

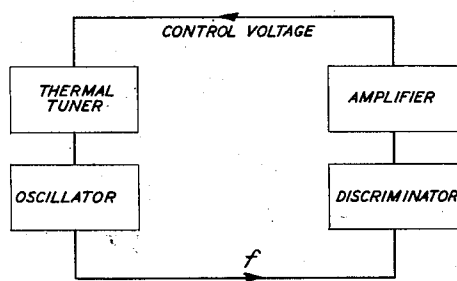
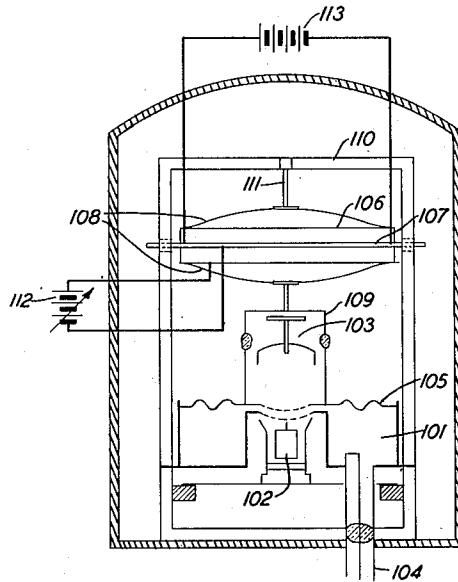
July 4, 1950

W. G. SHEPHERD
THERMALLY TUNABLE CAVITY RESONATOR
ELECTRON DISCHARGE DEVICE

2,513,371

Filed Feb. 1, 1945

3 Sheets-Sheet 1



INVENTOR
W. G. SHEPHERD
BY *Guy T. Morris*
ATTORNEY

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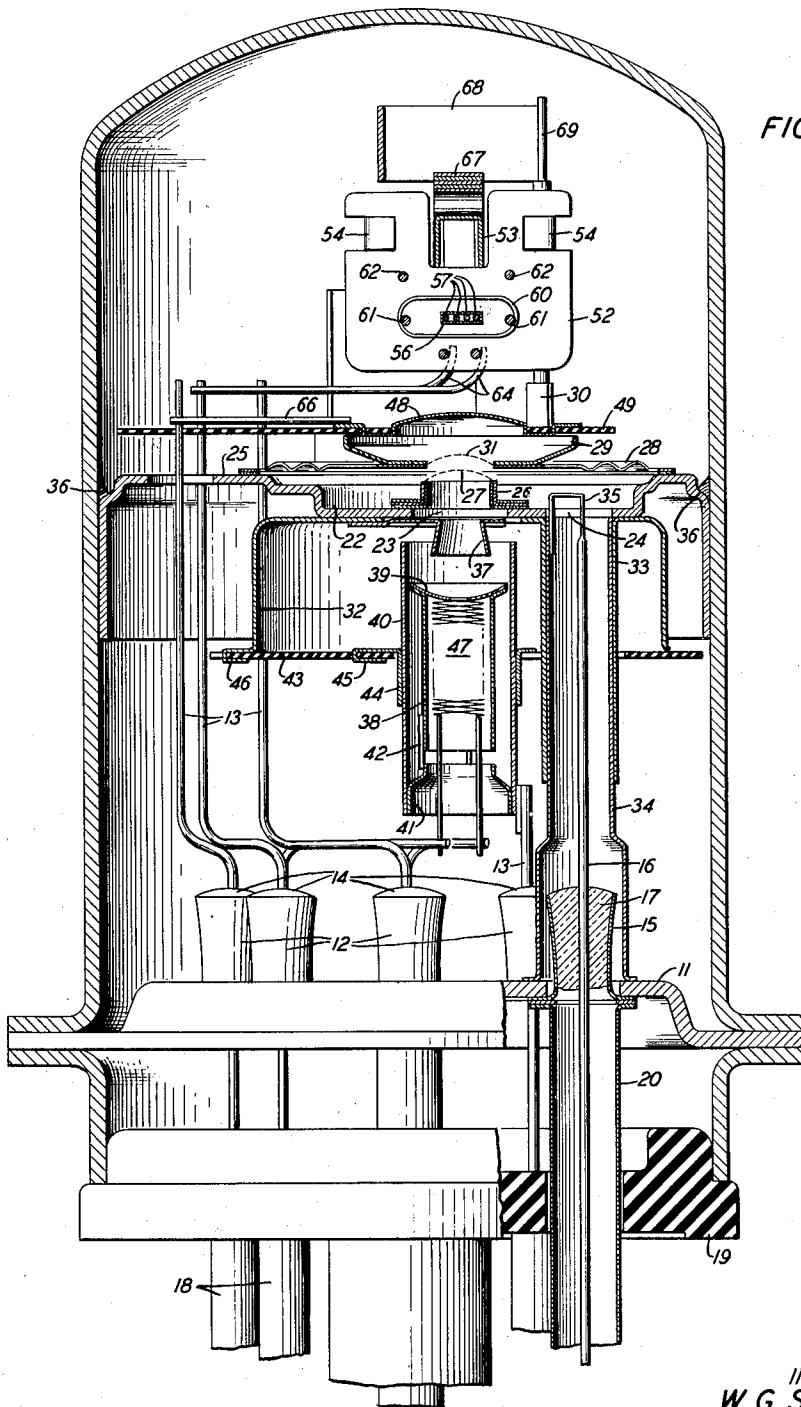


