Dec. 24, 1957 E. C. OKRESS 2,817,823

CIRCULAR WAVEGUIDE OUTPUT FOR MAGNETRONS

Filed Dec. 11, 1953 2 Sheets-Sheet 1

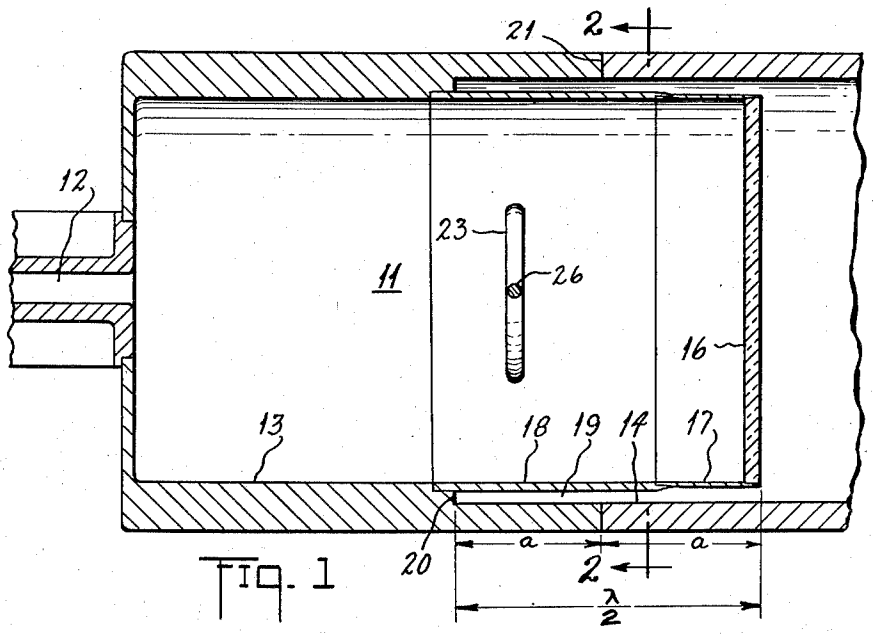


FIG. 1

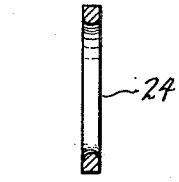


FIG. 3

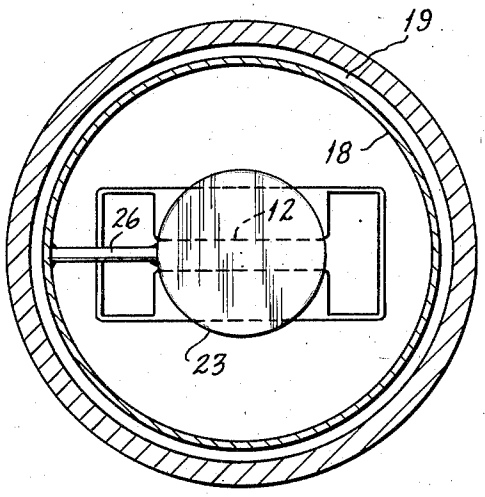


FIG. 2

INVENTOR.
ERNEST C. OKRESS
BY
Lee I. Huntzberger
ATTORNEYS

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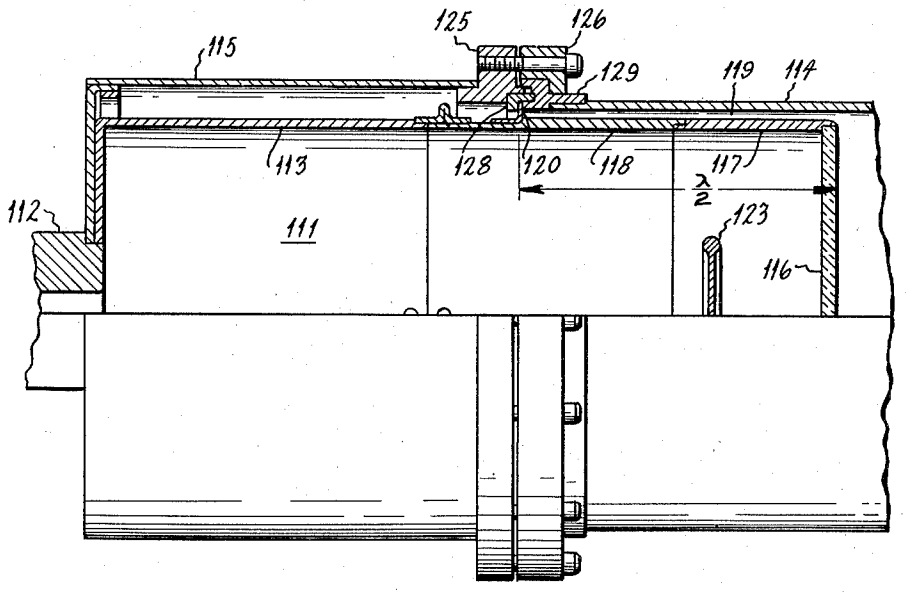


