July 29, 1947. K. C. DE WALT 2,424,805

HIGH FREQUENCY MAGNETRON

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Fig. 1.

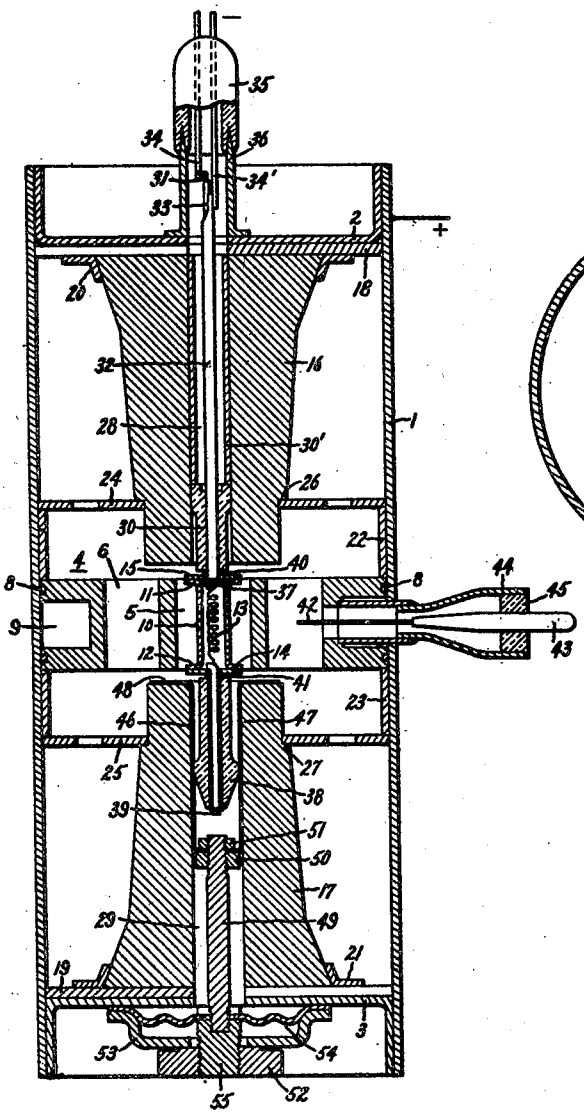
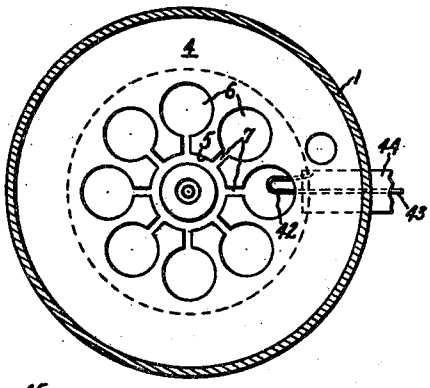


Fig. 2.



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HIGH-FREQUENCY MAGNETRON

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13 Claims. (Cl. 250—27.5)

1

My invention relates to high frequency electric discharge devices of the space-resonant type, and more particularly to ultra high frequency magnetrons.

In the construction and operation of high frequency electric discharge devices of the space-resonant type, where the natural frequency of the devices is determined by the distributed electrical constants of one or more of the elements such as the anode structure, it has been required heretofore to provide a number of devices having different natural frequencies, or operating frequencies, where the load requirement demands an appreciable range of frequencies. In accordance with the teachings of my invention described hereinafter, I provide a new and improved electric discharge device of the magnetron type which permits the use of a single discharge device to meet these requirements.

It is an object of my invention to provide a new and improved high frequency electric discharge device of the space-resonant type.

It is another object of my invention to provide a new and improved electric discharge device of the magnetron type.

It is another object of my invention to provide a new and improved high frequency electric discharge device of the magnetron type, the operating frequency of which is controllable or adjustable.

