April 8, 1941. A. V. HAEFF 2,237,878

ELECTRON DISCHARGE DEVICE

Filed Feb. 2, 1939 3 Sheets-Sheet 1

Fig. 3

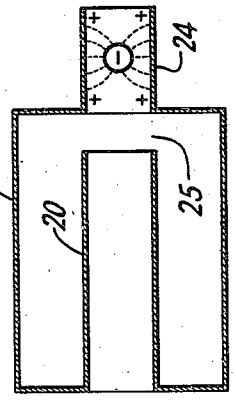


Fig. 2

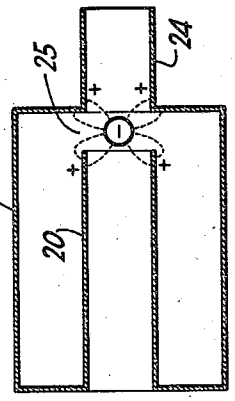


Fig. 1

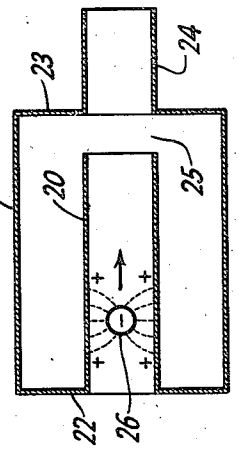


Fig. 5

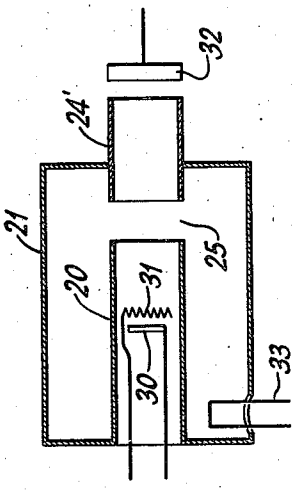
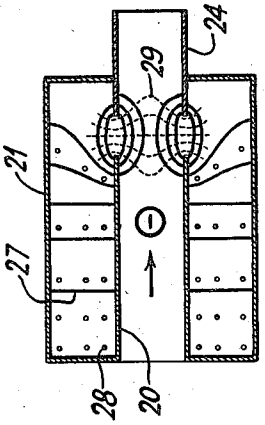


Fig. 4



INVENTOR.
ANDREW V. HAEFF

BY Charles McClain

ATTORNEY.

