July 4, 1950 | J. R. PIERCE | 2,513,359

ELECTRON DISCHARGE DEVICE OF THE CAVITY RESONATOR TYPE

Filed Feb. 1, 1945 | 2 Sheets-Sheet 1

FIG. 1

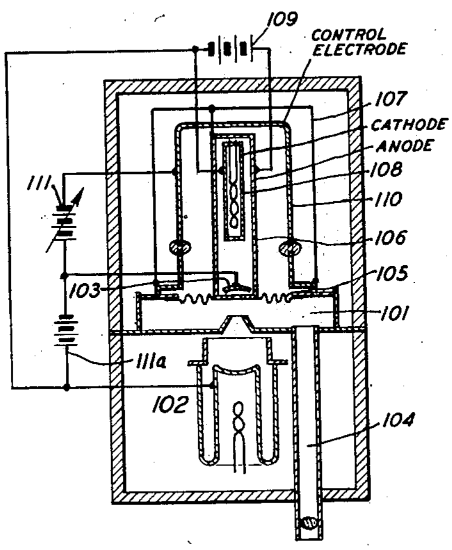


FIG. 3

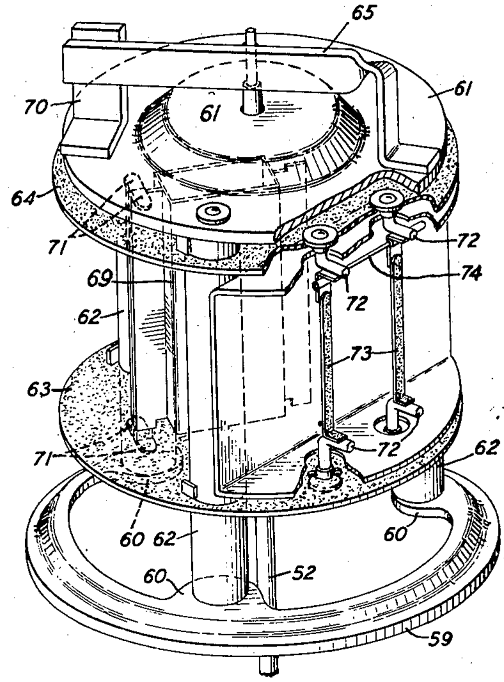
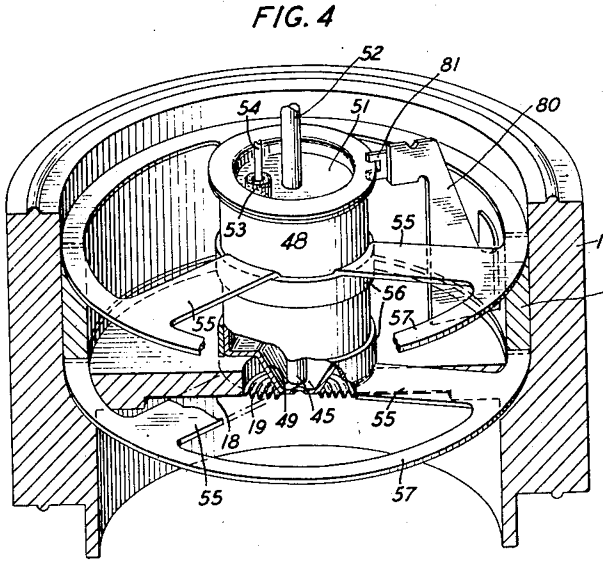


