March 7, 1944. E. STEUDEL 2,343,487

ELECTRON DISCHARGE DEVICE

Filed Aug. 30, 1941 2 Sheets-Sheet 1

Fig. 1

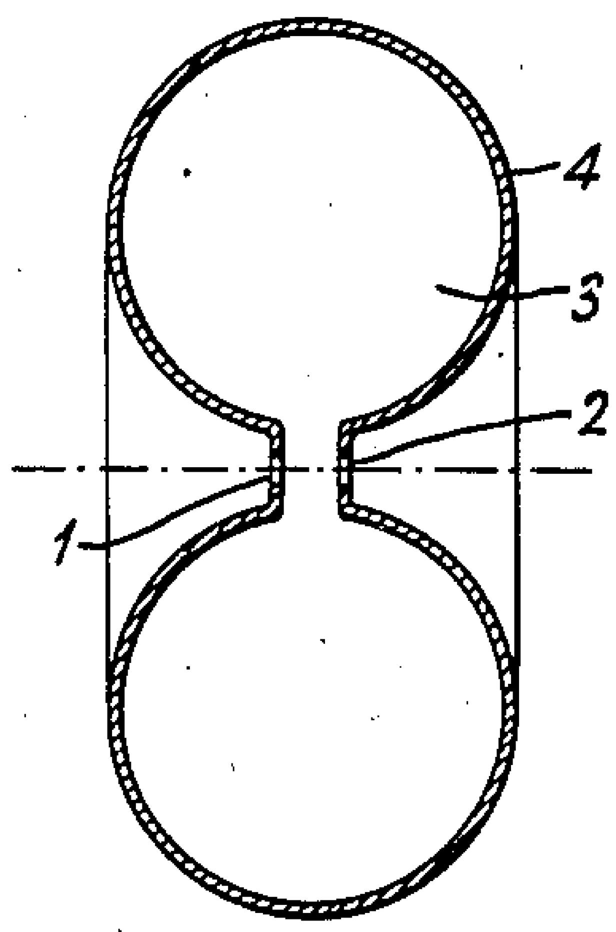

Fig. 2

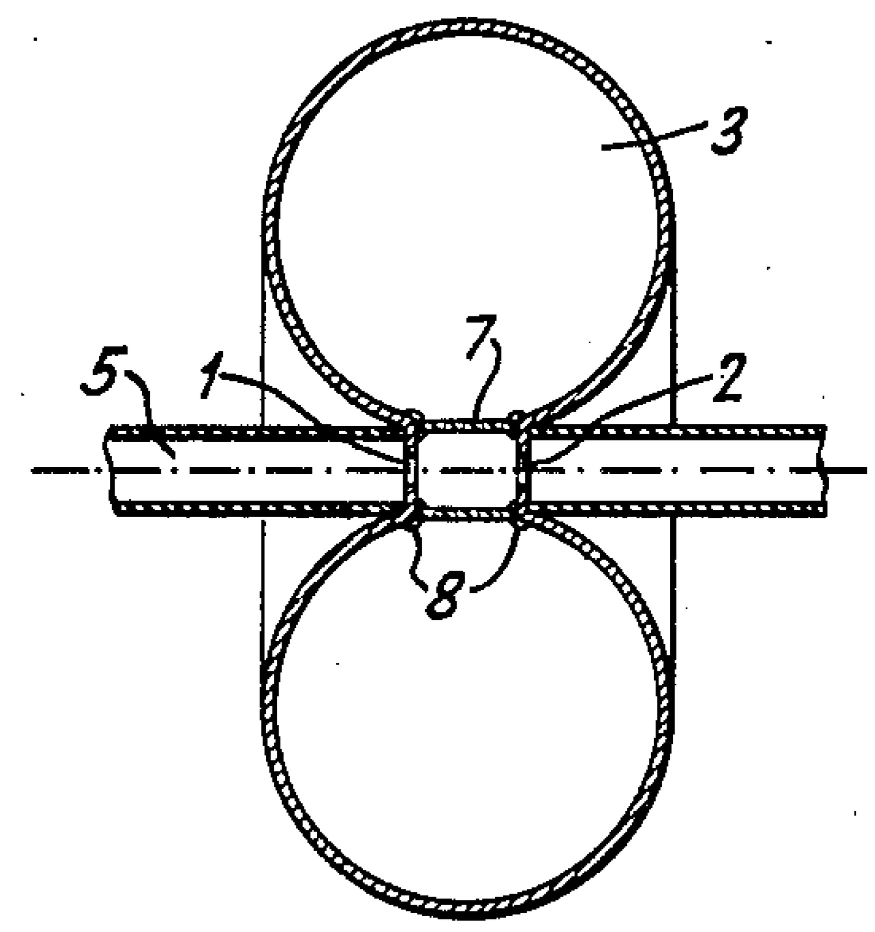