April 8, 1941. A. V. HAEFF 2,237,878

ELECTRON DISCHARGE DEVICE

Filed Feb. 2, 1939 3 Sheets-Sheet 2

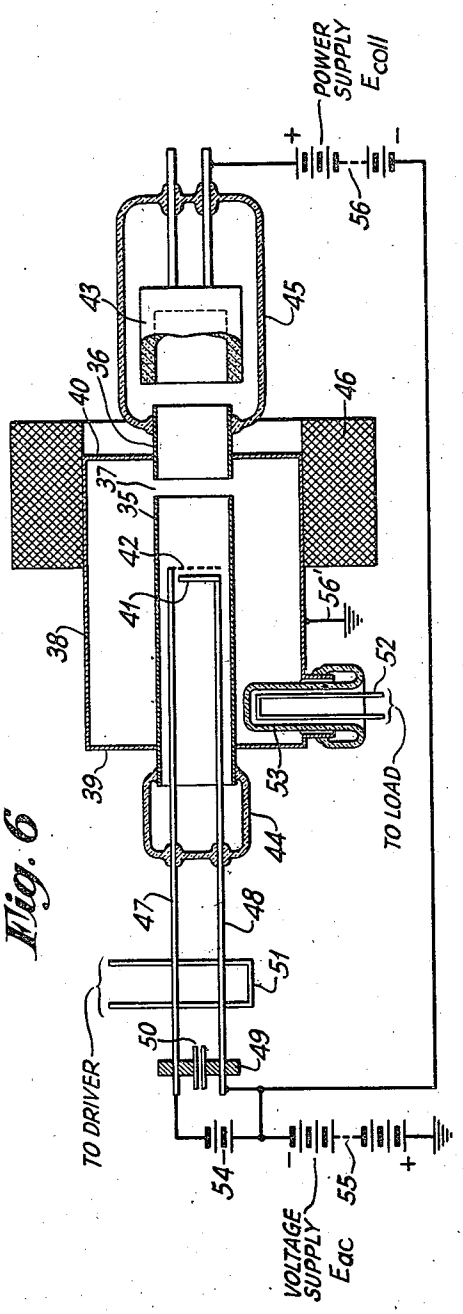


Fig. 6

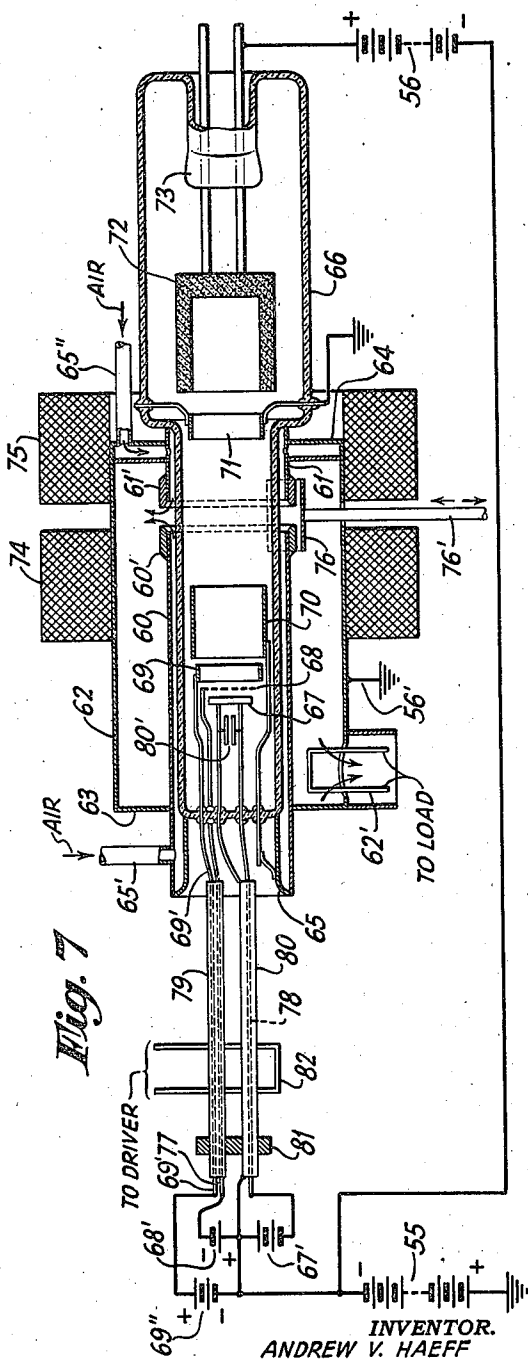


Fig. 7

INVENTOR.
ANDREW V. HAEFF

BY Charles McClair

ATTORNEY.

