Nov. 19, 1968 G. E. GLENFIELD 3,412,284

MICROWAVE TUBE APPARATUS HAVING AN IMPROVED SLOT MODE ABSORBER

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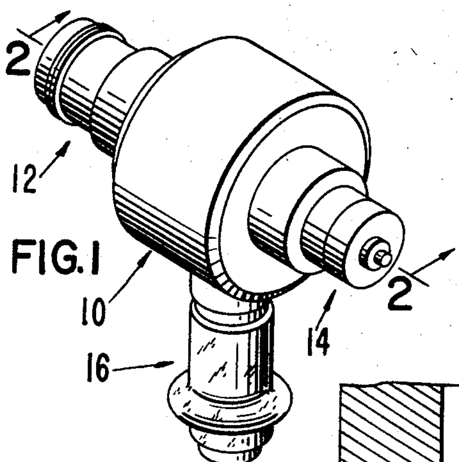

FIG. 1

FIG. 2

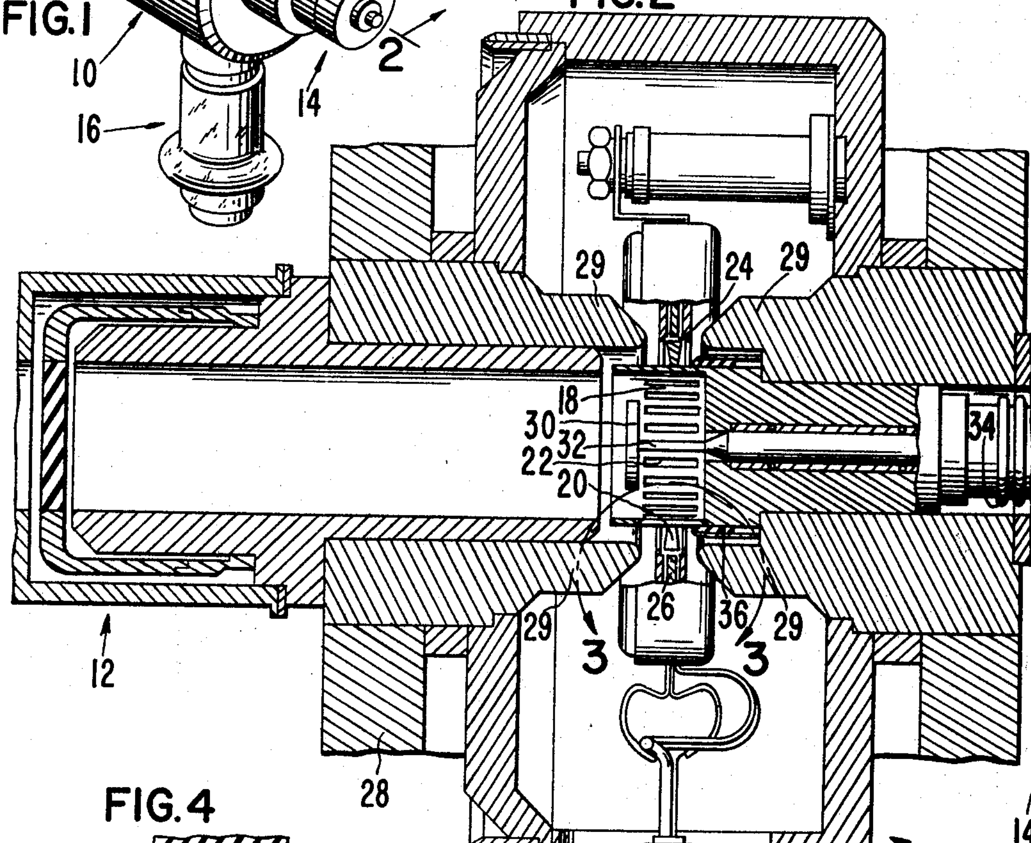

FIG. 4

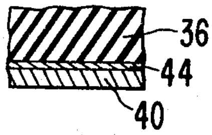

FIG. 3

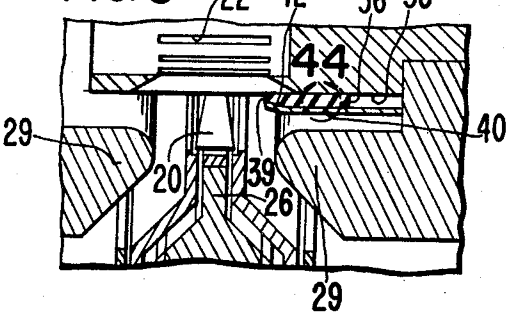

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FIG.5

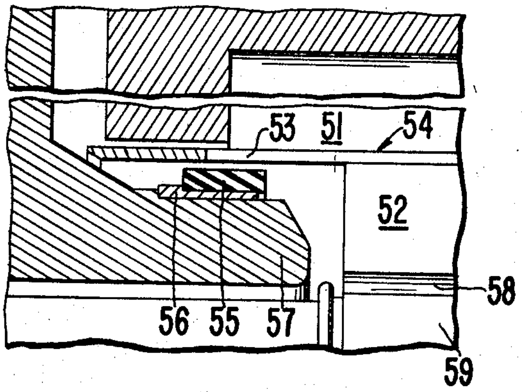


FIG.6

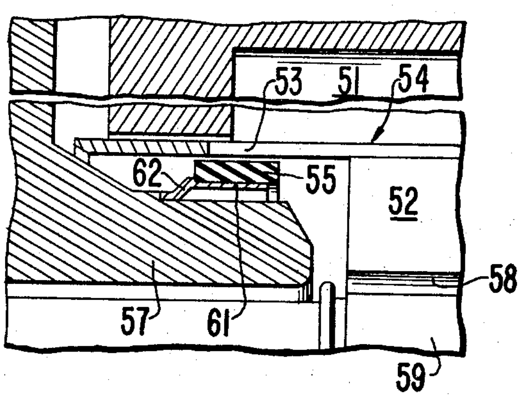
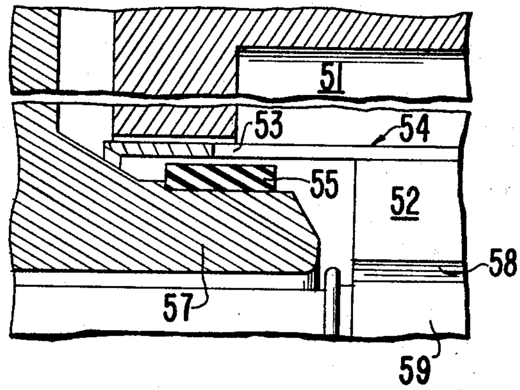


FIG.7



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MICROWAVE TUBE APPARATUS HAVING AN IMPROVED SLOT MODE ABSORBER

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ABSTRACT OF THE DISCLOSURE

A coaxial magnetron tube is disclosed. The tube includes a cathode electrode concentrically disposed of an anode electrode structure. The anode electrode structure includes a circular array of anode resonators facing the cathode electrode and defining a magnetron interaction region in the space therebetween. The anode structure includes a circular electric mode cavity resonator coaxially disposed of the array of anode resonators and communicating with the anode resonators via an array of axially directed coupling slots communicating through the anode structure between alternate ones of the anode resonators and the circular electric mode cavity resonator. The array of coupling slots serves to lock the π mode of the array of anode resonators to the circular electric mode of the cavity resonator. A slot mode absorbing member is disposed adjacent the ends of the slots for selectively damping unwanted oscillations associated with radio frequency energy storage in the slots. The slot mode absorbing member comprises a porous ceramic member impregnated with carbon. A metallic support member is bonded to the lossy ceramic member over a substantial surface area thereof which is on the opposite side of the lossy member from the slots, whereby thermal energy is uniformly distributed over the slot mode absorbing member to prevent fracture in use.