It is a still further object of my invention to provide a new and improved electric discharge device of the magnetron type including a tunable or controllable space resonant region or cavity, or cavities.

It is another object of my invention to provide a new and improved ultra high frequency electric discharge device of the magnetron type provided with temperature responsive frequency controlling means.

It is a still further object of my invention to provide a new and improved ultra high frequency magnetron of the space-resonant type which is provided with readily accessible external frequency controlling or adjusting means.

Briefly stated, in the illustrated embodiment of my invention I provide a new and improved ultra high frequency electric discharge device or oscillator of the magnetron type including a space resonant region, or regions, the natural frequency of which is controllable or adjustable by means of a member which is positionable with respect to the anode structure comprising the space resonant region, thereby affording means for controlling or adjusting the operating frequency of the device. In accordance with a further feature of my invention, the frequency controlling means may be operated in response to the temperature of the device to compensate automatically for temperature variations, thereby maintaining the operating frequency of the discharge device, or system, at a substantially constant value for a predetermined setting of the frequency controlling means.

2

Fig. 1 of the accompanying drawing diagrammatically illustrates an embodiment of my invention as applied to an electric discharge device of the magnetron type employing a pair of magnetic field pieces oppositely disposed relative to a centrally located anode structure including a space resonant cavity, or cavities; and Fig. 2 is a detailed view of the anode structure.

Referring particularly to Fig. 1, there is shown an elongated cylindrical container the lateral wall structure of which is provided by a single metal envelope or containing member 1, preferably of tubular form, constructed of a ferromagnetic material such as cold rolled steel, or the like. The ends of the container are enclosed by flanged members 2 and 3 which are welded or otherwise hermetically joined to the containing member 1. The outer surface of the envelope or member 1 may be provided with a plurality of heat dissipating means such as fins (not shown).

Within the containing member 1 and approximately at its central region there is provided an anode structure 4 shown in plan view in Fig. 2. The anode structure comprises a circular member which has a relatively large central opening 5 and a series of smaller openings 6 arranged symmetrically about the central opening 5. The central opening is joined to the openings 6 by means of a plurality of radially extending slots 7.

The anode structure 4, which preferably consists of copper, is supported by being brazed to the interior wall surface of member 1. To facilitate the brazing operation, small channels 8 are cut into the outer periphery of the structure 4, and these are used to receive rings of brazing material applied before the anode structure is inserted within the containing member 1. A relatively large circumferentially extending channel 9 may be employed to reduce the overall weight of the structure.

Within the central opening 5 of the anode structure, I employ an indirectly heated cathode comprising a sleeve 10, of nickel or other suitable material, having flanges 11 and 12 at the ends thereof. This sleeve, which may be coated

externally with a suitable activating material such as barium oxide, contains a filamentary heating element 13 by which the sleeve 10 may be maintained at an electron emissive temperature. One end of the cathode sleeve 10 is enclosed by a metal disc 14 and the other end of the sleeve is enclosed by an apertured disc 15. In the operation of the electric discharge device a space charge is developed in the space between the cathode sleeve 10 and the surrounding anode structure 4 by the application of a suitable potential impressed between the cathode structure and the containing member 1. The containing member 1, to which the anode structure 4 is directly connected, may have impressed thereon a unidirectional potential, such as a positive potential, and the other terminal for the unidirectional circuit is connected to the cathode structure by apparatus to be described presently.

The electrons which constitute the space charge are given a spiral or orbital motion by a magnetic field which is produced by electromagnetic structure, or by permanently magnetized field pieces to be described presently. The resultant gyrations or oscillations of the electrons constituting the space charge produce excitation of the anode structure at a frequency which is correlated to the natural frequency of the space resonant regions which is determined by physical dimensions of the openings 6 considered in conjunction with the slots 7. The function of the anode structure in this respect may be explained from one point of view by considering that it is made up of a plurality of space resonant regions in each of which inductance is provided by a wall surface bounding one of the circular openings 6 and capacitance is provided by the opposing surfaces of one of the slots 7. Assuming this point of view, it will be seen that the operating frequency is in a large measure determined by the dimensions of the openings 6.