April 8, 1941. A. V. HAEFF 2,237,878

ELECTRON DISCHARGE DEVICE

Filed Feb. 2, 1939 3 Sheets-Sheet 3

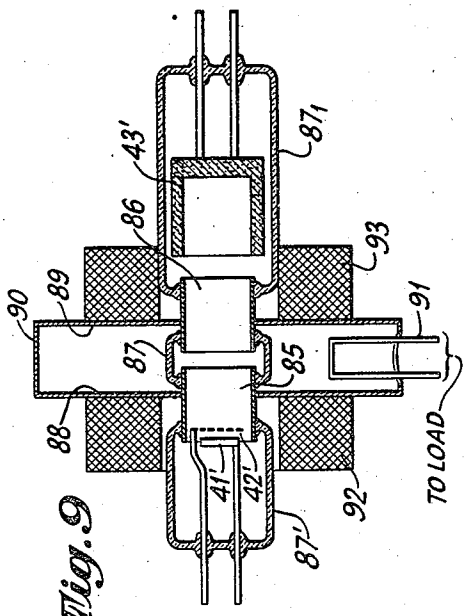


Fig. 9

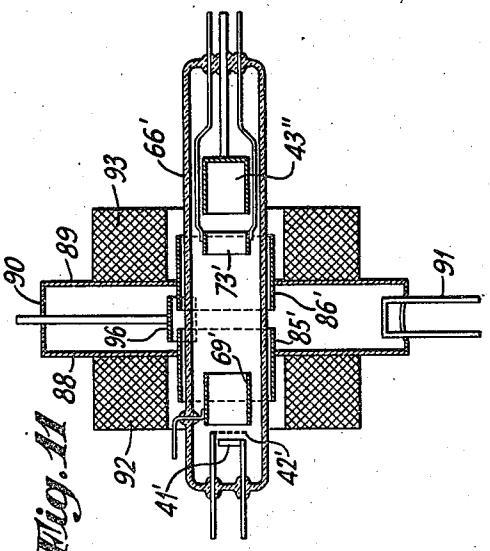


Fig. 11

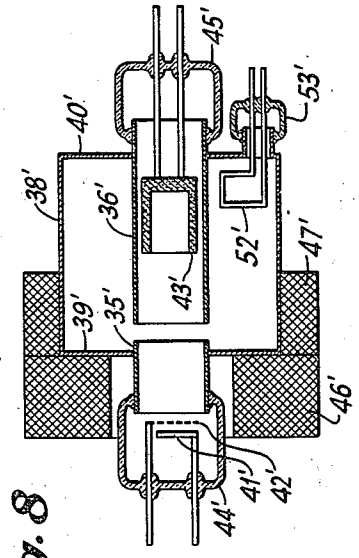


Fig. 8

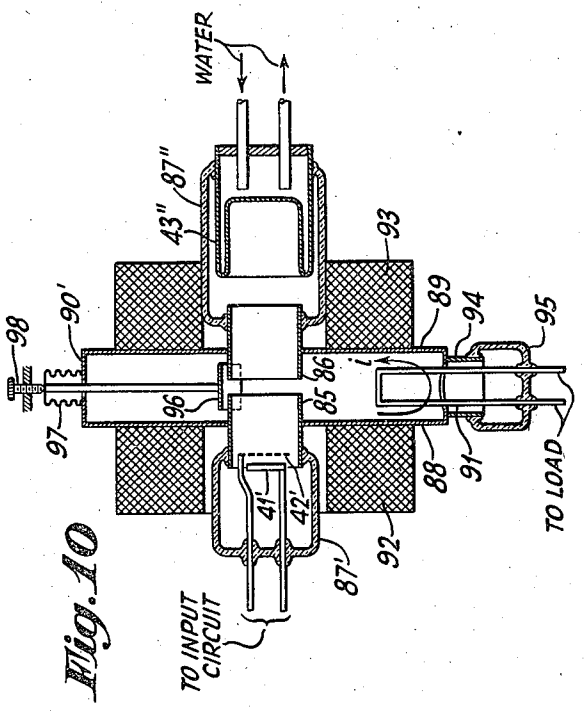


Fig. 10

INVENTOR.
ANDREW V. HAEFF

BY Charles McClain

ATTORNEY.

Patented Apr. 8, 1941 2,237,878

UNITED STATES PATENT OFFICE

2,237,878

ELECTRON DISCHARGE DEVICE

Andrew V. Haeff, East Orange, N. J., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application February 2, 1939, Serial No. 254,239

18 Claims. (Cl. 250—27.5)

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

It is well known that conventional tubes become inoperative at very high frequencies. The principal difficulties which prevent operation at high frequencies are due chiefly to the following factors, that is, the finite electron transit time producing abnormal loading of the input circuit and loss of trans-conductance of the tube, difficulty in obtaining necessary small coupling between the output electrode and the input electrode which results in regeneration or excessive loading of the output circuit due to the reflected input losses and the consequent loss of power output and efficiency, and increased losses in the circuit due to the presence of large circulating currents at high frequencies and due to an increase in effective resistance of the circuit.

