Sept 3, 1957 J. KLINE 2,805,362

MECHANICAL TUNING FOR MAGNETRONS

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FIG. 1

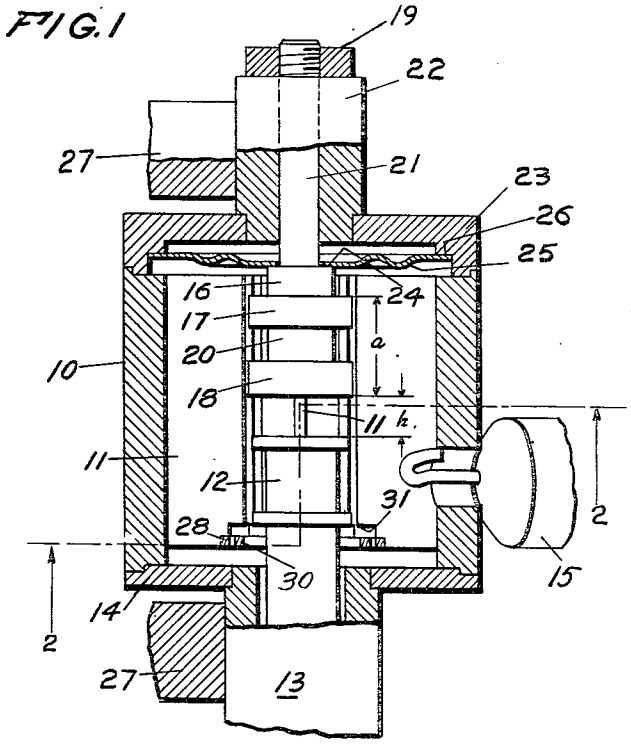
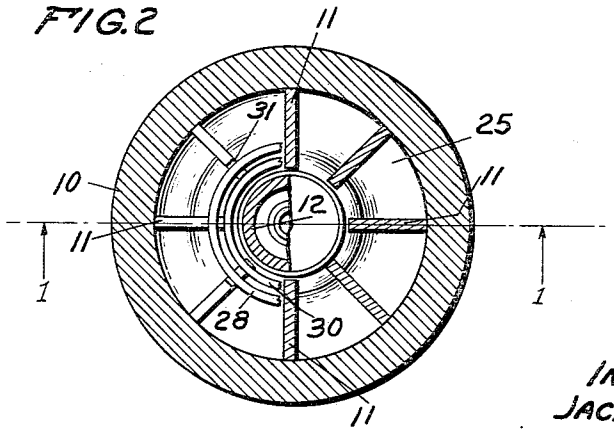