In order to provide a magnetic field of sufficient intensity to permit the apparatus to function in its intended manner, there are provided within the containing member 1 tapered magnetic pole pieces 16 and 17 which are directed axially of the containing member 1 and may extend in close proximity to the upper and lower surfaces of the anode structure 4. For present purposes, these pole pieces may be assumed to be permanently magnetized in such a sense that the north pole of one faces the south pole of the other.

To assure the existence of the magnetic field of the required intensity, the pole pieces 16 and 17 should be constructed of a magnetizable substance having a high coercive force and a high energy factor. One of the materials which may be used for this purpose is that class of alloys including aluminum, nickel and cobalt. Alloys of this type are described, for example, in the Mishima Patents No. 2,027,994 to No. 2,028,000.

As a means for providing a low reluctance connection between the base ends of the magnetic pole pieces 16 and 17, the pole pieces may be respectively seated upon relatively thick disc-like members 18 and 19 constructed of ferromagnetic material, such as steel. For the purpose of securing the pole pieces rigidly to the discs 18 and 19, I may employ clamping rings 20 and 21 slipped over the pole pieces and welded to the disc members.

The desired precise placement of pole pieces 16 and 17 with reference to the anode structure 4 may be obtained by the use of spacing rings

22 and 23. As will be observed from Fig. 1, each of these rings is interposed between one surface of the anode structure 4 and the surface of the apertured discs 24—25, each disc in turn being in abutment with a properly positioned and formed shoulder on the adjacent pole piece as indicated at 26 and 27. The spacing rings 22 and 23 may be welded in place before the pole pieces are inserted within the containing member 1.

Pole pieces 16 and 17, inasmuch as these elements are positioned within the containing member 1, may be employed as supporting means for the cathode structure. This may be done, for example, by constructing the pole pieces 16 and 17 to have alined central openings or centering holes 28 and 29, respectively, which extend through the axial or longitudinal dimension of the pole pieces and afford communicating channels through which elements to be described presently extend.

As a means for supporting the cathode structure in spaced relation between the faces of pole pieces 16 and 17 and for centering the cathode structure in the enlarged opening 5 of anode structure 4, I may employ a construction disclosed and claimed in a copending patent application of George M. White, Serial No. 465,401, filed concurrently herewith, and which is assigned to the assignee of the present application. This construction comprises a supporting and centering insulator 30 which is closely fitted to the inner surface of the pole piece 16 and which receives and supports a rigid concentric cable.

This cable is constructed to have sufficient rigidity to maintain the cathode structure firmly in the desired central position, and comprises a centrally located conductor 31, an outer concentric conductor 32 and an interposed insulating tubular sheath 33. Conductors 31 and 32 are connected, respectively, to lead-in terminal wires 34 and 34' which are embedded in a vitreous seal 35. This seal may be of the desired character to facilitate establishing a hermetic joint to the metallic construction of the discharge device, and may be joined to a flanged cylindrical member 36 which is welded to the outer surface of member 2.

At its lower extremity, the inner conductor 31 extends through the aperture in disc 15 and is secured to the disc by means of a washer 37 which is welded or soldered thereto. Inner conductor 31 is connected to the upper terminal of the cathode heating element 13.

To center the cathode structure and as a means for insulating the cathode structure from the magnetic pole piece 17 and the tuning or frequency controlling means to be described presently, I provide a centering insulator 38 having a longitudinal opening therethrough and supporting a center pin 39 of metallic construction which is turned over at its upper end and to which the lower terminal of the cathode heating element 13 is conductively connected, thereby completing the circuit for the energization of this cathode heating element. The circuit, of course, is completed through disc 14, sleeve 10, disc 15 and conductor 32.