FIG. 4



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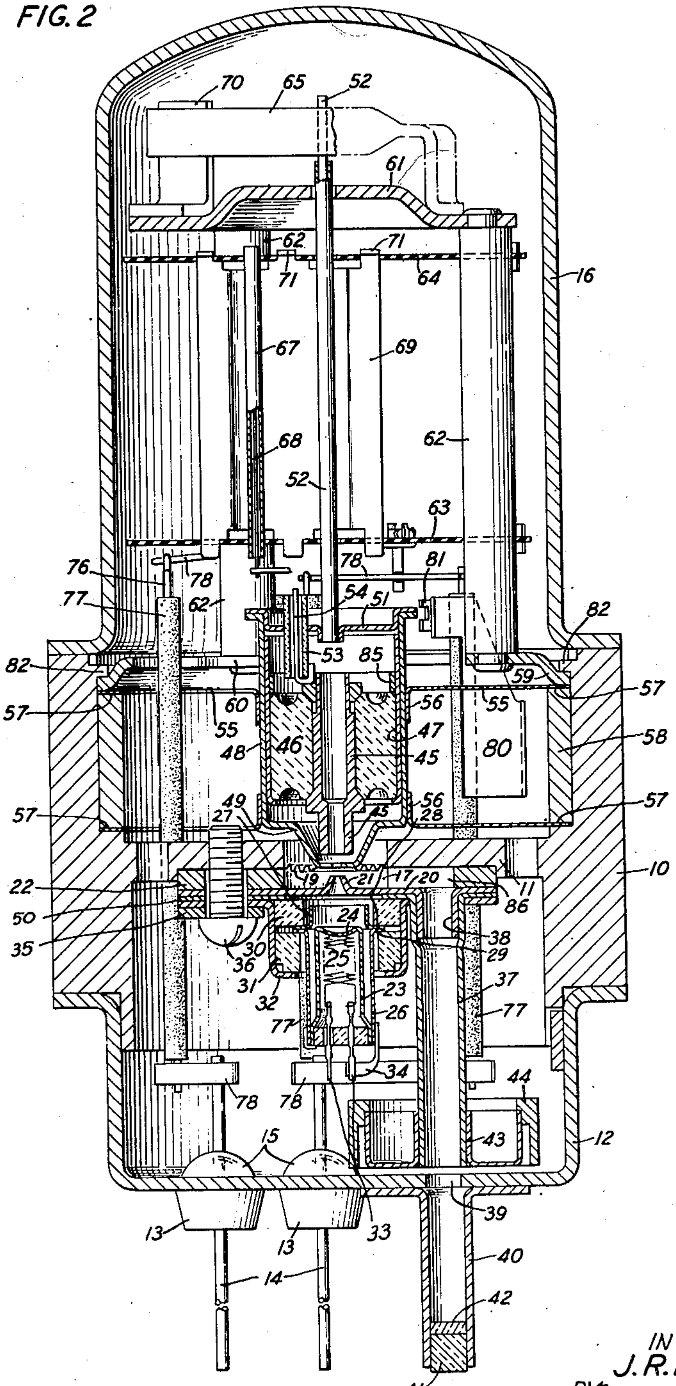
2 Sheets-Sheet 2

FIG. 2



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Patented July 4, 1950 2,513,359

UNITED STATES PATENT OFFICE

2,513,359

ELECTRON DISCHARGE DEVICE OF THE CAVITY RESONATOR TYPE

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Application February 1, 1945, Serial No. 575,587

1 Claim. (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 Feb. 1, 1945, of S. O. Ekstrand and E. J. Walsh jointly and Serial No. 575,586, filed February 1, 1945, of F. H. Best.

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 thereof, the heat in the present invention is generated by electron bombardment of said strain-producing element or operating means therefor.

The invention, in an important aspect, is an improvement over that disclosed in W. G. Shepherd application, Serial No. 575,585 filed February 1, 1945, and a specific object of the invention to provide a more facile and sensitive, while at the same time more energetic, control over the generation of heat by electron bombardment than is afforded by the Shepherd invention. This object is achieved by the use of a third electrode (that is, in addition to the electron source and bombarded element) in the tuner unit, the potential on which with relation to the electron source determines the extent and velocity of electron flow from the cathode to the bombarded element.

A still further object is to provide a more simple functional relationship between the thermally expansible element and the portion of the cavity resonator primarily concerned in the tuning function. This object is achieved by constituting the thermally expansible element itself as the drive means for the said portion of the cavity resonator.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description

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with reference to the accompanying drawing in which:

Fig. 1 discloses, partially diagrammatically and in section, and with a minimum necessary detail to teach the principles of the invention, an illustrative embodiment of the invention; and,

Figs. 2, 3 and 4 illustrate in complete structural detail an embodiment of the invention which has proved effective in practice, Fig. 2 comprising an elevational view mainly in section of such embodiment and Figs. 3 and 4 comprising respectively a perspective view of the thermal tuning unit assembly included in the Fig. 2 organization and a perspective view of the coupling between said tuner unit assembly and the cavity resonator, which also is a part of said organization, portions of the structure being broken away to show details thereof more clearly.