Fig. 3a

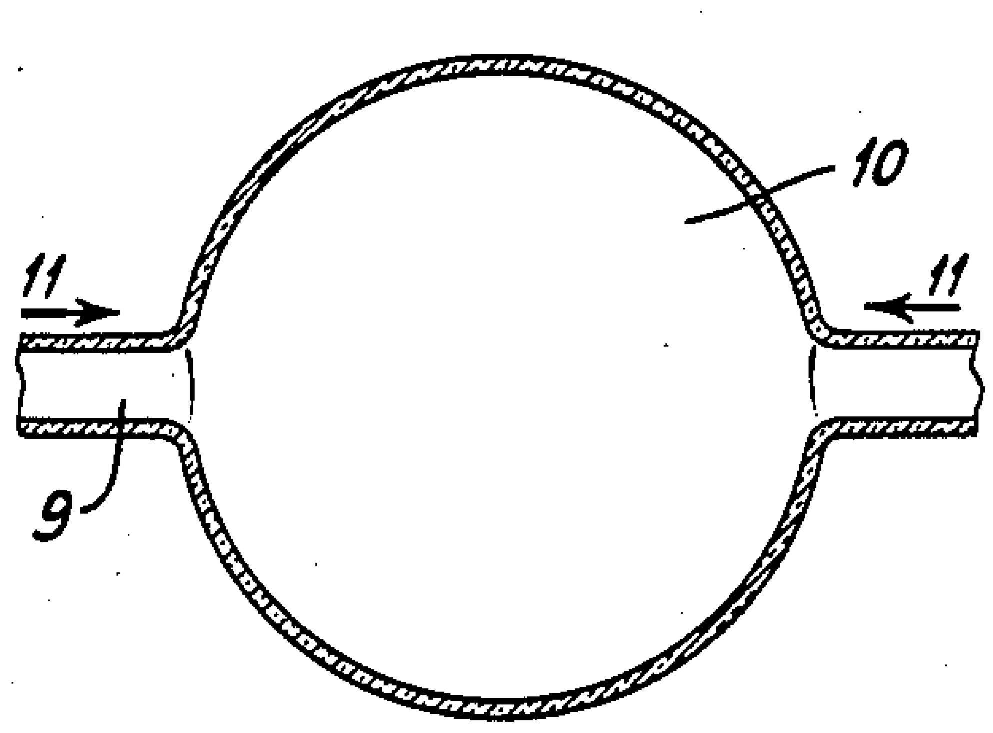

Fig. 3b

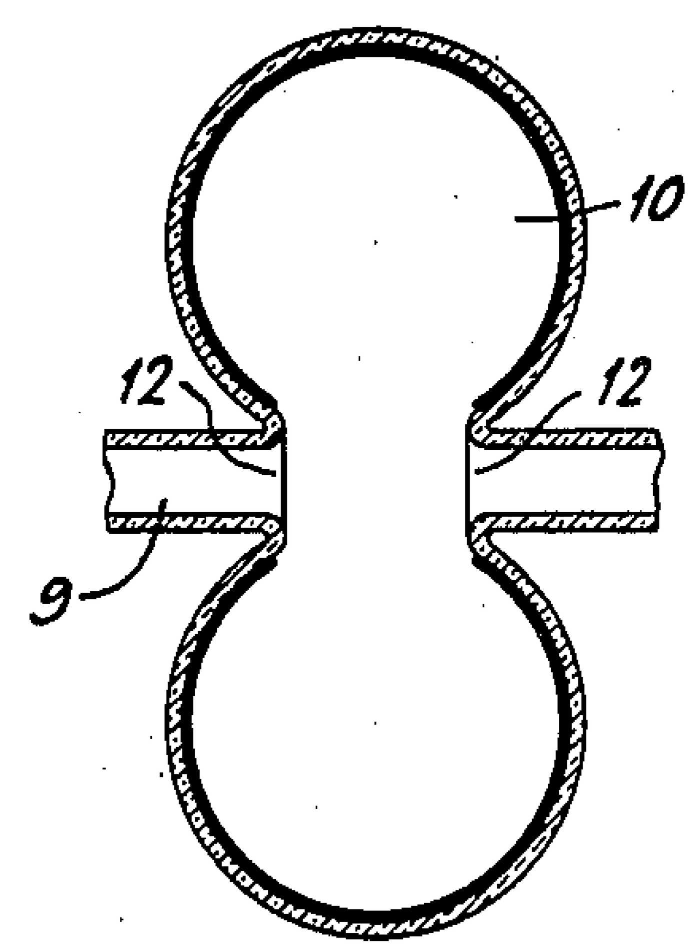

Fig. 3c

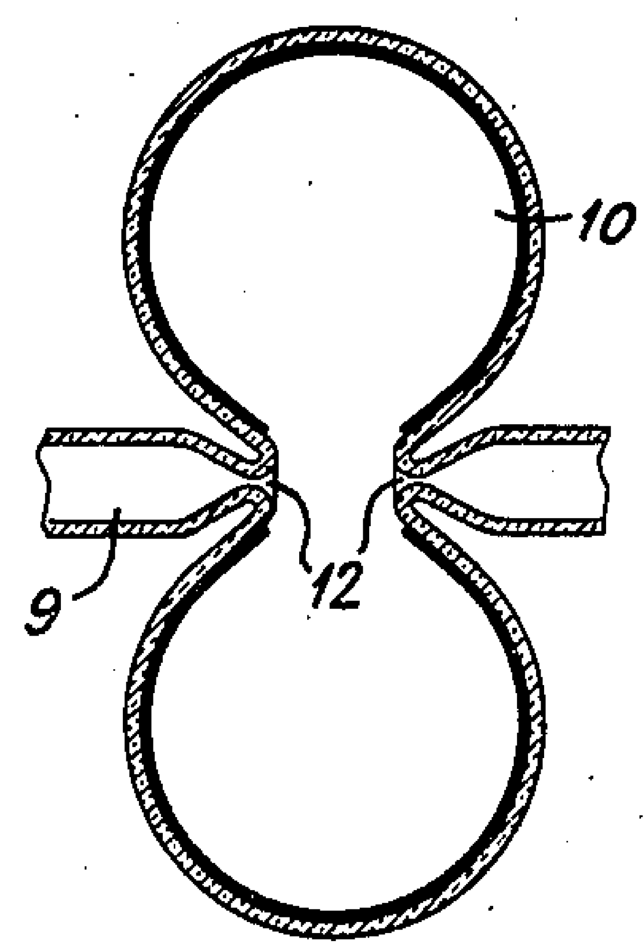

Fig. 4

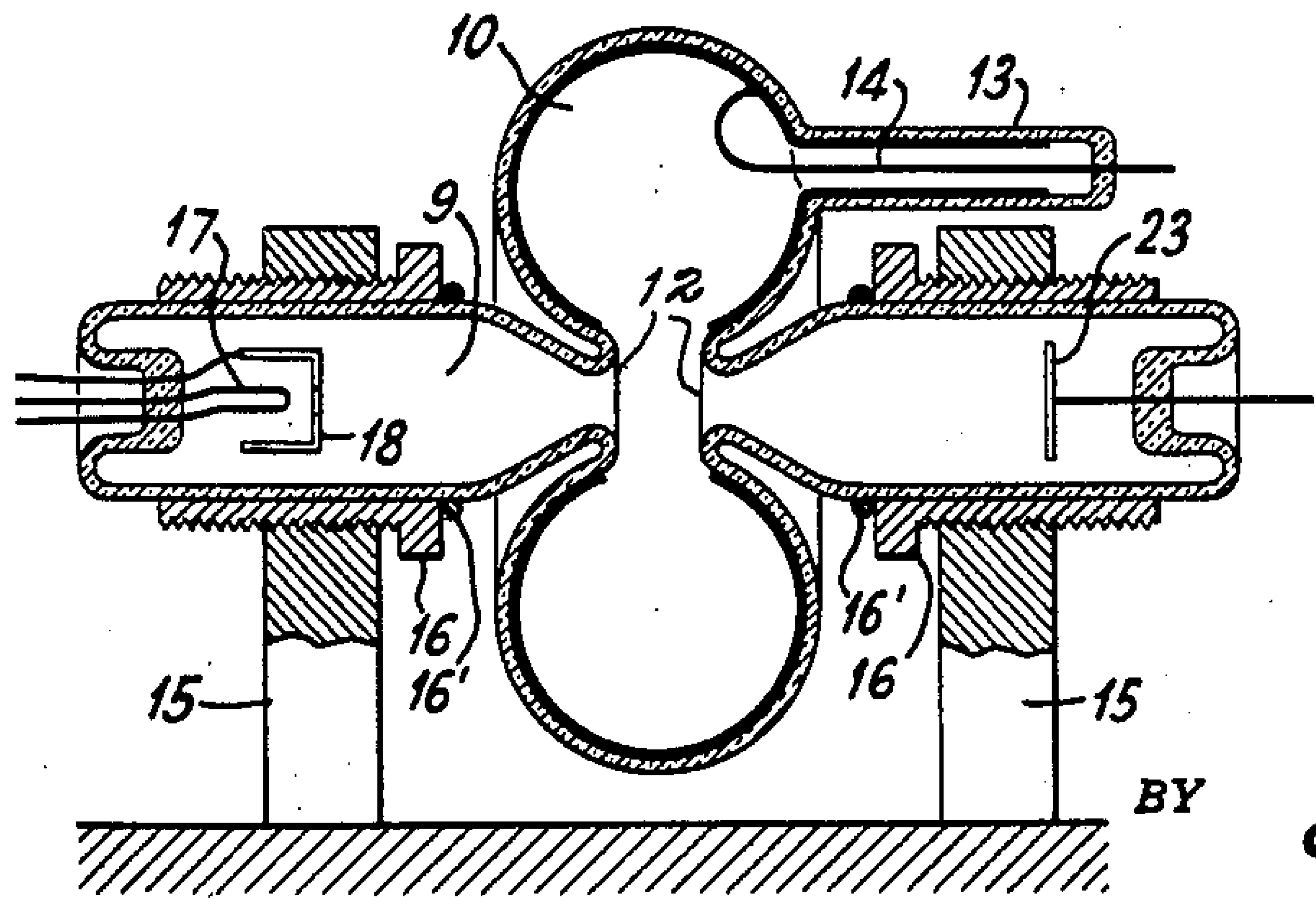