Nickel rings 40 and 41 are employed between insulator 30 and disc 15, and insulator 38 and disc 14, respectively. By this construction, all the elements comprising the insulating and supporting construction for the cathode are maintained in close alinement or position, restricting radial as well as axial movement thereof. Rings

40 and 41 also serve to minimize heat flow from the cathode.

Energy may be derived from the electric discharge device, and more particularly from the space resonant regions defined by the openings 6, by electrode means such as a loop 42 which extends into one of the openings and which may comprise an extension of one conductor of a concentric or coaxial transmission line which includes an inner conductor 43 and an outer conductor 44, the two conductors being sealed in order to maintain the desired low pressure condition within the containing member 1. A vitreous seal 45 may be employed for this purpose.

I provide means for controlling the natural frequency of a cavity, or cavities, defined by the anode structure 4 and the region between the anode structure and the cathode, thereby providing means for controlling or adjusting the operating frequency of the electric discharge device as an entirety. More particularly, I provide means which is adjustable or controllable in spaced relation with respect to the anode structure 4 for controlling the effective distributed inductance and capacitance of the various space resonant cavities or regions. This means may comprise a member having an appreciable area facing the anode structure and which is spaced therefrom and positionable with respect thereto to control the effective characteristics of the space resonant cavities. In one form of my invention, the frequency controlling means or tuning structure may comprise a conductive member 46 having a cylindrical part 47 which extends an appreciable distance into the opening 29 in the magnetic pole piece 17 and includes a disc-like or flanged part 48 having an appreciable area opposite the anode structure 4. The member 46 is positionable or controllable axially of the elements of the discharge device, and may be moved from the position indicated in Fig. 1 of the drawing to a point, or points, intermediate the lower surface of the anode structure 4 and the pole face of magnetic pole piece 17.

It will be observed that flanged part 48 lies in the vicinity of and is variably positionable relative to the ends of the slots 7. In this manner, the member 46, and particularly part 48, is located at a place relative to the electrode assembly which affords ready control of the net or effective reactances of the various space resonant regions.

In order to facilitate adjustment of the position of the member 46, without impairing the desired insulating and centering functions of insulator 38, the cylindrical part 47 of member 46 is arranged to slide or move therebetween; that is, the insulator 38 remains in the position illustrated but the member 46 may be readily moved or adjusted relative to the stationary magnetic pole piece 17 and the insulator 38.

I provide externally accessible means for controlling the position of member 46 and this means may comprise an actuating rod 49 permanently connected to the lower end of the part 47 of member 46, which may be turned in and secured to the actuating rod 49 by a suitable mechanical expedient, such as nuts 50 and 51 placed on opposite sides of the turned-in end of part 47.

Actuating rod 49 is terminated in an externally accessible adjusting or controlling means, such as a thumb nut 52, which in turn is in engagement with a metallic member 53 ultimately supported by the flanged member 3. As a means for sealing the opening 29 and to permit ready

adjustment of the position of the actuating rod 49 and member 46, I provide a deformable member, such as a metallic diaphragm 54, which is welded or soldered at its flanged periphery to member 3 and diaphragm 54, thereby constituting an hermetical joint. Diaphragm 54 is also sealed to a threaded center screw 55 which also engages the lower threaded extremity of actuating rod 49, thereby completing the sealing structure for the actuating means for member 46. Due to the relatively low pressure within the enclosure for the elements of the discharge device, downward motion of the actuating rod 49 is obtained by adjusting nut 52 to move the diaphragm downwardly. It will be appreciated that the external or atmospheric air pressure tends to move the diaphragm upwardly by virtue of the difference in pressures acting upon the inner and outer surfaces of the diaphragm.