Fig. 4

INVENTOR.
ERNEST C. OKRESS

BY

Lee J. Huntzberger
ATTORNEYS

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CIRCULAR WAVEGUIDE OUTPUT FOR MAGNETRONS

Ernest C. Okress, Montclair, N. J., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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12 Claims. (Cl. 333—98)

This invention relates to an elongated circular waveguide output for magnetrons and more particularly to a circular waveguide in which the window offers minimum impedance to flow of electromagnetic energy and provides a hermetic vacuum seal.

The energy output of a magnetron is supplied generally to an antenna system or other load through a waveguide network. Reference is made to an antenna system for illustration only and is not intended in the limiting sense. Several factors need to be taken into account in order to provide for proper and efficient coupling between the magnetron and the waveguide system. One factor evolves from the magnetron's being evacuated. Since the waveguide system is mechanically linked to one of the resonating cavities of the magnetron a carefully designed hermetically sealed window arrangement must be provided adjacent the junction of the magnetron and the waveguide system for maintaining the evacuated condition with the magnetron. Considering the window's function as an hermetic seal, the window should offer zero impedance to the flow of electromagnetic energy along the waveguide while at the same time completely withstanding the atmospheric pressure. Due to the desired proximity of the window to the magnetron, the window also must be able to withstand the high thermal radiation resulting from the intensely hot cathode. A second factor concerns impedance matching. A low impedance load is presented to the magnetron resonator system by a transducer 12 of Fig. 1 connected to the waveguide 13 of Fig. 1. The presence of the window must be taken into account in this loading.

In the prior art electromagnetic energy from a magnetron was generally transferred to an antenna system through a waveguide system including rectangular waveguides. Rectangular waveguides were initially selected for this purpose for a number of reasons, e. g., no polarization problems are present in rectangular waveguides; rectangular waveguides have a lower characteristic impedance relative to circular guides for the dominant mode and, in addition, more data was available on rectangular waveguide terminations for magnetrons. However, there are difficulties present in the use of rectangular waveguide terminations for magnetrons. The greatest difficulty resulting from the use of rectangular waveguide terminations for magnetrons is that there is lower breakdown voltage at the window. The window mounted in an iris in rectangular guide presents a small arc-over gap to the transverse electric field. To overcome this low breakdown voltage resort was had to pressurizing the waveguide system. Pressurizing of a waveguide system especially the larger sizes in the decimeter band has proven to be both costly and difficult. Moreover the use of rectangular waveguide terminations involves more complex structure and heavier parts in the decimeter band than does circular waveguide terminations.

This invention represents a departure from the prior art through the use of a circular waveguide termination

for magnetrons. The window is secured within the waveguide through a yielding support. The yieldable support permits the window to practically float free from externally developed waveguide stresses, of the supporting structure and thereby avoid rupture. A half wavelength coaxial slot is provided adjacent said yieldable supporting structure for the window so as to remove direct connection of supporting a structure while presenting a substantially continuous path for the electromagnetic energy from one side of the window to the other side thereof and into the waveguide system. The further departure of this invention from the prior art is exemplified by the novel matching and thermal shielding means that are provided for the waveguide window.

An object of this invention is to provide a circular waveguide output for magnetrons.

Another object is to provide a waveguide output for magnetrons especially in the decimeter band which does not require pressurizing of the waveguide system as a solution for arc-over.

Another object is to provide a waveguide output for magnetrons involving less complex structure at the junction between the magnetron and the waveguide.

Another object is to provide improved thermal shielding and matching for waveguide windows.

The window mismatch may be compensated by the transformer 12 but this is a costly process when the physical and electrical properties of the dielectric window cannot be maintained sufficiently accurate.