FIG. 3

INVENTOR
W. G. SHEPHERD
BY *Guy F. Morris*

ATTORNEY

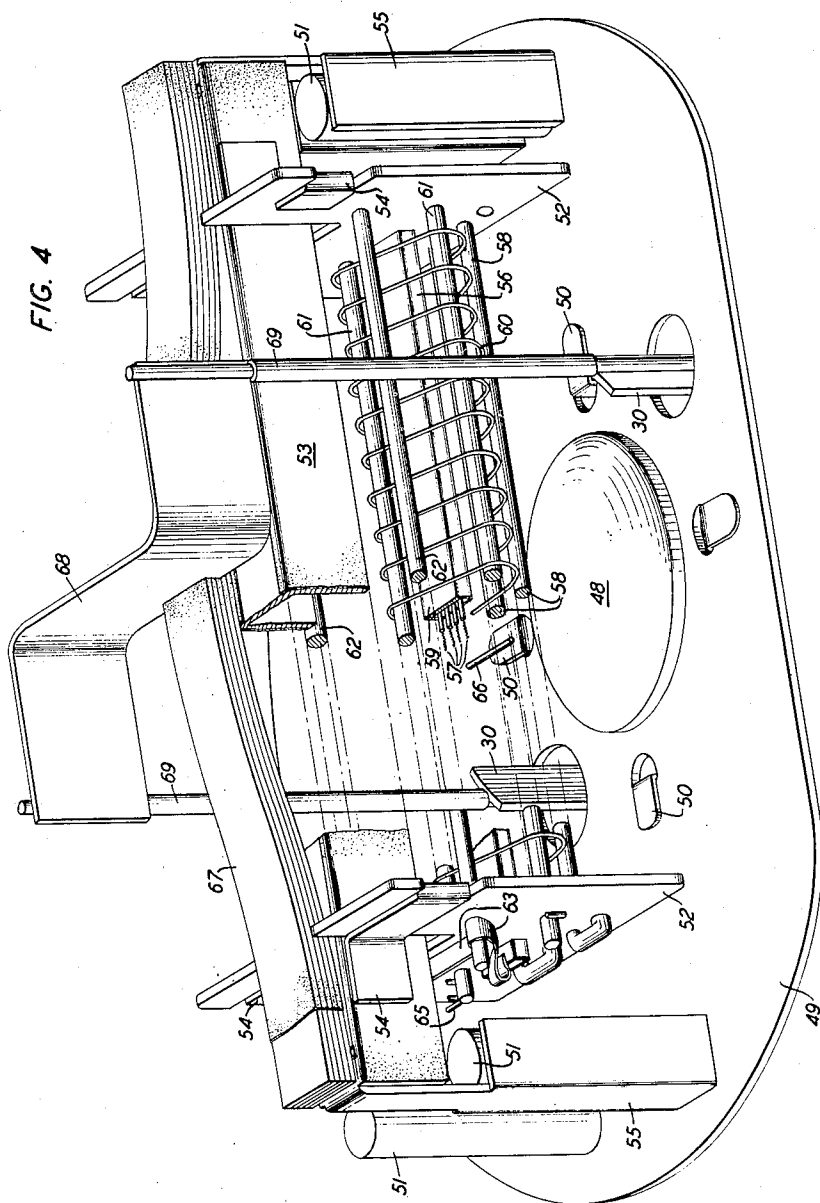
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3 Sheets-Sheet 3



INVENTOR
W. G. SHEPHERD
BY *Guy T. Morris*
ATTORNEY

UNITED STATES PATENT OFFICE

2,513,371

THERMALLY TUNABLE CAVITY RESONATOR
ELECTRON DISCHARGE DEVICEWilliam G. Shepherd, Summit, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application February 1, 1945, Serial No. 575,585

4 Claims. (Cl. 315-5)

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This invention relates to electron discharge devices and, in one practical embodiment, to a reflex oscillator of the types disclosed in the applications Serial No. 575,584, filed February 1, 1945, of S. O. Ekstrand and E. J. Walsh jointly and Serial No. 575,586, filed February 1, 1945, of F. H. Best, to the extent that the present invention relates to the thermal tuners for the cavity resonators thereof. This is especially true of the first-mentioned, and the later numbered figures of the drawing for the present application will be found to be substantial duplicates of certain of the figures thereof, said Ekstrand and Walsh invention relating to structural details of the oscillator tube as a whole.