In accordance with another feature of my invention, I also provide means for automatically controlling the electric discharge device to maintain the operating frequency thereof substantially constant irrespective of temperature variations. More particularly, I provide means for controlling the position of the part 48 of member 46 in accordance with temperature variations of the discharge device, thereby assuring the supply of constant frequency electromagnetic energy to the output electrode means. One form of temperature compensating means which I provide may comprise a construction of actuating rod 49 to have a configuration and of a metal or alloy the temperature-coefficient of expansion of which is such that the position of the flanged part 48 automatically assumes a proper position to effect the desired control of the natural frequency of the space resonant cavities defined by anode structure 4. For example, the actuating rod 49 may be constructed of a suitable alloy.

Furthermore, in order to obtain the desired compounding, over-compounding, or under-compounding of the frequency in response to temperature, the actuating rod 49 and member 46 may be constructed and the metal and dimensions thereof chosen so that the desired frequency controlling operation utilizes the temperature coefficients of expansion and characteristics of both of these elements. In other words, the net movement of the part 48 and member 46 in response to temperature will then be controlled by the characteristics of both the actuating rod 49 and member 46.

In addition, the masses and the configurations of rod 49 and member 46 may be chosen so that the rate of response of the frequency controlling operation is predeterminable; that is, by the proper choice of the relative weights of these elements and the thermal capacities thereof, the rate at which the temperature compensatory action takes place is controllable or determinable.

Upon the application of voltage, such as a unidirectional voltage, to containing member 1 and the cathode structure, the discharge device and particularly the space charge within the region between sleeve 10 and anode structure 4, will be set into oscillation. The magnitude of the magnetic field density established by pole pieces 16 and 17 being established relative to the dimensions of the anode structure 4 and particularly the openings 6 and slots 7 so that the period of oscillation of the electrons constituting the space charge is substantially equal to the natural frequency of the various space resonant cavities or regions comprising openings 6 and slot 7. En-

ergy may be extracted from the space resonant system by means of loop 42 and concentric transmission line comprising conductors 43 and 44.

The natural resonance frequency of the respective space resonant regions in the anode structure 4, as stated above, is determined principally by the configuration and dimensions of openings 6 and slot 7. The effective reactances of these space resonant regions are controllable by means of member 46, and particularly the flanged part 48 thereof, which affords an appreciable area in proximity to the anode structure and consequently controls the effective reactances to control the operating frequency. For example, upon increase of tempertaure, the anode structure 4 will expand thereby tending to increase the operating frequency of the discharge device as a whole. The frequency controlling operation is obtained by either or both of members 48 and 49 to move the part 48 of member 46 nearer the anode structure 4, thereby mantaining the operating frequency constant for obtaining the desired compounding, under-compounding or over-compounding as wished. Movement of part 48 towards the anode surface tends to decrease the natural frequency of the various cavities.

The position of flanged part 48 of member 46 also exerts an effect on the characteristics of the space charge within the region defined by cathode sleeve 10 and the anode structure 4. The system is preferably arranged so that the joint effect of the part 48 on the characteristics of the anode-cathode region and the respective space resonant regions obtains the desired control or variation in the operating frequency of the system.

Actuating rod 49, by virtue of its temperature responsive characteristics, serves to automatically position the member 46 to maintain the frequency of oscillation of the discharge device substantially constant at the value determined by the initial adjustment of actuating rod 49 by means of the thumb nut 52. Of course, the thumb nut 52 may also be employed to vary or adjust the operating frequency of the device at will.

Certain features of the electric discharge device described above, including the metal enclosure, the anode structure and associated permanently magnetized magnetic pole pieces, are disclosed and broadly claimed in a copending patent application Serial No. 447,903, filed June 22, 1942, of Elmer D. McArthur and which is assigned to the assignee of the present application.

While I have shown and described my invention as applied to a particular configuration of elements, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A high frequency electric discharge device of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the oscillations of the electrons constituting the space charge between said cathode and said anode structure, magnetic pole pieces positioned on opposite sides of said anode structure and having therein alined openings, means positioned within said openings for maintaining said cathode in spaced relation between said pole pieces, and means for controlling the natural resonance frequency of said resonator comprising a movable member having a cylindrical part extending into the opening of one of said pole pieces and a flanged part affording an appreciable area facing said anode structure.