Another object is to provide a circular waveguide output for magnetrons wherein the waveguide window does not rupture under internally developed stresses.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a partial cross-sectional view of a circular waveguide terminating at a magnetron and including a preferred embodiment of the invention,

Fig. 2 is a vertical cross-section taken along the plane 2—2 of Fig. 1,

Fig. 3 is a sectional view of an alternative matching means that may be used in the device of Fig. 1. Fig. 3 is on a reduced scale from Fig. 1, and

Fig. 4 shows another embodiment of the invention in a form more practical to produce.

There is shown in Fig. 1 a circular waveguide output assembly 11 particularly for magnetrons in the decimeter band. The assembly is adapted to be connected to one of the resonant cavities of a magnetron for permitting efficient transfer of the electromagnetic energy generated in the magnetron, not shown, to an antenna system. One of the resonant cavities of the magnetron is coupled conventionally to the waveguide assembly or transducer 11 through a transformer such as an H transformer 12 having a central inlet. The transducer 11 comprises a first section 13 of circular waveguide forming a solid and rigid ring and joined at its constricted end to the H transformer 12, and a second section 14 of circular waveguide which is joined to waveguide section 13. A dielectric window 16 is secured within the waveguide assembly 11 proximate to the transformer 12. The spacing between the dielectric window 16 and the transformer 12 is dependent in part upon the thermal radiation from the cathode of the magnetron that normally reaches the surface of the window 16. Due to the fact that the cathode of the magnetron operates at a very high temperature (1400–1600° C. brightness) and further due to the fact that the portion of the thermal radiation that passes through the H transformer is such as to create sharp temperature gradients in various

portions of the assembly **11** because it does not transmit enough of the thermal radiation, the dielectric (e. g. AI–200 coors ceramic or the like) window cannot be placed too close to the H transformer because if it were it would crack. Likewise it is undesirable to mount the window **16** too far away from the H transformer since the disadvantages of a substantially increased evacuated volume are undesirable. The window **16** is shown at a compromise distance from the transducer **12**. Since the window **16** is still at a relatively short distance from the H transformer **12** a considerable amount of heat still will be generated in the window **16** by the absorbed thermal radiation from the cathode. If the window **16** is rigidly mounted in its supporting structure the stresses developed in the window as a result of the unequal heating, could cause it to crack. To mitigate this undesirable effect, the window **16** is brazed in the nonrigid portion **17** of the first waveguide section **13**. Portion **17** is made of metal which matches the thermal expansion characteristics of the ceramic window or is a soft metal (e. g. oxygen free copper) and furthermore the portion **17** is sufficiently thin to further permit almost free expansion and contraction of the window **16** due to the presence of thermal stresses therein. The portion **17** may be formed from or as an extension of the inside wall **18** of the cylindrical slot **19**. In effect slot **19** forms one end of the first section **13** of circular waveguide into a resilient ring portion **17** and a coaxial rigid ring **18**.

Because of the discontinuity between the window and the waveguide system beyond, a waveguide half-wavelength coaxial slot or bypass **19** is provided. The waveguide half-wavelength coaxial bypass is measured from the end **20** of the slot **19** to the remote surface of the window **16**. With this arrangement the electromagnetic energy flowing through the window sees a short circuit or zero impedance at the open end of gap **19**. To minimize losses at the break or plumbing joint **21** it is best to place it between the waveguide sections **13** and **14** intermediate the half-wavelength coaxial bypass. The plumbing joint is a distance *a* from each end of the half-wavelength coaxial bypass.

A thermal shield and matching means **23** in the form of a cylindrical disk is provided between the H transformer output and the window **16**. The other advantage of a disk **23** aside from these important factors is the ease with which it may be handled. There is little difficulty or expense in modifying it or assembling it in place within the waveguide as shown.

In Fig. 3 there is shown an alternate matching means for use in the assembly **11**. This matching means is an iris **24** the outside diameter of which is the same as the inside diameter of waveguide section **13**. Iris **23** is mounted axially in waveguide section **13**. For some electrical purposes the iris **24** has advantages over the disk **23**. For example when the window **16** does not absorb much thermal radiation and the dielectric constant of the window **16** is low so that it presents a small mismatch to the waveguide **13**.