The principal object of this invention is to provide a means for tuning a cavity resonator by change in its dimension which is exceedingly rapid, while at the same time, perhaps contrary to normal expectation, facile and sensitive, in operation. Additional, and more specific objects, will be evident from the following brief statement of the physical structure and attributes of the tuning system of the invention.

The invention makes use of thermal tuning and, therefore, to a distortion or dimensional change of the cavity resonator by the application of a stress, with a resultant strain, induced by thermal expansion. As distinguished from a thermal tuner which is older in the art, in which the heat, upon which the necessary expansion is predicated, is generated by a current flowing through the strain-producing element itself, or through an operating means therefor, the heat in the present invention is generated by electron bombardment of said strain-producing element or operating means therefor. The bombarded element and the source of the bombarding electrons may be thought of as corresponding to the anode and cathode, respectively, of an electron discharge diode. The control effect is regulated by the potential difference between these elements, which determines the extent and effect of the bombardment.

As compared with the above prototype in which the heat is generated by the I^2R loss in a conducting current medium the present invention has the great advantage as to flexibility, sensitivity, availability of standard supply sources and the like. This prototype means inherently implies the use of a large current at a low potential, a condition difficult to realize in practice, when the critical quantitative requirements are kept in mind. Resort to the use of a transformer would tend to improve the potential and current rela-

tionship but would itself introduce an expensive and complicating factor and besides, which is much more important, would tend to lessen the effectiveness of the control. As compared with mechanical tuners, which would be another alternative, the device of the invention has the great advantage of possibility of remote control.

The invention while applicable generally to electrical tuning is especially adapted to the tuning of cavity resonators, where positional control of the significant tuning element is of relatively great importance. Its application is not limited to the cavity resonators of reflex oscillators although perhaps having its best exemplification therein. The invention may be used with external regulation of the difference of potential by means of which the control is effected. However, it might well be a part of an automatically frequency stabilized oscillator or oscillator system, where an oscillator frequency is either controlled in equality with a standard frequency or a constant frequency difference between the output of two unit oscillators, of which one is to be controlled by the invention, is the desideratum. This last is well exemplified in a well known and well reputed ultra-high frequency war weapon auxiliary which embodies a heterodyne receiver-transmitter in which it is necessary to cause the frequencies of two local oscillators to track, therefore maintaining a constant frequency difference, when the independently variable frequency is caused to vary. By the system of control whereby this auxiliary achieves a large part of its effectiveness and in which the device of the present invention may be embodied, there occurs, impulsively, a certain control facility which tends to cause the controlled oscillator frequency to overshoot in its effort to accommodate itself to the situation. The invention as applied to said oscillator makes possible, by its unusual rapidity of response, an equally rapid mitigation or compensation of this overshooting effect, without any concomitant ill-effects which might normally be expected to attend the same.

The invention also contemplates certain specific detail of the tuning system whereby its effectiveness, in the aggregate, may be very greatly increased. For instance the bombarded element may with advantage be coated with a zirconium product to aid the getting operation when the tube is being evacuated, and which subsequently, by its black body radiation characteristic, promotes the rapid withdrawal of heat, as required by theoretical consideration. No practical alternative has been found for this expedient. When

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it is used care must be taken to prevent the exposure of any element in the mechanical train which eventually drives the resonator movable elements to the radiation from the zirconium-coated surface, since any radiation on such an element would tend by a thermal expansion, to affect the operation of the invention in not entirely predictable ways. For an analogous reason the heating of the bombarded element should be derived as much as possible from the electron bombardment, since this can so easily be controlled, so that heat radiation directly thereto from the cathode should be minimized, as by the use of as small a solid angle as possible subtended by the bombarded element with respect to said cathode. Again somewhat analogously to the above, and assuming that some radiation cannot be prevented from reaching the parts in said train contiguous to the diode elements, a copper, or the like, plating on said parts would tend to prevent their heating to above a critical temperature by providing a path for rapid heat dissipation by conduction. This feature is especially useful in view of the desirability and use of a particular alloy for the element most in question which itself does not have a very high heat conductivity.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description taken with reference to the accompanying drawing in which:

Fig. 1 represents, partly in section, a highly diagrammatic and simplified version of what at least in part is shown in accurate detail in different views by Figs. 3 and 4, to teach the basic principles of the invention in its simplest and most basic form;

Fig. 2 is a conventionalized circuit diagram illustrating the use of the invention as a part of an automatically frequency stabilized oscillator;

Fig. 3 is an elevational view mainly in section of an electron discharge device illustrative of one embodiment of an oscillator tube embodying the invention; and

Fig. 4 is a perspective view of the thermal tuner assembly included in the device illustrated in Fig. 1, portions of this assembly being broken away to show details thereof more clearly.

It may be of service to the Patent Office, in its prosecution of this application, to know that Figs. 3 and 4 herein are duplicates of Figs. 1 and 4 of the Ekstrand and Walsh application noted in the statement of invention except for the minor (so far as concerns illustration) changes having to do with the zirconium and copper plating features above described in the statement of invention. The portion of the specification describing these figures is likewise transcribed effectively word for word from said Ekstrand and Walsh application with the same exceptions. Since the same reference characters will be used herein as in said Ekstrand and Walsh application, except as necessitated by the varying minor changes as above, the labeling of Figs. 1 and 2, which are original in the present application, will represent a new series beginning with reference numeral 101.

Referring to Fig. 1, cavity resonator 101 might well be the resonator of a reflex oscillator of Figs. 3 and 4, or perhaps one of the cavity resonators of a Klystron-type device as in the United States patent to Varian 2,242,275, May 20, 1941, or the resonator of a device like that disclosed in Llewellyn 2,190,668, February 20, 1940. Its con-

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formity is not of present importance although special considerations would usually prescribe the reentrant cross-section resonator here illustrated. In Fig. 1 the organization as a whole to the extent that it contains structure beyond that pertaining to the resonator itself and its tuning means suggests a reflex oscillator because of the assemblages 102 and 103 diagrammatically representing respectively an electron gun for impelling a beam of electrons through the cavity resonator by means of its imperforate opposed boundary walls and a means, sometimes known as a repeller, for reversing the direction of said electrons to eventually cause them to retrace the resonator. The coaxial line 104 provides an alternating current coupling to the resonator for whatever purpose desired depending on the specific attributes of the organization as a whole.

The significant element for present purposes is the elastic diaphragm 105, by a movement of which normal to its direction of extension its spacing from the nearest adjacent wall section in the path of the beam may be varied with the consequent variation in tuning of the resonator, together with the means for actuating said diaphragm. This last constitutes the thermal control unit of the invention. It comprises a thermally expansible electron bombarded element 106 cooperating with source of electrons 107, the two elements therefore simulating the usual anode and cathode of an electronic diode. The resultant thermally induced movement of the ends of element 106 is transmitted to the diaphragm through bows 108 whose material or operating temperature or both are such that they do not expand materially and a mechanical coupling principally comprising yoke 109 rigidly attached to the diaphragm. The tuner unit has rigid attachment to and support by the supporting element 110 by element 111. The bows are rigidly attached to the ends of the anode 106 but the bow-anode-cathode assembly is loosely mounted in the support so as to accommodate a sufficient longitudinal movement (that is longitudinal only with respect to the direction of electron flow from gun 102) to make possible a frequency adjustment of the resonator as a direct function of such movement. While a single bow would be permissible, the use of the two bows magnifies the resultant movement. The use of a single bow, namely, the lower bow of Fig. 1, would permit the rigid attachment of the above assembly to the support all around. The later numbered figures exemplify this idea.

Except as has already been explained, the operation of the Fig. 1 device should be obvious. The tuning movement of the diaphragm is a function of the thermal condition of the bombarded element which itself is a function of the potential impressed between it and the cathode which determines the number and velocity of the bombarding electrons. This potential may be varied as desired for that purpose. Reference numeral 112 diagrammatically indicates a variable direct potential source with this in mind and reference numeral 113 similarly diagrammatically shows a source of exciting current for said cathode. It is, of course, obvious that indirect heating could alternatively be used for said cathode, as in fact would be desirable, and that many other changes could be made in the organization without affecting the principle of operation of the invention.

Fig. 2 indicates, in general, how the external control may be automatic. Some portion of the

output of the controlled oscillator would be fed into the discriminator circuit which would then convert a frequency deviation from the desired frequency into a potential having a sign dependent upon the direction of the arrow. This potential would then be amplified and fed into the thermal tuner device. The frequency f required by the system could well be, alternatively, the difference frequency of the transmitter-heterodyne receiving system mentioned in the statement of invention. The functional labeling in Fig. 2 obviates the necessity for other labeling of the parts.