Figs. 2, 3 and 4 of the drawing are substantial duplicates, in fact exact duplicates to all intents and purposes of Figs. 1, 3 and 4 of the above-identified F. H. Best application, which is being filed currently herewith. Because of the use of the same reference characters in Figs. 2, 3 and 4 of the present case as in Figs. 1, 3 and 4 of Best, a new series of reference characters, beginning with numeral 101 will be used for Fig. 1, which is original in this application.

Referring now to Fig. 1, the cavity resonator 101 thereof is here shown exceedingly diagrammatically as the frequency determining element of a reflex oscillator, this type of oscillator, which employs velocity variation in a particular way and which is principally characterized by the use of a single cavity resonator to perform the functions otherwise requiring the use of at least two such resonators, is now well known in the art. The later numbered figures disclosed as above, a complete embodiment of such an oscillator. This oscillator is completed as to its more essential elements in Fig. 1 by the electron gun shown generally at 102 and by repeller electrode 103. By the electron gun, electrons are generated and impelled through imperforate boundary walls of said resonator toward the repeller electrode which repels or reflects them preferably without actual interception of any of them in the process. The electrons then retrace their path through the resonator to there impart energy to it so that such resonator can function analogously as the tuned circuit of a lower frequency oscillator. Energy may be abstracted therefrom by coaxial conductor or the like 104.

It is important to note that the invention has principally to do with the movement of flexible diaphragm 105 of said cavity resonator axially of it and therefore in the direction of electron flow so as to linearly vary its natural frequency responsive to said movement. It is therefore impartial as to the particular function of the resonator in the general organization so that the resonator could equally well be, for example, one of the cavity resonators of the so-called Klystron disclosed in United States patent to Varian 2,242,275, May 20, 1941, or the cavity resonator of the related organization disclosed in Llewellyn 2,190,668, February 20, 1940. These organizations are cited only by way of examples and the principle of the invention is operative with respect to any cavity resonator whatever which is adapted by design for tuning in the manner required regardless of how said resonator is used in combination.

The diaphragm 105 is directly actuated by the extension or contraction of a thermally responsive element 106 which is rigidly fixed at its top to support 107. Because so rigidly fastened the change of length of element 106 is reflected altogether as a corresponding movement of the diaphragm. This drive means is distinguished by its simplicity and directness although, as exemplified in the more practical embodiment of the later numbered figures, the design may easily be such as to provide the requisite degree of linearity with other desirable qualities without attendant sacrifices of otherwise desirable properties because of this simplicity and directness.

Said thermally responsive drive element 106 responds to heat generated in the same by bombardment by electrons emanating from electron source 108, which therefore simulates in function and may well simulate in appearance the conventional cathode of electron discharge devices generally. The potential source 109 cooperates to this end, that is, to insure that electrons emanating from the cathode are attracted to the bombarded element or anode. Although the heating effect, as conditioned quantitatively by the electron bombardment, is a function of this cathode-anode potential, as in the related Shepherd invention, the control here contemplated is achieved by the use of a third electrode 110 which exerts a controlling effect on the electron stream quite analogous to that of the usual control electrode of a thermionic triode device. Although the control electrode 110 is outside of the cathode and anode, this relationship is not necessary although it would tend to be used for reasons of convenience. Conventionalized variable source 111 is shown as providing a means for varying the negative potential on this control electrode and hence the tuning effect eventually impressed on the cavity resonator.

The tuning adjustment of the resonator by the medium of the three electrode control units may be exercised externally of the oscillator or, as is disclosed among other things in the Shepherd application, the control may be automatic to determine an equality, or constant difference, of frequency, with a standard wave. As used in a reflex oscillator the tuning unit could even be thought of as a part of the oscillator organization to the extent that its cathode and control electrode could be connected respectively to the cathode and repeller electrode of said oscillator as shown. Source 111_a, as conventional, impresses a negative potential with respect to the oscillator cathode or electron gun 102 on the repeller 103. The resonator has a positive potential with respect to said cathode impressed from source 109 which is common to the oscillator and control unit. The cathodes of the oscillator and control unit are connected as shown, so that the control electrode of the control unit has impressed on it a variable potential with respect to its cathode from said source 111 in conjunction with source 111_a. When connected in this way, when the oscillator is slightly tuned, as it might be in practice, by change of repeller potential, the means of this invention would tend to conform the tuning of the cavity resonator to the new condition.