The principal object of my invention is to provide an improved electron discharge device particularly suitable for use at high frequencies.

More particularly it is an object of my invention to provide an electron discharge device in which electron transit time is not critically related to the period of oscillation, which will function satisfactorily at frequencies at which conventional tubes fail to operate, and in which high frequency losses are minimized.

A further object of my invention is to provide an electron discharge device particularly suitable for use as an amplifier at very high frequencies.

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 of my invention, Figure 5 is a simplified diagrammatic representation of an electron discharge device made according to my invention, and Figures 6 to 11 inclusive are longitudinal sections of electron discharge devices made according to my invention, the associated voltage sources being shown in Figures 6 and 7.

A better understanding of my invention can be had by discussing the principle involved. To illustrate the principle involved in electron discharge devices made according to my invention reference is had to 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 quarter wave concentric 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 circuit as the 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 equi-potential 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 the 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 31 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 tube in longitudinal section and made according to my invention. The main body of the tube, which constitutes a quarter wave concentric line output tank circuit includes a pair of tubular coaxial members or electrodes 35 and 36 separated axially by a gap 37 and electrically connected to a concentric outer cylinder or tubular member 38 by means of end plates 39 and 40. Mounted within the tubular member 35 is an indirectly heated cathode 41, the heater of which is not shown, and a grid 42. These electrodes may be disc or rectangular shaped. Electrons supplied by the cathode 41 are projected axially within the cylinders 35 and 36 to a collecting electrode 43 preferably of carbon. The glass cup members 44 and 45 close the ends of the tubular members 35 and 36 to provide with the member 38 an envelope for the electrodes, the cup-shaped member 44 being sealed to the tubular member 35 and the cup-shaped member 45 being sealed to the electrode 36 which will be referred to as a screening electrode. The solenoid 46 may be provided for focusing the electrons from the cathode 41 into a well defined beam along the axis of the tubular electrodes 35 and 36. The electrodes 41 and 42 are suitably supported by means of the conductors 47 and 48. A parallel wire transmission line is attached to these conductors. This line forms the input circuit which is tuned by the bridging member 49 provided with the by-passing condenser 50. A loop 51 serves to couple the input circuit to a driver. To permit the tank circuit to be coupled to a load, a reentrant glass portion 53 is extended through an aperture in the outer tubular member 38 to permit the insertion of a coupling loop 52. The source of voltage 54 connected between the grid and cathode provides a proper bias on grid 42, voltage source 55 being provided for applying to the tank circuit by means of conductor 56' a voltage higher than that applied to the collecting electrode by the power supply 56.

When a high potential E_{ac} at 55 is applied between the cathode and the electrodes 35 and 36 and a voltage E_{coll} at 56 between the cathode and collector 43 a stream of electrons from the cathode 41 focused by the magnetic field of the solenoid 46 is projected toward the collector 43 without impinging on either electrode 35 or 36. If a radio frequency voltage is applied between control grid 42 and cathode 41 by exciting the input circuit the electron stream will be periodically modulated in intensity. Pulses of electrons traversing the gap 37 will induce radio frequency currents in the electrodes 35 and 36. If the excitation frequency is adjusted to the resonance frequency of the output circuit 35, 38 and 36, a high impedance will exist across the gap 37 at this frequency. Consequently, currents induced in electrodes 35 and 36 by electron pulses will produce a high radio frequency voltage across the gap 37. The phase of this voltage at or near resonance will be such as to decelerate electrons passing during the half period of maximum intensity of electron current in the stream. The energy of the decelerated electrons is converted by the tank circuit into energy of the electric and magnetic fields in the resonant space between the inner 35 and outer 38 cylinders and then transferred to the useful load by the coupling loop 52.

