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RESNATRON WITH SEPARATE RETARDING FIELD

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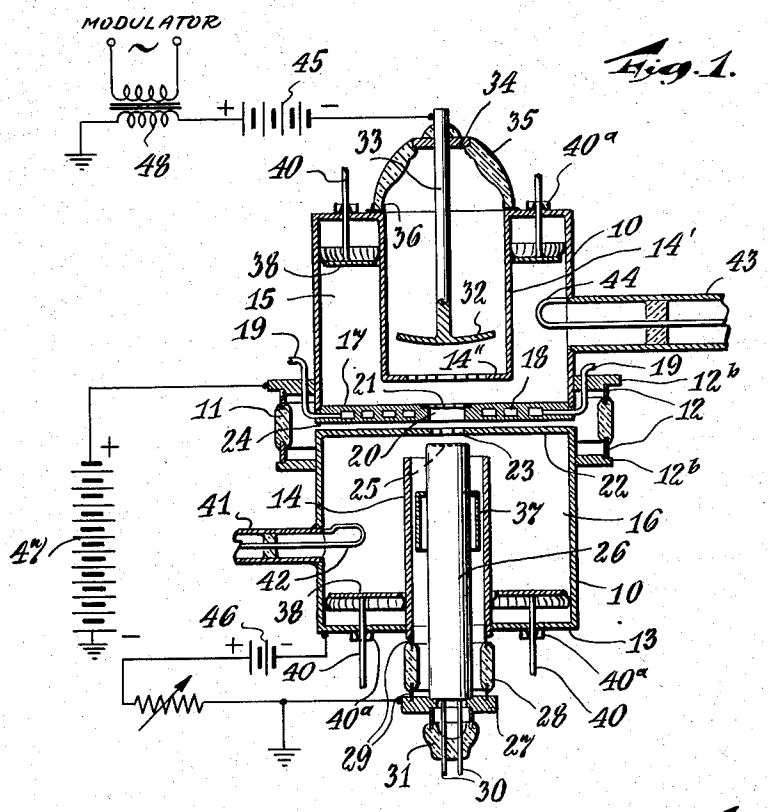


Fig. 1.

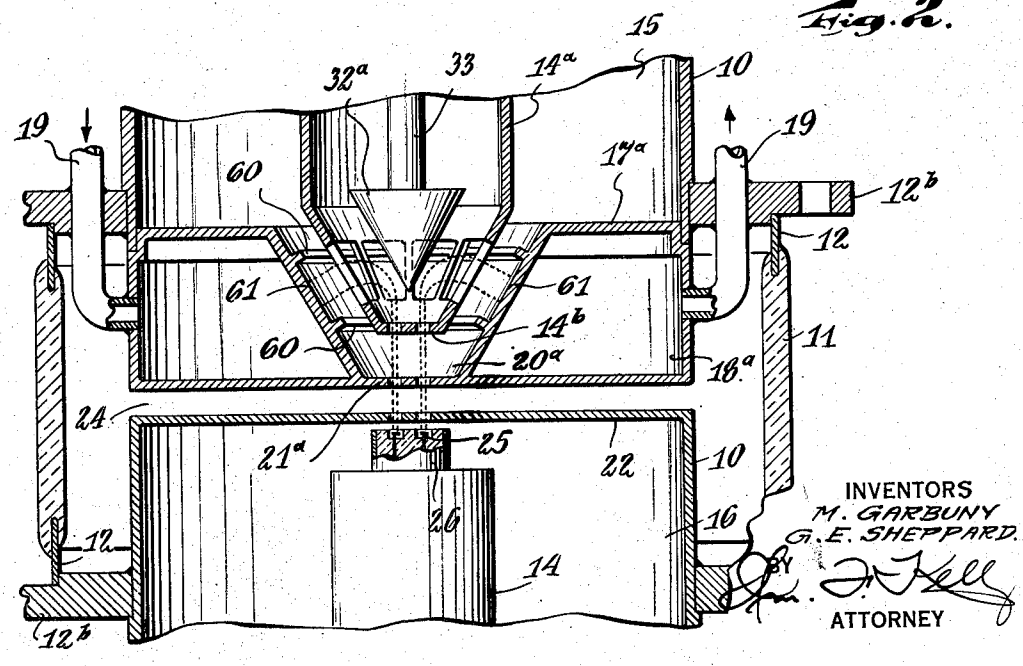


Fig. 2.