Referring now to the remaining figures of the drawing, the electron discharge device therein illustrated comprises a highly evacuated enclosing vessel housing therein a reflex oscillator, including a cavity resonator, and a thermally sensitive element for tuning the resonator and forming a part of a thermionic tuner unit. The enclosing vessel comprises a cylindrical metallic body 10 having an inwardly extending annular flange 11, a cup-shaped metallic base member 12 sealed, as by welding or brazing, to one end of the body 10 and having therein a plurality of eyelets 13 to which leading-in conductors 14 are sealed hermetically by vitreous masses or beads 15, and a metallic, cup-shaped cap or closure 16 sealed, as by welding or brazing, to the other end of the body 10.

The reflex oscillator comprises a generally toroidal cavity resonator 17 bounded by a metallic disc 18 having a flexible, annularly corrugated diaphragm portion 19, a second rigid metallic disc 20 having a central frusto-conoidal portion 21 aligned with a central opening in the diaphragm portion 19 and a metallic spacer ring 22.

Opposite the frusto-conoidal portion 21 and axially aligned therewith is an electron gun which includes a cylindrical cathode member 23 having a concave end surface 24 coated with electron emissive material, a heater filament 25 within the cathode member, a heat shield 26 encompassing the cathode member and a cylindrical beam forming electrode 27. The beam forming electrode 27 and shield 26 are provided with juxtaposed flanges 28 and 29 respectively which are joined to each other and are held between insulating discs 30 and 31 seated within a flanged cup-shaped member 32. The cathode member 23 is affixed at one end to the shield 26 and the latter is connected electrically to one of the leading-in conductors 33 for the heater filament 25 by a tie wire 34. The elements of the electron gun together with the discs 19 and 20, the spacer 22 and a second spacer ring 50 are locked to the flange 11 by a C-shaped washer or clamping member 35 and a plurality of screws 36, only one of which is shown, threaded into the flange 11.

The frusto-conoidal member 21, beam forming electrode 27 and cathode are so constructed and arranged, in ways known in the art, that electrons emanating from the surface 24 are concentrated into a converging beam substantially focussed upon the gap between the smaller end of the member 21 and the portion of the diaphragm 19 opposite thereto.

Energy may be taken from the oscillating field within the resonator 17 by way of a wave guide which may be of rectangulated cylindrical cross-section, and comprises an inner portion 37 affixed to an eyelet 38 on the disc 20 adjacent a slot 86 in the ring 22, the portion 37 extending into immediate proximity to an aperture 39 in the base member 12, and an outer portion 40 affixed to the base member 12, in alignment with the inner portion 37 and sealed hermetically at its outer end by a vitreous mass 41 abutting a ceramic disc 42 fitted within the portion 40.

The inner portion 37 of the wave guide has affixed thereto a trough-shaped metallic annulus 43 which in turn mounts a metallic cylinder 44, the annulus 43 and cylinder 44 defining a choke joint with the juxtaposed portion of the base 12 to prevent loss of energy from the guide 37, 40.

Opposite the diaphragm 19 and aligned with the central aperture therein is a tubular repeller electrode 45 which is locked in a cylindrical ceramic body 46 fitted within a cylindrical metallic sleeve 47 and locked therein by a collar or band 85. The sleeve 47 is secured within a metallic coupler element 48 having a tapered end portion 49 secured to the diaphragm 19. The other end of the coupler 48 has affixed thereto a rigid metallic disc 51 to the center of which a rigid metallic drive rod 52 is secured. For reasons which will appear presently, the drive rod 52 is of a material, such as stainless steel, having a high temperature coefficient of expansion and contraction. Extending through an insulating tubulature 53 carried by the disc 51 is a leading-in connector 54 for the repeller electrode 45.

The assembly comprising the coupler 48, 49 and repeller electrode 45 is supported for axial movement as a unit by a pair of resilient spider members, the arms 55 of which, as shown in Fig. 4, radiate from integral collars 56 affixed to the coupler 48, to integral annuli 57 seated against opposite ends of a cylindrical spacer 58 fitted within the body 10.