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Fig. 5

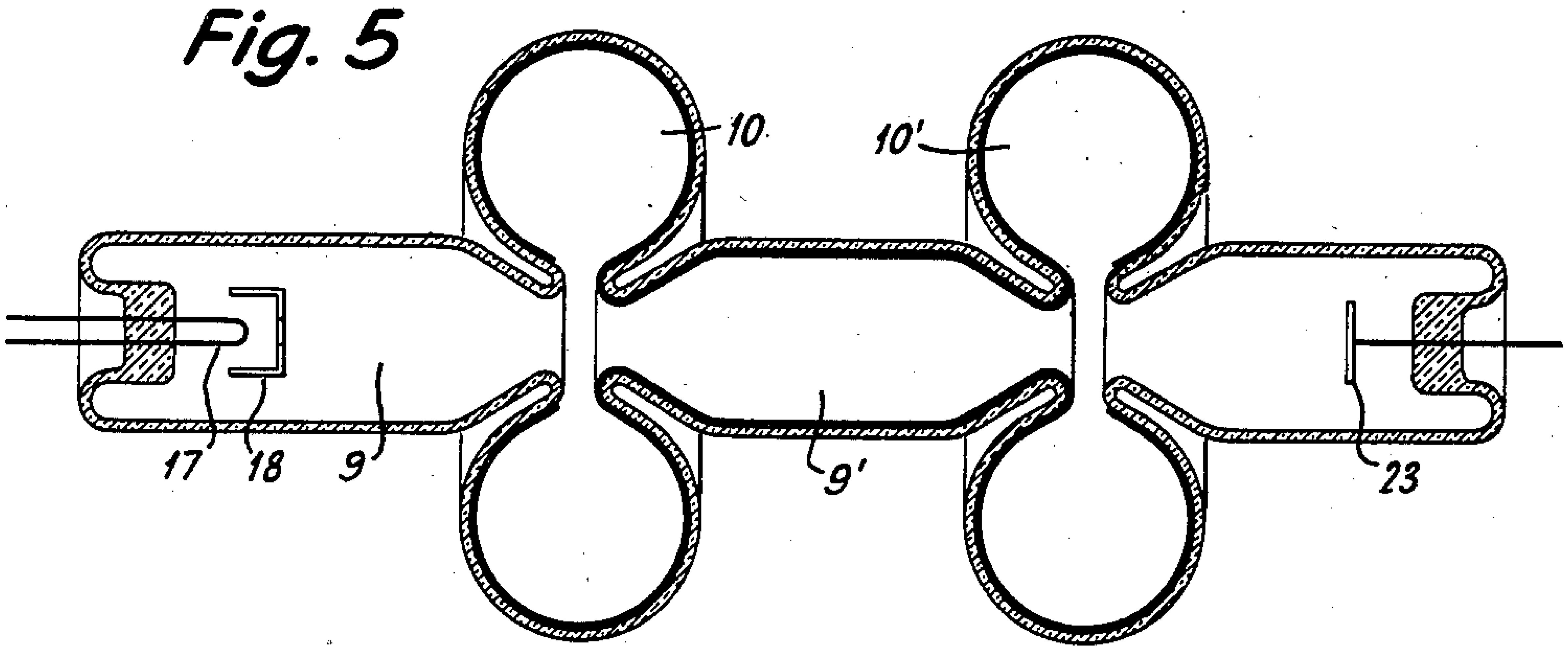


Fig. 6

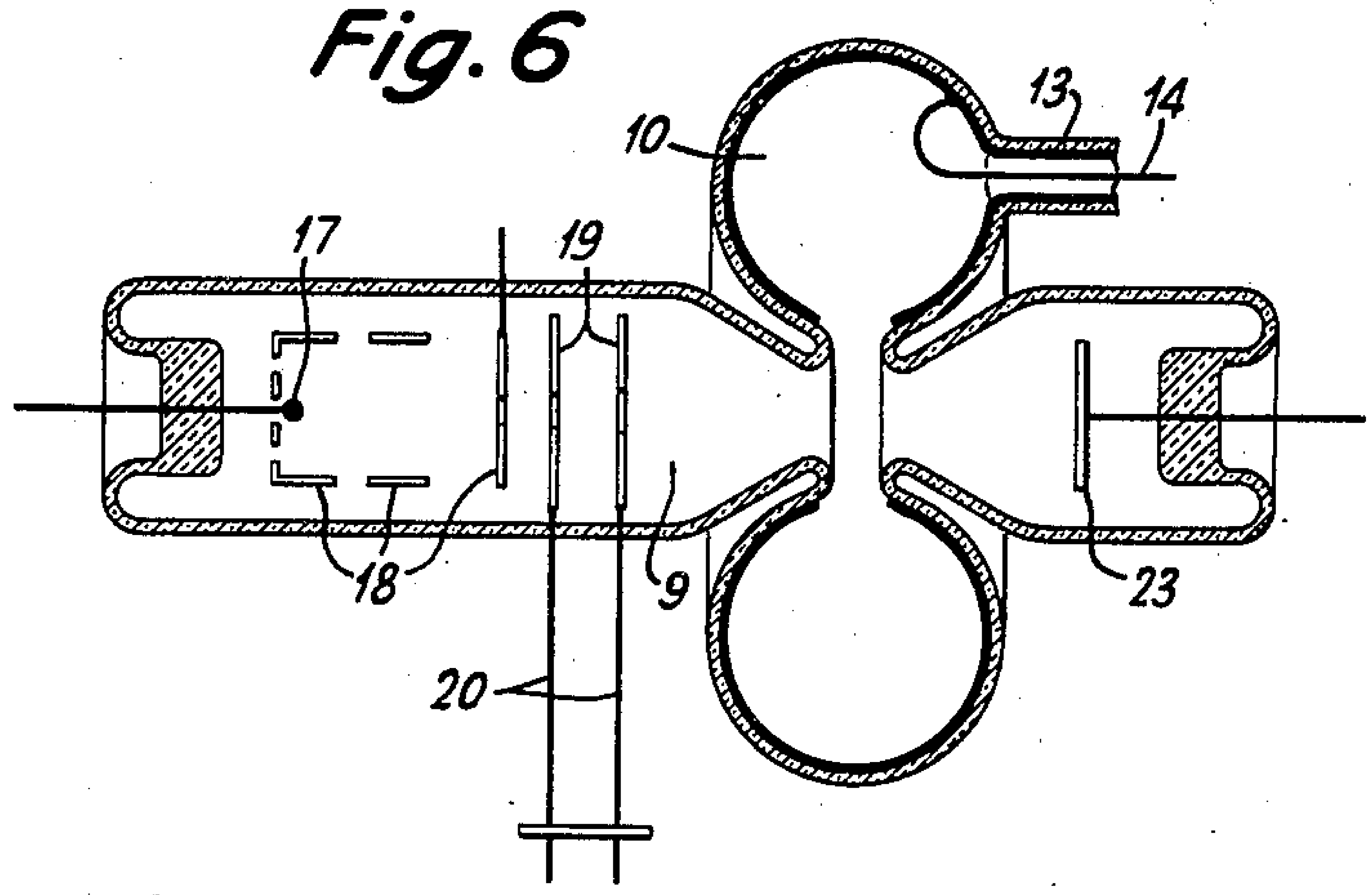
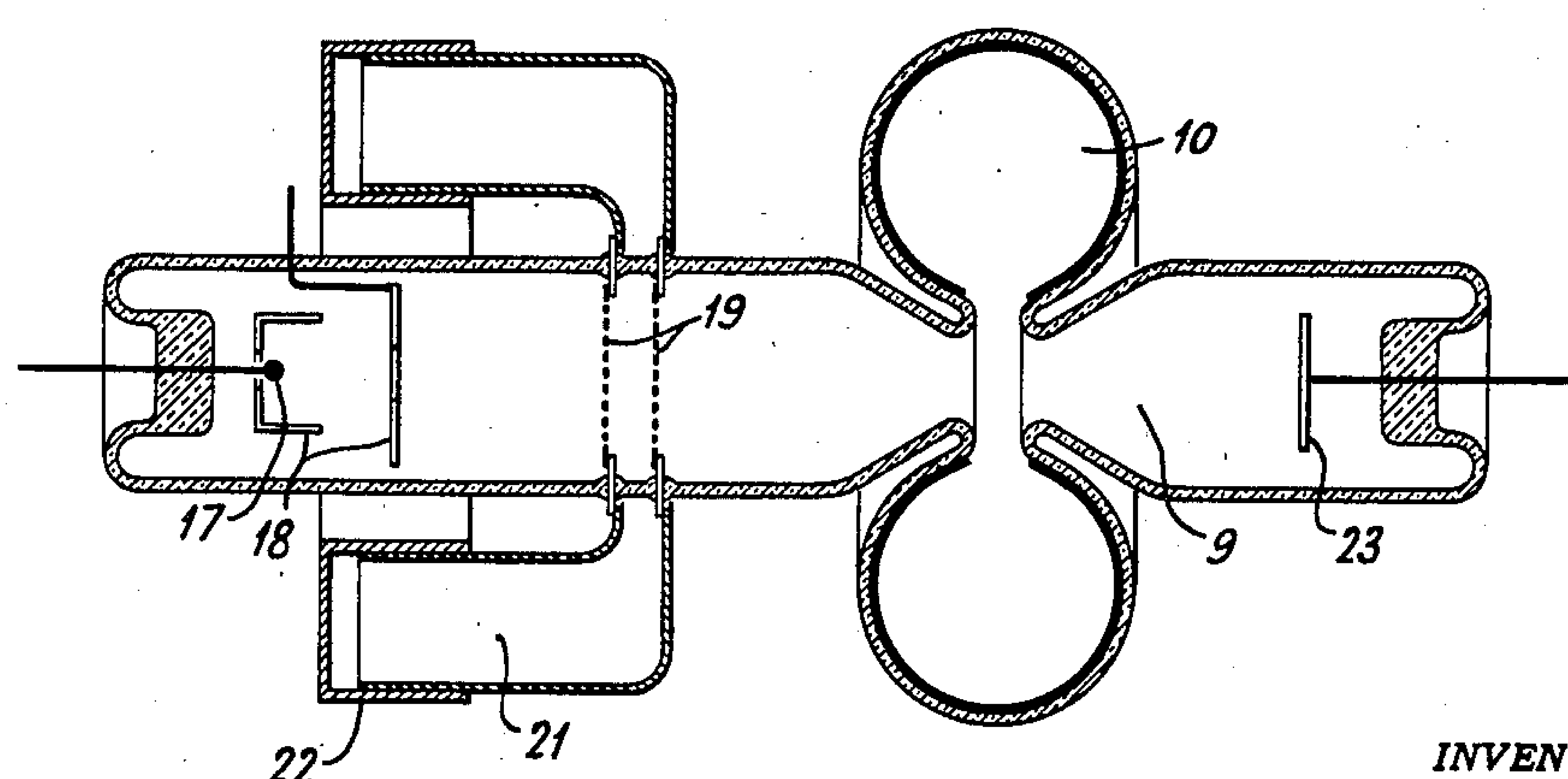


Fig. 7



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ELECTRON DISCHARGE DEVICE

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Application August 30, 1941, Serial No. 408,959
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6 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices particularly suitable for use at high frequencies and utilizing so-called resonant cavity tank circuits.

