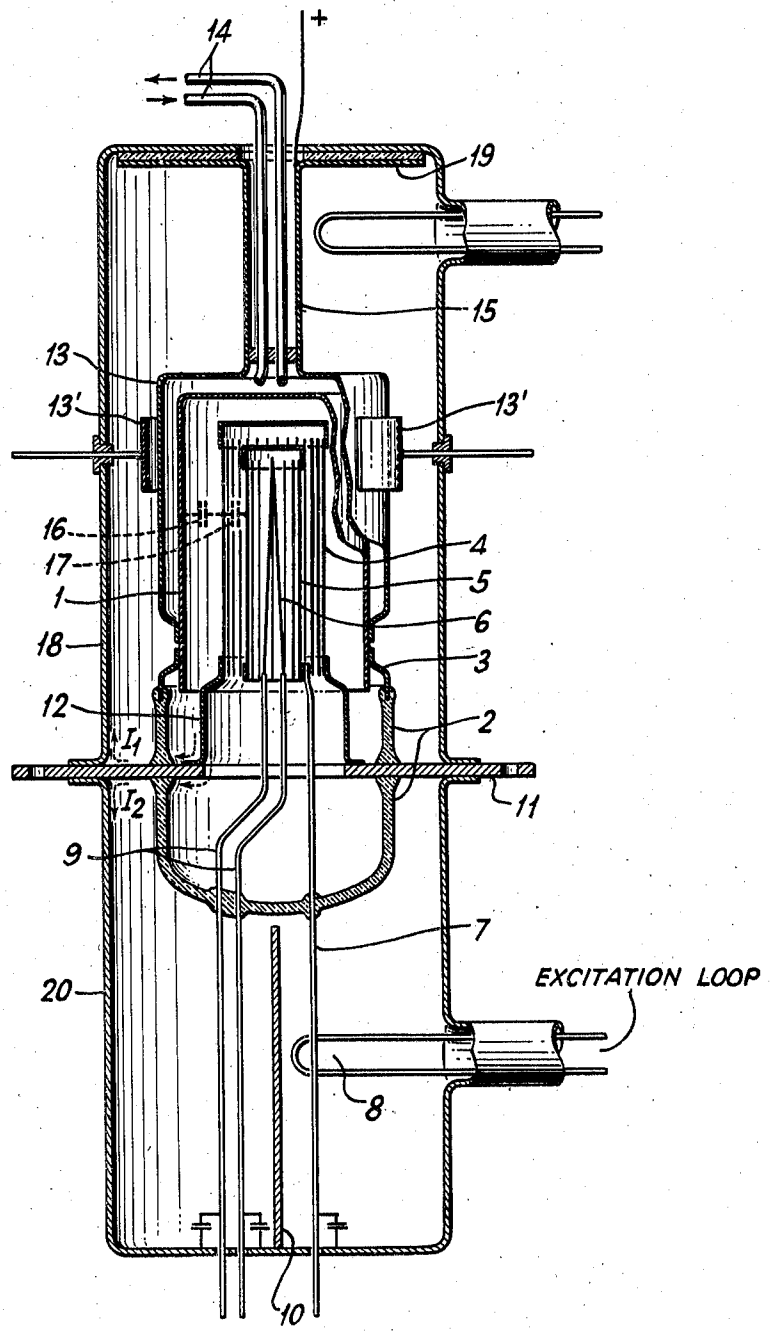
Jan. 14, 1941. P. D. ZOTTU ET AL 2,228,939

HIGH FREQUENCY POWER TUBE

Filed Sept. 30, 1938 4 Sheets-Sheet 1

Fig. 1



INVENTORS
PAUL D. ZOTTU, LEON S. NERGAARD
AND ANDREW V. HAEFF

BY Charles McCain
ATTORNEY.