The radio frequency fields penetrate only a short distance inside the tubular electrode 35 and inside the screening electrode 36, a distance effectively less than their diameter so that by positioning the cathode 41, control electrode 42 and the collector 43 at suitable distances from the gap 37, the coupling between the output tank circuit and these last three mentioned electrodes can be made practically negligible. To reduce electron transit time between the control grid 42 and the gap, the electrodes 35 and 36 can be operated at suitably high potentials to increase the speed of the electrons past the gap. However, to obtain high efficiency, the collector electrode potential can be adjusted to a value just sufficient to collect all decelerated electrons and usually has to be only slightly higher than the effective peak radio frequency voltage existing across the gap. The adjustment of the accelerating potential E_{ac} is not at all critical. It is usually adjusted to such a value that the transit time of electrons across the effective length of the gap (smaller than the diameter of the electrode 35) is a fraction of a period so that the loss in transconductance due to transit time is small. With proper design and a sufficient focusing field there is no current to electrodes 35 and 36, so that these electrodes dissipate no energy. The power is supplied only by the collector power supply 56.

In Figure 7 is shown an arrangement in which the output electrodes and tank circuit are external to the tube envelope. In this case the inner tubular member or electrode 60 and screening eelctrode 61 are joined and electrically connected to the outer tubular member 62 by means of conducting plates 63 and 64. These elements form the concentric line output tank circuit. The resonant frequency of the tank circuit may be varied by means of the adjustable condenser plate 76 movable by insulated rod 76' toward and from the electrodes 60 and 61 to increase or decrease the capacity coupling between these two electrodes. The edges of the electrodes 60 and 61 are thickened and rounded as at 60' and 61' to prevent excessive radio frequency fields at the gap with a consequent dielectric loss in the glass envelope 66 housing the cathode and collector electrodes. To minimize these losses the glass envelope may be provided with a short section near the gap made of low loss dielectric such as special glass, quartz or ceramic. 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 reentrant portion 65 contacting the glass envelope and forming with the inner tubular members 60 and 61 a hollow tubular casing around the envelope into which air can be forced through tubes 65' and 65'', as indicated. The whole external concentric line tank circuit and the glass envelope can be separated at will. Envelope 66 which fits within the concentric tank circuit is provided with an indirectly heated cathode 67 (heater not shown), control grid 68 and focusing electrode 69, which can be maintained at either control grid potential or any suitable potential serving to concentrate the electron stream at the start and making it possible to use considerably weaker magnetic foucusing fields from solenoids 74 and 75 without undesirable current absorption by the acceelrating electrodes 70 and 71 positioned between the cathode and collector electrode 72 supported from the press 73. The reason for using the accelerating electrodes 70 and 71 is to avoid the undesirable effects of charges on the glass wall due to bombardment by stray electrons. The electrodes 70 and 71 are positioned at a suitable distance from the gap between the electrodes 60 and 61 of the output tank circuit so that the radio frequency fields from the space between the tubular members 60 and 62 do not reach them, and thus electrodes 70 and 71 do not form a part of the output circuit and do not carry circulating currents. The electron stream from the cathode 67 modulated by grid 68 focused by the electrode 69 traverses the gap between electrodes 60 and 61. As in the previous case 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 71 will be collected by means of electrode 72. Radio frequency energy is transferred from the tank circuit by the coupling loop 62' to the load.

A parallel wire transmission line comprising tubular conductors 79 and 80 tuned by a conducting bridge 81 form the input circuit. Conductors 69' and 77 connected to the focusing electrode 69 and grid 68 extend through tubular member 79 and are connected to the voltage sources 69'' and 68' to provide the biasing voltages for the focusing electrode 69 and the grid 68. The tubular member 80 and the insulated conductor 78 within the tubular member furnish the cathode heating current from the source of voltage supply 67' and the conductor 80 at the same time acts as the cathode lead. Adequate by-passing for high frequency currents is provided by the condenser 80', preferably placed inside the glass envelope and connected between the heater and cathode leads. Radio frequency coupling between the transmission line conductor 79 and 80 and the grid and the focusing electrodes is due to the inherent capacity between these conductors and the insulated leads within the hollow conductor tubes. If necessary, additional condensers for capacity

coupling can be provided between the conductor tubes and the leads.