Heretofore coaxial magnetron tubes have employed slot mode absorbers for absorbing the energy of the unwanted slot mode of resonance. Typically the slot mode absorber has taken the form of a lossy ring-shaped member usually made of carbon impregnated alumina which is disposed adjacent a circular array of axially directed resonant slots which communicate through the back wall of an array of vane resonators into a relatively large coaxial circular electric mode cavity for locking the π mode of the vane resonators to the circular electric mode of the coaxial cavity. This circular array of coupling slots forms a resonant system and may store energy at one of its resonant frequencies. Since the slot resonators, like the coaxial cavity, are coupled to the magnetron interaction region via the intermediary of the vane resonators, it is possible for the slot resonators, if they can store sufficient energy, to lock the vane resonators to the slot mode of resonance rather than to the desired circular electric mode of resonance of the coaxial resonator. The purpose of the slot mode absorber is to absorb the energy of the slot resonant mode thereby preventing it from storing sufficient energy to lock the vane resonator to its resonant frequency

In microware tubes operating at high power levels, i.e., 350 kilowatts peak and 120 watts average at 3 gigacycles, the energy absorbed by the slot mode absorber becomes very high. Prior slot mode absorber support arrangements, as exemplified by U.S. Patent 3,169,211, filed Apr. 26, 1961 and issued Feb. 9, 1965 and U.S. application 223,499, filed Sept. 13, 1962, have had the mode absorber ring loosely held within a metallic retaining ring assembly. It has been found that this type of absorber support structure provided inadequate thermal conductivity from the mode absorber to a suitable heat sink. Poor transfer of heat to

the heat sink resulted in localized overheating of the slot mode absorber producing fracture and/or excessive outgassing thereof.

In the present invention, the slot mode absorber is provided with an axially coextensive metallic sleeve, as of copper, bonded or otherwise intimately joined in a thermally conductive manner to the mode absorber whereby heat is more evenly distributed over the mode absorber and conduction of heat therefrom to a suitable heat sink is facilitated.

The advantage of this improved mode absorber support structure is that the peak and average power output of the microwave tube employing same is greatly increased, when compared to prior tubes, without producing failure or excessive outgassing of the mode absorber.

The principal object of the present invention is to provide an improved crossed field microwave tube.

One feature of the present invention is the provision of an improved slot mode absorber having an axially coextensive thermally conductive sleevse, as of copper, bonded or otherwise intimately joined to the absorber via the intermediary of a thermally conductive joint whereby transfer of heat from the absorber to a suitable heat sink is facilitated to prevent failure or excessive outgassing of the mode absorber in use.

Another feature of the present invention is the same as the preceding feature wherein the thermally conductive joint is formed by brazing the conductive sleeve to the mode absorber.

Another feature of the present invention is the same as any one or more of the preceding features wherein the mode absorber is directly brazed to a pole piece of the magnetic circuit of the tube structure whereby the pole piece serves the dual function of conductive sleeve and heat sink.

Another feature of the present invention is the same as any one of the preceding wherein the mode absorber is made of carbon impregnated ceramic.

These and other features and advantages of the present invention will become more apparent after a perusal of the following specification taken in connection with the accompanying drawings wherein,

FIG. 1 is a perspective view of a reverse magnetron tube, according to the invention;

FIG. 2 is a fragmentary cross section view, taken along the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary enlarged cross section view of the structure of FIG. 2 delineated by line 3—3;

FIG. 4 is an enlarged fragmentary view of a portion of a structure of FIG. 3 delineated by line 4—4;

FIG. 5 is a fragmentary cross section view of an alternative tube structure characteristic of a normal coaxial magnetron and embodying the mode absorber of the present invention;

FIG. 6 is an alternative structure to that of FIG. 5; and

FIG. 7 is an alternative structure to that of FIG. 5.

With reference to FIGURE 1, a reverse magnetron comprises a hollow tubular supporting body **10**, which may be made of copper, to which is brazed a tubular output waveguide assembly **12** and a tuner assembly **14**, all in axial alignment. A cathode lead-in insulator structure **16** extends from the main body **10** in quadrature with the axially aligned output waveguide and tuner assembly, respectively.

In FIG. 2, a section of the magnetron is depicted wherein a circular electric mode cavity **18** is disposed centrally of the supporting anode body **10** along the axis of the tube. A circumferential array of outwardly directed vanes **20** surround the circular electric mode cavity **18** and form an arrangement of anode resonators by the spaces between adjacent vanes. Alternate anode resonators are electromagnetically coupled to the circular electric mode cavity **18** by means of axially directed slots **22** communicating through the common wall between the anode resonators and the circular electric mode cavity. A magnetron interaction region **24** surrounds the outer tips of the vanes **20** and is defined by the space between the vanes and a surrounding cathode emitter ring **26**.

