Dec. 24, 1957 J. KLINE ET AL 2,817,790

MAGNETRON OUTPUT COUPLING MEANS

Filed July 26, 1954 2 Sheets-Sheet 1

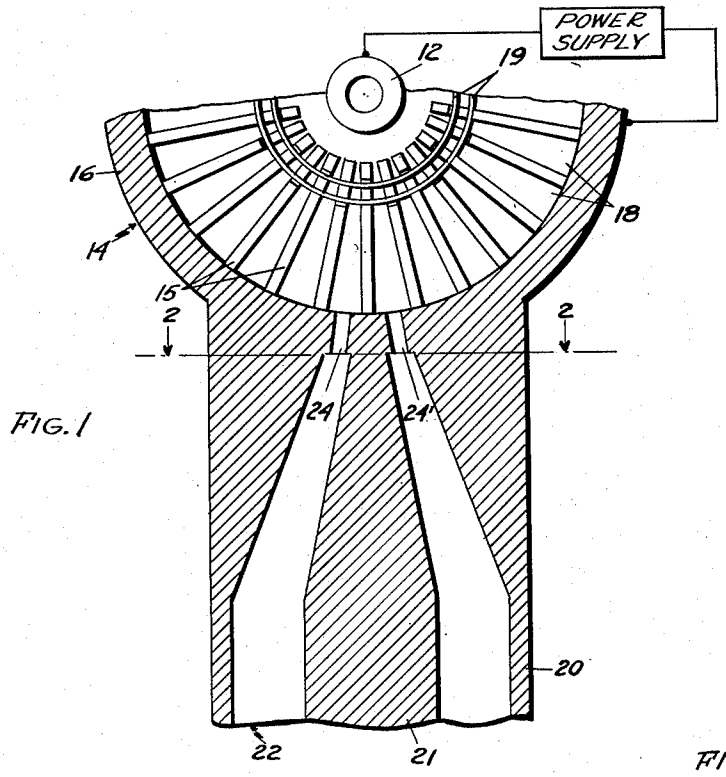


FIG. 1

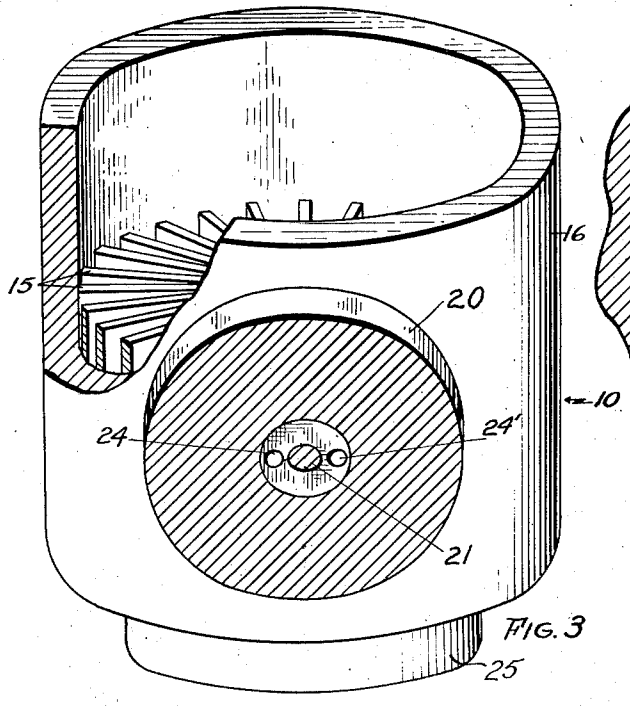
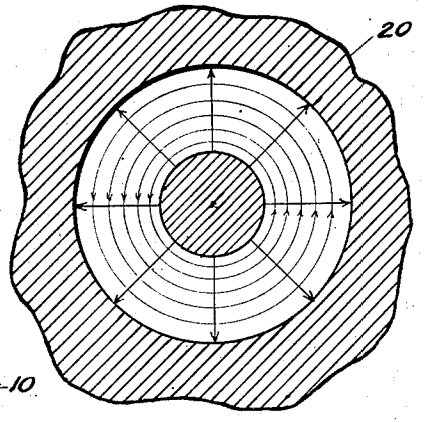


