July 19, 1966 R. C. SIBLEY 3,262,009

MAGNETRON TUNABLE BY HYDRAULICALLY VARYING THE CAVITY PENETRATION OF CONDUCTIVE MATERIAL WITHIN A MAGNETIC FIELD PERMEABLE TUBE

Filed Feb. 27, 1963 2 Sheets-Sheet 1

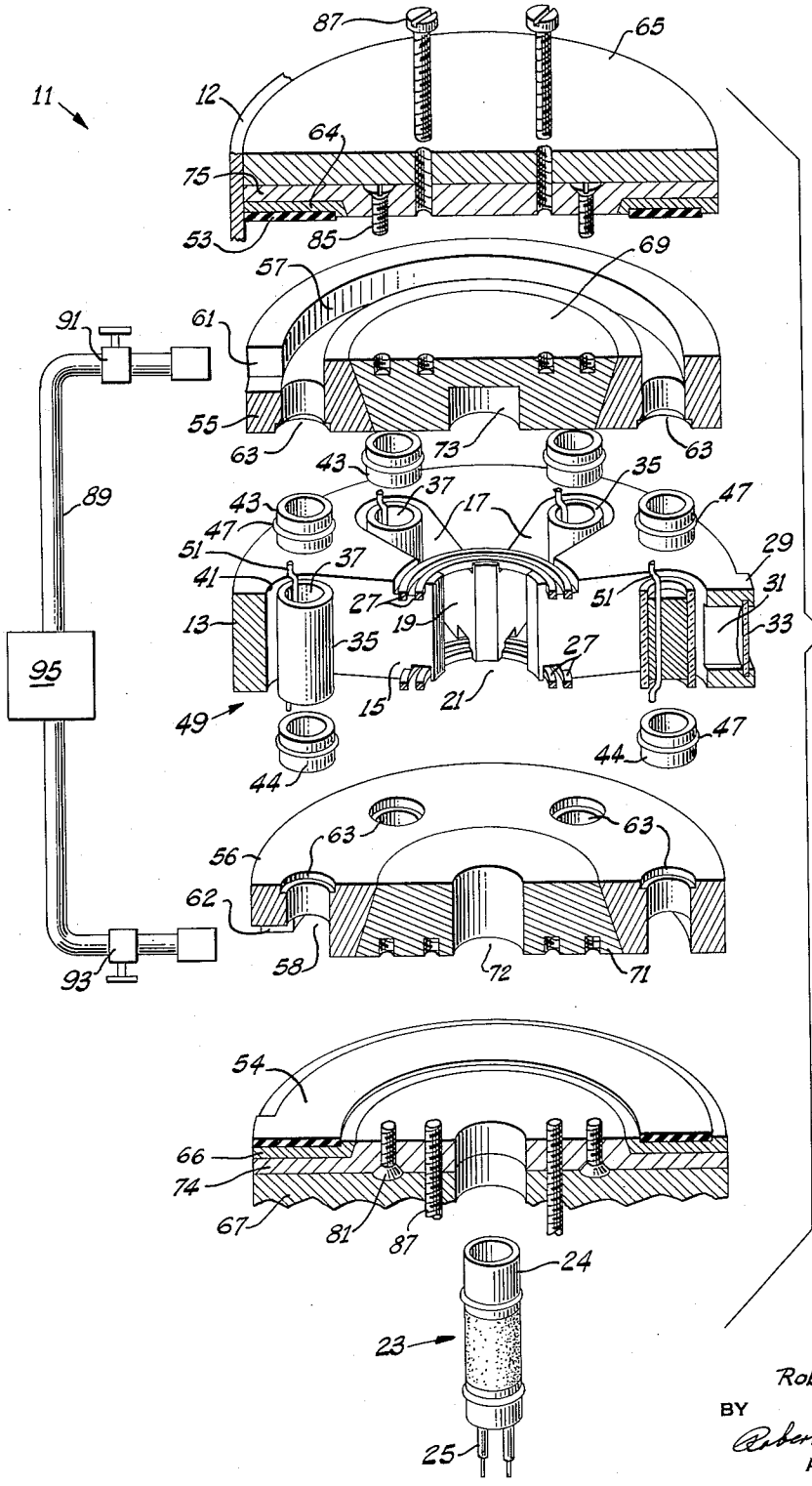


Fig. 1

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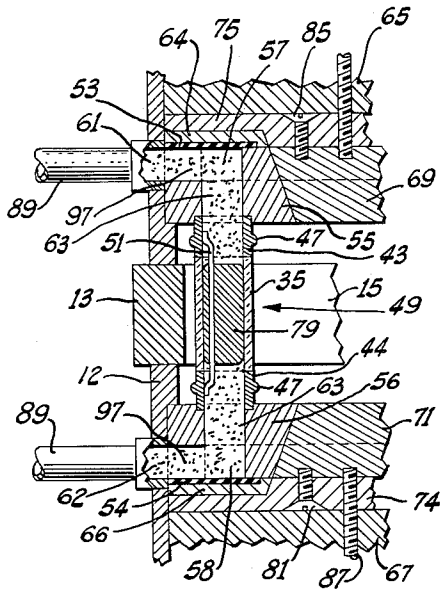


Fig. 2

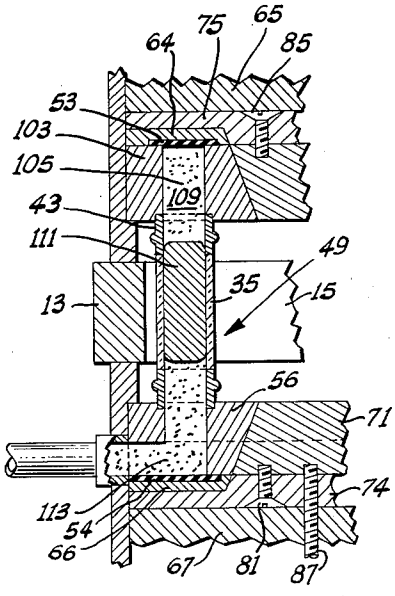


Fig. 3

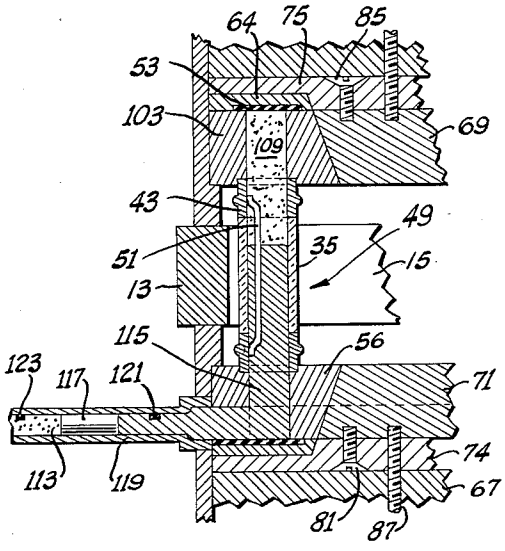


Fig. 4

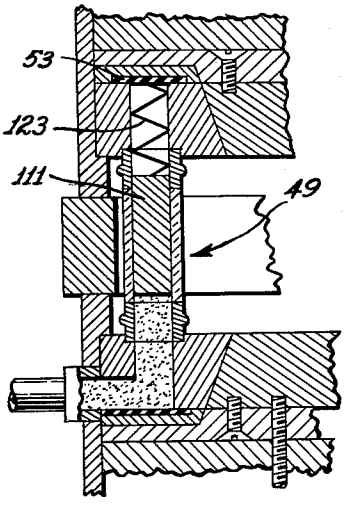


Fig. 5

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MAGNETRON TUNABLE BY HYDRAULICALLY VARYING THE CAVITY PENETRATION OF CONDUCTIVE MATERIAL WITHIN A MAGNETIC FIELD PERMEABLE TUBE

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9 Claims. (Cl. 315—39.55)

This invention relates to tunable high frequency crossed field electron discharge devices and more particularly to multi-cavity magnetrons wherein several or all of the resonator cavities are capable of being tuned to desired frequencies. The invention is particularly advantageous for tuning multi-cavity magnetrons structurally proportioned for operation in the X-band frequency range of 11,500 to 9,500 megacycles or lower. In this band, a 10 to 12 percent tuning range can be advantageously achieved by use of the invention.

In a typical tunable magnetron of the type desired above, the anode structure comprises a plurality of adjacent resonators arranged in circular array and separated by radial walls or vanes extending inwardly from a common cylindrical outer wall and opening into a central longitudinal bore defining a central anode chamber wherein a thermionic cathode is axially positioned. Conventional means for tuning a magnetron of the aforementioned construction usually involves conductive metal pins or plungers moving into and out of several or all of the resonator cavities.