Jan. 14. 1941. P. D. ZOTTU ET AL 2,228,939

HIGH FREQUENCY POWER TUBE

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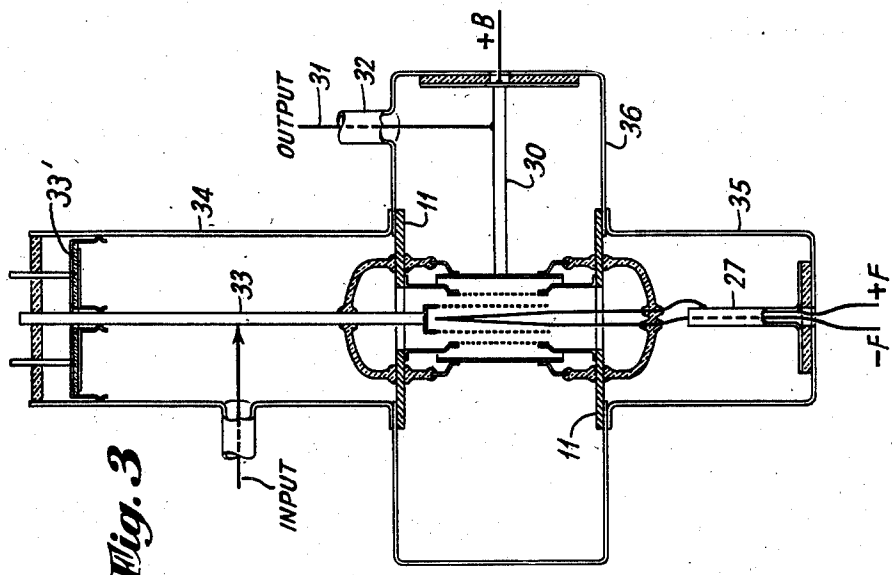


Fig. 3

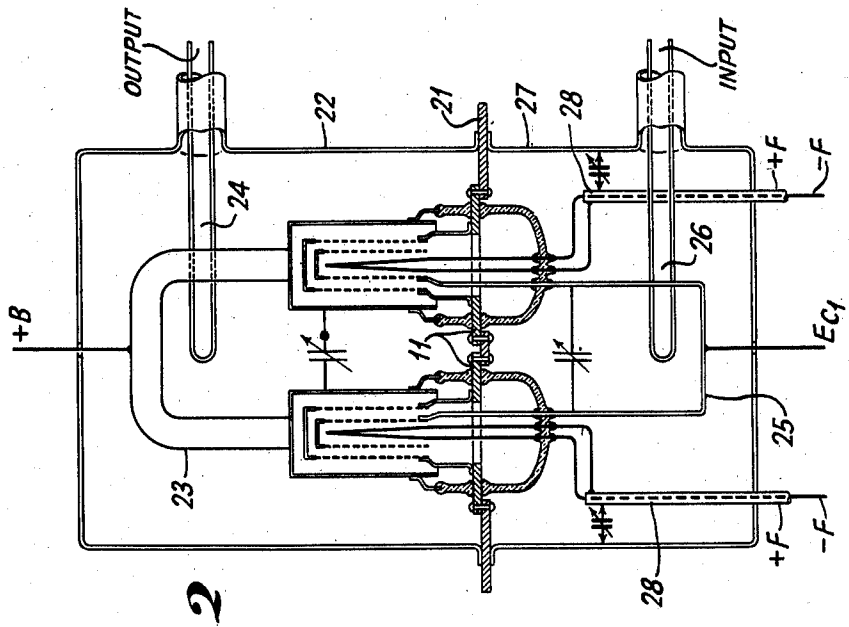


Fig. 2

INVENTORS
PAUL D. ZOTTU, LEON S. NERGAARD
AND ANDREW V. HAEFF

BY Charles McClain
ATTORNEY.