A strong axial magnetic field of 12,000 to 15,000 gauss for the magnetron interaction region **24** is provided by a magnet structure **28** (only partially shown in FIG. 2) enveloping the anode body **10**. The magnet **28** has a re-entrant internal magnetic gap extending in the axial direction through the magnetron interaction region **24** between magnetic pole pieces **29** disposed on oppposite sides of the anode vanes **20**.

To tune the tube about its center frequency, a turing disk **30**, carried by an axial rod or plunger **32**, is positioned within the cavity **18** defining a movable end wall thereof. The disk **30** may be driven axially by means of a captured nut and bellows assembly **34**, partially shown.

In accordance with this invention, a slot mode absorber **36** (shown in enlarged form in FIG. 3) is mounted adjacent the cylindrical anode wall **38**. The annular slot mode absorber **36** is positioned adjacent the ends of the slots **22** and suppresses the undesired slot mode.

The slot mode absorber **36** is formed from an alumina ceramic or beryllium oxide material that is about 30% porous and is impregnated with sucrose $C_{12}H_{22}O_{11}$. Before impregnation, the surface of the absorber which is remote from the slotted wall **38** is metalized with molybdenum manganese to within 0.010" from the tapered tip **39** of the absorber. Prior to assembly in the tube, the impregnated body is fired at about 910° centigrade in a hydrogen atmosphere to reduce the sucrose to carbon, thereby providing a lossy black surface.

As illustrated in FIG. 3, the slot mode absorber **36** is jacketed with an axially coextensive high thermal conducting thin sleeve **40**, made for example of 0.007" thick copper sheet. The copper jacket **40** is joined to the absorber and the pole piece **29** by brazing, for example. The jacket **40** is substantially coextensive with the surface of absorber **36** which is remote from the slots and follows a gradual taper **42**, about 30°, at one end of the absorber. As a result of the gradual taper, the tip of the absorber **36** has a larger cross-sectional area than a configuration with a sharp taper in order to facilitate transfer of heat from the thin tip of the absorber **39** to the remainder of the absorber and to the jacket **40**. The taper **42** affords convenient assembly when inserting the absorber into position during manufacture.

The other end of the heat conductive sleeve or jacket **40** is bonded to the pole piece **29** whereby heat may be readily transferred to and dissipated in the more massive body of the metallic pole piece thereby forming a heat sink. In effect, the mode suppressor is placed in thermal communication with a heat sink providing a good heat conduction path and prohibiting it from experiencing localized elevated temperatures.

Brazing of the metallic jacket **40** to the ceramic body **36** may be achieved by metalizing the ceramic structure prior to carbonization. A metallic layer **44** (shown in FIG. 4) formed from a mixture of maganese, titanium, molybdenum or tungsten, by way of example, is applied to the ceramic. After impregnation of the ceramic, the brazing process is accomplished by means of the metalizing layer **44**. Details of the formation of such assemblies are described in detail in U.S. Patent 3,197,290.

The copper jacket **40** provides a means of uniform thermal distribution over the mode absorber **36** thereby precluding localized heating. By providing uniform heat distribution over the absorber structure, fracture of the absorber is avoided, and by drawing heat from the absorber undesirable formation of gas is minimized. Therefore, the operating power level over a wide range of frequencies is substantially increased.

In one successful embodiment, a tunable reverse magnetron of the type shown in FIGS. 1–3 was operated at 340 kilowatts power, 120 watts average at 3 gigacycles without evidence of mode absorber heating problems. Not only is a stable mode suppressor realized, but higher power levels are achieved.

Referring now to FIG. 5 there is shown an alternative embodiment of the present invention for use in normal coaxial magnetron tubes of the type wherein a circular electric mode resonant cavity **51** surrounds a circular array of vane resonators **52** and is coupled thereto via the intermediary of an array of axially directed slots **53** communicating through a common wall **54** therebetween. Such a tube structure is shown and described in U.S. Patent 3,169,211, issued Feb. 9, 1965. The same slot mode control problem exists in this type of magnetron tube as exists in the reverse coaxial magnetron previously described and depicted in FIGS. 1–3.