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RESNATRON WITH SEPARATE RETARDING FIELD

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4 Claims. (Cl. 315—6)

This invention relates to an electronic tube for ultra high frequencies and has particular relation to an electronic tube of the resnatron type such as described in our companion application Serial No. 206,744, filed January 19, 1951.

Said companion application explains the general construction and desirable characteristics of both prior art and our improved resnatrons, pertinent hereto but not deemed necessary to repeat in full herein. The present invention distinguishes from the said companion application essentially in the repeller construction and assembly in the resnatron and introduces desirable differences and improvements thereover.

The present invention accordingly is directed to improved construction and operation of the anode of a resnatron supplemental to the desiderata set forth in said companion application.

Referring to the accompanying drawing, in which like numerals of reference indicate similar parts in both figures thereof:

Fig. 1 is a longitudinal sectional view of a resnatron corresponding to the more detailed showing of said companion application and illustrating the improved repeller construction and assembly; and

Fig. 2 is a similar longitudinal sectional view of that portion of a resnatron which differs from Fig. 1, and showing a modified repeller, repeller housing and screen grid and cooling arrangement for the screen grid.

In the specific embodiment of the invention illustrated in said drawing, and referring more especially to Fig. 1, we show an envelope fabricated as a body of revolution about an axis and made as two metallic outer cylinders or body sections 10, 10 arranged endwise toward each other and upon an axis common to both. The ends facing toward each other of said body sections are held in proximity to, but with insulative spacing from each other, by a glass or other endless band insulator 11 lapping said ends and sealed to metal collars 12 the far margins of each of which are soldered or otherwise secured vacuum-tight to annular flanges 12*b* encircling and sealed to the outside cylindrical surfaces of the body sections proximate to the facing ends of said sections. The outer or far ends of the cylinders or body sections 10 are sealed by metallic or other headers 13, 13'. Carried by, sealed to and projecting inwardly of the cylinders from said headers are coaxial inner metallic cylinders 14, 14' which extend from their respective headers toward each other, but with greater spacing between the approaching ends thereof than between the proximate ends of the outer cylinders.

The chambers within the outer cylinders around and beyond the inner cylinders toward their proximate ends are arranged to constitute cavity resonators, of which one will be herein designated the anode resonator 15 and the other designated the cathode resonator 16 for purpose of distinguishing therebetween. The proximate ends of the two cavity resonators have end walls parallel to and adjacent each other with sufficient spacing for insulative purposes. The end wall 17 of the anode resonator is

shown provided with a spiral channel 18 therein, the ends of the channel having pipes 19 connected therewith for supply and discharge of a cooling medium, such as water, for said wall. Said end wall 17, has, at its center, a hole or passage 20 therethrough disposed axially of the outer cylinder and opposite the end of the inner cylinder. A formaninous or other member 21 is located across said hole or passage as a fixed part of said anode resonator end wall. Said end wall, with its hole and foraminous member, accordingly has a structure constituting it both a screen grid and an anode, as well as an end wall for the resonator.

The other chamber, above described as the cathode resonator 16, has an end wall 22 at the center of which is a hole or passage 23 of corresponding size to and aligned with hole or passage 20 of the screen grid or anode resonator end wall 17. It will be observed that this end wall 22, as well as above-described end wall 17 of the anode resonator, and both passages 20 and 23 through said walls, and gap 24 between said walls, are all within the evacuated interior of the tube or device.

An indirectly or directly heated cathode 25 is provided within cathode resonator 16 in axial alignment with and close proximity to the hole or passage 23 in end wall 22. Said cathode is carried at the inner end of a hollow core 26 located coaxially within the resonator inner cylinder 14. The cathode is electrically connected to said core which accordingly constitutes a lead-in as well as a support for the cathode. The outer end of the core is seated in and soldered to an end plate 27 with a vacuum-tight joint and the plate is supported at the exterior of header 13 by a glass or other insulative cylindrical band 28 sealed at its edges to oppositely projecting collars 29 respectively soldered vacuum-tight to the outwardly directed rim of inner cylinder 14 and to the inwardly directed face of the end plate 27. Lead-in wires 30 for the cathode heater are introduced into the said core through the end plate 27 and with the aid of an appropriate seal 31.