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HIGH FREQUENCY POWER TUBE

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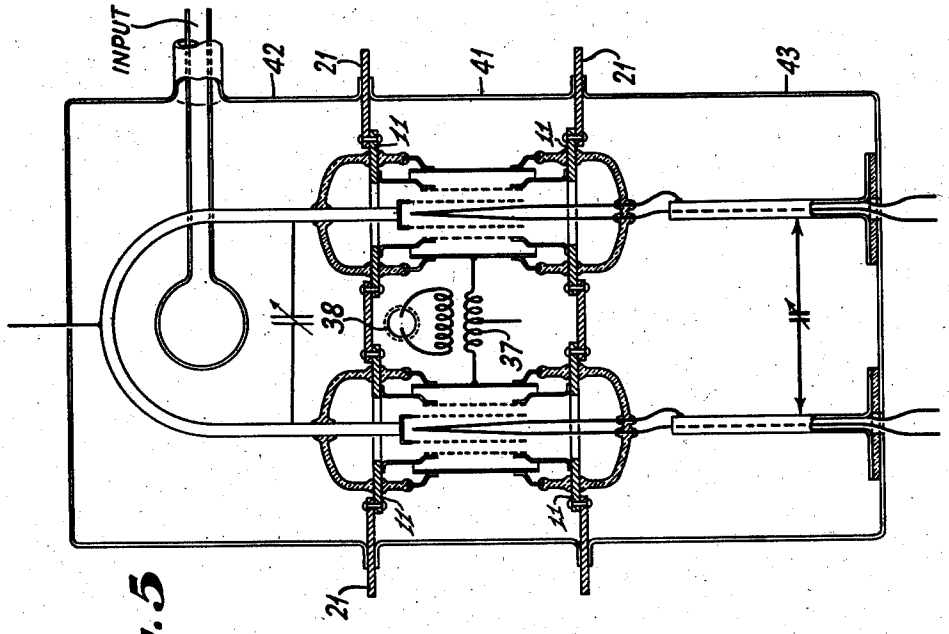


Fig. 5

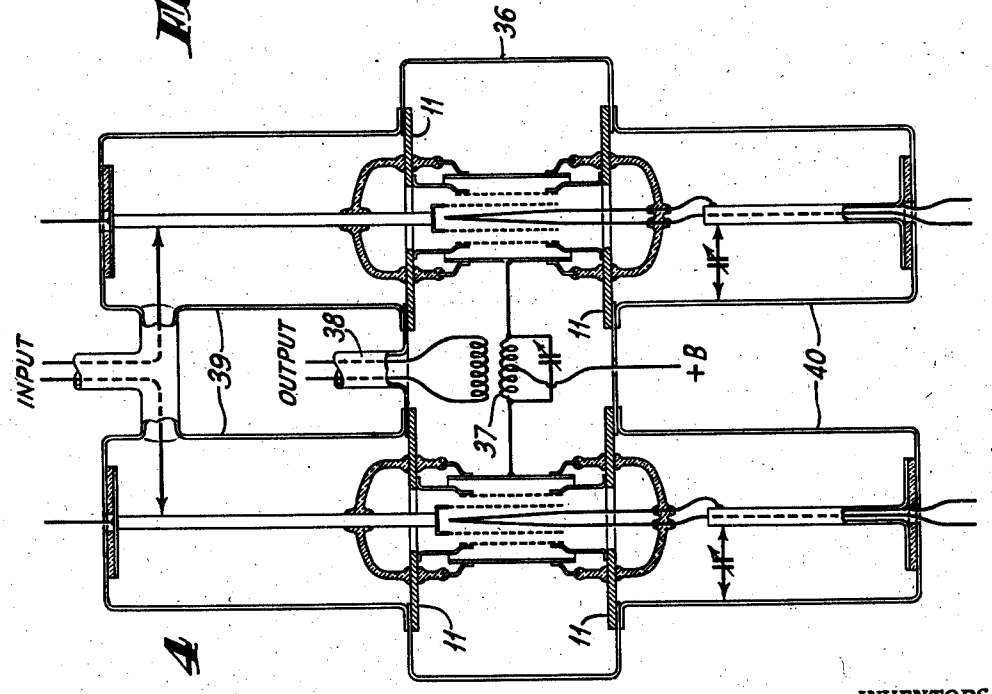


Fig. 4

INVENTORS
PAUL D. ZOTTU, LEON S. NERGAARD
AND ANDREW V. HAEFF,

BY Charles McClair
ATTORNEY.

