

Nov. 25, 1941.

B. SALZBERG

2,263,648

ELECTRON DISCHARGE DEVICE

Filed May 16, 1940

2 Sheets-Sheet 1

Fig. 3

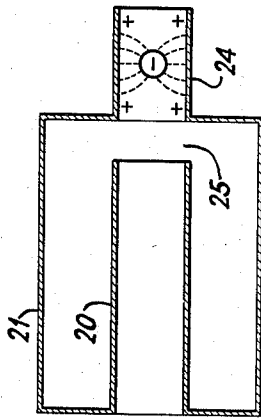


Fig. 2

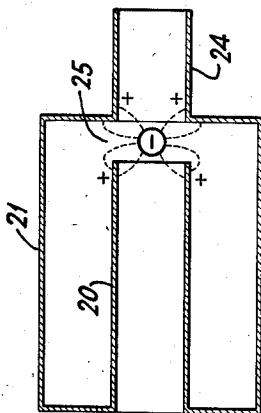


Fig. 1

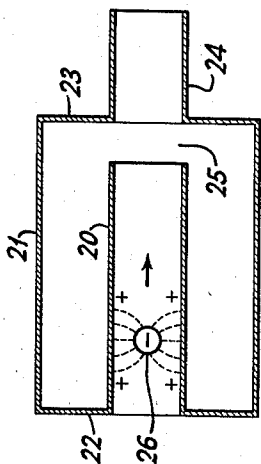


Fig. 5

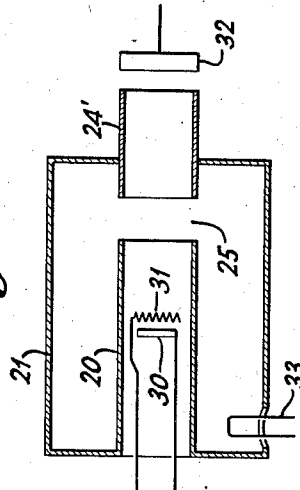
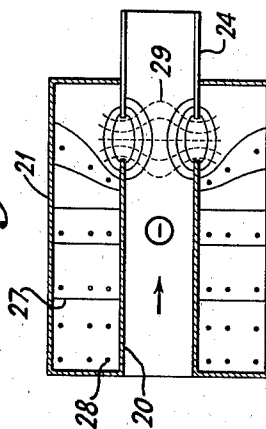


