 and the parallel anode segment cooperate in defining a TEM mode transmission line designated 28 in FIGURE 3. With tab 26 connected to strapping ring 15 in the manner shown in FIGURES 3 and 4 and at π mode operation the full vane-tip-to-vane-tip voltage is applied to the transmission line 28 at the end between the strapping ring and the vane. Thus, R.F. power is adapted for being propagated radially outwardly toward the wall of the envelope. This power is propagated through the envelope by means of a rectangular output window 30 radially aligned with the transmission line 28. The window 30 is provided in the insulator 9 between the anode terminals and comprises a rectangular area provided by coating the remainder of the insulator internally and externally with conductive coatings 31. More specifically, both the inner and outer surfaces of the ceramic insulator 9 are provided with a metal coating 31, as by metalizing in accordance with any of the well-known techniques, except for aligned rectangular uncoated areas adapted for providing a single rectangular R.F. transmission section in the insulator. In the just-described arrangement electromagnetic wave energy propagates down the TEM mode line 28 and through the window 30 with a field configuration similar to a TE_{01} mode in a rectangular waveguide. Outside the window the energy propagation continues in a TE_{01} mode in a ridged rectangular waveguide section included in the above-noted external output coupling means 3.

As best seen in FIGURES 1 and 2, the output coupling means 3 comprises a box-like electrically conductive construction including a lower section 32 which is machined to provide a central longitudinally extending ridge 33. The box-like construction also includes a cover 34 which is secured in place by any suitable means such as the illustrated machine screws in FIG. 2 and so that the inner surface of cover 34 is adapted for cooperating with opposed inner surface of the lower section 32 to define a rectangular ridged waveguide. Both the lower section 32 and the cover 34 define an aperture 35 therethrough one end to receive the magnetron device 2 in the manner illustrated in FIGURES 1 and 2. On the upper surface of cover 34 there is provided a coupling means 3 including a perpendicularly extending coaxial arrangement of an outer conductor 36 rigidly mounted on cover 34, and an inner conductor 37 rigidly electrically conductively coupled to the ridge 33. Alternatively, coupling means 3 can be coupled to a waveguide transmission line instead of the coaxial conductors 36 and 37.

The portion of the aperture 35 in the lower section 32 includes a counterbore 38 which provides a rim shoulder arrangement 38 (FIG. 5) for receiving the anode-supporting terminal 7. As best seen in FIGURES 2 and 5 the diameter of counterbore 38 is greater than the outside diameter of the terminal 7 to provide an annular space therebetween. Electrical contact is effected between anode terminal 7 and the rim or sidewall of the counter-

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bore 38 by means of a corrugated electrically conductive spring element which presses radially inwardly at many contact points about the circumference of the terminal 7. Thus, suitable electrical contact is effected without imposing mechanical strain on the ceramic-to-metal seals between the anode terminal 7 and adjacent ceramic elements.

In order to minimize mechanical strains on the ceramic-to-metal seals between the ceramic elements and the other anode terminal 8, terminal 8 is formed of metal stock which is thin relative to that of anode terminal 7. In one preferred embodiment of the invention, terminal 8 is formed of soft 0.010 inch thick copper. Thus, terminal 8 is flexible and malleable and adapted for being engaged by a contact surface with minimal transmission of strain to the ceramic-to-metal seals. Additionally, the outer peripheral section 8' of terminal 8 is frusto-conical and is adapted for engaging a corresponding frusto-conical surface 40 (FIG. 5) formed on the rim of the portion of aperture 35 in the cover 34.

As best seen in FIGURE 5, the magnetron tube device 2 is retained in the external coupling means 3 by a retaining element such as clamp 41, and suitable fastening means such as the machine screws is illustrated in FIG. 2. Retaining element 41 includes a frusto-conical surface 42 which bears on the frusto-conical section 8' of terminal 8 and presses it into secure conforming engagement with the frusto-conical contact rim surface 40 on cover 34. In this arrangement the outer portion 8' of the terminal 8 is clamped between surfaces 40 and 42 which provides desired electrical contact. Also, inasmuch as the clamping effect occurs at the peripheral frusto-conical rim portion 8' of terminal 8, and terminal 8 is flexible and has a substantial injurious radial dimension, no substantial stresses are transmitted to the seals between the terminal 8 and adjacent ceramics 6 and 9. As mentioned above, electrical contact with terminal 7 is made through the corrugated spring contact member 39. Thus, electrical contact to each terminal is effected in a relatively non-rigid manner. Additionally, and as best seen in FIGURE 5, the spacing between the inner surface of the cover 34 and the top surface of the ridge 33 corresponds to the spacing between the terminals 7 and 8, or in other words, the height of the output window 30 in the insulator 9.

Further, and as best seen in FIGURE 2, the ridge 33 is coaxially aligned with the transmission line 28 and the window 30 and the sides of the ridge 33 are tapered and are aligned with the window side edges indicated by 44 in FIGURE 4. This construction insures satisfactory continuation of the energy propagation in the mentioned TE₀₁ mode as it propagates toward the coaxial output 35 after having emerged from the window 30.

Thus, I have provided a voltage tunable magnetron device having the resonant structure thereof completely contained in the device envelope and adapted for increased operating frequency. Additionally, I have provided relatively simple means for extracting R.F. power from the device without subtracting from the mentioned operating frequency. By way of example of the effectiveness of this device, apparatus has been constructed according to the foregoing teaching which is effective for providing frequency voltage tuning from 5,210 mc. to 5,435 mc. with power output over 10 watts and an efficiency exceeding 28%. As also pointed out above, my structure provides for coupling the R.F. energy out of the magnetron and transmitting it to a transmission line in a manner which adapts the assembly for satisfactory operation with minimal transmission of strains to the ceramic-to-metal seals in the device envelope. Thus, my apparatus enables the continued use of butt-sealed envelope constructions which facilitate manufacture and enables the construction of devices of minimal size.