During operation of the device, electrons emanating from the cathode surface 24 are projected across the gap in the cavity resonator 17 and are velocity varied due to the oscillating field within the resonator. The velocity varied electron stream issuing from the aperture in the diaphragm 19 is subjected to a retarding field due to the repeller electrode 45, whereby the direction of motion of the electrons is reversed and the electrons are again projected into the resonator in the form of a density varied stream to deliver energy to the field within the resonator and thus to sustain oscillations. The oscillation frequency will be dependent, of course, upon the resonant frequency of the resonator and the latter, in turn, is dependent upon the configuration of the cavity. The configuration and, hence, the resonant frequency, is adjustable by deflection of the diaphragm 19. As is apparent, displacement or deflection of the diaphragm may be effected by longitudinal motion of the drive rod 52. Such motion of the rod 52 is realized and controlled accurately by varying the temperature of the rod to cause it to expand or contract to tune the cavity resonator to the desired frequency. The control of the rod is effected by a thermionic unit, of which a portion of the rod constitutes the anode.

The thermionic tuning unit is fabricated as a unitary assembly which comprises, as shown clearly in Figs. 2 and 3, an annular foundation member or platform 59 provided with integral ears 60 and a dished plate 61, the member 59 and plate 61 being coupled together by rigid posts 62 abutting the plate 61 and the ears 60. Supported in parallel relation by the posts 62 are a pair of insulating discs 63 and 64 which mount, in turn, a cathode and a control electrode cooperatively associated with the drive rod 52. The latter extends through oversized apertures in the discs 61, 63 and 64 and has its upper end secured to a rigid bridge defined by a bracket 70 and a bent strap or lever 65 affixed to the disc 61.

The cathode of the tuner unit comprises a cylindrical metallic tube 67 parallel to the rod 52 and having a coating of electron emissive material upon its outer surface, and a folded heater filament 68 within the cathode tube 67. The control electrode 69 is of rectangular form, encompasses the cathode 67 and rod 52 and is locked to the insulating discs 63 and 64 by integral bent-over tabs 71.

In the fabrication of the device, after the tuner assembly has been mounted as described hereinafter, the strip or lever 65 is flexed to move the drive rod 52 longitudinally, and thus to move the coupler-repeller electrode assembly and displace the diaphragm 19, to tune the cavity resonator to a prescribed frequency. The end of this strip is then affixed, as by welding, to the bracket 70. Thereafter, as will be apparent, the natural frequency of the resonator will vary in accordance with longitudinal expansion and contraction of the drive rod 52, one end of the rod being fixed against displacement by the bridge 65, 70. The length of this rod at any time will be dependent upon the temperature thereof and the temperature, in turn, will be determined by the bombardment of the rod by electrons emanating from the cathode 67, the rod, as noted heretofore, serving as an anode. The electron current to the rod is controllable by the control electrode 69. Thus, by adjusting the potential of the electrode 69, the resonant frequency of the cavity resonator may be altered or maintained fixed despite variations in the configuration of the cavity resonator due to temperature effects in the operation of the device.

It is evident that extremely fine tuning of the cavity resonator is attainable. Also, inasmuch as the repeller electrode 45 is coupled mechanically to the diaphragm 19 and moves therewith, the spacing of the repeller electrode relative to the diaphragm is fixed, whereby, for any given potentials upon the elements of the oscillator, the transit times for electrons leaving the cavity resonator and returning thereto likewise are fixed. Further, because of the mounting of the coupler 48 by the spiders, displacement of the coupler is linear whereby a predeterminable relation between resonator frequency and control electrode potential is achieved.

Supported from the discs 63 and 64 by bent wires 72 locked to these discs are a pair of filaments 73 which are coated with a getter material and are connected electrically at one end by a fuse wire 74. A protective shield 75, mounted upon two of the posts 62, is interposed between the control electrode 69 and the getter coated filaments. During the evacuation treatment of the device, a suitable current is passed through the filaments 73 by way of the leading-in conductors for two of the electrodes of the device, to flash the getter material. An increased current pulse is then applied to melt the fuse wire 74 and, thus, break the electrical connection between the two conductors mentioned.

Electrical connection between the leading-in conductors 14 and the electrodes of the oscillator and thermionic tuner unit may be established by way of conductors, for example wires 76 encased in insulating sleeves 77, to which the conductors 14 and electrodes are connected by tie wires or strips 78. The specific connections may be varied, of course, and will be apparent without further description.