Fig. 4



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2 Sheets-Sheet 2

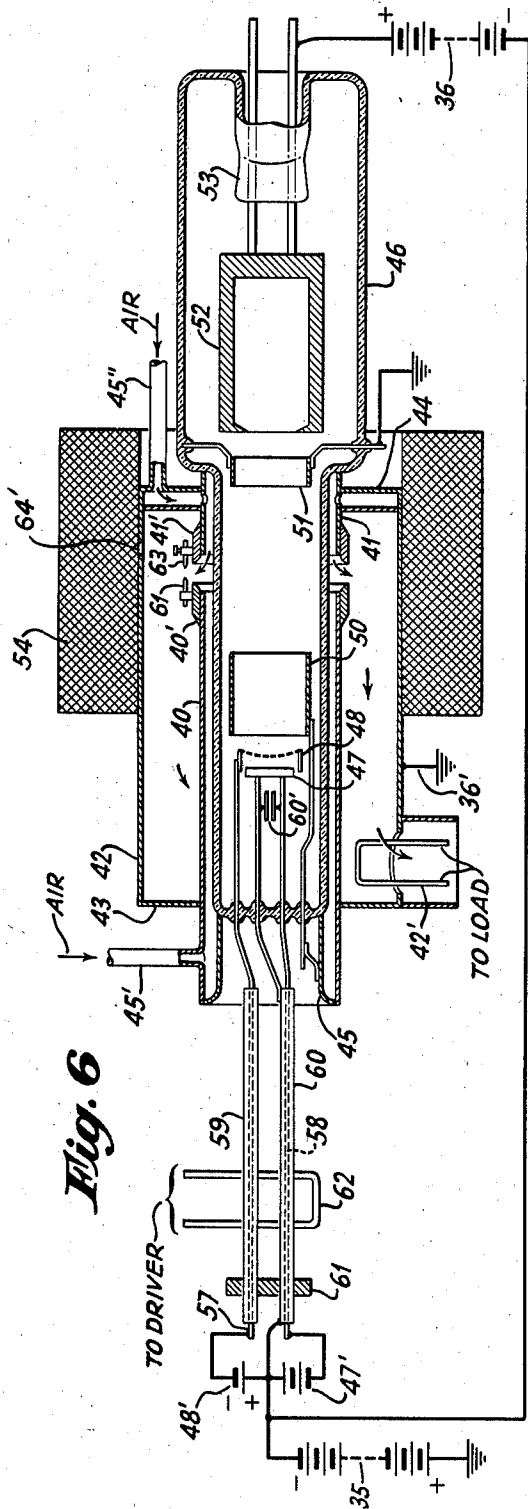


Fig. 6

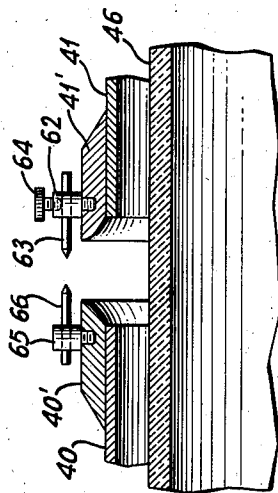


Fig. 7

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2,263,648

ELECTRON DISCHARGE DEVICE

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Application May 16, 1940, Serial No. 335,477

4 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices, more particularly to such devices suitable for use at high frequencies.

My invention relates specifically to the type of tube described and claimed in the co-pending application of Andrew V. Haef, Serial No. 254,239 filed February 2, 1939 and assigned to the same assignee as the present application.

One of the tubes there described consists of an elongated evacuated envelope containing a cathode, control grid and accelerating electrode at one end of the envelope, and a second accelerating electrode and collector electrode in the other end of the envelope. Surrounding the envelope is a concentric line tank circuit comprising a pair of axially spaced inner tubular members separated by a gap and electrically connected to an outer tubular member coaxial with and concentric with the inner tubular members at the ends of the outer tubular member by metallic disc members. The tank circuit is so positioned with respect to the electrodes within the envelope that the gap is between two accelerating electrodes so that a modulated stream of electrons passes across the gap in moving from the cathode to the collector electrode to excite the tank circuit. An electromagnet may surround the tank circuit for providing a longitudinal focusing magnetic field.

In such a tube, a high frequency alternating current is induced in the concentric line tank circuit or the external resonator circuit, as it may be called, by a modulated electron beam moving from the cathode to the collector. Since the circuit is placed as closely as possible to the glass envelope to obtain close coupling with the beam, and since the circuit has very low losses, a very high voltage may be built up across the gap portion of the circuit when the circuit is not loaded. Such a condition can be suddenly brought about by accidental disconnection of the load or in case the oscillator drives an amplifier by accidental opening of the amplifier load circuit such as may be caused by the burn-out of a following tube or the like, or by the loss of a radiator during a storm. This high voltage causes dielectric losses in the portion of the glass envelope which is adjacent the circuit gap. This in turn causes heating in the glass, which increases the dielectric losses and the phenomena builds up until the glass finally punctures.

Glasses which have a poor power factor, that is in which the dielectric losses are large, are believed to have these losses because of free or loose electrons within the glass, which upon the

application of a high potential difference between two points on the glass cause a flow of current through the glass between the two points at different potentials. This causes heating within the glass and increases the losses until finally the glass becomes so hot that it melts and punctures. To cure this defect, glasses of better dielectric qualities, that is ones having a high power factor or lower losses, have been substituted. While this is a partial solution it does not provide the necessary protection for the glass envelope since it is only partially effective in reducing the causes for the breakdown. Other means do not readily suggest themselves inasmuch as the tank circuit is a hollow arrangement with a gap inside and not readily accessible. The gap must remain exposed directly to the electron beam and cannot be shielded inasmuch as this would prevent operation or excitement of the tank circuit by the electron beam. The placing of condensers across the gap is not permissible inasmuch as the inherent characteristics of the tank circuit provide the necessary capacity, the tank circuit being the equivalent of distributed inductance and capacity along its length internally of the tank circuit. The obvious method of curing the above defect by utilizing a better grade of glass failed to solve the problem.

The object of my invention is to provide an improved tube of the type described in which the danger from breakdown in the glass envelope is substantially reduced or eliminated.