The insertion of the metal plungers into the resonator cavities modifies the resonating frequencies thereof either inductively, capacitively, or in combinations thereof, depending upon the specific region within the resonator which is predominantly affected. Plunger orientation in the space near the back or outer wall of the resonator cavity produces maximum inductive tuning, while moving the region of plunger insertion forwardly within the cavity toward the central bore opening increases the capacitive tuning effects.

In order to achieve simultaneous tuning of all desired cavities, the metal tuning pins are usually spacedly affixed to a common ring which, in turn, is attached to a piston-like member capable of being moved by means external of the magnetron. Surrounding the piston member and associated with it is a metal bellows-type seal which facilitates motion of the piston while maintaining the vacuum within the internal magnetron anode region. Thus, unitary motion is provided for the plurality of internal metal plungers which are movably oriented within the evacuated resonator cavities.

The bellows seal mentioned above is subjected to a large force differential which must be overcome in consummating desired movement of the internal tuning pins since the expansible movement of the bellows operates against atmospheric pressure. The inability to overcome this force differential at a high rate of speed is a limiting factor to the tuning speed characteristics of the tube. In addition, operational flexure of the metal bellows produces cold working of the metal along the lines of flexure with resultant crystallization or embrittlement of the bellows metal which provides a fatiguing condition precursory to fracture and contributory to unpredictable life reliability. Also, at high tuning speeds, bellows resonance is sometimes encountered as another troublesome problem.

Internally, i.e., within the magnetron structure described above, guide sleeves or rings connected with the anode structure are usually required to maintain proper alignment of the individual tuning pins positionally within each of the resonator cavities being tuned. In this instance, it is desirable that definite and deliberate frictional

contact be maintained between the individual tuning pins and guide sleeves or rings to prevent detrimental heat rise in the pins and tuning slope variations due to pin resonances. However, these guide sleeves and tuning pins present frictional drag and rapid wear problems when driven at high velocities necessary to achieve rapid sweeping of desired frequency ranges.

Accordingly, it is an object of this invention to reduce the aforementioned disadvantages by improving and simplifying multi-cavity magnetron tuning.

Another object is to provide efficient tuning means capable of being repetitively cycled or maintained at a desired frequency.

A further object is to eliminate anode arcing in tunable magnetrons.

The foregoing objects, as well as other objects which will become apparent after reading the following description, are achieved in one aspect of the invention by the provision of a multi-cavity magnetron having a plurality of magnetic-field-permeable pressure-tight tubes longitudinally positioned within one or more of the resonator cavities for confining movable tuning material.

Depending upon the type of tuning desired, i.e., inductive or capacitive, these tubes are located in the resonator cavities relative to the back walls or forward openings thereof. Each tube contains a specific quantity of electrically conductive metal that is movable therein. The ends of the individual field-permeable tubes may be sealed into metal extension tubes and thence into common manifolds located on parallel planes with the anode structure positioned therebetween. Each manifold may have an external outlet for connection to a common pump and valve arrangement forming a closed pressure-tight system.

A quantity of inert gas or hydraulic liquid may be used in the manifold system which, by pressure regulation, will cause the tuning material within the several magnetic-field-permeable tubes and extensions to move simultaneously and equidistantly into and out of the resonator cavities, thereby effecting cavity tuning of the magnetron.

For a better understanding of the present invention, together with other and further objects, advantages, and capabilities thereof, reference is made to the following disclosure and appended claims in connection with the accompanying drawings in which:

FIG. 1 is an exploded perspective sectional view of a multi-cavity magnetron detailing one embodiment of the tuning means;

FIG. 2 is a sectional view of the magnetron assembly shown in FIG. 1;

FIG. 3 shows a modification of the tuning structure illustrated in FIG. 2;

FIG. 4 illustrates another modification of the tuning mechanism; and

FIGURE 5 shows a modification of the tuning structure illustrated in FIGURE 3.