FIG. 3

FIG. 2



INVENTORS
JACK KLINE
CARLTON G. LEHR
BY Elmer J. Gorn
ATTORNEY

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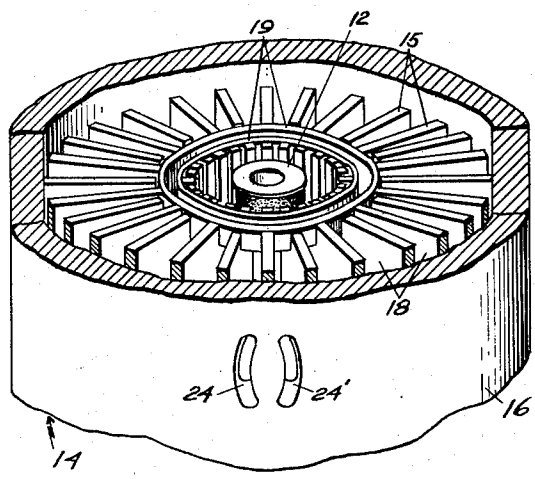
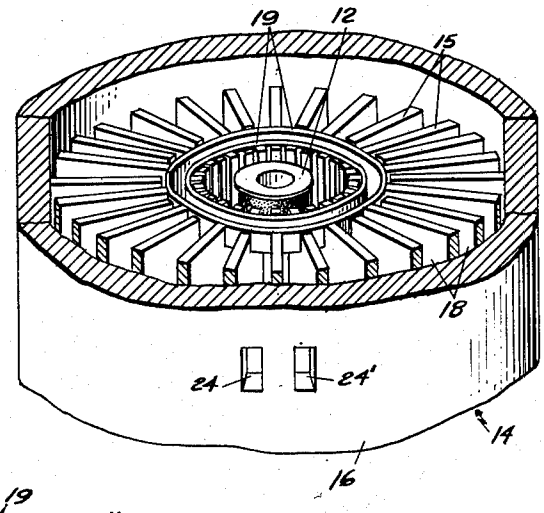


FIG. 4

FIG. 5



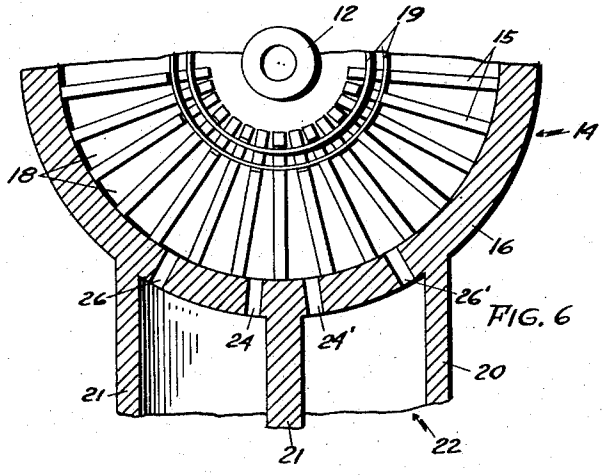


FIG. 6

INVENTORS
JACK KLINE
CARLTON G. LEHR
BY Elmer J. Gorn
ATTORNEY

United States Patent Office

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MAGNETRON OUTPUT COUPLING MEANS

Jack Kline, Concord, and Carlton G. Lehr, Waltham, Mass., assignors to Raytheon Manufacturing Company, Waltham, Mass., a corporation of Delaware

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This invention relates to a magnetron output coupling device and, more particularly, to means for coupling high frequency energy from a multiple cavity magnetron into a coaxial output transmission line.

In many magnetron applications, the energy generated by the magnetron is transmitted to the load circuit by way of a coaxial transmission network. Coaxial output coupling devices of the prior art have used coupling loops inserted within one of the cavity resonators. Such coupling devices become unwieldy for magnetrons having a relatively large number of vanes, such as those operating at low voltage, or for magnetrons having relatively small physical dimensions because of operation at very high frequencies. Where the distance between anode segments is small, the size of the coupling loop is limited and extreme care must be taken not to short adjacent anode segments by said coupling loop. Furthermore, coupling loops are difficult to adjust and each loop must often be adjusted by hand for each tube.

In accordance with this invention, the energy produced by the magnetron is extracted from one or more pairs of cavity resonators through slots formed in the anode cylinder. The coaxial line interposed between the magnetron and the load may be connected directly to the anode cylinder, or may be connected to a coaxial impedance matching section whenever slot design alone is insufficient to provide adequate coupling between magnetron and load.