The generation of ultra-short waves is attended with ever-increasing difficulties in proportion as the frequency is raised. There are several factors which aggravate the problem of producing high frequencies. In the first place, these difficulties are a function of or due to the tube properties. Another fact, however, is that the associated circuits become increasingly poorer in their operation as the frequency is increased. For example, the resonance resistances of modern oscillation circuits in the longer wave bands or lower frequencies, are of an order of magnitude of 10^6, while in the short-wave band and the ultra-short-wave band, that is at the higher frequencies, they drop as low as a few hundred. Such a decrease is due to the relatively more marked growth of the capacitance at the expense of the inductance, which, in turn, is proportional to the ever decreasing dimensions of the oscillation circuit and the geometric forms thereby required. Among the tube properties which render the task of generating ultra-high frequencies more difficult, it is the transit time of the electrons which plays an appreciable part together with the geometric construction of the oscillation circuit.

It is known in the art, with a view to avoiding these difficulties, to provide oscillatory circuits other than the conventional. Moreover, to preclude these difficulties, substantially different forms of tubes have been adopted, that is to say, tubes which basically possess no difficulties due to transit time effects for the reason that the transit time effect is being utilized in them. In what has been called transit-time, drift or beam tubes and sometimes referred to as velocity modulated or inductive output tubes predicated for their operation upon velocity modulation, a beam of electrons is subjected to velocity modulation at a certain point. In other words, the electrons which pass this particular point are accelerated or decelerated, according to the instant when they travel past this point. The velocity-modulated beam of electrons may thereupon be changed into a density modulated beam. This is accomplishable in the type of tube here dealt with by causing the electron beam, after velocity modulation thereof, to traverse a space free from fields in which the fast electrons are enabled to catch up with the slower ones with the result that at the end of this field-free space, bunched or collected or grouped electrons having considerable charge densities leave the field free space. Now, if the density-modulated beam of electrons passes through a structure or system capable of oscillation, it is possible to excite the structure or system at its natural frequency. The electrons of the beam as a result are deprived of energy, the latter reappearing in the form of oscillatory energy in the structure or system serving as the circuit. With velocity modulation the input impedance of such a tube is high even where ultra-high frequencies are dealt with.

Now, the operation of these beam or drift tubes, in turn, is closely associated with the use of chamber resonators or so-called resonant cavity tank circuits, for these resonant cavity tank circuits possess the high resonance resistance required in high frequency work. What is necessary to observe is that in the operation of beam tubes a relatively high potential is used with the tube, such high potential being necessitated both for the beam generation and preservation as well as for working the tube with the lowest possible dissipation of energy. Another point is that high potentials are desirable in order that higher output powers may be obtained. The above-mentioned conventional beam tubes can not be operated with large currents, first, on the ground that this is attended with technical difficulties because of the comparatively poor emission density of the conventional sources of electrons, and secondly, because the electrons are incapable of being bunched together to result in high densities. In other words, these conventional tubes are characterized by high potential and low currents, or, putting it in different terms, by a high internal resistance. If, then, a generator having a high internal resistance is called upon to excite an oscillatory circuit, the latter must possess a high resonance resistance for otherwise the energy transfer would be correspondingly poorer.

However, it is not only the oscillatory circuit, but also the input circuit causing the velocity modulation which can make advantageous use of a chamber resonator seeing that for marked velocity modulation, because of the low initial speed of the electrons, comparatively high potentials are required. The use of chamber resonators thus becomes absolutely necessary in these velocity modulated beam or drift tubes. The use of chamber resonators offers a number of special advantages which, in themselves, would make the employment of chamber resonators desirable or imperative. Inasmuch as the field of the oscillating chamber oscillator exists only inside this chamber or space, while no external field arises, special advantages arise in the operation of these tubes for the reason that input and output ends are decoupled. The dimensions of chamber resonators, even where extremely high frequencies are dealt with, are relatively large so that, contradistinct from what is necessary, for instance, in the case of the magnetron or other conventional short-wave generators or oscillators, the question of reduced dimensions of the electrodes is not a problem. Small electrodes such as used in conventional tubes known in the art, impose a limitation upon the efficiency and performance for the reason that these small electrodes, owing to power dissipation inside the tube, become excessively heated, and this imposes a thermal limitation upon the efficiency. Thus, chamber resonators also have a number of special advantages in tubes of the kind considered. However, resonators of the type disclosed in the earlier art involve the demerit that they can be tuned only when special constructional steps are taken.

It is, therefore, an object of my invention to provide an improved form of electron discharge device particularly suitable for use at high frequencies and utilizing improved forms of resonant cavities.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings in which Figure 1 is a diagrammatic cross section of a resonant cavity tank circuit of the type described; Figure 2 is a modification of the tank circuit shown in Figure 1; Figures *3a*, *3b* and *3c* show steps in the formation of a resonant cavity tank circuit in accordance with my invention; Figure 4 is a finished electron discharge device incorporating my invention; Figure 5 is a modification of the device shown in Figure 4, and Figures 6 and 7 show still further modifications of an electron discharge device made according to my invention.