FIG. 2



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FIG. 3

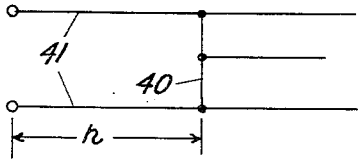


FIG. 4

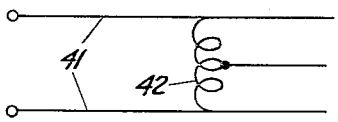
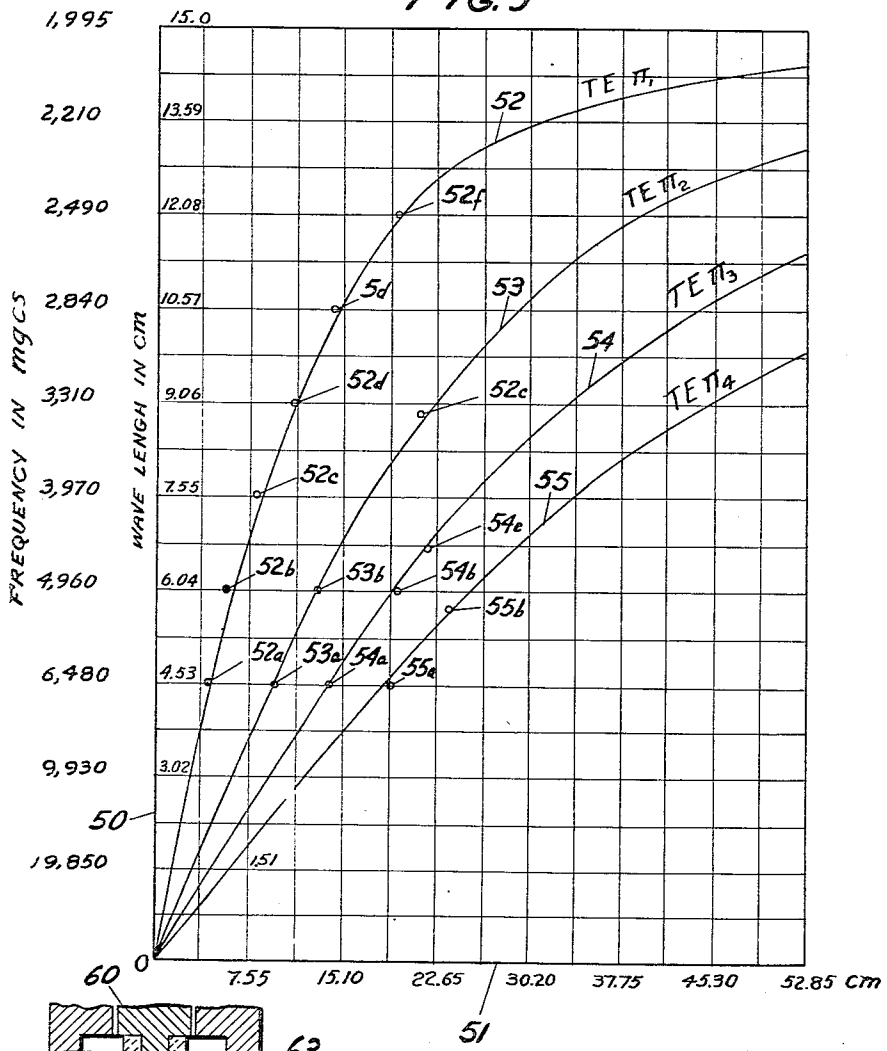


FIG. 5



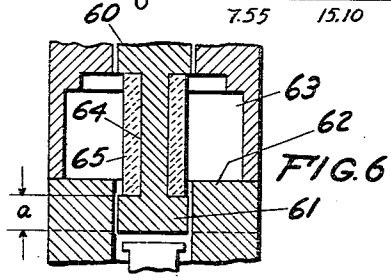


FIG. 6

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MECHANICAL TUNING FOR MAGNETRONS

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Application August 12, 1954, Serial No. 449,397

10 Claims. (Cl. 315—39.61)

This invention relates to mechanical means for tuning a magnetron.

In some applications of multicavity magnetrons it is desirable to be able to tune the oscillator over a wide range of frequencies. This can be done by the known capacitive and inductive tuners. However, when the magnetron anode is formed with many small cavities or when a complicated cavity geometry is used such conventional tuning structures are no longer practical.

The desired broad band tuning range can be achieved in such cases by extending the anode structure of a vaned or multicavity anode beyond one end of the cathode in the axial direction and positioning a structure within the vane tips for axial movement. This structure operates as a noncontacting short across the wave guide considered as formed by the extended anode. The tuning structure can be formed of conductive material as a solid cylinder, or such a cylinder with one or more enlargements. The noncontacting nature of the short requires that some means be provided to prevent energy escaping into the space beyond the short. Coatings of a lossy material applied beyond the short prevent the leakage of energy and thus the development of undesired modes of oscillation. In addition to tuning over a broad band of frequencies, the structure is relatively simple to design and build. It does not introduce interfering modes of operation to the magnetron. Its tuning curve can be quite closely approximated by a mathematical formula. The simplicity of the shape of the tuning structure makes it easier to apply cooling structures to it than to some capacitive tuners.