An electron repelling electrode, herein referred to as repeller 32 is provided within the anode resonator and, as shown, within the inner cylinder 14' in said resonator. To accommodate said repeller within the inner cylinder 14', said cylinder may have a greater diameter than required for and provided with the inner cylinder 14 of the cathode resonator 16. Furthermore, the end of said inner cylinder 14' of the anode resonator toward and in proximity to the screen grid 17 is provided with a partial closure or transverse grid termination 14'' parallel to said screen grid. Electrons from the cathode may accordingly approach the repeller, but the metallic enclosure provided by inner cylinder 14' and the closure 14'' shields or protects the repeller almost entirely from the radio frequency field and confines the direct current repeller field of the repeller within the said enclosure.

Said repeller 32 is shown convex or centrally bulging toward the screen grid-anode and is shown supported from its concave side by a lead-in post 33 located coaxially within the anode resonator inner cylinder 14'. The remote end of said post from the repeller is sealed through the header 13' for purposes of support and external electrical circuit connections. The specific construction here shown for the inner cylinder closure portion of said header 13' comprises a metallic disc 34 soldered or otherwise secured vacuum-tight to the said lead-in post, the outer periphery of said disc being sealed in a glass dome 35 the basal margin of which is in turn sealed to a metallic flange 36 soldered or otherwise secured vacuum-tight to the upper end of the anode resonator.

It may be here noted that by enclosing said repeller within the inner cylinder, no chokes are required for the lead-in post. However, cathode core 26 is provided with

a choke 37 to prevent leakage of high frequency power from the cathode resonator through seal 28 into outer space. This choke is constructed in accordance with usual practice a quarter wave-length in dimension from a closed to an open end and with the open end directed outwardly, thereby presenting an effect of short circuit at the closed end of the choke across the gap between the resonator inner cylinder and said core.

Both resonators are tunable, for which purpose each is conventionally shown as provided with an annular piston 38 in the annular space between the outer and inner cylinders 10 and 14 and 10 and 14'. These pistons are each carried from and slidably mounted by a plurality of rods 40 parallel to the cylinder axis and projecting through the header 13. A suitable bellows 40*a* or other vacuum-retaining seal is provided between each rod and the header, permitting necessary sliding of the rod in the header and cylinder for tuning purposes and yet maintaining a vacuum-tight condition between the rod and header.

A coaxial line 41 terminating as a loop 42 is introduced into the cathode resonator and constitutes a radio frequency input from a suitable source which may conveniently be a feed-back of a part of the radio frequency energy produced in the anode resonator. The anode resonator is also shown equipped with a coaxial line 43 terminating as a loop 44 in said resonator and constituting a radio frequency output. Both coaxial lines 41 and 43 are constructed to be vacuum-tight so as to maintain the vacuum in said resonators.

Appropriate direct current potentials are applied to the repeller, cathode and screen grid-anode, and according to the present showing, separate sources 45, 46 and 47 respectively are here depicted, although, as in the companion application above-mentioned, suitable tapping from a single source may be arranged. The repeller may also be connected, as through transformer 48 with a desired source of modulation for uses and purposes more fully explained in said companion application.

The potentials applied to the several electrodes are proportioned to cause a copious flow of electrons from the cathode to proximity of the repeller and reflection from the repeller back to the screen grid-anode. Divergence of the electrons in the reflected path is desirable so that the non-foraminous part of the screen grid in its function as anode will intercept the electrons. Such divergence is obtained by virtue of the convex surface of the repeller and is permitted by virtue of the grid termination 14'' having an open work area considerably greater in diameter than the foraminous area of the screen grid 21.

Referring now to Fig. 2, it may first be said that the parts broken away and not shown would be, if shown, exact duplicates of the corresponding parts of Fig. 1. A pair of tunable resonators each having outer and inner metallic cylinders and input and output connections are accordingly to be understood as included in both showings.

In Fig. 2, the metallic end wall 17*a* of the anode resonator 15 is shown hollow so as to provide a cooling chamber 18*a* therein to which pipes 19 are connected for supply and discharge of a cooling medium. Said end wall 17*a* has, at its center, a frusto-conical hole or passage 20*a* therethrough disposed axially of the outer cylinder 10 and with the larger end or flare of said passage directed away from the cathode. The smaller end of the said passage toward the cathode is provided with a foraminous member or grid 21*a* as a fixed part of the end wall structure. As in Fig. 1, said end wall 17*a* with its frusto-conical passage and foraminous member 21*a* constitutes in part both an anode and a screen grid as well as, in its entirety, an end wall for the resonator.