One sample of a tube made according to my invention has an external member 62 of a length of 6" and diameter of 2", the inner tubular members 60 and 61 having a diameter just sufficiently large to permit slipping the concentric line unit over the end of the envelope 66 having an outside diameter of 1¼". The gap between the inner tubular member 60 and 61 was of the order of $\frac{3}{16}$". The accelerating electrode 71 with a width of ½" was spaced 2" from the accelerating electrode 70 having a width of 1", the focusing electrode being spaced $\frac{1}{16}$" from the edge of the accelerating electrode 70. The collecting electrode 72 has an outside diameter of 2" and a depth of 2". It is of course understood that these dimensions could be changed or varied for different frequencies and for different power outputs.

The tube was operated under the following conditions: At a frequency of 450 megacycles, power output of 110 watts was obtained, the driving power being about 10 watts and the efficiency about 35%. The accelerating voltage applied to electrode 70 and 71 was of the order of 6000 volts and the collector electrode voltage of the order of 2000 volts. The collector current was approximately 150 milliamperes. The extremely low loss in the accelerating electrodes 70 and 71 is shown by the fact that less than .1 milliamperes was the current to these electrodes. This performance which is readily obtained with a tube made according to my invention contrasts sharply with tubes and circuits of conventional design when an attempt is made to operate them at the higher frequencies.

A modified form of my invention is shown in longitudinal section in Figure 8. Here the cathode 41' and grid 42' are outside of the tubular conductor 35' and the collector 43' inside the tubular electrode 36'. The glass cup members 44' and 45' seal the ends of the tubular members which with the outer tubular member 38' are electrically connected by plates 39' and 40' thus forming the tube envelope. The solenoids 46' and 47' furnish a magnetic field and coupling to an output circuit is obtained by means of loop 52' suitably sealed in plate 40' by means of the glass cup-shaped member 53'.

A further modification showing a symmetrical type of circuit is shown in longitudinal section in Figure 9. The tubular electrode members 85 and 86 are electrically connected to the conducting discs or plates 88 and 89, which with the cylindrical short circuiting member 90 form the tank circuit. The member 87 is sealed to the tubular members 85 and 86 and form with the cup shaped members 87, and 87' an envelope for the cathode 41' and grid 42' as well as the collector 43'. The magnetic field is furnished by solenoids 92 and 93, the coupling to the load being made by means of coupling loop 91 extending through an aperture in the ring shaped member 90. Electrodes 85 and 86 are made long enough to minimize penetration of the radio frequency fields developed across the gap between the two electrodes. The diameter of the space defined by the circular disc shaped conductors 88 and 89 and the cylindrical short circuiting member 90 determine the resonant frequency of the output circuit. A condenser of the type shown in Figure 7 could be used to vary the resonant frequency. Because the tank circuit members 88, 89 and 90 are outside the tube envelope proper, they can be changed to provide a tank circuit having a different resonant frequency.

In Figure 10 is shown a modification of the symmetrical type shown in Figure 9 in which a coupling condenser plate 96 is supported by bellows seal 97. The coupling can be adjusted by means of screw member 98. Collector electrode 43" is hollow to provide for water cooling as indicated. Cup shaped members 87', 87" and 95, the last sealed to the extension 94, provide the necessary insulating supports for the various electrodes and coupling loop.

Figure 11 differs from Figures 9 and 10 in that the tubular electrodes 85' and 86' along with the remainder of the tank circuit and tuning condenser 96 are mounted on the exterior of the glass envelope 66', at one end of which is mounted a cathode 41' and grid 42', and in the other end collector electrodes 43", accelerating electrode 69' and 73' being provided between the cathode 41' and collector 43". This construction permits separation of the envelope and tank circuit at will.