Referring in detail to FIGURES 1 and 2, there is shown a magnetron structure **11** comprising a casing **12** and a formed anode block **13** having a number of radially spaced walls or vanes **15** extending interiorly in a convergent manner to form a plurality of like resonator cavities **17**. These cavities have forward openings **19** into an axial bore **21** wherein there is longitudinally positioned an electron emissive cathode **23** containing a thermionic heater **25**. Shorting rings or straps **27** are conventional structures usually associated with multi-cavity magnetrons of this nature to provide mode stability. A waveguide output **29** communicates with one of the resonator cavities **17** by means of a longitudinal opening or slot **31** in the back wall thereof. A window **33**, suitable for the passage of microwave energy, is hermetically affixed to the waveguide output **29**.

Each of several or all of the resonator cavities 17 has longitudinally and spacedly mounted therein a magnetic-field-permeable pressure-tight tube 35 as of ceramic, hard glass, or quartz having a hollow interior 37.

For X-band operation, these tubes 35 may have an external diameter of approximately .100 to .120 inch and an internal diameter in the neighborhood of .080 to .100 inch. As previously stated, these field-permeable tubes 35 are cavity oriented to produce the desired tuning effect. As shown in FIGURES 1 and 2, they are substantially positioned in the rear portions of the resonator cavities 17 in spaced relationship with the backs or outer walls 41 of the cavities 17, and as such are oriented substantially for inductive tuning effects. As has been heretofore mentioned, the array of field-permeable tubes 35 may be moved forwardly within the cavities 17 toward openings 19 to achieve tuning results of a capacitive nature.

Referring to FIGURE 2, the magnetic-field-permeable tubes 35 are of a length slightly in excess of the height of anode wall 15 and have like metallic extension tubes 43 and 44 of similar internal diameters hermetically sealed thereto as by welding or brazing to form a composite tripartite tubular structure 49. Extension tubes 43 and 44 are of a suitable metal such as an iron-nickel-cobalt alloy of the type commercially available from Westinghouse Electric Corporation under the trade name Kovar. These tubes have peripheral folds or expansion portions 47 to provide for longitudinal expansion of the composite tripartite tubular structure 49. There is contained within each tripartite longitudinal tube 49, proximal to the sidewall thereof, a metallic arc-prevention electrical conductor 51 in the form of a wire or ribbon as of molybdenum or Kovar. The ends of this conductor are affixed to extension tubes 43 and 44, as by welding or brazing to insure electrical contact therewith. For clarification, these conductors are shown in FIGS. 2 and 4 as being positioned substantially away from the sidewalls of the tripartite tubes 49.

On either side of the anode block 13 and spaced therefrom are two circular metallic manifolds 55 and 56 preferably made of copper or copper alloy having substantially a concave bore contour conventional of end fillers. Each of these manifolds contains like circular conductor chambers 57 and 58 which have a plurality of spaced ports or openings 63 dimensionally matching the ends of tripartite tubes 49 and are hermetically sealed thereto as by welding or brazing to form a closed manifold system having external openings 61 and 62 which subsequently function as inlet and outlet connections. Circular manifolds 55 and 56 have removable cap portions 64 and 66 which facilitate access to the plurality of tripartite tubes 49 and conductor chambers 57 and 58, respectively. Compression closure sealing rings 53 and 54 are seatingly associated with cap portions 64 and 66 to effect pressure seals therewith for conductor chambers 57 and 58.

There are positioned on either side of the anode block 13, in spaced planar relationship therewith, magnet pole structures 65 and 67 of iron or steel having terminal portions 69 and 71 formed substantially as conical frustums being diametrically and angularly dimensioned to mate with the concave bores of the circular end filler manifolds 55 and 56.

Magnet pole piece 67, aside from accommodating end filler manifold 56, is substantially conventional in design and structure having hermetically sealed therein the positioning structure, not shown, for supporting cathode 23.

Manifold 56 is peripherally seated in magnetron casing 12 and hermetically affixed thereto as by brazing or welding. The pole terminal portion 71, containing an axial bore 72 to accommodate the passage therethrough of the supporting structure for cathode 23, is mated with the bore of manifold 56 and hermetically sealed therein. Pole piece lamination 74 is formed to provide recessed peripheral accommodation for manifold cap 66 which is

seated for compression closure on sealing ring 54. Pressure sealing of cap 66 to end filler manifold 56 is achieved by clamping pole lamination 74 to pole termination portion 71 by utilizing a plurality of equidistantly spaced threaded securing means 81, two of which are shown in FIG. 1. The remainder of the pole piece structure 67, partially shown, may be attached by suitably threaded securement 87 or by other means such as welding or brazing.