The following analysis indicates a quantitative basis for a design of the thermal control system of the invention.

f_0 be the actual oscillation frequency
 f be the frequency required by the system
 $\delta f = f - f_0$

Then using a frequency demodulation method of detecting the error we obtain as the voltage output of the demodulator upon amplification

$$V = a\delta f \quad (1)$$

where a may be positive or negative dependent upon the design of the demodulator. Its sign must, of course, be made consistent with the direction of action of the thermal tuning device.

Let E_0 represent the voltage applied across the diode when the frequency was f_0 . Then the power originally dissipated in the diode will be

$$P = KE_0^{5/2} \quad (2)$$

and the power dissipated in the diode when the system requires a shift to frequency f will be

$$P = K(E_0 + a\delta f)^{5/2} \quad (3)$$

Let T be the temperature of the control system and let the temperature of the sink into which heat is lost be at temperature T_1 . Heat will be lost to the sink in general by two means.

(1) Conduction loss in which case the rate will be $k(T - T_1)$, where k is a constant involving the thermal properties length and cross-sectional area of tuner and its supporting members.
 (2) Radiation loss for which the rate will be $\epsilon(T^4 - T_1^4)$ where ϵ involves the emissivity of the tuner and its surface area. Either or both types of loss may be incorporated in the tuner design dependent upon the particular requirements.

Let H be the heat content produced by electron bombardment of the control system. The time rate of change of heat content will be

$$\frac{dH}{dt} = P - k(T - T_1) - \epsilon(T^4 - T_1^4) \quad (4)$$

To a first approximation the frequency error, δf , will be proportional to the change in gap spacing required to compensate for this error, i. e. $\delta f = \beta \delta x$. The thermal tuning system will have a thermal displacement characteristic given by some function,

$$\delta x = F(T) \quad (5)$$

Further the heat content, H of the thermal tuner will be given by $H = CT$ (6)

where C involves the specific heat and volume of the control system.

Then

$$\frac{d\delta x}{dt} = F'(T) \frac{dT}{dt}$$

where

$$F'(T) = \frac{dF}{dT}$$

Thus

$$\frac{d\delta f}{dt} = \frac{\beta d\delta x}{dt} = \frac{\beta F'(T)}{C} \frac{dH}{dt} = \frac{\beta F'(T)}{C} [K(E_0 + a\delta f)^{5/2} - k(T - T_1) - \epsilon(T^4 - T_1^4)] \quad (7)$$

This equation enables one to specify a number of things about the control system.

(1) If the frequency change is to be in a direction such that the temperature of the control system is to increase then the rate of change of frequency is limited only by the power input available and the characteristics of the discriminator circuit. In other words it is limited only by the possible magnitude of the term $a\delta f$.

(2) If the frequency change is to be in a direction such that the temperature of the control system is to decrease, then the rate of change of frequency cannot exceed

$$\begin{aligned} \frac{a\delta f}{dt} &= -\frac{\beta F'(T)}{C} [k(T - T_1) + \epsilon(T^4 - T_1^4)] \\ &= -\beta C F'(T) \left[kT \left(1 - \frac{T_1}{T} \right) + \epsilon T^4 \left(1 - \frac{T_1^4}{T^4} \right) \right] \quad (8) \end{aligned}$$

This simply states the obvious fact that one can do no better than to shut off the heat. There are several illuminating facts evident from Expressions 7 and 8. Systems have been proposed in which speed of operation was to be obtained by bleeding large quantities of heat away corresponding to making the bracketed quantity in Equation 8 large. This has the disadvantage, however, that it requires a large power input to be effective and may be characterized as a brute force method of obtaining speed of operation. It is apparent from (8) that speed may be obtained by making the factor

$$\frac{\beta F'(T)}{C}$$

large. This has the advantage that it will provide speed of operation in both directions. In order to make the factor large three things are required.

(1) β should be large. This relates the change of gap spacing of the resonant cavity to the change of resonant frequency. If β is to be large the gap spacing should be small. However, the gap spacing is usually dictated by electronic considerations and must therefore be considered a constant.

(2) $F'(T)$ should be large. This step is somewhat contrary to one's first impulse in designing a system since it says that the rate of change of displacement with temperature should be large. In designing a mechanical tuner one strives to make the analogous quantity, the rate of change of displacement per unit of change of mechanical control small. This is done in order to make possible accurate settings rather than speed of adjustment. Accuracy of control in the present instance is provided by the sensitivity of the discriminator circuit, i. e., the factor a should be made large.