The disc **23** is centrally and axially mounted in the waveguide by means of a rod **26**, and transversely disposed as illustrated by Fig. 2. This rod and disc arrangement is preferably referred to as a lollypop type of simultaneous matching means and thermal shield. If the rod **26** supporting the disc **26** is round and of small diameter (i. e. $\frac{1}{25}$ of diameter of waveguide **13**) and is mounted within the waveguide so that its axis is perpendicular to the plane of polarization of the dominant electromagnetic wave transmitted along the circular waveguide. The presence of the rod **26** will have no effect on the electromagnetic energy. There is one very decided advantage in the use of the disc which advantage is not present when using the other type of matching means described above. Since the disc **23** is located between the window **16** and the output of the transformer **12** it shields the window **16** from the direct thermal radiation from the magnetron cathode. This result is particularly desirable since it tends to minimize the destructive effect of the heat radiation on the window **16**. The insertion loss of this matching means is negligible.

In operation the window **16** of the waveguide terminal assembly for the magnetron, not shown, serves to maintain the evacuated condition within the magnetron. Due to its proximity to the magnetron and due to the fact that a portion of the heat radiated by the cathode of the magnetron passes through the slot of the H transformer **12** and reaches the surface of the window **16** in a magnified pattern of the H transformer the latter heats up non-uniformly. The portion **17** of the waveguide section **13** upon which the window **16** is mounted is made up of physical matching metal and sufficiently thin so as not to impose extra stresses above those that are created within the window **16** due to the non-uniform heat radiation and to more uniform electromagnetic energy losses within the window. The coaxial bypass **19** which is a waveguide half-wavelength long for the dominant (TE_{11}) mode in circular waveguide serves the purpose of providing continuity between the two sections of waveguide **13** and **14**. Since the bypass **19** is divided at the quarter wavelength point, a conventional friction butt joint can be readily used between sections **13** and **14** as the longitudinal current is practically zero at that point for the dominant (TEM) coaxial mode. The window assembly disclosed connects the magnetron to a waveguide network, provides a vacuum seal, allows electromagnetic energy to be freely transmitted. Since circular waveguide has the undesirable feature that the plane of polarization for the modes of oscillation and particularly for the dominant one is not unique, caution needs to be observed in the placement of unsymmetrical discontinuities, in any deviation from roundness of the waveguide, and in contact between sections of waveguide, to avoid serious consequences. This disadvantage can be corrected by a copending patent application, Serial No. 360,993, filed June 11, 1953, by inventor. These disadvantages are corrected by the use of the septate supported disk **23** which locks the plane of polarization in the manner described in the cited patent application. The window can withstand higher electric fields before electric breakdown occurs on the air side in contrast to the window in rectangular waveguide when operating at atmospheric pressure and without special gas insulation.

The embodiment of the invention shown in Fig. 4 is one practical form which can be readily built with minimum difficulty by those skilled in the art. The reference numerals used are in the one hundred series but correspond to the reference numerals in the range 0–100 used in Fig. 1 for indicating corresponding parts. The wall of waveguide section **113** is thinner than that of waveguide section **13**. Waveguide section **113** is enveloped by a tubular structural member **115** concentric with waveguide section **113**. One end of tubular structural member **115** is fixedly secured to the H transformer **112** by means of a flanged disk **110** contiguous with the constricted end of waveguide section **113** which is likewise fixedly secured to the H transformer **112**. Adjacent waveguide portions **117** and **118** that are coaxially secured to waveguide section **113**, correspond to portions **17** and **18** in Fig. 1, in that portion **117** is non-rigid and made of metal which matches the thermal expansion characteristics of the ceramic window **116** and is sufficiently thin to further permit almost free expansion and contraction of the window **116** due to the presence of thermal stresses therein. The portion **118** is a rigid ring. The thermal shield and matching means **123** corresponds to member **23** in Fig. 1. The assembly **111** is secured relative to the main section of waveguide **114** through the aid of bolted clamping rings **125** and **126**. A flanged ring **120** is secured to the portion **118** at a distance equal to one-half wavelength from the outer surface of the window to provide a half-wavelength coaxial bypass slot **119** corresponding to slot **19**

of Fig. 1. Suitable securing means embodying ring-like members 128 and 129 including therebetween the edge of flanged ring 121 and in turn securely clamped between the clamping rings 125 and 126 provides an accurate rigid connection between the assembly 111 and the waveguide 114.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. An improved output arrangement for magnetrons comprising an elongated waveguide, said waveguide being circular in transverse section, one end of said waveguide being constricted to form an inlet adapted for communication with a resonant cavity of a magnetron, said elongated waveguide including a portion adjacent its constricted end which portion is so constructed and ararnged as to provide an axially directed annular slot, said portion including an inside ring of the same inside diameter as the portion of said waveguide immediately contiguous to its constricted end, said inside ring being the inner boundary of the annular slot and terminating in a free end one-half wavelength from the bottom of the annular slot, and a ceramic window for sealing the free end of said inside ring of said portion, the free end of said inside ring being of such material and so designed as to be yieldable in response to strains in said ceramic window, whereby said ceramic window does not rupture due to internal stresses developed therein resulting from temperature changes.