Jan. 14, 1941. P. D. ZOTTU ET AL 2,228,939

HIGH FREQUENCY POWER TUBE

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Fig. 6

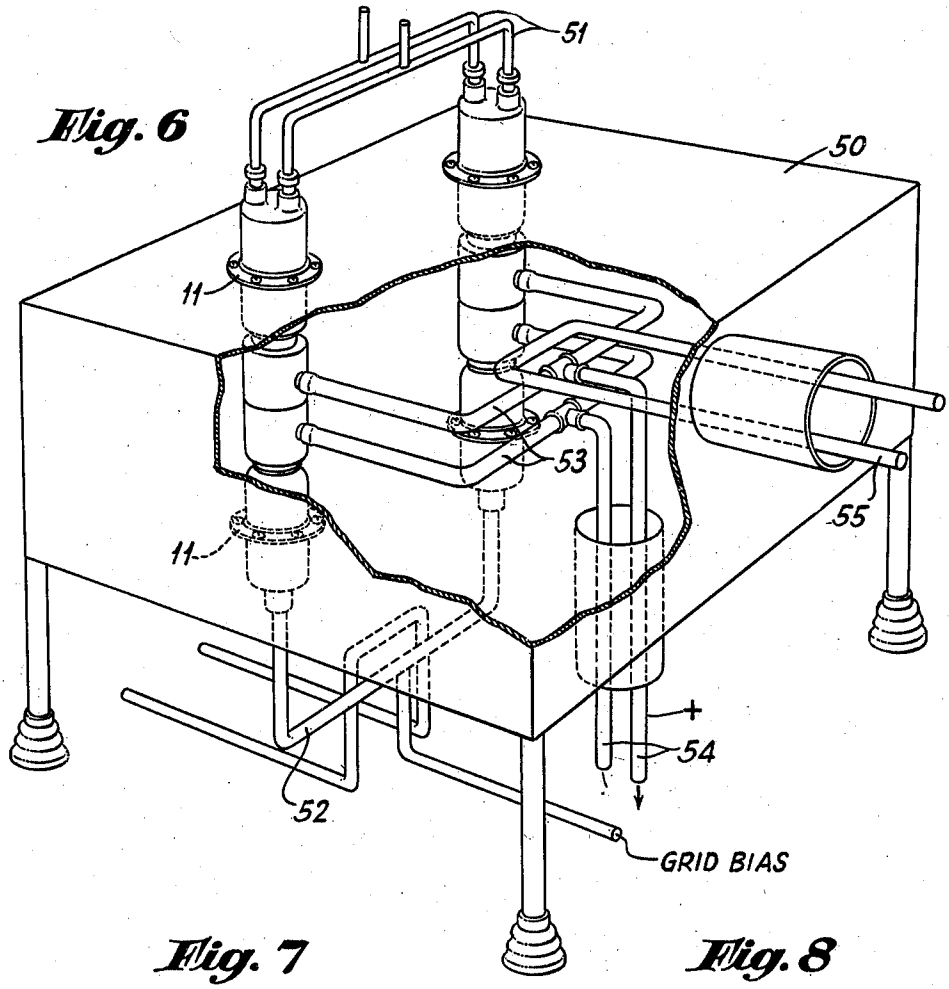


Fig. 7

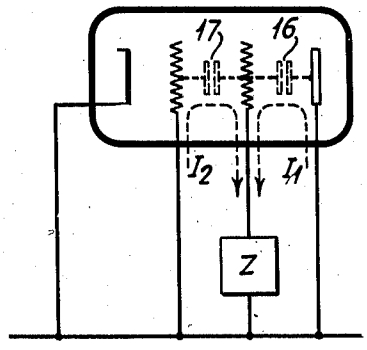
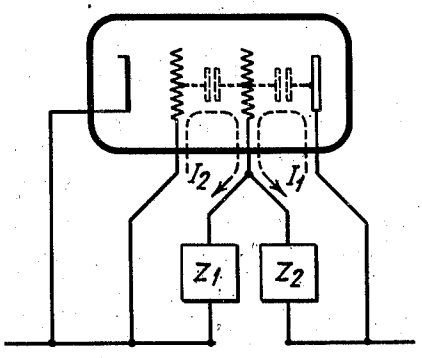


Fig. 8



INVENTORS
PAUL D. ZOTTU, LEON S. NERGAARD
AND ANDREW V. HAEFF

BY Charles McClair
ATTORNEY.