2. A high frequency electric discharge device of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the motion of the electrons constituting the space charge between said cathode and said anode structure, a pair of magnetic pole pieces for establishing a magnetic field and positioned on opposite sides of said anode structure, said pole pieces being provided with alined openings, a pair of insulating means each positioned in a different one of said openings for maintaining said cathode in spaced relation with respect to said anode structure, and means for controlling the natural frequency of said resonator comprising a cylinder-shaped member extending between one of said pole pieces and the insulating means in said opening of said one pole piece and being provided with a flanged part affording an appreciable area facing said anode structure.

3. A high frequency electric discharge device of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the motion of the electrons constituting the space charge between said cathode and said anode structure, a pair of permanently magnetized pole pieces positioned on opposite sides of said anode structure and each being provided with an opening, insulating means in each of said openings for maintaining said cathode in spaced relation with respect to said anode structure and the pole faces, and an adjustable means for controlling the natural frequency of said resonator comprising a member extending into the opening of one of said pole pieces and positioned between said one pole piece and the insulating means of said one pole piece and being provided with a flanged part affording a substantial area facing said anode structure.

4. A high frequency electric discharge device of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the motion of the electrons constituting the space charge between said cathode and said anode structure, a pair of permanently magnetized pole pieces positioned on opposite sides of said anode structure and each being provided with an opening, insulating means in each of said openings for maintaining said cathode in spaced relation with respect to said anode structure and the pole faces, an adjustable means for controlling the natural frequency of said resonator comprising a conductive member extending into the opening of one of said pole pieces and positioned between said one pole piece and the insulating means of said one pole piece and being provided with a flanged part affording a substantial area facing said anode structure, and externally accessible means connected to said adjustable means for controlling the position of said flanged part relative to said anode structure.

5. A high frequency electric discharge device

of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the motion of the electrons constituting the space charge between said cathode and said anode structure, a pair of permanently magnetized pole pieces positioned on opposite sides of said anode structure and each being provided with an opening, insulating means in each of said openings for maintaining said cathode in spaced relation with respect to said anode structure and the pole faces, an adjustable means for tuning the natural frequency of said resonator comprising a member extending into the opening of one of said pole pieces and positioned between said one pole piece and the insulating means of said one pole piece and being provided with a flanged part affording a substantial area facing said anode structure, and temperature responsive means connected to said last mentioned means for controlling the position of said flanged part relative to said anode structure.

6. A high frequency electric discharge device of the magnetron type, comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the motion of the electrons constituting the space charge between said cathode and said anode structure, a pair of permanently magnetized pole pieces positioned on opposite sides of said anode structure and each being provided with an opening, insulating means in each of said openings for maintaining said cathode in spaced relation with respect to said anode structure and the pole faces, an adjustable means for tuning the natural frequency of said resonator comprising a member extending into the opening of one of said pole pieces and positioned between said one pole piece and the insulating means of said one pole piece and being provided with a flanged part affording a substantial area facing said anode structure, a metallic member connected to said last mentioned means and extending therefrom, means sealing said last mentioned member comprising a deformable metallic member joined to said enclosure, and actuating means connected to said deformable member.

7. A high frequency electric discharge device of the magnetron type, comprising a plurality of cooperating electrodes including a cathode and an anode structure defining a cavity resonator circuit to be energized in accordance with the oscillations of the electrons constituting the space charge between said cathode and said anode structure, an enclosing envelope for said electrodes, a pair of alined magnetic pole pieces positioned on opposite sides of said anode structure and each having therein an opening extending longitudinally therethrough, a pair of insulating means each positioned in a different one of said openings and comprising means for maintaining said cathode in spaced relation with respect to said anode structure and the faces of said pole pieces, means for controlling the natural frequency of said resonator and comprising a member having a part extending into the opening of one of said pole pieces and positioned between the insulating means of said one pole piece and said one pole piece, said last mentioned member having a part affording an appreciable area facing said anode structure, means for positioning said last mentioned member longitudinally along the axis of said pole pieces between the pole face of said one pole piece and said anode structure and comprising an actuating rod extending to a point outside said envelope, a metallic deformable member sealed to said envelope, and actuating means engaging said rod and sealed to said deformable member.