The mechanical construction of the coaxial output coupling device in accordance with the invention is relatively simple since the coupling slots or irises may be formed readily in the anode cylinder as by drilling, and the coaxial coupling device may be accurately secured to the anode cylinder by a simple brazing technique, as contrasted with the usual coaxial coupling loop or probe previously used. In some cases it is possible to go directly from the magnetron anode to the coaxial load without the use of tapered sections, thereby effecting economy of construction.

The coupling according to the invention further eliminates the necessity of using a very small coaxial section where the vane-to-vane spacing is small. In this way electrical losses are reduced and mechanical problems related to small tolerances are simplified.

The coaxial coupling device may be considered as a coaxial wave guide whose principal or diminant mode is the transverse electromagnetic or TEM mode. The magnetic flux lines in this mode, as viewed along the cross-section of the coaxial guide, encircle the central conductor and their direction at a given point on one side of the central conductor is opposite to the direction on the other. In order to properly excite this TEM mode with energy from the magnetron cavity resonators, the magnetic field in the magnetron and coupling slots should be directed in approximately the same direction as the field in the TEM mode of the coaxial wave guide. As is well known in the art, the magnetic flux in adjacent cavity resonators of a magnetron operating in the pi mode is in phase opposition. The lines of force of the

R. F. field in the magnetron anode structure follow a serpentine path through the magnetron resonant system, being directed in a first direction in a given cavity resonator, in the opposite direction through the adjacent cavity resonator, in the first direction through the next resonator, etc. Thus, the field first set of alternately disposed cavity resonators is in phase opposition to the field in a second set of alternately disposed cavity resonators positioned between said first set. The magnetic lines of force in a slot pair having slots leading into cavity resonators having fields of opposite phase will be directed in opposite directions. By coupling such slots to different sides of the coaxial line, the fields in the slots will conform substantially with that of the TEM mode of the coaxial wave guide. By coupling energy by way of slots leading into adjacent cavity resonators whose field distribution is of opposite phase into the coaxial output wave guide, the proper excitation of the latter for a maximum transfer of energy is achieved.

The degree of coupling may be further increased by using two or more pairs of slots. One slot of each of the pairs which connects to a cavity resonator of a first set may be coupled to one side of coaxial output wave guide, while the other slot of each pair which connects to a cavity resonator of the second set may be coupled to the other side of the coaxial wave guide.

In the drawing:

Fig. 1 is a cross-sectional view of a magnetron output coupling device in accordance with the invention;

Fig. 2 is an enlarged cross-sectional view of a coaxial conductor taken along line 2—2 of Fig. 1;

Fig. 3 is a perspective view, partially broken away, of a magnetron output coupling device of Fig. 1;

Figs. 4 and 5 are fragmentary views indicating the position of coupling slots of various configuration in the anode cylinder of the magnetron; and

Fig. 6 is a cross-sectional view of a modification of the magnetron output coupling device of Fig. 1.

Since the invention resides in the means for extracting energy from the magnetron, only that portion of the magnetron necessary to the understanding thereof will be shown herein.

Referring to Fig. 1, a portion of a magnetron of the well-known vane type is shown which includes a centrally positioned cathode 12 and an anode structure 14 surrounding said cathode. The anode structure consists of a plurality of radially disposed anode vanes or members 15 extending inwardly from an anode cylinder 16 which forms part of the magnetron envelope. A plurality of cavity resonators 18 is defined by each adjacent pair of said anode members and the portion of said anode cylinder lying therebetween. The anode structure may also be provided with a pair of spaced concentric straps 19, which are connected in the well-known manner to alternate anode vanes to prevent undesirable moding.

Although an anode structure of the vane type is shown, the invention is applicable to any magnetron having a plurality of cavity resonators such as a hole-and-slot type magnetron.

Integral with the anode cylinder 16 is a radially disposed tubular extension 20 forming the outer conductor of a coaxial wave guide 22. The inner conductor 21 of wave guide 22 may also be an extension of a portion of said anode cylinder lying within the boundaries of said tubular extension. Alternatively, the coaxial wave guide 22 may consist of a coaxial line which is welded or otherwise securely attached to the outer wall of anode cylinder 16 in the appropriate position.

The inner and outer conductors of the coaxial wave guide may be tapered, as shown in Fig. 1, whenever necessary to provide appropriate impedance matching between the magnetron and the coaxial line leading to the load.

A pair of irises or slots 24 and 24' are provided in the wall of anode cylinder 16 for extracting energy from two adjacent cavity resonators 18 whose magnetic fields are at all times in phase opposition when operating in the pi mode. The size of the slots is a function of the degree of coupling required, the greater the coupling the larger being the slot size.