After hermetically affixing the plurality of tripartite tubes 49 into the respective parts 63 of manifolds 55 and 56, in proper spaced relationship with anode block 13, the opposite pole piece 65 is next considered. This magnet pole structure is also of laminated construction. Terminal portion 69 contains a centered recess 73 to accommodate the terminal end 24 of cathode 23. As previously mentioned, this conical frustum portion 69 is externally formed for circular engagement with manifold 55 to which it is sealed to provide a hermetic closure.

Thus far there has been described an integrated structural unit which at this stage of construction may be processed, baked, and evacuated. The tuning means is not complete at this stage, but since the manifold system associated with tuning is pressurally different than the interior of the magnetron, there is no hindrance to the processing of the heater 25, cathode 23, and anode 13 portions. A vacuum may be drawn through conventional structures, not shown, in conjunction with pole piece 67; and the heater 25, cathode 23, and anode 13 region sealed as a processed unit.

Since circular manifold 55 has a removable cap portion 64, tuning materials 79 may be placed in the tripartite tubes 49 subsequent to the processing of the internal magnetron structure. Pole piece lamination 75 is formed to provide recessed peripheral accommodation for manifold cap 64 which may be seated for compression closure in conjunction with sealing ring 53. The sealing of cap 64 to end filler manifold 55 is pressurally accomplished by clamping pole lamination 75 to terminal portion 69 through the utilization of a plurality of equidistantly spaced threaded securing means 85, two of which are shown in FIG. 1. Thenceforth, the remaining structure of pole piece 65 is added by a plurality of suitable threaded securement 87.

Several electrical conductive tuning materials 79 can be introduced into the longitudinal tripartite tubes 49 and movably contained therein. The electrical conductivity of this material 79 is important as the conductivity of the material is related to tuning effectiveness. Since the magnetron tuning characteristics can be altered by changing the composition of the movable tuning material 79, a number of materials can be considered for this function. As in other high frequency microwave phenomenon, it is essentially the surface characteristics of the conductive materials that assume greater importance in effectual results.

Mercury is an electrical conductive liquid metal adaptable for usage as movable tuning material 79. It has a boiling point of 350° C. which is well above the 150–200° C. anode operating temperature. Since this tuning material is added to the magnetron tuning manifold system after processing, the tube bake-out and processing temperatures need not be considered. If it is desirable to increase the electrical and thermal conductivities of mercury, a liquid amalgam can be formed for example as with silver.

Specific quantities of mercury, liquid amalgam, or metal bearing liquid 79 are positioned in like manner in all tripartite tubes 49. In each tube the quantity of tuning material is equal to the height of the anode block 13, but this may be varied in accordance with tuning requirements. The manifold openings 61 and 62 are connected by tubular conduction means 89 through valving means 91 and 93 with external pressure means 95. The medium 97 for moving the tuning material 79 such as dry nitro-

gen or high temperature hydraulic liquid can be introduced into the tuning system at pressure means **95** and pressurized to cause simultaneous movements of tuning materials **79** in all tripartite tubes **49** so that the tuning materials are made to move into and out of the resonator cavities **17** through predetermined programming of pressure means **95** and valving means **91** and **93**. As the mercury tuning material **79** moves within tripartite tube **49**, it is in contact with the metallic arc-prevention electrical conductor **51** which has previously been mentioned. This conductor **51** not only prevents arcing between the mercury tuning material **79** and the anode block **13** but also aids in cooling the tuning material **79**. Further cooling is enhanced by conduction contact of the tuning material with the metallic extension tubes **43** and **44**. If an inert gas medium **97** is used for moving the tuning material **79** with respect to resonator cavities **17**, a pressure modification may be introduced by closing valving **91** and using the gas contained within top manifold **55** and top extension tubes **43** to form a gaseous back-pressure cushion acting on one side of liquid tuning means **79** in counteraction to the actuated pressure applied to the other side of tuning material **79**.