A ringlike lossy slot mode absorber **55** is disposed adjacent the ends of the slots **53** for absorbing the energy of the unwanted slot resonant mode. In this embodiment, the mode absorber, as of carbon impregnated alumina ceramic, previously described, is brazed to a thermally conductive metallic sleeve **56**, as of copper, which in turn is brazed to a massive iron pole piece **57** of the tube's magnetic circuit. The massive iron pole piece thereby forms a heat sink for the mode absorber. The magnetic circuit, which includes the pole piece **57**, provides a strong axial magnetic field in the annular magnetron interaction region **58** between the array of anode vanes **52** and a cathode emitter **59**. The copper sleeve **56**, which forms a bonded interface between the mode absorber **55** and the pole piece, allows good heat transfer from the absorber to the heat sink and yields a uniform heat distribution over the mode absorber **55** to prevent thermally produced shock and fracture.

Referring now to FIG. 6, there is shown an alternative embodiment to the structure of FIG. 5, wherein a thermally conductive metallic cylindrical sleeve **61**, as of copper, is brazed substantially over its length to the mode absorbing ring **55** but is only brazed at its constricted end portion **62** to the pole piece **57**. This configuration permits strains produced by differences in thermal expansion between the pole piece **57** and the mode absorber **55** to be taken up by flexure of the thin flexible sleeve **61** while providing a good thermal path along the length of the mode absorber **55** to the heat sinking pole piece **57**.

Referring now to FIG. 7, there is shown another alternative embodiment of the structure of FIG. 5 wherein the metalized mode absorber ring **55** is brazed directly to the pole piece **57** over substantially its entire axial and circumferential length whereby a low resistance heat path to the heat sinking pole piece **57** is obtained to provide the aforementioned advantages.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed:

1. In a coaxial magnetron, a cathode electrode, an anode electrode structure coaxially disposed of said cathode and having a circular array of anode resonators facing said cathode electrode, said anode and cathode being spaced apart to define a circular crossed field interaction region therebetween, said anode structure having a circular electric mode cavity resonator formed therein coaxially with said cathode and said array of anode resonators, means forming an array of axially directed coupling slots formed in said anode structure and communicating through said anode structure between alternate ones of said anode resonators and said circular electric mode cavity resonator for locking the π mode of said array of

anode resonators to the circular electric mode of said cavity resonator, means for extracting radio frequency output wave energy from said circular electric mode resonator for use, slot mode absorbing means disposed adjacent the ends of said slots for selectively damping unwanted radio frequency oscillations which cause radio frequency energy storage in said slots, said slot mode absorbing means comprising a porous ceramic member, said ceramic member having its pores impregnated with carbon to make said ceramic member lossy for radio frequency energy, the improvement comprising, a metallic support member bonded to said lossy ceramic member over a substantial surface area of said ceramic member which is on the opposite side of said ceramic member from said array of slots, whereby thermal energy is uniformly distributed over said mode absorbing member.

2. The apparatus according to claim **1** wherein said metallic support member is a metallic sleeve which is in turn bonded via a thermally conductive joint to a more massive heat sinking means whereby heat is readily transferred from said mode absorbing member to said heat sinking member.

3. The apparatus according to claim **1** wherein said mode absorber member is ring-shaped and said support member is tubular, and bonded in substantially coextensive axial extent with said ring-shaped absorber member.

4. The apparatus according to claim **1** wherein said support member is a magnetic pole piece of a magnetic circuit of the tube apparatus, whereby said support also serves as a heat sinking member for said mode absorber member.

5. The apparatus according to claim **2** wherein said heat sinking means is a magnetic pole piece of a magnetic circuit of the tube apparatus.

6. The apparatus according to claim **2** wherein said sleeve has a wall thickness less than the mode absorber member and less than 0.07" to facilitate flexure thereof under thermally produced stress to prevent fracture of said mode absorber member in use.

7. The apparatus according to claim **3** wherein said support member is a cylindrical pole piece member of a magnetic circuit of the tube apparatus disposed inside of and bonded to the inside surface of said lossy ring-shaped mode absorber member, whereby said pole piece serves as a heat sink for said mode absorber member.

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