Figure 1 illustrates a chamber resonator or resonant cavity tank circuit of the kind now used in connection with velocity modulated or inductive output beam tubes. The electrons intended to excite the resonator traverse it in the direction marked 1—2. If the space 3 bounded by the wall or shell 4 serves as a modulator, it is able to modulate a beam of electrons of uniform velocity on its path from 1 to 2 with an incidental production of velocity modulation. Detuning (change of tuning) of such a space or chamber, for instance, can be made by change of the distance 1—2. However, the identical effect could be attained also by altering the toroidal surface. As pointed out above, the beam of electrons traverses the chamber or space at the points marked 1—2. This path 1—2, therefore, must be thoroughly exhausted. Hence, either the whole chamber must be evacuated or else at least the middle part 1—2.

If the second method is adopted, then preferably a form of construction known in the art must be chosen of a kind as shown by way of example in Figure 2. In this construction the space or chamber is divided into two parts by the quartz cylinder 7, that is to say, into the toroidal body and into the cylindrical body bounded by the quartz cylinder 7. The latter may be sealed in respect to the toroidal body 3 by a rubber packing at 8. The electron beam in this known type of construction traverses the tube 5 and, after it has traversed the grid 1, it passes through the quartz tube 7 and grid 2. In lieu of rubber gaskets or packing, it is also possible to use material possessing low dielectric losses for packing purposes. However, these chamber resonators possess the disadvantage that the quartz rings are the source of considerable damping. As a result arrangements must be given preference in which, in contradistinction to the scheme just outlined, there is no dielectric in the interior.

Now, the present invention is concerned with high frequency tube utilizing a resonant cavity tank circuit in which the use of dielectric material in the interior of the resonator is avoided. According to the invention, the chamber resonator consists of a toroidal space or chamber which is bounded by an interior metallized glass wall or shell, the said chamber or hollow space being in communication with an axial glass tube traversed by the electron beam. These chamber resonators distinguish themselves by the fact that their manufacture is extremely simple. Production of such a chamber may be started from a glass tube or pipe piece 9 as shown in Figure *3a* which in its middle is expanded into the shape of a sphere 10. If, then, the latter is compressed in the direction of the arrows 11 while the glass material is still soft, there results a body or structure as shown in Figure *3b* which consists of a glass tube 9 which is in communication with the toroidal body 10 through the openings 12. By application of simple and convenient methods known in the glass blowing arts, the passage holes or openings 12 may be suitably reduced still further, thus resulting eventually in a body as represented in Figure *3c*. This body then has the shape of a chamber resonator, for all that remains to be done is to metallize the interior of this structure, the metallization consisting preferably of a silver coating.

Chamber resonators of the invention distinguish themselves by a number of special features and advantages. In the first place, the ultrahigh frequency field arises only on the surfaces of the inner coat and enters only slightly into the same. Inasmuch as silver is a particularly good conductor, the requisite metal coat consists of a readily produced tenuous film of silver. The resonator may then be exhausted and be connected with other parts of the tube which are to be joined thereto. To tune a resonator as here disclosed all that is needed is to exert pressure upon the two openings 12 so that these openings will come closer together. It may be mentioned that the glass yields sufficiently in order that tuning may be accomplished within limits.

It will be understood that the resonator of this invention may be fitted with appendages or extensions for attaching and bringing in and out coupling lines. A resonator equipped with such a tunable coupling loop 14 as just mentioned is illustrated in Figure 4. The lead to the coupling loop 14 is placed inside the extension tube 13 which is also silver coated. The assembly is supported by props 15 fitted on the tubular extensions 9. To exert pressure upon the openings 12, screws 16 are provided, abutting against beads 16′ on the extensions. A cathode 7, control grid 18 and anode 23 are also provided.

The arrangement of the invention could be used to advantage also in cases where a density modulated electron beam traverses successively a plurality of resonators, say, to the end of producing phase-displaced ultra high frequency potentials. All that is necessary to this end is to blow the required number of chambers consecutively in one and the same glass pipe and to then fashion these chambers in a manner as hereinbefore described. If desired, all of the generators could be made to work upon a single energy feeder line, for this would mean a particularly good utilization of the electron beam and its energy.

In Figure 5, the envelope 9 has been extended and provided with two hollow chambers 10 and 10' for forming successive resonant cavity tank circuits and properly coated with metallic substances or conducting substances on the interior as indicated. The intermediate tubular member 9' may also be coated, this coating being electrically connected to the coating within the hollow chamber. The cathode 17 and beam forming control grid 18 are positioned in one end of the envelope and the anode and collector 23 in the other. The first resonant cavity tank circuit 10 can then be used to modulate the beam and the second cavity tank circuit 10' may be utilized to inductively extract energy from the beam. The intermediate tubular member 9' provides a field free space in which the electrons may drift to accentuate the action of the modulating chamber 10'.