Thus in a tube made according to my invention electron transit time effects are minimized by utilizing electrons of high velocity. This is accomplished without increasing dissipation and loss in efficiency by separating the functions of the output electrode and current collecting electrode and by making use of electron focusing. The output-input coupling is reduced to a negligible value by screening and separation of the electrodes and circuits. The high frequency losses due to high frequency voltages are minimized by current carrying electrodes of large periphery.

In addition to the above advantages high efficiency results due to collection of the electrons at low-velocity and high-power output is attained because the collector may be made of adequate size without influencing the performance of the output circuit. A non-regenerative amplification is made possible through the reduction of the output-input coupling to a negligible value.

Other uses to which my invention may be put are for example frequency multiplication and generation of oscillations.

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 a tank circuit including a pair of concentric tubular members and another tubular member coaxial with and spaced axially from the inner of the two concentric tubular members to provide a gap between the coaxial tubular members, a cathode for supplying electrons axially of said coaxial tubular members past said gap, a grid for modulating said stream of electrons prior to its passage past said gap and means for collecting the electrons passing through said tubular members.

2. An electron discharge device having a tank circuit including an inner tubular member and a concentric outer tubular member, said mem-

bers being spaced from each other and connected at one end by a conducting member, a third tubular member coaxial with the inner tubular member and spaced from the inner tubular member to provide a gap, a conducting member connecting the other end of the outer tubular member to said third tubular member, means for projecting a stream of electrons axially of said inner tubular member across said gap, means for modulating said stream of electrons prior to the passage of the stream across said gap, and means for collecting the electrons in said stream after passage of the electrons across the gap.

3. An electron discharge device having a cathode for supplying electrons, a collector electrode spaced from said cathode for receiving said electrons, means including an oscillating tank circuit having a pair of coaxial tubular members spaced axially to provide a gap between said coaxial tubular members and a concentric outer tubular member surrounding said coaxial tubular members and electrically connected at each end to a different one of said tubular members, said tubular members being positioned between the cathode and collector electrode whereby electrons moving from the cathode to the collector electrode will pass axially through the tubular members across said gap.

4. An electron discharge device having a cathode for supplying electrons and a collector electrode spaced from said cathode for receiving said electrons, an oscillating tank circuit including a pair of coaxial tubular electrodes spaced axially to provide a gap between said tubular electrodes and positioned between the cathode and collector electrode so that electrons moving from the cathode to the collector electrode will pass axially through the tubular electrodes across said gap, an outer tubular member concentric with and surrounding said coaxial tubular electrodes and having each end connected to one of said coaxial tubular members and forming therewith a closed compartment, and insulation means closing the opposite ends of said tubular coaxial members to provide an envelope for said cathode and collecting electrodes.

5. An electron discharge device including a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to form a gap and a concentric outer tubular member conductively secured at each end to one of said coaxial tubular members, a cathode and grid positioned adjacent one end of one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode.

6. An electron discharge device including a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to form a gap, and a concentric outer tubular member conductively secured at each end to one of said coaxial tubular members, a cathode and grid positioned adjacent one end of one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode, and insulation means closing the opposite ends of the coaxial tubular members to form an envelope for said cathode, grid and collecting electrode.

7. An electron discharge device including a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to form a gap and a concentric outer tubular member electrically connected at each end to one of said coaxial tubular members, a cathode and grid positioned adjacent one end of one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other of said pair of coaxial tubular members for receiving the electrons from the cathode, and insulation means closing the opposite ends of the pair of coaxial tubular members to form an envelope for said cathode, grid and collecting electrode, and means including an electromagnetic coil for focusing the electrons projected through said coaxial tubular members from said cathode to said collecting electrode into a well defined beam.

8. An electron discharge device including a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to form a gap and a concentric outer tubular member electrically connected at each end to one of said coaxial tubular members, a cathode and grid positioned in one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode, insulation means closing the opposite ends of the pair of coaxial tubular members to form an envelope for said cathode, grid and collecting electrode, means including an electromagnetic coil for focusing the electrons projected through said coaxial members from said cathode to said collecting electrode into a well defined beam, and a loop conductor extending through the outer tubular member for inductively coupling the concentric line tank circuit to an output circuit.