Patented Jan. 14, 1941

2,228,939

UNITED STATES PATENT OFFICE

2,228,939

HIGH FREQUENCY POWER TUBE

Paul D. Zottu, West Caldwell, Leon S. Nergaard, Bloomfield, and Andrew V. Haeff, East Orange, N. J., assignors, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application September 30, 1938, Serial No. 232,520

9 Claims. (Cl. 250—27.5)

Our invention relates to means for mounting electron discharge devices, particularly to means for electrically shielding high power devices operated at ultra high frequencies.

In electron tubes operated as amplifiers and oscillators at moderate power levels and at moderately high radio frequencies, sufficient shielding of the input and output electrodes may be obtained by a screen grid interposed between the electrodes and maintained at some fixed potential through a lead-in wire sealed in the envelope of the tube. In tubes operated at ultra high frequencies such as 50 megacycles or higher and at moderately high power levels the usual screen grid is ineffective in isolating the magnetic and electric fields of the anode, control grid, and their connected circuits. Among the factors contributing to this loss of isolation is interelectrode coupling around the ends of the screen and between lead wires and circuits. Further, the impedance of the usual wire type lead-in for the screen grid is high at ultra high frequencies and causes undesirable voltage variations on the screen grid.

An object of our invention is means to prevent interaction between the input and output electrodes and circuits of ultra high frequency tubes.

A further object of our invention is to minimize undesirable voltage variations in the screen grid operated at ultra high frequencies caused by impedance in the screen grid lead.

It can be shown that if equal and opposite currents flow in the inner pair of three concentric tubular conductors of infinite length no magnetic or electric field results in the space between the outer two of these conductors, and that if equal and opposite currents flow in the outer pair of these three concentric conductors no magnetic or electric field is produced within the center conductor. We have found that if in such a system the intermediate cylinder is perforate there is exhibited for practical purposes the same conditions of isolation as exhibited by the three imperforate tubular conductors and as a result the tubular control grid of a tube could be completely isolated from the anode by interposing a perforate cylinder or screen grid concentric with and between the anode and control grid were it not for electric and magnetic coupling between the anode and control grid around the end of the screen grid and for undesirable effects caused by the screen grid lead impedance.

In a conventional screen grid tube, each of the circulating currents through the interelectrode capacities between the control grid and screen grid, and between the screen grid and anode, flows in the screen grid lead. If, then, there is impedance in the screen grid lead there is mutual coupling between the two circuits. The circulating energy of one circuit will affect the voltage and current in the other circuit, and therefore the anode and control grid are effectively coupled. Even the slightest lead inductance displays appreciable voltage drop at ultra high frequency where large circulating currents are flowing, as in the screen grid-plate circuit, and there results a serious loss of screening. As the screen grid impedance cannot be completely eliminated, we have, in accordance with our invention, provided means to confine to effectively separate leads the two circulating currents from the screen grid and to isolate the two circulating currents so that no mutual coupling will be possible. Preferably this means comprises an impervious disc centrally apertured and joined along the periphery of the aperture to the end of the tubular screen grid. The two surfaces of the disc are isolated for ultra high frequency current and provide separate leads to the screen grid because of well-known skin effect, the effective depth of penetration of current into a copper conductor, for example, being less than .001 inch at 70 megacycles. Then, to prevent the two circulating currents from the screen grid from coming together at the outer periphery of the disc, we extend the two surfaces of the disc to completely enclose the electrically adjacent electrode and its circuit.

The characteristic features of our invention are defined with particularity in the appended claims and preferred embodiments are described in the following specification and shown in the accompanying drawings in which

Figure 1 shows in section a tube with a press and leads at one end and with novel screen grid lead-in construction and shielding;

Figure 2 is a sectioned view of a shielding arrangement for two tubes in push-pull, the tubes being similar in construction to the tube of Figure 1;

Figure 3 shows a tube with a press and leads at each end of the envelope and a preferred shielding construction;

Figures 4 and 5 show in section two tubes similar to the tube of Figure 3 connected for push-pull operation;

Figure 6 shows in perspective two tubes with

leads at each end mounted for push-pull operation; and

Figures 7 and 8 show, respectively, the current paths in a conventional tube and in our improved tube.