Other and further objects and advantages of this invention will become apparent as the description thereof progresses, reference being had to the accompanying drawings wherein:

Fig. 1 is a section along the line 1—1 of Fig. 2 of a magnetron embodying the invention;

Fig. 2 is a section along the line 2—2 of Fig. 1;

Fig. 3 is a schematic diagram of a shorted transmission line, the approximate equivalent of the electrical circuit of the invention;

Fig. 4 is a schematic diagram of such a transmission line shunted by an inductance, a closer approximation of the electrical circuit of the invention;

Fig. 5 shows a series of tuning curves for a tunable magnetron of the type shown in Figs. 1 and 2; and

Fig. 6 is a somewhat schematic diagram of a modification of the invention.

In Figs. 1 and 2 the reference numeral 10 designates the anode shell of a magnetron with radial vanes 11 forming a plurality of resonant cavities. A cathode 12 is concentrically located within the vanes 11 and mounted in an opening in the lower pole piece 13 that is fixed in an opening in the lower cover plate 14. An output coupling 15 of any of the well-known designs is mounted in an opening in the outer circular wall of the anode 10 and protrudes into one of the cavities. It will be noted that the vanes 11 extend up beyond the cathode 12. A

cylindrical plunger 16 formed with two enlarged sections 17 and 18 with a central reduced section 20 between them is centrally located within the space defined by the tips of the vanes 11. A threaded extension 21 of the plunger 16 is brought up through an opening in the upper pole piece 22 set in an opening in the upper cover plate 23. A nut 19 is screwed on the threaded portion of the plunger 16 that extends from the pole piece 22. This extension 21 is formed with a shoulder 24 to which a diaphragm 25 is attached. The diaphragm is attached at its outer edge to a shoulder 26 formed on the upper cover plate 23. Any convenient structure that permits mechanical movement through a vacuum tight seal can be used for this purpose. The upper pole piece 22 and the lower pole piece 13 are connected to the magnet 27 to complete the magnetic circuit through the reaction space of the tube. Two straps 28 and 30 are mounted in notches 31 in the bottom of the vanes 11 in the well-known manner.

The operation of the structure is best understood by regarding the extended anode 10 with its vanes 11 as a wave guide or other transmission line with radio frequency energy propagated axially along it as shown schematically in Fig. 3. The plunger 16 can be regarded as a noncontacting movable short 40 terminating the transmission line 41 to form a circuit resonant at a frequency determined by the geometry of the vanes and the plunger and the distance h of the lower face of the plunger, or shorting bar 40 from the upper face of the cathode 12 to form the end of the transmission line 41 as shown schematically in Fig. 3. Each anode cavity can be considered as a separate wave guide with a radial cross-section. If the resonant wavelength is so chosen that it is greater than the cutoff wave length of these smaller wave guides formed by the vanes, and the length of the anode beyond the top of the cathode is long enough, the cavities will act like shunting inductances represented by coils 42 in Fig. 4 and these wave guides will have a virtually constant reactance for all positions of the plunger 16. The anode resonant frequencies and the wave guide wave length can be shown to be related as follows:

$$\lambda_g=\frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda_c}\right)^2}} \tag{1}$$

where

$$\lambda_c=\lambda_n,\ \lambda\frac{n}{2}-1,\ \lambda\frac{n}{2}-2,\ \text{etc.}$$

are the wave lengths at different modes.

λ_0=free space wavelength at the resonant frequency.

λ_g=waveguide wavelength corresponding to a particular mode characterized by λ_c.

At resonance the length of the anode above the cathode h equals

$$\frac{\lambda_g}{4} \text{ which makes } \lambda_g=4h$$

in the case of anode cavities shorted at one end and $\lambda_g=2h$ in the case of anode cavities open at both ends, substituting the first value in Equation 1 and rearranging

$$\lambda_0=\frac{\lambda_c}{\sqrt{1+\left(\frac{\lambda_c}{4h}\right)^2}} \tag{2}$$

More generally for the n mode:

$$\lambda_0=\frac{\lambda_n}{\sqrt{1+\left(\frac{\lambda_n}{4h}\right)^2}} \tag{3}$$

The effect of the straps **28** and **30** is to add capacitive loading to the end of the wave guide. This added capacitive loading can be accounted for mathematically as a correction to the effective length *h*.