The electromagnetic field distribution within the coaxial wave guide for the TEM mode is shown in Fig. 2. The electric field lines are radial as shown in the heavy lines of Fig. 2, while the magnetic field lines, shown by the light lines of Fig. 2, are transverse to the electric lines and encircle the inner conductor. Since the slots are positioned at the rear of the cavity resonators where the R. F. magnetic field is strongest and where the R. F. electric field is relatively weak as compared with that at the vane tips or openings into the cavity resonators, the coupling to the coaxial wave guide by way of the slots 24 and 24' is largely inductive.

A transverse magnetic field for tube 10 may be provided by means of a conventional magnet, not shown completely, but one of whose pole pieces 25 is indicated in Fig. 3.

The configuration of the slots is more or less a matter of choice. Circular slots such as shown in Figs. 1 and 3 may be used and, if more coupling is required, these slots may be extended to form arcuate slots such as shown in Fig. 4. Rectangular slots such as shown in Fig. 5 are mechanically easier to produce and are substantially as effective.

As previously pointed out, the magnetic flux of the high frequency magnetic field in the magnetron extends through one cavity resonator in a first direction, passes over an anode segment or vane and passes through the adjacent cavity resonator in the opposite direction. The field distribution in slots 24 and 24' is in opposite directions inasmuch as they are coupled to cavity resonators of opposite phase. Since slots 24 and 24' are disposed on opposite sides of the inner conductor 21 of coaxial wave guide 22, the flux lines are in one direction on one side of the inner conductor, and in the opposite direction on the other side of the inner conductor. The flux therefore is in a direction suitable for properly exciting the TEM mode of the coaxial wave guide, such as illustrated in Fig. 2.

The amount of energy extracted from the magnetron resonant system may be increased by using more than a single pair of slots, as shown in Fig. 6. In the modification of Fig. 6, an anode cylinder contains a second pair of slots 26 and 26' in addition to the slots 24 and 24' already described in Figs. 1 and 3 to 5. Slot 26, which is located on the same side of the inner conductor 21 as slot 24, is coupled to a cavity resonator whose magnetic field is in phase with that of the cavity resonator to which slot 24 is coupled. Similarly, slot 26' which is located on the same side of conductor 21 as slot 24' is coupled to the cavity resonators whose magnetic field is in phase with that of the resonator to which slot 24' is coupled.

The direction of the lines of magnetic force in the slots coupling energy into the same side of coaxial wave guide is thus the same and the slots are effectively in parallel. Likewise, the lines of magnetic force of the electromagnetic energy in the slots coupled into the opposite side of the coaxial wave guide are similarly directed.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In combination, a magnetron comprising an anode structure including an electrically conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to and extended inwardly from said envelope, each adjacent pair of said anode members together with that portion of said envelope lying therebetween defining a cavity resonator, means for establishing a high frequency electromagnetic field within said cavity resonators whose magnetic lines of force in a first set of alternately disposed cavity resonators are oppositely directed from those in a second set of alternately disposed cavity resonators lying between said first set, a coaxial wave guide having inner and outer conductors connected only to the external portion of said conductive envelope and supported entirely by said envelope, said cylindrical envelope containing at least one pair of coupling slots, one of each said pair of slots being in energy coupling relationship between one of said cavity resonators of said first set and one side of said coaxial wave guide, and the other of each said pair of slots being in energy coupling relationship between one of said cavity resonators of said second set and the other side of said coaxial wave guide.

2. In combination, a magnetron comprising an anode structure including a substantially cylindrical electrically conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to said envelope, each adjacent pair of said anode members together with that portion of said envelope lying therebetween defining a cavity resonator, means for establishing a high frequency electromagnetic field within said cavity resonators, a coaxial wave guide supported entirely by said cylindrical envelope, said cylindrical envelope containing slot means for coupling energy from corresponding cavity resonators into said wave guide, said field in said slots being directed in substantially the same direction as the field in the dominant mode of said coaxial wave guide.

3. In combination, a magnetron comprising an anode structure including a substantially cylindrical electrically conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to said envelope, each adjacent pair of said anode members together with that portion of said envelope lying therebetween defining a cavity resonator, means for establishing a high frequency electromagnetic field within said cavity resonators, a coaxial wave guide supported entirely by said cylindrical envelope, said cylindrical envelope containing slot means for coupling energy from corresponding cavity resonators into said wave guide, said field in said slots being directed in substantially the same direction as the field in the TEM mode of said coaxial wave guide, said slots being free of electrical discontinuities.