The envelope of the so-called single ended tube shown in Figure 1 comprises a cylindrical metal anode 1 closed gas-tight at its lower end by a cylindrical glass bulbous end section or bulb 2 joined coaxial with the anode by sealing ring 3 welded or brazed to the anode and sealed along its lower edge to the rim of the glass bulb. Within the anode are concentric screen grid 4, control grid 5 and cathode 6, the cathode being shown as a conventional V type filament for simplicity of illustration, although the preferred cathode would have a plurality of straight parallel heater wires arranged in a cylindrical surface concentric with the other electrodes. The control grid is preferably a series of parallel straight wires arranged in a cylindrical surface to minimize inductance between the ends of the grid and closed at its upper end with a metal cap. Spacers not shown are provided to hold the control grid in fixed spaced relation to the other electrodes, the control grid being connected to lead wire 7 sealed in the bottom of the glass bulb and inductively coupled to an input or excitation loop 8. The control grid lead is preferably shielded from the cathode heating wires 9 by a metal partition 10. To minimize the impedance of the screen grid throughout its length it is also constructed preferably of straight wires longitudinal of and parallel with the axis of the anode and like the control grid is arranged in a cylindrical surface concentric with the other electrodes and is closed at its upper end with an impervious metal cap.

To reduce the impedance of the screen grid lead-in conductor and to provide two effectively separate current paths to the screen grid, the conductor is made of a centrally apertured disc or lead-in ring 11, the ring being thick compared to depth of current penetration and sealed in the glass with its outer edge extending radially outward from the bulb, and the periphery of the aperture in the disc being coaxial with the electrodes in the tube as disclosed in our United States Patent 2,113,671 issued April 12, 1938. The two glass portions of the bulb may be butt sealed to opposite faces of the disc or may be joined to the disc with short upstanding feather-edged ridges embedded in the glass and brazed to the disc. The lower end of the screen grid is joined to the periphery of the disc aperture by a short impervious metal cylinder 12 concentric with the electrodes and fastened as by brazing or welding at its ends to the disc and the electrode. The junction between the disc and the cylinder 12 is continuous and impervious throughout the annular surface of contact between the two metal pieces.

The metal water jacket 13 surrounding the anode may conveniently communicate at its upper end to the pipes 14 of a fluid cooling circulating system. The cooling pipes are mounted in a tubular extension 15 rising from the end of the jacket, the length of the extension being preferably chosen equal to some multiple of an odd number of quarter wavelengths of the frequency of operation. The electrical length of the output circuit may be adjusted by tuning condensers 13' comprising semi-circular plates on rods slidable through the sides of the housing. The direct current energizing potential for the anode is preferably applied at a nodal point on the output transmission line which is at the outer end of tube 15 in the example shown.

The inherent capacity between the anode and screen grid diagrammatically represented in dotted lines in Figure 1 and as condenser 16, permits considerable current I_1 to flow between the anode and screen grid, the path for this current being completed in circuits outside the tube. Likewise current I_2 flows through the capacity 17 between the control grid and screen grid, the circuit for this current also being completed outside the envelope. These two currents in the conventional tube, Figure 7, must flow through a common screen grid lead with its inherent impedance Z. The mutual coupling between the circuits due to the impedance Z permits interaction between the input and output electrodes and causes unstable and inefficient operation.

According to our invention, the two currents I_1 and I_2 are separated, as diagrammatically represented in Figure 8, so that the voltage drop across the impedance Z_2, say, cannot be impressed on the control grid nor the voltage across Z_1 impressed on the anode. To separate the two currents, disc 11, Figure 1, is made thicker than the effective depth of penetration into the ring of the high frequency currents. Current I_1 on the upper surface of the ring is conducted upwardly and deflected from the outer edge of the ring by a metal shell or housing 18 erected on the ring and extending upwardly around the anode and the output circuit 15, the upper end of the housing being turned in to enclose the output circuit. To short circuit the upper end of the output circuit and the housing for high frequency currents, the anode extension 15 is preferably flared with a large flange 19 and capacitively coupled to the housing.