If *a* is taken as being either twice or four times the length *h* as indicated above, the tuning rate can be shown to be:

$$\frac{d\lambda}{\lambda^3}=\frac{da}{a^3} \qquad (4)$$

The recessed section **20** of the plunger **16** has the effect of a choke. It serves to isolate the region beyond the shunt from the region between the shunt and the interaction space that would otherwise have an effect on the resonant frequency.

The variation of frequency is shown in Fig. 5 plotted vertically along the line **50** and a dimension *a* equal to twice the length of the effective portion of the extension of the anode structure beyond the reaction space, plotted horizontally along the line **51**. The curves **52**, **53**, **54** and **55** show the calculated relationship between the effective length of the extension for the fundamental Pi mode and higher Pi modes. The points **52** *a*, *b*, *c*, *d*, *e*, and *f*, **53** *a*, *b*, and *c*, **54** *a*, *b*, and *c*, and **55** *a* and *b* are experimentally determined points from measurements made by cold testing a representative magnetron having a tuning structure made in accordance with the invention. It will be noted that the relationship between the displacement of the plunger and the resulting frequency is approximately linear at higher frequencies for the fundamental Pi mode and less linear for the lower frequencies in the higher mode.

Fig. 6 shows another embodiment of the invention. A tuning plunger **60** is formed with a single enlarged section **61**. This plunger is shown suspended within the cylindrical space defined by the vanes **62** of the anode cavity **63**. The restricted portion **64** of the plunger **60** has a coating **65** of a lossy material, preferably a cermet, that is, a mixture of ceramic and metallic materials which serves to cause losses that present a termination to the active portion of the plunger. The impedance of this termination is relatively independent of the geometry of the cavity beyond the effective portions **61** of the plunger **60**.

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. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space.

2. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material, formed with a portion having a reduced cross-sectional area located between portions of larger cross area, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space.

3. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure

for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space, comprising a threaded extension on said piece mounted in said anode structure and a flexible diaphragm connecting said piece and said anode structure.

4. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in juxtaposition to the openings in the anode cavities, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space.

5. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in juxtaposition to the openings to the anode cavities, a layer of lossy material about the piece immediately behind the enlarged portion, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space.

6. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in juxtaposition to the openings to the anode cavities, a layer of a mixture of ceramic and metallic material about the piece immediately behind the enlarged portion.

7. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area located between portions of larger cross-sectional area, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space comprising a threaded extension on said piece mounted in said anode structure and a flexible diaphragm connecting said piece and said anode structure.

8. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in juxtaposition to the openings to the anode cavities, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space comprising a threaded extension on said piece mounted in said anode structure and a flexible diaphragm connecting said piece and said anode structure.

9. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure

for producing a magnetic field in the space between said cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in juxtaposition to the openings to the anode cavities, a layer of lossy material about the piece immediately behind the enlarged portion, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space comprising a threaded extension on said piece mounted in said anode structure and a flexible diaphragm connecting said piece and said anode structure.

10. A tunable electron discharge device comprising a cathode, an anode structure formed with resonant cavities arranged coaxially about said cathode and extending beyond said cathode, means adjacent said anode structure for producing a magnetic field in the space between said

cathode and anode, a cylindrical piece of conductive material formed with a portion having an increased cross-sectional area in justaposition to the openings to the anode cavities, a layer of a mixture of ceramic and metallic material about the piece immediately behind the enlarged portion, means to support said piece coaxially within said anode in the space beyond said cathode and to move said piece axially within said space comprising a threaded extension on said piece mounted in said anode structure and a flexible diaphragm connecting said piece and said anode structure.

References Cited in the file of this patent

UNITED STATES PATENTS

2,408,237 Spencer ---------- Sept. 24, 1946