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 Figures 1 to 4 inclusive are schematic diagrams illustrating the principles involved in the tube described in the above identified Haef application, Figure 5 is a simplified diagrammatic representation of an electron discharge device made according to the Haef disclosure, Figure 6 is a longitudinal section of an electron discharge device utilizing the principles described in connection with Figures 1 to 5 inclusive and also incorporating my invention, and Figure 7 is an enlarged diagrammatic representation showing details of my invention.

A better understanding of my invention can be had by discussing the principles of operation involved in one form of electron discharge device using a beam and made according to the co-pending application of Andrew V. Haef, identified

above. This tube is illustrated in Figures 1 to 4 inclusive.

In Figure 1 is schematically shown the longitudinal schematic section of a quarter wave concentric line tank circuit comprising an inner tubular conductor 20 which may be cylindrical in cross section, and a hollow outer tubular conductor 21 concentric with the inner conductor 20 and electrically connected to the inner conductor 20 by the conducting plate 22. A second tubular conductor 24 which may be referred to as the aperture extension is coaxial with the conductor 20 and spaced axially from the conductor 20 to provide a gap 25. This tubular conductor 24 and the outer conductor 21 are connected by the conducting plate 23. This arrangement provides a resonant concentric line tank circuit. If a negatively charged body 26 is projected axially through the inner conductor 20 from left to right, the conditions of the charge distribution on the tank circuit as the charged body 26 is moved along the interior of conductors 20 and 24 is indicated in Figures 1 to 4 inclusive. As shown in the figures, there is a positive charge, equal to the negative charge induced on the inside of the inner conductor near the body. However, initially no charge appears on the outer surface of the inner conductor 20. The induced charge moves with the charged body along the inner surface of conductor 20 until the end of the inner conductor 20 is reached. During the passage of the charged body across the gap 25, the charge is partially imaged on the end of the inner conductor 20 and partially on the outer conductor 24 as shown in Figure 2. The passage of the charged body beyond the gap 25 into the conductor 24 causes the induced charge all to appear on the inner surface of the conductor 24 as shown in Figure 3. The induced charge in transferring from the end of the inner conductor to the conductor 24 flows back over the outer surface of the inner conductor 20 and the inner surface of conductor 21, thus constituting a current flow in the quarter wave tank circuit. If charged bodies are projected past the gap in proper phase and frequency relationship with respect to the resonant frequency of the tank circuit, the circuit may be made to oscillate vigorously merely by the passage of the charged bodies past the gap.

Figure 4 illustrates the configuration of the electric and magnetic fields within the resonant space of the tank circuit when the latter is excited. The solid lines 27 represent the electric field distribution and the circles 28 represent the magnetic lines of force. The dashed lines 29 represent the equipotential surfaces in the gap. Along the major part of the length of the tank circuit the direction of the electric field is substantially radial. However, at the gap 25 the electric field has an axial component. The electric field does not penetrate very far inside the open end of the inner conducting member 20 or inside the conductor 24, but is confined effectively to the space defined approximately by the limiting equipotential lines 29 shown in the figures. The space inside the inner conductor 20 and inside the conductor 24 is essentially field free, therefore no work will be done on a charge moving inside the inner conductor 20 by the electric field until the charge reaches the gap 25. If the charge traverses the gap at the instant when the electric force is in the direction from 20 to 24, the charge will be decelerated, its energy being given up to the tank circuit. A charge crossing the gap during the opposite half cycle when the

field is reversed will be accelerated and absorb energy from the circuit. If, however, the number of charges traversing the gap during the first half cycle is greater than during the second, the net effect will be that energy is supplied to the tank circuit.

Thus, the tank circuit may be excited by passing groups of electrons at the proper frequency across the gap between the conductors 20 and 24. The motion of the electrons in the interior of the inner conductor 20 has no effect on the current in the tank circuit. Also, high frequency electromagnetic fields which will be generated within the resonating space of the tank circuit penetrate but a short distance inside the conductor 20 and conductor 24 which act as a screen electrode so that the electrons will be influenced by these fields only during their passage across the gap.