In building transmitters of stable frequency it will be unnecessary to make the output chamber resonator tunable. In fact, in such a case thick glass stock is preferably employed. However, it will then be necessary to build the modulator so that it may be tuned. Figures 5 and 6 show examples of such an arrangement. In the embodiment shown in Figure 6 electrodes 19 are interposed between the resonator 10 and the beam generating or gun system comprising the cathode 17 and the electrodes 18, said electrodes 19 being united with a Lecher-wire line 20. The said electrodes 19 and the said line 20 play here the part of a tunable modulator. If desired, the tunable modulator could also have a form of construction as illustrated in Figure 7 in which the grids 19 are associated with a chamber or hollow resonant cavity tank circuit 21 which is fitted with a telescoping or trombone extension or slide 22, for closing the opening in the hollow wall of the cup-shaped cavity 21.

The metallic coat or deposit upon the glass wall, if desired, could also consist of strata of different metals. It may also be found expedient to place the layer of metal upon a coating of carbon or graphite.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device having means for supplying a beam of electrons and other means for receiving said beam of electrons and a cavity resonator intermediate said two means and provided with a gap surrounding the path of the beam of electrons between said two means, a pair of spaced control members forming a gap therebetween extending transversely of the path of the beam of electrons between said beam supplying means and the cavity resonator, a pair of concentric coaxial cup-like members provided with registering apertures registering with said control members and coupled thereto and a member of U-shaped cross section telescopically positioned over the ends of the cup-like members closing said ends to provide an adjustable cavity resonator.

2. An electron discharge device having an elongated envelope provided with an electron supplying means at one end and means for collecting said electrons at the other end, a cavity resonator provided with a gap surrounding the electron discharge path, a pair of grid control members between said electron supplying means and said resonator and transverse to the electron discharge path and spaced from each other in the direction of travel of the electrons, a cup-shaped member coaxial with and surrounding the electron discharge path and provided with an aperture registering with one of said grids and electrically coupled thereto, a second cup-shaped member coaxial with and surrounding the first cup-shaped member but spaced therefrom and having an aperture registering with the other of said grids and electrically coupled thereto and a member engaging the lips of said cup-shaped members and bridging the space between said cup-shaped members providing a cavity resonator.

3. An electron discharge device having an elongated envelope of insulating material provided with an electron supply means at one end and means for collecting said electrons at the other end, said envelope being formed with an enlarged portion forming a hollow chamber and coated on the inside with conducting material and providing a cavity resonator having a gap surrounding the electron discharge path and lying in a plane transverse to said discharge path, a pair of grid control members between said electron supply means and resonator transverse to the electron discharge path and spaced from each other in the direction of travel of the electrons, a cup-shaped member coaxial with and surrounding the electron discharge path and provided with an aperture registering with one of said grids and electrically coupled thereto, a second cup-shaped member coaxial with and surrounding the first cup-shaped member but spaced therefrom and having an aperture registering with the other of said control grids and electrically coupled thereto and means engaging the lips of said cup-shaped members and bridging the space between said members providing a cavity resonator.

4. An electron discharge device having an envelope of insulating material provided with an electron supply means at one end and means for collecting said electrons at the other end, said envelope being formed with an enlarged portion forming a hollow chamber and coated on the inside with conducting material providing a cavity resonator provided with a gap surrounding the electron discharge path and lying in a plane transverse to said path, a pair of grid control members between said electron supply means and resonator transverse to the electron discharge path and spaced from each other in the direction of travel of the electrons, a cup-shaped member coaxial with and surrounding the electron discharge path and provided with an aperture registering with one of said grids and electrically

coupled thereto, a second cup-shaped member coaxial with and surrounding the first cup-shaped member but spaced therefrom and having an aperture registering with the other of said grids and electrically coupled thereto and a member of U-shape cross section telescoped over the lips of said cup-shaped members and bridging the space between said members providing a tunable cavity resonator.

5. An electron discharge device having an elongated envelope provided with an electron supplying means at one end and a collector for collecting said electrons at the other end, a pair of spaced electrodes between said electron supply means and said collector and transverse to the electron discharge path and spaced from each other in the direction of travel of the electrons, a cup-shaped member coaxial with and surrounding the envelope and provided with an aperture registering with one of said electrodes and electrically coupled thereto and a second cup-shaped member coaxial with and surrounding the first cup-shaped member but spaced therefrom and having an aperture registering with the other of said electrodes and electrically coupled to said last electrode, and a member engaging the lips of said cup-shaped members and bridging the space between said cup-shaped members providing a cavity resonator.

6. An electron discharge device having an elongated envelope provided with an electron supplying means at one end and a collector for collecting said electrons at the other end, a pair of spaced electrodes between said electron supplying means and said collector and transverse to the electron discharge path and spaced from each other in the direction of travel of the electrons, a cup-shaped member coaxial with and surrounding the envelope and provided with an aperture registering with one of said electrodes and electrically coupled thereto and a second cup-shaped member coaxial with and surrounding the first cup-shaped member but spaced therefrom and having an aperture registering with the other of said electrodes and electrically coupled to said last electrode, and a member engaging the lips of said cup-shaped member and bridging the space between said cup-shaped members for providing a cavity resonator, said member engaging the lips of said cup-shaped members being of annular form and having lips telescoping with the lips of said cup-shaped members, said member being movable axially of the envelope for varying the resonant frequency of said cavity resonators.

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