While I have shown and described a specific embodiment of my invention, I do not desire my invention to be limited to the particular forms shown and described, and

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I intend by the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A magnetron device comprising in combination, an envelope, a pair of spaced annular terminals sealed in the side wall of said envelope and defining a wall section therebetween, a resonant anode structure supported within said envelope from one of said terminals, R.F. output means comprising a radially extending element conductively interconnecting said anode structure and the other of said terminals inside of said envelope and cooperating with said anode structure to define a transmission line extending radially toward the wall section of said envelope between said terminals, and an R.F. output window in said wall section and radially aligned with said transmission line.

2. A magnetron device according to claim 1, wherein said wall section between said terminals is insulative and is completely opaque with respect to R.F. energy and means providing a limited area in said wall section constituting said R.F. window.

3. A magnetron device according to claim 1, wherein said other terminal comprises a thin flexible element relative to said one terminal and includes a radially inwardly extending tab comprising said conductive element.

4. A magnetron device comprising an envelope, a pair of axially spaced annular terminals sealed in the side wall of said envelope on opposite sides of an insulative section thereof, an anode structure supported in said envelope on the inner portion of one of said terminals and including circumferentially spaced radially extending segments defining a plurality of resonator cavities and a central space, a negative electrode disposed in said space and cooperating with said anode structure to define an interaction space, strapping means conductively interconnecting a plurality of said anode segments, a conductive element interconnecting the inner portion of said other terminal and said strapping means and cooperating with one of said segments to define an R.F. output transmission line extending radially toward said insulative wall section of said envelope, and the surface of said insulative wall section being completely coated with a conductive material except for an area radially aligned with said transmission line and constituting an R.F. output window.

5. A magnetron device comprising a pair of insulative end caps, a pair of annular metal terminals and an annular insulator arranged in alternate butt-sealed relation with the rim of each of said end caps sealed to one of said terminals and said annular insulator sealed between said terminals to provide an envelope, an anode structure supported in said envelope on the inner portion of one of said terminals and including circumferentially spaced radially extending segments defining a center space, a negative electrode disposed in said center space and cooperating with said anode structure to define an interaction space, strapping means conductively interconnecting a plurality of said anode segments, a conductive element interconnecting the inner portion of said other terminal and said strapping means and cooperating with one of said segments to define an R.F. output transmission line extending radially toward said annular insulator between said terminals, and coating means on said annular insulator defining an R.F. window in said annular insulator radially aligned with said transmission line.

6. A magnetron device according to claim 5, wherein at least the inner surface of said annular insulator is completely metallized except for a rectangular area constituting said R.F. output window.

7. A magnetron device according to claim 5, wherein one of said end caps supports a non-emissive cathode extending in said central space in said anode and cooperates therewith to provide said interaction space, and the other of said end caps supports an emitter axially displaced relative to said non-emissive cathode and means

for directing electrons axially into said interaction space,
 8. A magnetron device according to claim 5, wherein said one terminal comprises a substantially rigid washer-like element whereby said anode structure is supported rigidly in said envelope and at least the outer portion of said other terminal comprises a relatively thin and flexible frusto-conical section, whereby said device is mountable securely in a circuit without imposing undue strains on said seals.

9. In combination, a rectangular waveguide section, a magnetron device comprising an envelope including a pair of spaced annular terminals sealed in the side wall of said envelope, said terminals being coupled to the opposite walls of said waveguide section, an anode structure supported from one of said terminals within said envelope, R.F. output means comprising a conductive element interconnecting the inner portion of the other of said terminals and said anode structure and cooperating with said anode structure to define an output transmission line extending radially toward the wall section of said envelope between said terminal members and coaxially aligned with the longitudinal axis of said waveguide section and the wall section of said envelope between said terminals being conductive, and means providing a non-conductive portion of said wall section as an R.F. output window aligned with both said transmission line and waveguide section.

10. In combination, a rectangular waveguide section, a magnetron device including a plurality of annular insulators and a plurality of generally annular terminals arranged in alternate butt-sealed relation and providing a generally cylindrical envelope for said device, one of said terminals being rigid and the other relatively flexible, said waveguide section having an aperture therethrough defining a pair of rim surfaces, each said terminal making circumferential contact with a respective rim of said aperture in said waveguide for thereby R.F. coupling said device to said waveguide section, an anode structure supported from said rigid one of said terminals within said

envelope and comprising a plurality of circumferentially spaced radially extending segments, R.F. output means comprising a conductive element interconnecting the inner portion of said flexible terminal and said anode structure and cooperating with one of said anode segments to define a transmission line extending radially toward the insulator between said terminals and coaxially aligned with the longitudinal axis of said waveguide section, and said insulator between said terminals having the surface thereof completely coated with a conductive material except for an axea axially aligned with said transmission line and waveguide section and constituting an R.F. output window therebetween.

11. The combination of claim 10, wherein said flexible terminal is frusto-conical, and is retained in secure conforming engagement with a frusto-conical contact surface on the corresponding side of said waveguide section.

12. The combination of claim 10, wherein said rigid terminal is seated in an annular recess in the corresponding side of said waveguide section and is of a smaller diameter than said recess, and resilient conductive means is provided in the annular space between said rigid terminal and the side wall of said recess for effecting annular R.F. contact between said rigid terminal and waveguide.

13. The combination of claim 10, wherein said waveguide section is of the ridged type, said rigid terminal electrically contacts the ridge of said waveguide section, said R.F. window of said device is in the plane of the space between said ridge and the opposite wall of said waveguide section, and said ridge tapers toward said window.

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GEORGE N. WESTBY, *Primary Examiner*.