(3) The factor C should be made small. This is to be expected since it states that the volume and specific heat of the tuning system shall be small. This is analogous to saying that the amount of energy stored in electrical circuit should be small if a rapid response is desired.

It has been pointed out previously that cooling may be accomplished either by radiation or con-

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duction. Referring to Equation 8 it will be apparent that, regardless of which method is employed, if speed of operation is to be maintained throughout the range of interest the temperature, T , must remain at all times sufficiently larger than T_1 so that the ratio

$$\frac{T_1}{T}$$

does not approach too closely the value of unity.

The remaining part of this specification will cover an organization complete in structural detail for tuning a particular reflex oscillator unit that has been found effective in practice. As was indicated in the statement of invention this disclosure will be the same as that for the Ekstrand and Walsh application filed concurrently herewith except for the few modifications of certain of the elements constituting a part of the present invention, also noted in the statement of invention.

It should be noted also that although this disclosure covers the invention so far as concerns the principle of inducing heat for tuning by electron bombardment a three-electrode organization, instead of a diode organization is shown for achieving this purpose. This three-electrode means is the invention of John R. Pierce and, with other features is the subject of his application Serial No. 575,587, filed February 1, 1945. It should be obvious that in this practical organization as a whole (Figs. 3 and 4) a diode could alternatively be used to generate and control the electron stream.

Referring now to Figs. 3 and 4 of the drawing and at first to Fig. 3, the electron discharge device therein illustrated comprises a highly evacuated enclosing vessel including a metallic, flanged cylindrical portion 10, the flange on which is sealed to a metallic base 11, as by welding or brazing. The base 11 has joined thereto a plurality of eyelets 12 to which a plurality of leading-in conductors 13 are sealed hermetically by vitreous beads 14, and has joined thereto also an eyelet 15 to which a conductor 16 is sealed hermetically by a vitreous bead 17. The conductors 13 are connected to terminal pins 18 carried by an insulating disc 19 mounted from the base 11; the conductor 16 constitutes a part of a coaxial line, the outer conductor 20 of which is defined in part by an elongated cylinder depending from the base 11.

Mounted within the enclosing vessel 10, 11 are a cavity resonator assembly, an electron gun and a thermionic tuner assembly. The resonator assembly comprises a metallic member having a cylindrical flange 21, adapted to fit slidably within the cylindrical portion 10 of the enclosing vessel and joined thereto by brazing material 36, the metallic member having also a dished portion 22 eccentric with respect to the flange 21 provided with a central aperture 23 and another aperture 24, and an intermediate portion 25. Mounted by the dished portion 22 and coaxial with the aperture 23 therein is a grid assembly, shown clearly in Fig. 3, comprising a pair of telescoped eyelets 26 between which the edge portion of a dished or concavo-convex grid 27 is clamped and secured on by brazing or welding.

Secured to the intermediate portion 25, as by welding, is a concentrically corrugated, centrally apertured, metallic diaphragm 28, which may also be radially slotted, which mounts a dished driving or coupling member 29 having

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thereon a number of tabs 30. The aperture in the diaphragm 28 is coaxial with the aperture 23 and has extending thereacross a concavo-convex grid 31. The slots in diaphragm 28 extend as near as may be to the inner and outer periphery of the diaphragm exclusive of the grid 31 as is consistent with the structural stability. They are for the purpose of more uniformly distributing the stress and, therefore, of avoiding a tendency toward an unsymmetrical distortion.

The dished portion 22, diaphragm 28 and outer eyelet 26 bound a substantially toroidal cavity having therein a gap bounded by the grids 27 and 31. Because of the construction of the grid assembly 26, 27, it will be appreciated that the surfaces of this assembly forming portions of the boundary walls of the cavity are accurately controllable and fixed so that the cavity constants and, hence, the cavity frequency conform accurately to prescribed values. The resonant frequency of this cavity is dependent upon the position of the diaphragm 28 and is adjustable by flexing the diaphragm in the manner described hereinafter.

Supported from the dished portion 22 is a metallic cup-shaped member 32 having thereon a cylindrical sleeve 33 in which a metallic conductor 34 is telescopically fitted, the latter being supported from the base 11 and coaxial with the conductor 16. The inner end of the conductor 34 is reversely bent as shown at 35 and affixed to the sleeve 34 to define a coupling loop between the resonant cavity and the coaxial line 16, 20, 34. Also supported from the dished portion 22 and in axial alignment with the grids 27 and 31 is a frusto-conical member 37 which constitutes the end or nose electrode of an electron gun.