Current I_2 flowing on the under side of the ring and in the input circuit is confined in a housing 20 joined to the under side of the ring and enclosing the input circuit. In Figure 1 the circuits coupled to the input and to the output electrodes of the tube are enclosed in integral extensions from the sides of the housings.

Circulating current I_1 flowing between the anode and screen grid finds a closed circuit along the inner wall of housing 18, along the upper surface of disc 11, through cylinder 12 to the screen grid, and through capacity 16 to the anode. Circulating current I_2 flowing between the control grid and screen grid likewise finds a closed circuit along the inner surface of housing 20, along the under side of disc 11, through cylinder 12, and through capacity 17. At no point do these two currents become common or coupled except in the concentric cylindrical structure of the electrodes where their fields produce no mutual coupling in accordance with the well-known concentric conductor phenomenon.

Our method of isolating the anode from the control grid is equally effective in two tubes connected either for parallel or push-pull operation. In Figure 2 are shown two tubes similar to the tube of Figure 1, mounted side by side on a large plate 21 apertured to receive the two lead-in rings 11. Housing 22 is joined to the upper surface of plate 21 and completely encloses the anodes and the output circuit, preferably comprising a solid conductor loop 23 joined at its end to the two anodes. Direct current voltage for the anodes is connected to the electrical center of the loop and the output circuit 24 is inductively coupled to the loop and led out through a tubular extension

of the housing. The input circuit of the tubes preferably comprises a loop 25 between the two grids inductively coupled to input loop 26 and is enclosed in housing 27 joined to the underside of plate 21. Each filament is energized through concentric conductors 28 which are tuned with respect to each other or with respect to ground to minimize the high frequency impedance and the potential difference between filament and ground. In high frequency operation where the effective depth of penetration of the high frequency currents is slight, all circulating currents between the anode and screen grid are confined to the interior of housing 22, while all currents circulating between the screen grid and control grids are confined to the interior of housing 27.

Figure 3 shows a tube with the screen grid supported at each end upon lead-in rings 11 as disclosed in our above mentioned patent. Here three housings may be conveniently employed, for the anode, for the control grid and for the cathode circuits respectively. Housing 36 joined to the screen grid flanges completely encloses the anode and its tuned transmission line 30, terminating at its outer end in a plate capacitively coupled to the anode housing. In this embodiment the output circuit comprises a wire 31 concentric with anode housing extension 32 and tapped at the optimum RF voltage point on the transmission line 30. The input conductor is similarly tapped to the tuned grid transmission line 33 enclosed in housing 34 joined to the upper flange 11. The electrical length of the input and output circuits are preferably adjustable. The electrical length and tuning of line 33, for example, may be adjusted by a short circuiting condenser 33' comprising two metal discs joined to opposite sides of an insulating washer. The outer periphery of one disc is held in slidable contact with housing 34 and the other disc slides on line 33. The two push rods through the end insulator provide easy adjustment of the electrical length and tuning of the input circuit. As in Figure 2, the cathode is tuned by concentric conductors and is enclosed in housing 35 capacitively coupled to the cathode conductors at its lower end and joined at its other end to the lower flange 11.

In Figure 4 two double ended tubes are shown connected in push-pull with a single housing 36 imperviously joined to each of the four flanges 11 and enclosing the output circuit comprising an inductance 37 connected at its ends to the two anodes and coupled to an output circuit lead in to the anode enclosure through a shielding conduit 38 joined at its end to the housing 36. Individual housings 39 surround the two tuned input circuits comprising tuned rods tapped intermediate their ends to the input wires. Individual housings 40 enclose the two cathode circuits.

In Figure 5 are shown two double ended tubes arranged in push-pull with complete housing shields enclosing the anodes, the grids, the cathodes and their circuits. Housing 41 is joined to the plate 21 which supports the screen grid lead-in rings 11 and is similar in function to housing 36 of Figure 4, while the input circuits to the two control grids are enclosed in housing 42 and the cathodes are enclosed in housing 43.