In Figure 5 is shown schematically in section an electrode arrangement of a tube embodying my invention and operating on the principle described above. Mounted within the inner conductor 20 is a conventional cathode 30 and a grid 31, which supply the pulses of electrons in the proper phase relation necessary to excite the tank circuit. A collector electrode 32 may be placed beyond the screening electrode or aperture extension 24'. If now a high potential is applied between the cathode and the tank circuit including electrodes 20 and 24' and also between the collector 32 and cathode 30, a stream of electrons from the cathode will flow toward the collector. If a high frequency voltage is applied between the control grid and the cathode, the electron stream will be periodically modulated in intensity. Pulses of electrons traversing the gap 25 will induce high frequency currents between the electrodes 20 and 24'. If the excitation frequency is adjusted to the resonant frequency of the tank circuit a high impedance will exist across the gap 25 at this frequency. The induced currents, therefore, will produce a high radio frequency voltage across the gap 25. The phase of this voltage at or near resonance will be such as to decelerate electrons traversing the gap during the half period of maximum intensity of the electron current in the stream.

The energy lost by the electrons is transformed by the tank circuit into the energy of the electromagnetic field within the resonating space between the inner and outer conductors and then may be conveyed to the useful load by means of a coupling loop such as, for example, 33 extending through an aperture in the outer tubular conductor 21 of the tank circuit.

The high frequency electromagnetic field existing in the resonant space of the tank circuit penetrates only a short distance inside the tubular electrode 20 and inside the tubular screen electrode 24. Therefore, by positioning the control electrode 30 at a suitable distance from the gap 25 the coupling between the input electrodes 30 and 31 and the output electrodes 20 and 24' can be reduced to a negligible value. The collector electrode is also placed at an adequate distance from the gap to minimize coupling between it and the tank circuit. This results in a reduction of the losses caused by the absorption of radio frequency energy from the tank circuit by the collector.

To minimize the transit time effects the electrodes 20 and 24' can be operated at suitable high potentials with respect to the cathode. The adjustment of these potentials is not critical because the functioning of the tube does not

depend critically upon the electron transit time. This is because the electrons are effective in exciting the output circuit only during the short period of time that they pass through the field extending through the gap 25. The current collecting electrode 32 can be operated at a much lower potential than the conductors 20 and 24 and in order to obtain a high efficiency it is usually operated at a potential just sufficient to collect all decelerated electrons. To improve the functioning of the device an electrostatic or magnetic focusing of the electron stream can be utilized to prevent electrons from impinging on the high potential electrodes 20 or 24. Thus these electrodes will not dissipate energy and all of the power generated in the tube will be supplied by the low voltage collector power supply.

In Figure 6 is shown a practical embodiment of my invention in which the output electrodes and tank circuit are external to the tube envelope. In this case the inner tubular member or electrode 40 and screening electrode 41 are joined and electrically connected to the outer tubular member 42 by means of conducting plates 43 and 44. These elements form the concentric line output tank circuit. The edges of the electrodes 40 and 41 are thickened and rounded as at 40' and 41' to reduce excessive radio frequency fields at the gap with the consequent dielectric loss in the glass envelope 46 housing the cathode and collector electrodes. To provide cooling for the tube and particularly to effect adequate cooling of the glass envelope in the region of maximum electric field at the gap a special cooling arrangement can be provided as shown by providing a re-entrant portion 45 contacting the glass envelope and forming with the inner tubular members 40 and 41 a hollow tubular casing around the envelope into which air can be forced through tubes 45' and 45'', as indicated. The whole external concentric line tank circuit and the glass envelope can be separated at will. Envelope 40 which fits within the concentric tank circuit is provided with an indirectly heated cathode 47 (heater not shown), control grid 48 and for focusing the electron beam a magnetic focusing field by solenoid 54 to prevent undesirable current absorption by the accelerating electrodes 50 and 51 positioned between the cathode and collector electrode 52 supported from the press 53. One of the reasons for using the accelerating electrodes 50 and 51 is to avoid the undesirable effects of charges on the glass wall due to bombardment by stray electrons. The electrodes 50 and 51 are positioned at a suitable distance from the gap between the electrodes 40 and 41 of the output tank circuit so that the radio frequency fields from the space between the tubular members 40 and 42 do not reach them, and thus electrodes 50 and 51 do not form a part of the output circuit and do not carry circulating currents. The electron stream from the cathode 47 modulated by grid 48 traverses the gap between electrodes 40 and 41. A high radio frequency voltage will be developed across the gap and electrons will be decelerated in the gap and finally after passing accelerating electrode 51 will be collected by means of electrode 52. Radio frequency energy is transferred from the tank circuit by the coupling loop 42' to the load.