8. A magnetron comprising an enclosure, a pair of permanently magnetized pole pieces within said enclosure spaced to provide a gap therebetween, cooperating electrode elements located in said gap and including a cathode and an anode structure having a plurality of openings therein the defining walls of which provide a plurality of cavity resonator circuits to be energized in accordance with the movement of electrons emitted by said cathode, a tuning member within said enclosure positioned between one of said pole pieces and said anode structure, said one pole piece having a longitudinal passage formed therein extending to the exterior of said enclosure, and an operating member connected with said tuning member and positioned within said passage for varying the position of said tuning member.

9. A high frequency electric discharge device of the magnetron type comprising a plurality of enclosed cooperating electrodes including a cathode and an anode structure having a plurality of openings formed therein the defining walls of which provide a plurality of cavity resonator circuits to be energized in accordance with the electrons emitted by said cathode, means including a pair of pole pieces positioned on opposite sides of said anode structure providing a magnetic field in the space between said cathode and said anode structure, a tuning member positioned within said envelope between one of said pole pieces and said anode structure, said one pole piece having a longitudinal passage formed therein and means including an elongated metal member positioned in said passage and connected between said tuning member and the enclosure of said device for automatically adjusting the position of said tuning member in response to the temperature of said last mentioned means.

10. A magnetron comprising an enclosure, a pair of magnetic pole pieces within said enclosure and spaced apart to provide a gap therebetween, cooperating electrodes located in said gap and including a cathode and an anode structure supported from said envelope and substantially surrounding said cathode, said anode structure defining a plurality of cavity resonator circuits to be energized in accordance with the movement of electrons emitted by said cathode, means including said pole pieces establishing a magnetic field in the region between said anode structure and said cathode, a member positioned between said anode and one of said pole pieces, and means connected with said member extending through said one of said pole pieces to the exterior of said enclosure for positioning said member including an elongated member having a different temperature coefficient of expansion than said envelope whereby said member is automatically adjusted in position with respect to said anode structure to compensate for changes in the resonant frequency of said anode structure resulting from temperature changes.

11. An ultra high frequency electric discharge device of the magnetron type comprising a plurality of cooperating electrodes including a cathode and an annular anode structure having a central opening through which said cathode extends and providing a plurality of cavity resonators, a

pair of magnetic pole pieces longitudinally displaced from said anode structure and each having therein a longitudinal channel, means mounted in the channel of one pole piece supporting said cathode and constituting a heating current lead, an adjustable tuning member positioned between the other piece and said anode structure, and means supporting and adjustably positioning said tuning member comprising a longitudinal rod positioned within the channel of the other pole piece.

12. An electric discharge device of the magnetron type comprising a plurality of cooperating electrodes including a resonant anode structure, a magnetic pole piece juxtaposed to said anode structure and having therein a longitudinal channel, an adjustable tuning member positioned between said pole piece and said anode structure, and means supporting and adjustably positioning said tuning member comprising an adjustable supporting member positioned within the channel of said pole piece.

13. An electric discharge device of the magnetron type comprising a plurality of cooperating electrodes including a cathode and an annular anode structure having a central opening through which said cathode extends and including a cavity resonator, a magnetic pole piece juxtaposed to said anode structure and having therein a longitudinal channel, an adjustable tuning member positioned between said pole piece and said anode structure, and means supporting and adjustably positioning said tuning member comprising a

longitudinal rod positioned within the channel of said pole piece.

KENNETH C. DE WALT.

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