2. An output arrangement for magnetrons as described in claim 1 wherein said dielectric window and the free end of said inside ring have substantially the same expansion characteristics in the range of temperatures traversed.

3. An output arrangement for magnetrons as described in claim 1 wherein said inside ring of said portion is tapered to a thin resilient metal end which favorably matches the ceramic window expansion characteristics in the operating range.

4. An output arrangement for magnetrons as described in claim 1 in which the inside ring is stepped to provide decreasing thickness from the bottom of the annular slot to said window.

5. An improved output arrangement for magnetrons as described in claim 1 and further including an impedance matching means fastened inside the ring.

6. An improved output arrangement for magnetrons as described in claim 5 wherein said matching means includes a centrally positioned transverse disk, said disk serving the additional function of thermally shielding said window.

7. An improved output ararngement for resonant cavity microwave energy generators, said output arrangement comprising; a circular waveguide, said waveguide having a first straight portion of uniform diameter whose length is on the order of one wavelength of the desired frequency, one end of said first portion of said waveguide being so constructed and arranged whereby it is adapted to be connected in communication with the resonant cavity of a microwave energy generator; a window; the opposite end of said first portion of said waveguide being thin-walled to be relatively yieldable and of material which favorably matches the window expansion characteristics in the operating temperature range, said window being hermetically sealed in the opposite end of said first portion of said waveguide; said waveguide having a second portion of larger diameter than said first portion and coaxial with and sealed to said first portion one-half wavelength from the cpposite end of said first portion of said waveguide to provide a one-half wavelength slot, whereby

said first portion and said second portion of said waveguide provide a substantially continuous path for microwave energy at the desired frequency.

8. An improved output arrangement for resonant cavity microwave generators as defined in claim 7 wherein said window is flat.

9. An improved output arrangement for resonant cavity microwave energy generators, said output arrangement comprising; a circular waveguide having a first straight portion whose length is on the order of one wavelength of the desired frequency, one end of said first portion of said waveguide being so constructed and arranged whereby it is adapted to be connected in communication with the resonant cavity of a microwave energy generator; a window hermetically sealed in the opopsite end of said first portion of said waveguide; a disk; a short length of rod secured radially to the inside of said first portion of said waveguide perpendicular to the plane of polarization of the dominant mode and secured to the periphery of said disk whereby said disk is positioned axially and transversely in said first portion of said waveguide and functions as a matching means and thermal shield for said window; said waveguide having a second portion of slightly larger diameter than said first portion and secured coaxially to said first portion one-half wavelength from the opposite end of said first portion of said waveguide whereby said first portion and said second portion of said waveguide provide a substantially unimpeded path for microwave energy at the proper frequency.

10. An improved output arrangement for magnetrons comprising; a section of waveguide constricted at one end to form an inlet adapted for communication with a resonant cavity of a magnetron; a window secured in said section of waveguide adjacent the constricted end thereof; a disk; and a rod secured to said disk and to the inside of said section of waveguide whereby said disk is positioned axially in said waveguide between said window and the constricted end of said waveguide and functions as a matching means and thermal shield for said window.

11. An improved output arrangement for magnetrons as defined in claim 8 wherein said window is flat.

12. An improved output arrangement for magnetrons comprising; a section of circular waveguide, one end of said section of circular waveguide being constricted to form an inlet adapted for connection with a resonant cavity of a magnetron, said section of circular waveguide including, adjacent its constricted end, a portion which is constructed and arranged to provide an axially directed annular slot, said portion including an inside ring forming the inner boundary of the annular slot and terminating in a free end one-half wavelength from the bottom of the annular slot, a flat window hermetically sealed in the free end of said inside ring, a disk, a short rod secured to said disk and to the inside of said ring whereby said disk is positioned axially in said ring between said window and the constricted end of said section of waveguide to function as a combined matching means and thermal shield for said window.

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