A related modification is shown in FIGURE 3 wherein the top manifold **55** is replaced by a terminal tube structure **103** which is of similar shape and external dimensions but wherein common conductor chamber **57** and external opening **61** are eliminated. The structure **103** contains a plurality of individual longitudinally spaced bores **105** which are matched and sealed to tripartite tubes **49**. These bores are terminally sealed with a cap **64** and a compression seal **53**, which are pressurally held in place by pole lamination **75**. By this procedure, the individual tripartite tubes **49** and contiguous bores **105** are individually capped and gaseous pockets **109** of inert atmosphere such as nitrogen are trapped between movable tuning means **111** and closure seal **53** to provide a cushion of back pressure to counteract the pressurized movement of tuning means **111** as by liquid or gas **113** through manifold **56**. Thus a back-pressured reciprocating force is provided. As shown in FIGURE 5, an alternate means for imparting back pressure to tuning means **111** is accomplished by suitably positioning a tempered metallic compressive and expansive means such as a resilient helix **123**, shown schematically, in each tube **49** substantially adjacent the closure seal **53**.

Individually, tuning means **111** is longer than magnetic field permeable tube **35** so that constant electrical contact may be maintained between tuning means and either of extension tubes **43** or **44** to prevent arcing to the anode **13**. Tuning means **111** is a cylindrical member having an electrically conductive metallic surface and may be a metallic solid, a metallic plated ceramic, or a closed evacuated metallic capsule. Its diametrical dimension is slightly less than the internal diameter of tripartite tube **49** to provide for a sliding piston-type movement therein. Thus the material composition of the tuning means must be expansively compatible with that of the tripartite tubular structure **49** to maintain efficient sliding relationship without compression loss. Although not shown, the rod-like tuning member **111** may be equipped with a set of circuliar expansion rings to provide a compression fit under temperature variations when a critical mismatch of materials exists.

As mentioned heretofore, surface conductivity is important in tuning effectiveness. Therefore, movable tuning means **111** may utilize external platings or claddings of desired metals such as copper, aluminum or silver on moly, tungsten, or ceramic base materials. Ferromagnetic materials should be avoided because of their retentivity of induced magnetism from the magnetron field which is a factor hindering tuning material movement for desired tuning efficiency.

As shown in FIGURE 4, the triparitite tubular structure **49** and the terminal tube structure **103** are the same as shown in FIGURE 3. Contained therein a liquid tuning material **115** such as mercury, mercury amalgam, or a metal bearing liquid in the form of columns extending from the full circular manifold **56** into tripartite tubes **49**. A circular rod-like member **117** actuated by pressurized liquid or gas **113** is movable as a piston within tube **119** between internal stops **121** and **123**, causing tuning liquid **115** to rise in tripartite tube **49**. Gaseous pocket **109** of inert atmosphere is compressed as a counteracting back-pressure cushion as previously described. In order to maintain equal quantities of tuning liquid **115** in each of the tripartite tubes **49**, it is important that a partial volume of tuning liquid **115** be contained in each tube **49** at maximum phase of liquid **115** withdrawal.

As described above, the movable tuning material may be moved completely through the resonator cavities **17** and returned in like manner, or it may be fluctuated into and out of a certain depth or height of the resonator cavities, or it may be stationarily maintained at a desired penetration of the cavities. In addition, the tuning materials may be varied to accomplish desired tuning effects. Also, the tuning means described herein is adaptable to applications wherein several anode structures may be spacedly positioned in stacked sequence. Thus a versatile, yet simplified, tunable multi-cavity magnetron has been provided which is capable of rapid and repetitive frequency cycling and is not limited by arcing or the fatigue of flexible tuning members. Also, the need for unwieldly internal and external tuning structures and accessories has been eliminated.

While there have been shown and described what are at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

1. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

a plurality of magnetic field permeable pressure-tight tubes extending through at least some of said resonator cavities;

electrically conductive tuning material movably contained within said tubes; and

fluid pressure means operatively connected to said tuning material to provide movement thereof within said tubes to achieve like frequency tuning of said resonator cavities.

2. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

two like pressure manifolds sealed to the open ends of said longitudinal tubes in parallel planes perpendicular to said tubes with said anode structure positioned therebetween;

electrically conductive tuning material movably contained within each of said tubes;

a quantity of inert gas contained within said manifolds; and

pressure means operable upon said gas to provide movement of said tuning material equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

3. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longi-

tudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

two like pressure manifolds sealed to the open ends of said longitudinal tubes in parallel planes perpendicular to said tubes with said anode structure positioned therebetween;

a column of electrically conductive liquid movably contained within each of said tubes,

a quantity of inert gas contained within said manifolds; and

pressure means operable upon said gas to provide movement of said columns of electrically conductive liquid equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

4. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

two like pressure manifolds sealed to the open ends of said longitudinal tubes in parallel planes perpendicular to said tubes with said anode structure positioned therebetween;

a rod-like column of electrically conductive material movably contained within each of said tubes;

a quantity of inert gas contained within said manifolds; and

pressure means operable upon said gas to provide movement of said rod-like columns of electrically conductive material equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

5. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally sapced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

two like pressure manifolds sealed to the open ends of said longitudinal tubes in parallel planes perpendicular to said tubes with said anode structure positioned therebetween;

a rod-like column of electrically conductive material movably contained within each of said tubes;

a quantity of liquid contained within said manifolds; and

pressure means operable upon said liquid to provide movement of said rod-like columns of electrically conductive material equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

6. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

a tube terminal structure providing a closure cap for one end of said longitudinal tubes, said terminal structure being positioned in a plane perpendicular to said tubes with said anode structure positioned in spaced parallel relationship thereto;

a pressure manifold sealed to the open ends of said longitudinal tubes in a plane perpendicular to said tubes said manifold being in a plane parallel with said terminal structure and spaced therefrom with said anode structure positioned in spaced relationship therebetween;

a quantity of electrically conductive liquid filling said manifold and movably contained partially within each of said tubes;

pressure means operable upon said liquid to provide movement thereof equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

7. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

a tube terminal structure providing a closure cap for one end of said longitudinal tubes, said terminal structure being positioned in a plane perpendicular to said tube with said anode structure positioned in spaced parallel relationship thereto;

a pressure manifold sealed to the open ends of said longitudinal tubes in a plane perpendicular to said tubes, said manifold being in a plane parallel with said terminal structure and spaced therefrom with said anode structure positioned in spaced relationship therebetween;

a cylindrical member having an electrically conductive surface movably contained within each of said tubes;

a quantity of inert gas contained within said manifold; and

pressure means operable upon said gas to provide movement of said tuning member equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities.

8. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

a tube terminal structure providing a closure cap for one end of said longitudinal tubes, said terminal structure being positioned in a plane perpendicular to said tube with said anode structure positioned in spaced parallel relationship thereto;

a pressure manifold sealed to the open ends of said longitudinal tubes in a plane perpendicular to said tubes, said manifold being in a plane parallel with said terminal structure and spaced therefrom with said anode structure positioned in spaced relationship therebetween;

a cylindrical member having an electrically conductive surface movably contained within each of said tubes;

a quantity of inert gas contained within said manifold;

pressure means operable upon said gas to provide movement of said tuning member equidistantly and simultaneously within each of said longitudinal tubes to achive like frequency tuning of said resonator cavities; and

a like quantity of inert gas confined within each of said tubes between the closure cap thereof and the adjacent surface of said tuning member to provide a resilient gaseous cushion for imparting back pressure to said tuning member in reciprocation to pulsed pressure means.

9. In a tunable magnetron having an anode structure formed to provide a plurality of evacuated resonator cavities opening into an axial bore wherein a cathode is longitudinally positioned and substantially centrally spaced, cavity tuning means comprising:

magnetic field permeable pressure-tight tubes longitudinally mounted in said resonator cavities;

a tube terminal structure providing a closure cap for one end of said longitudinal tubes, said terminal structure being positioned in a plane perpendicular to said tube with said anode structure positioned in spaced parallel relationship thereto;

a pressure manifold sealed to the open ends of said longitudinal tubes in a plane perpendicular to said tubes, said manifold being in a plane parallel with said terminal structure and spaced therefrom with said anode structure positioned in spaced relationship therebetween;

a cylindrical member having an electrically conductive surface movably contained within each of said tubes;

a quantity of inert gas contained within said manifold;

pressure means operable upon said gas to provide movement of said tuning member equidistantly and simultaneously within each of said longitudinal tubes to achieve like frequency tuning of said resonator cavities; and

a tempered metallic helix, capable of compression and expansion, positioned within each of said tubes adjacent the closure cap thereof and the tuning member to provide a resilient cushion for imparting back pressure to said tuning member in reciprocation to pulsed pressure means.

References Cited by the Examiner

UNITED STATES PATENTS

3,187,220 6/1965 Dench ---------- 315—39.55

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