The electron gun includes a cathode member 38 having a concave electron emissive surface 39 coaxial with the electrode 37, and a cylindrical beam forming electrode 40 coaxial with the emissive surface and mechanically coupled to the cathode member 38 by a ring 41 and a plurality of wires or strips 42, only one of which is shown. The unit comprising the cathode member and beam forming electrode is supported from an insulating disc 43 by a flanged collar 44 locked to the disc by tabs 45, the disc being supported, in turn, by the member 32 to which it is locked by tabs 46. A heater filament 47 is disposed within the cathode member 38 and is supported, by extensions thereof, from two of the leading-in conductors 13. The emissive surface 39 and electrodes 37 and 40 are constructed and arranged, in ways known in the art, so that electrons emanating from the emissive surface are concentrated into a converging beam substantially focussed upon the gap between the grids 27 and 31.

Opposite the grid 31 and axially aligned therewith is a cup-shaped repeller electrode 48 which is affixed to an insulating plate 49 by locking tabs 50, the plate 49 being supported from the intermediate portion 25 and in preassigned space relation to the grid 31 by a plurality of studs 51, for example four, secured to the portion 25. The insulating plate 49 and the studs 51 mount also a thermionic tuner assembly, shown in detail in Fig. 4.

This assembly comprises a pair of parallel insulating plates 52 seated upon the plate 49 and held in spaced relation by a channeled anode 53 to which they are locked by metallic strips 54. The anode 53 is provided with extensions 55

which are affixed, as by welding, to respective studs 51. Supported by the insulating plates 52 in alignment with the anode 53 is a hollow flattened cathode member 56 enclosing a heater element 57, for example a W-shaped filament coated with insulating material, the ends of the filament being connected to wires or rods 58 which extend between the plates 52 and are connected to certain of the lead-in wires 13. The surface 59 of the cathode member toward the anode 53 has thereon a coating of electron emissive material.

It was noted in the early part of the description and just before reference to Figs. 3 and 4 that it is important for the efficient operation of the tuning principle that the heated element, that is the anode, should lose its heat rapidly. This may be aided, in the case where the principal cooling is caused by radiation, by improving the black body characteristics of the anode of the tuner. This characteristic may conveniently be achieved by the use of zirconium sprayed on all the surfaces of the anode except that directly exposed to the tuning bows. The zirconium then serves a double function, because of its physical characteristics as sprayed on it has a good black body constant and because of its chemical characteristics it serves as a getter for gas emitted by the anode. This latter function is most important in a tube of this type. In most vacuum tubes the parts are heat treated in the tube during processing to temperatures greatly in excess of the final operating value in order to insure that gas release in operation will be minimized. This cannot be done in general in a thermal control element because of the danger of damage by exceeding the stress limits in the tuner itself or the element it controls. It has been found that the zirconium in intimate contact with the element to be heated effectively takes up the gas without high temperature processing.

The cathode is encompassed by a flattened helical grid 60 carried by a pair of wires or posts 61 which extend between the plates 52 and are suitably fixed therein. Between the grid and anode are a pair of rods or wires 62 which are tied electrically to the cathode 56 by a strip 63 and constitute a focussing or suppressor electrode.

The anode 53 is connected electrically to the cavity resonator by way of the studs 51 and the cathode 56 and electrodes 62 are connected in common to one of the leading-in conductors 13 by the strip 63. The rods or wires 58, to which the ends of the heater 57 are connected as noted heretofore, are connected to respective conductors 13 by the wires 64 and the grid 60 is connected to another of the conductors 13 by a tie wire 65. The repeller electrode 48 is associated electrically with another conductor 13 by a tie wire 66 affixed to one of the tabs 50. The effect of these connections is that the heater filaments for the two cathodes are in parallel, although this is only for purposes of convenience, and that the respective electrodes of the oscillator and tuner therefor are electrically separate except to the extent that the anode and cavity resonator itself are connected.

Associated with the anode 53 is a laminated bow member 67 the ends of which are affixed as by welding, to the anode at points in alignment with the studs 51 to which the anode extensions 55 are secured. The bow member 67 has welded thereto a rigid cross-piece 68 which

mounts a pair of rigid parallel rods 69 fixed thereto and to the tabs 30 in the driving member 29.