9. An electron discharge device including a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to form a gap and a concentric outer tubular member connected by a conducting plate at each end to one of said coaxial tubular members, a cathode and grid positioned in one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other coaxial tubular member for receiving the electrons from the cathode, and insulation means closing the opposite ends of the coaxial tubular members to form an envelope for said cathode, grid and collecting electrode, means including an electromagnetic coil for focusing the electrons projected through said coaxial members from said cathode to said collecting electrode into a well defined beam, a loop conductor extending through the outer tubular member for inductively coupling the concentric line tank circuit to an output circuit, and a transmission line having one end connected to the grid and the other end connected to said cathode for coupling said electron discharge device to a driving circuit.

10. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and a collecting electrode for receiving said modulated stream of electrons, and a quarter wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially to provide a gap and surrounding the discharge path between the cathode and an-

ode whereby electrons from the cathode to the anode traverse the gap between said tubular members, and means including a conductor extending across the gap between said coaxial members but spaced from said coaxial members and movable transversely with respect to said coaxial members for varying the capacity coupling between said coaxial members to change the frequency at which the tank circuit will oscillate.

11. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member to form with said tubular members a closed compartment.

12. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member and electromagnetic means surrounding each of said tubular members for focusing the electrons from the cathode to the collecting electrode into a well defined beam.

13. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member, and a solenoid surrounding each of said tubular members for focusing the electrons from the cathode to the collecting electrode into a well defined beam, and a conductor bridging the gap and overlapping but out of contact with the adjacent ends of the coaxial tubular members and movable transversely of the coaxial tubular members to change the capacity coupling between said members.

14. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member to form a tank circuit and a conductor bridging the gap and overlapping but out of contact with the adjacent ends of the coaxial members and movable transversely to the coaxial members to change the capacity coupling between said members to vary the frequency at which the tank circuit will oscillate, and a conducting loop extending through an aperture in said conducting cylindrical member to couple the tank circuit to a load.

15. An electron discharge device having a tank circuit comprising a unitary hollow body with a passageway extending through said hollow body and having a gap within said passageway extending entirely around said passageway in a plane transverse to said passageway, a cathode for supplying electrons axially of said passageway past said gap, a grid for modulating said electrons prior to said passage past said gap, and means for collecting the electrons after the passage of electrons past said gap.

16. An electron discharge device including a quarter-wave concentric line output tank circuit having a pair of coaxial tubular members spaced axially and forming a gap, and a concentric outer tubular member connected by conducting plates at each end to one of said coaxial tubular members, a cathode and grid positioned in one of said pair of coaxial tubular members for supplying electrons axially of said coaxial tubular members past said gap and a collector electrode adjacent the end of said other coaxial tubular member for receiving electrons from said cathode, means including an electromagnetic coil surrounding said outer tubular member for focusing electrons projected through said coaxial members from said cathode to said collecting electrode into a well defined beam, a loop conductor extending through the outer tubular member for inductively coupling the tank circuit to an output circuit and a transmission line having one end connected to a grid and the other end connected to said cathode for coupling said electron discharge device to a driving circuit.

17. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons, and an electrode for collecting electrons in said stream, a pair of coaxial tubular members spaced axially and forming a gap therebetween surrounding the discharge path between the cathode and collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and a conducting member electrically connecting said plates at their peripheries, and electromagnetic means surrounding said tubular members for focusing the electrons projected from the cathode to the collecting electrode in a well defined beam.

18. An electron discharge device having a tank circuit comprising a hollow body formed by the surface of revolution of a geometric figure and having a resonant frequency and having a passageway extending through said hollow body, said passageway having a gap extending entirely around said passageway in a plane transverse to said passageway, a cathode for supplying electrons axially of said passageway past said gap, a grid for modulating said electrons prior to said passage past said gap, and means for collecting the electrons after the passage of electrons past said gap.

ANDREW V. HAEFF.