4. In combination, a magnetron including an anode structure having a substantially cylindrical electrically-conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to said envelope, each adjacent pair of said anode members together with that portion of the envelope lying therebetween at least partially defining a plurality of cavity resonators, a coaxial wave guide having outer and inner conductors positioned entirely externally of said anode structure, means for establishing a high frequency electromagnetic field within said cavity resonators whose magnetic lines of force in one set of alternately disposed cavity resonators are oppositely directed from those in a second set of alternately disposed cavity resonators lying between said first set, said coaxial wave guide having a pair of allochiral regions bounded by said inner and outer conductors, said inner conductor being connected to a portion of said cylindrical envelope substantially in line with one of said anode members and supported entirely by said envelope, said envelope containing at least one slot coupling means having a first portion thereof extending between a cavity resonator of said first set and one of said allochiral regions, said slot coupling means further including a second por-

tion extending between the cavity resonators of said second set and the other of said allochiral regions of said wave guide, said outer conductor being connected to said envelope outside the region of said slot coupling means.

5. In combination, a magnetron including an anode structure having a substantially cylindrical electrically-conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to said envelope, each adjacent pair of said anode members together with that portion of the envelope lying therebetween at least partially defining a plurality of cavity resonators, a coaxial wave guide having outer and inner conductors positioned entirely externally of said anode structure, means for establishing a high frequency electromagnetic field within said cavity resonators whose magnetic lines of force in one set of alternately disposed cavity resonators are oppositely directed from those in a second set of alternately disposed cavity resonators lying between said first set, said coaxial wave guide having a pair of allochiral regions bounded by said inner and outer conductors, said inner conductor being connected to a portion of said cylindrical envelope substantially in line with one of said anode members and supported entirely by said envelope, said envelope containing a plurality of slot coupling means each having a first portion thereof extending between a cavity resonator of said first set and one of said allochiral regions, each of said slot coupling means further including a second portion extending between the cavity resonators of said second set and the other of said allochiral regions of said wave guide, said outer conductor being connected to said envelope outside the region of said slot coupling means.

6. In combination, a magnetron including an anode structure having a substantially cylindrical electrically-conductive envelope and a multiplicity of radially disposed anode members all of which are electrically and mechanically connected directly to said envelope, each adjacent pair of said anode members together with that portion of the envelope lying therebetween at least partially defining a plurality of cavity resonators, a coaxial wave guide having outer and inner conductors positioned entirely externally of said anode structure, means for establishing a high frequency electromagnetic field within said cavity resonators whose magnetic lines of force in one set of alternately disposed cavity resonators are oppositely directed from those in a second set of alternately disposed cavity resonators lying between said first set, said coaxial wave guide having a pair of allochiral regions bounded by said inner and outer conductors, said inner conductor being connected to a portion of said cylindrical envelope substantially in line with one of said anode members and supported entirely by said envelope, said envelope containing a plurality of slot coupling means each having a first portion thereof extending between a cavity resonator of said first set and one of said allochiral regions, each of said slot coupling means further including a second portion extending between the cavity resonators of said second set and the other of said allochiral regions of said wave guide, said outer conductor being connected to said envelope outside the region of said slot coupling means, said slot coupling means being free of electrical discontinuities.

7. In combination, a magnetron including an anode structure having a substantially cylindrical electrically-conductive envelope and a multiplicity of radially disposed anode member all of which are electrically and mechanically connected directly to and supported entirely by said envelope, each adjacent pair of said anode members together with that portion of the envelope lying therebetween at least partially defining a plurality of cavity resonators, a coaxial wave guide having outer and inner conductors positioned entirely externally of said anode structure, means for establishing a high frequency electromagnetic field within said cavity resonators whose magnetic lines of force in one set of alternately disposed cavity resonators are oppositely directed from those in a second set of alternately disposed cavity resonators lying between said first set, said coaxial wave guide having a pair of allochiral regions bounded by said inner and outer conductors, said inner conductor being connected to a portion of said cylindrical envelope substantially in line with one of said anode members and supported entirely by said envelope, said envelope containing a plurality of slot coupling means having a first portion thereof extending between a cavity resonator of said first set and one of said allochiral regions, said slot coupling means further including a second portion extending between the cavity resonator of said second set into the other of said allochiral regions of said wave guide, said outer conductor being connected to said envelope outside the region of said slot coupling means, said slot coupling means being free of electrical discontinuities.

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