Inner cylinder 14*a* in anode resonator 15 has a partial closure or grid termination 14*b* at its end next the screen grid and said termination is frusto-conical and coaxial with, but spaced inwardly from, the frusto-conical passage wall of said screen grid 21*a*. The small end of the frusto-conical termination 14*b* is perforate for admitting electrons therein from the cathode, and the flaring wall of said termination is of open-work or grid construction to permit outflow of electrons therethrough to the frusto-conical passage wall of the screen grid-anode. Two parallel ribs 60, 60 are shown on the face of the frusto-conical passage wall spaced apart in approximate juxtaposition to the limits of the perforate area of the inner tube termination. The surface of the passage wall between said ribs constitutes a collector or anode 61 for the electrons and, obviously from the drawing, is disposed advantageously with respect to the cooling medium.

All electron repelling electrode, herein referred to as repeller 32*a* is provided within the inner cylinder and frusto-conical termination of said cylinder with the same advantages as described in connection with Fig. 1. Said repeller in this instance is conical and coaxial with the frusto-conical termination of the inner cylinder. The larger end of the conical repeller is directed toward the far end of the resonator and is mounted on and carried by lead-in post 33. With potentials applied, as will be understood from the foregoing description and from said companion application, electrons are reflected and in their reflected paths flow away from the repeller perpendicular to the nearest portion of the repeller surface or radially outward from the cone repeller to the collector or anode surface. In this construction, as with Fig. 1, interference is substantially avoided between the radio frequency field and the direct current repeller field.

The herein described reflex resnatron allows a density modulated beam of electrons to enter first the anode resonator then the repeller chamber where it encounters the reflecting direct current repeller field, and is reflected. On the way to and from the repeller field the beam traverses an opposing radio frequency field to which the beam surrenders kinetic energy. In the companion application above mentioned, the conversion efficiency depends strongly on the value of the retarding anode or reflector field because of the timing criterion, hence the device thereof provides self-modulation with small power of the modulator source 48. The simplicity of that device entails also certain rigorous constructional requirements; for instance, the superpositioning of retarding direct current and radio frequency fields in the output gap makes changes in the geometry effective for both fields in the same way. An example is that a change of screen-to-anode distance of that device to accommodate various values of the screen accelerating voltage (for changes of power level) also changes the tuning of the output cavity.

This drawback is avoided in the presently disclosed invention, gaining, also, certain other advantages. The tube of this invention, like resnatrons of the prior art, when used as an amplifier, has its electron beam first density modulated in the cathode-grid resonator 16 by an external driver or oscillator, or, when used as an oscillator, has its electron beam density modulated by feedback from the anode-grid resonator 15. The density modulated and preferably beam-formed electron stream passes an accelerating screen of relatively high potential to enter an output cavity or resonator 15 tuned to resonator 16. Usually in resnatrons, the anode is available to the electrons by direct flow of the electrons thereto, but in the present invention the electrons entering resonator 15 find a further grid or the like, 14*a* or 14*b*, which, with inner cylinder 14, substantially separates the radio frequency space from the retarding field of a repeller from which they are reflected toward the anode-screen. Thus the electrons traverse a radio frequency field first, that field being relatively free of a direct current component, and the electrons give up some energy to that field.

Next the electrons enter the inner or repeller chamber where they encounter the segregated retarding direct cur-

rent essentially static field of the repeller and thereby are reflected into the radio frequency space of resonator 15. During transit of the electrons in their reflected path in the resonator, radio frequency field polarity again opposes motion of the electrons and further energy is derived by the resonator from the electrons. The degree to which this is the case is determined by the modulating voltage on the reflecting electrode or repeller and the modulation in turn determines the instantaneous value of efficiency and output power level.

The device of the present disclosure has most of the advantages of our previously disclosed reflex resnatron. However, at the expense of an additional grid as herein described, the present invention offers additional features and advantages, some of which may be explained as follows:

(1) The invention attains a wide band width in use. The feature of wide bandwidth can be understood in the following way: Up to, and including the third grid, the device represents in all aspects the case of a conventional resnatron with plate and screen on the same direct current potential. If a certain power level P is maintained in the output cavity, a given loaded shunt impedance R_1 will produce a radio frequency gap voltage V, given by

$$V=\sqrt{2R_1P}$$

In the conventional resnatron R_1 is so adjusted that ideally electrons coming from the screen with an energy V_1 are just decelerated to speed zero, or substantially so, when they arrive at the plate, i. e., they have surrendered all their energy to the field. In the case of the disclosed device, however, one will choose under otherwise identical values of power and screen voltage V_1 a loaded shunt resistance

$$R=R_1/4$$

so that only half of the opposing radio frequency voltage is created. The electrons arrive then at the third grid, by way of example with one half of their initial energy eV_1, make a return trip in the retarding field and (with correctly adjusted transit time conditions) yield the second half or other balance of their energy on their way back to the screen-anode. The same considerations hold for electrons which, because of modulating or entrance phase conditions, do not yield all their energy. We have shown therefore that under otherwise identical conditions, the described device allows one quarter the usual loaded shunt resistance. This means in turn that, other things being equal, a reduction of the ideally loaded Q by a factor 4 is allowed, or that four-fold bandwidth is obtained over the conventional resnatron. This advantage is a direct result of the separation of retarding radio frequency and direct current fields, since the electrons have to traverse the entire length of the radio frequency field. The reflex resnatron, as described in our said companion application, allows the electrons to go only part of the way in the combined radio frequency and direct curernt field, so that a larger radio frequency voltage is necessary for opposition, necessitating a larger shunt resistance. The advantage is in part given away, whereas it is fully used in this device. In addition, it should be remembered that the input cavity is allowed to have very high Q, without affecting the bandwith of this modulating scheme.

(2) Flexible voltage adjustment is accomplished by the present invention. The resonance condition between the reflected beam transit times and the phase of the radio frequency field introduces the condition that for larger screen voltages the reflecting plate must recede from the screen. This can now be done without changing the tuning of the output cavity, since the latter is essentially isolated.

(3) This invention gains a desirable result of dispensing with chokes for the anode lead. The separation of repeller field and radio frequency space has the further advantage that no chokes are needed to insure direct current insulation of the plate without power leakage. Chokes are inconvenient because of the necessity of flexible design and because they introduce an additional load with respect to the modulating system.

(4) Higher efficiency is one of the important advantages of the present invention. The additional parameter gained in this device can be utilized to velocity modulate the density modulated beam. Thus overmodulation can effectively increase the efficiency of the operation.

We claim:

1. A resnatron comprising a cathode and a repeller opposite each other for direct flow of electrons from the cathode to the repeller, a resonator having a peripheral wall entirely beyond the cathode and surrounding said repeller and having an end wall also entirely beyond said cathode, said end wall having a grid in the path of direct flow of electrons from the cathode to the repeller, an enclosure for said repeller surrounded by said resonator said enclosure having passage openings for electrons following said path of direct flow from the cathode to the repeller and having passage openings for electrons reflected from the repeller on a path other than said path of direct flow from cathode to repeller.

2. A resnatron comprising a cathode resonator and an anode resonator, a screen grid between said resonators, a cathode in the cathode resonator, and a repeller surrounded by said anode resonator, said screen grid having passage for electrons on a path of direct flow from the cathode to the repeller, means for substantially segregating the direct current field of the repeller from the radio frequency field of the anode resonator, said means having grill openings for passing electrons reflected from the repeller, and said screen grid having an anode surface area imperforate to electron passage for receiving electrons reflected by said repeller, said area being beyond the cathode resonator and within the anode resonator.

3. A resnatron comprising a cathode resonator and an anode resonator, a screen grid between said resonators, a cathode in the cathode resonator, and a repeller surrounded by said anode resonator, said screen grid having passage for electrons on a path of direct flow from the cathode to the repeller, means for substantially segregating the direct current field of the repeller from the radio frequency field of the anode resonator, said means having grill openings for passing electrons reflected from the repeller, and said screen grid having an anode surface area imperforate to electron passage for receiving electrons reflected by said repeller, and having cooling means for said surface area of the screen grid.

4. A resnatron comprising a cathode and a repeller opposite each other for direct flow of electrons from the cathode to the repeller, a resonator having a peripheral wall entirely beyond the cathode and surrounding said repeller and having an end wall also entirely beyond said cathode, said end wall having a screen grid providing passage openings in direct line of electron flow from the cathode to the repeller and providing a non-formainous area out of direct line of electron flow from cathode to repeller, said repeller having means for reflecting electrons toward said non-foraminous area of said screen grid, an enclosure for said repeller, said enclosure having grid openings for receiving electrons on said direct line of electron flow and for passing reflected electrons by a different path to said non-foraminous area of said screen grid.

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