The anode 53 and bow member 67 are constructed of materials which should have widely different temperature coefficients of expansion and contraction if equally exposed to temperature conditions, in order to insure the requisite differential operating effect. Of course this differential effect could be otherwise insured while permitting use of like materials for the two elements by sufficient differentiation of exposure to the heat or, which amounts to the same thing, by differential insulation from heat. In one illustrative construction, the anode may be of a material, such as stainless steel, having a high temperature coefficient and the bow member may be of a material, such as an alloy of iron, cobalt and nickel known as "Kovar," having a low temperature coefficient. In pursuance of the idea that the bow should be effected only by the mechanical traction applied to it, so as to be thermally unaffected, it has been found very desirable to plate the bow, (the laminations thereof where laminated) with a high conductivity material such as copper. This enables the bow to rapidly dissipate any heat which tends to be generated in it, as by radiation from the cathode or anode. It happens that the preferred alloy, that is, the "Kovar," above mentioned while extremely desirable for other reasons, has a particular form of non-linear temperature-expansion characteristic that would tend to effect its operation as a thermally stable element when its temperature exceeds a super-threshold value. The copper plating insures that it does not exceed this value. As is apparent, longitudinal expansion and contraction of the anode, which action may be relatively free due to the flexibility of the unfixed portion of the extensions 55, results in bowing of the member 67 to a lesser or greater extent, whereby the cross-piece 68 is moved in the direction at right angles to the longitudinal axis of the anode. Motion of the cross-piece 68 is communicated to the driver member 29 by the rods 69 and thence to the diaphragm 28. Flexure of the latter results in alteration of the dimensions of the resonant cavity, and consequently, in the resonant frequency of the cavity.

The length of the anode at any time is determined by the anode temperature and this in turn is determined by the bombardment thereof by electrons from the cathode 56. The anode current is controlled by the potential of the grid 60. Thus, by controlling this potential, the resonant frequency of the cavity resonator may be adjusted or maintained substantially fixed at a prescribed value despite variations in the configuration of the cavity due to temperature effects.

It will be appreciated that because of the amplification of motion realized from the anode and bow member combination, sensitive control of the resonant frequency of the cavity is attained. Further, because motion of the rods 69 is essentially linear, and, therefore, piston-like motion of the diaphragm 28 obtains, accurate relationship between potential of the control grid 60 and resonant frequency is achieved.

It will be appreciated further that the tuner and resonator may be fabricated readily as individual assemblies which may then be associated by affixing the anode extensions 55 to the respective studs 51 and securing the rods 69 to

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the cross-piece 68 and tabs 30. When the assemblies have been associated and before the rods 69 are affixed to the cross-piece 68, the diaphragm 28 is flexed by adjustment of the position of the rods, as by a differential screw in a suitable fixture, to tune the cavity resonator to a preassigned frequency. The rods are then secured to the cross-piece while held in the adjusted position. Thus, the diaphragm is fixed initially, accurately at such position that during operation of the device it can be flexed to vary the material frequency of the cavity over a desired prescribed range. The resulting assembly, supported from the base 11 by the conductors 13 and 34, principally by the latter, is inserted into the vessel portion 10, the flange 21 fitting slidably within this portion as noted heretofore, and carrying thereon a ring of brazing material. The flange on the portion 10 is then sealed to the base 11 and heat is applied to braze the flange 21 to the vessel wall. Thus, in the completed device the electron gun, resonator and tuner are securely mounted by the flange 21 and the latter, being in intimate engagement with the vessel wall, facilitates radiation of heat from the resonator and prevents excessive heating thereof.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made thereon without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An oscillator comprising a mechanical-electrical network the natural frequency of which determines the characteristic frequency of oscillations including a movable element the position of which affects a frequency-significant dimension of said network, means for exciting said circuit organization to cause it to oscillate at its natural frequency, a cathode and an elongated anode, a mounting means for said cathode and anode, a bow-like elastic element connected adjacent its respective ends to said anode, said anode having a high temperature coefficient of expansion and contraction as compared with said bow-like element whereby its length varies

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in accordance with the heat induced by its bombardment by electrons from said cathode and means for aligning said mounting means and its attached anode and bow-like element so that said bow-like element is generally coplanar with said movable element whereby the resultant transverse movement of the bow-like element consequent on the thermally-induced changes in length of said anode are in the direction of the desired movement of said movable element, and means coupling said bow-like element to said movable element.

2. The organization specified in claim 1 in which the solid angle subtended by the anode at the cathode is as small as possible to insure the minimum effect from heat radiated to the anode from the cathode.

3. The organization specified in claim 1 in which the anode, except that portion in contiguity to, and thereby tending to radiate heat, on the bow-like element, is coated with zirconium.

4. The organization specified in claim 1 in which said bow-like element comprises two diverse metals one, as compared with the other, being most effective as an elastic material and the other, as compared with the first, being most effective as a heat conductor.

WILLIAM G. SHEPHERD.

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