The device described is designed especially for fabrication from several subassemblies which are facilely associated to constitute the complete device wherein all the parts are held securely in place and wherein the parts of the oscillator unit are aligned very accurately, for example coaxial within less than .001 inch. The general method of assembly and fabrication is, briefly, as follows: The disc 18, 19 is brazed to the flange 11 on the body 10. The spiders are secured to the coupler 48 by welding the collars 56 thereto and this assembly together with the spacer 58 is inserted into the body 10 and the spiders are brazed to the spacer 58, the latter is brazed to the body 10 and the smaller end of the frusto-conical portion 49 is brazed to the diaphragm 19. During this operation, the coupler 48 is centered accurately, as by a suitable jig, with respect to the body 10 and thus, is aligned accurately with the diaphragm. In order to prevent damage to the diaphragm during subsequent operations, a lock member 80 having a slotted end 81 for accommodating the flange on the coupler 48 is secured to the spacer 56, the slot being of such width as to limit axial motion of the coupler and, hence, displacement of the diaphragm, to, for example, of the order of a few thousandths of an inch.

A subassembly comprising the repeller electrode 45, insulator 46 and sleeve 47, constructed so that the repeller electrode is accurately coaxial with the outer surface of the sleeve 47, is inserted within the coupler 48 until the electrode 45 rests upon the frusto-conical portion 49 and then is withdrawn a distance requisite to establish the prescribed spacing between the repeller electrode and the diaphragm 19, whereupon the sleeve 47 is welded to the coupler 48. Thus, the repeller electrode 45 is aligned coaxially with the diaphragm 19. Using the repeller electrode as a guide, a suitable tool closely fitted thereinto, is inserted through the repeller electrode to punch an aperture in the diaphragm 19. As is evident, the aperture thus produced is accurately aligned with the repeller electrode.

The disc 20, ring 22 and inner portion 37 of the wave guide are fabricated as a subassembly, with the ring 22 accurately coaxial with the frusto-conical portion 21 and the ring 22 is then affixed, as by brazing, to the disc 18. During this operation, the apertures in the diaphragm 19 and frusto-conical portion are aligned accurately while viewing with a microscope.

Another subassembly comprising the cathode 23, 24 shield 26, insulators 30 and 31 and cup-shaped member 32, but not the heater 25, is then fabricated, aligned with the apertures in the portion 21 and diaphragm 19 while viewing with a microscope through the central aperture in the dished portion 24 of the cathode, and is then secured to the flange 11 by the screws 36.

The cap or closure 51 with the drive rod 52 fixed thereto, is affixed, as by welding, to the coupler member 48, a portion of the flange of the cap 51 being cut away, as shown in Fig. 4, to clear the slotted end portion 81 of the lock member 80. This portion is then bent away from the coupler member 48 and severed.

Subsequently, the thermionic tuner assembly is threaded over the rod 52 and the platform 59 is seated upon the upper spider member (in Fig. 2) and locked in place by forcing a portion of the body 10 thereagainst as indicated at 82 in Fig. 2. The drive rod 52 then is welded to the bridge piece 65 and the latter is flexed to tune the cavity resonator and welded to the bracket 70, as noted heretofore.

It is to be noted particularly that the construction above described enables very exact coaxial alignment of the elements of the oscillator whereby predeterminable and stable operating characteristics are obtained. Further, it will be noted that in the completed device the internal elements are mounted securely in fixed relation whereby the device may be subjected to relatively strong shocks without disturbance of the desired space relation of the parts.

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

What is claimed is:

An electron discharge device comprising, a frequency-significant mechanical-electrical network including a frequency determining movable element, means cooperating with said network comprising an electron discharge device constituting, with said network, an oscillation generating circuit whose characteristic frequency is the natural frequency of said frequency-significant circuit, and a frequency adjusting assembly comprising the anode of said electron discharge device, which has an elongated form and whose longitudinal axis extends in parallel with the desired direction of movement of said movable element and which is directly connected thereto, and having a high temperature coefficient of expansion and contraction whereby its length varies in accordance with its contained heat, the cathode of said electron discharge device, which is in electron bombarding relation to said anode, and a control electrode positioned in operative relation to said electrons and whose potential with respect to said cathode therefore determines the condition of the electron bombardment, and hence the heat condition, of said anode.

JOHN R. PIERCE.

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