A parallel wire transmission line comprising tubular conductors 59 and 60 tuned by a conducting bridge 61 forms the input circuit. Conductor 57 connected to grid 48 extends through tubular member 59 and is connected to the volt-

age source 48' to provide the biasing voltage for the grid 48. The tubular member 60 and the insulated conductor 58 within the tubular member furnish the cathode heating current from the source of voltage supply 47' and the conductor 60 at the same time acts as the cathode lead. Adequate by-passing for high frequency currents is provided by the condenser 60', preferably placed inside the glass envelope and connected between the heater and cathode leads. Radio frequency coupling between the transmission line conductor 59 and 60 and the grid is due to the inherent capacity between these conductors and the insulated loads within the hollow conductor tubes. If necessary, additional condensers for capacity coupling can be provided between the conductor tubes and the leads. Voltage source 35 provides the positive voltage for the tank circuit through conductor 36' and accelerating electrodes and source 36 a less positive voltage for collector 52.

In accordance with my invention as shown in greater detail in Figure 7, I provide adjacent the gap between the inner tubular members 40 and 41 a voltage limiting device across the high voltage ends of the external resonator circuit. This device is set to operate when the circuit voltage, by an assigned factor, is over the normal operating voltage, to provide an artificial load across the circuit when the circuit is improperly tuned or when the actual load is removed. In this way the voltage is kept from rising to dangerous values.

This device comprises the supports 65 and 62 which may be supported adjacent the gap. Needle points 66 and 63 are oppositely disposed from each other across the gap and spaced to have a gap less than the gap between the tubular members, needle point 66 being fixed and 63 being adjustable, set screw 64 being set when proper spacing between points is obtained to provide for voltage breakdown between the needle points at a predetermined voltage. The set screw 64 and the position of the needle 63 may be properly adjusted by means, for example, of a screw driver inserted through aperture 64' in the outer tubular member of the tank circuit to loosen the set screw and to move the needle in either direction after which set screw may be reset.

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 an envelope containing a cathode and grid providing a source of modulated electrons and a collector electrode for receiving said electrons and a hollow tank circuit having a pair of coaxial members spaced axially to provide a gap and surrounding said envelope and the discharge path between the cathode and collector electrode and positioned with the gap between the tubular members intermediate the cathode and collector electrode, and a device mounted adjacent said gap and comprising a terminal supported by each of the pair of coaxial members adjacent the gap, each terminal extending toward the other

and providing a gap therebetween less than that between the coaxial members.

2. An electron discharge device having an envelope containing a cathode and grid providing a modulated source of electrons, and a collector electrode for receiving said electrons and a hollow tank circuit having a pair of coaxial members spaced axially to provide a gap surrounding said envelope and a discharge path between the cathode and collector electrode with the gap between the tubular members intermediate the cathode and collector electrode, and solenoid means for focusing the electrons into a well-defined beam between the cathode and collector electrode and a voltage relieving device mounted adjacent said gap between the coaxial members and comprising a support on each of the coaxial members adjacent said gap and a spark terminal mounted in each support and extending towards the terminal on the other support across said gap, the spacing between the terminals being less than the gap between the coaxial members.

3. An electron discharge device including a quarter wave concentric line tank circuit having a pair of coaxial tubular members spaced axially and forming a gap and a concentric outer tubular member conductively secured at each end to one of said coaxial tubular members, an envelope containing a cathode and grid positioned adjacent one end of said one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collector electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode, and means providing a load across said gap at predetermined voltage conditions and comprising a support on each of

the coaxial tubular members and extending inwardly of the concentric line tank circuit and adjacent said gap, terminal members mounted in each support, one of said terminal members being adjustable axially of the tank circuit to increase or decrease the spacing between the terminal members, and means for fixing the position of said adjustable terminal member.

4. An electron discharge device including a quarter wave concentric line tank circuit having a pair of coaxial tubular members spaced axially and forming a gap and a concentric outer tubular member conductively secured at each end to one of said coaxial tubular members, an envelope containing a cathode and grid positioned adjacent one end of said one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collector electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode, and means for providing a load across said gap at predetermined voltage conditions and comprising a support on each of the tubular members and extending inwardly of the concentric line tank circuit and adjacent said gap, terminal members mounted in each support, one of said terminal members being adjustable axially of the tank circuit to increase or decrease the spacing between the terminal members and means for fixing the position of said adjustable terminal member, and said outer tubular member having an aperture registering with the support for the adjustable terminal member for permitting the insertion of an adjusting tool to position the adjustable terminal member.

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