In Figure 6 is shown a convenient method of mounting and electrically connecting two tubes constructed according to the invention described in our above mentioned patent. The upper and lower screen grid lead-in rings 11 are clamped or bolted to the upper and lower plates respectively of a box-like shield 50. Direct current supply leads 51, preferably about one-half a wave-length long, are connected at their ends to the filament terminals of the tubes and connected at their center to the direct current filament supply. The grids are tuned by conductor 52 to some value less than one-quarter of a space wavelength or a multiple thereof with the center connected to a direct current grid biasing source, the grid conductor being inductively coupled to a loop for excitation. The inlet and outlet nipples on water-cooling jackets of the anode are connected through tubular metal conductors 53 at the center of which are cooling fluid connections 54, which may extend downwardly through an opening in the shielding box. Direct current energizing potential for the anodes is preferably applied to the electrical center of the conductors 53 and a high frequency output circuit may conveniently comprise a conductor 55 inductively coupled as shown to the anode loop and extending outwardly through the side of a shield. The output conductors 55 are enclosed by a tubular shield extending from the housing 50, preferably to the outer ends of the conductors which may terminate at succeeding amplifier stage or in a load circuit, such as an antenna. In case conductors 55 are connected to a radiator they should be a sufficient distance from the housing 50 and grid loop 52 to prevent disturbing feedback. While the weight of the tubes may be borne by flanges 11 in the shielding box is may be desirable to mechanically support the tubes by their anodes. The grid circuit may alternatively be tuned by an exterior extension beyond the seal of the control grid, the extension being of such length that the grid circuit may be tuned by the long line or Lecher wire principle.

Tubes constructed and shielded according to our invention reduce to a minimum interaction between the anode and the control grid and prevent objectionable feedback, standing waves, and inefficient operation. The two surfaces of the ring to which the screen grid is connected, are essentially isolated for ultra high frequency currents by skin effect, and mutual coupling between the two circulating currents between the anode and screen grid and between the screen grid and control grid is prevented by metal housings joined to the ring and completely enclosing the output circuit from the input circuit. The outer peripheries of the discs are in effect extended to enclose the electrically adjacent electrodes and their circuits.

Shields that are mechanically and electrically impervious provide ideally shielded tubes, but in practice openings are often required in the shields for insulating bushings and for mechanical reasons. The size of the openings and the distance of the openings from the ends of the screen grid are important factors in determining the amount of energy that may be fed from one circuit to another. For example, a small opening at the inner periphery of the screen grid flange may produce more feedback than a large opening at the outer periphery of the flange, and considerably more feedback than would an opening in the wall of the screen housing removed several inches from the flange. Fortunately, the input power to the average amplifier may be varied as much as five percent by energy fed to the input circuit from the output circuit without harmful effects on efficiency and stability of operation.

Tubes constructed and mounted according to our invention prevent interaction between the input and output electrodes and circuits operating at ultra high frequencies. Many modifications may be made in the structural details of this novel tube and in the method of mounting and applying it in service without departing from the scope of this invention.

We claim:

1. An electron discharge device comprising a cylindrical anode with an insulating tubular section sealed gas-tight to one end, an annular lead-in ring extending radially through and sealed gas-tight in the wall of said section, a cathode and a control electrode concentric inside said anode, a screen grid between the control electrode and said anode joined at one end to the inner edge of said annular lead-in ring, and a shielding housing enclosing said anode and joined to the ring throughout the outer periphery of the ring.

2. An electron discharge device comprising a cylindrical anode, an insulating bulbous section sealed gas-tight to one end of the anode, an annular lead-in ring extending radially through and sealed gas-tight in the wall of said bulbous section, concentric tubular cathode, control grid and screen grid electrodes inside said anode, the tubular screen grid being joined along its rim at one end to said ring, and a metal housing enclosing said anode joined in a continuous impervious junction to said ring exteriorly of and around said bulbous section.

3. An envelope having an insulating portion, a tubular anode concentric with a cathode, a tubular control grid and a tubular screen grid inside said anode, a lead-in conductor for said screen grid comprising an impervious plate extending through said insulating section of said envelope, the end of said tubular screen grid being joined throughout its periphery to said plate, a metal housing joined to said plate and enclosing said anode, the junction between said housing and plate being continuous and around the insulating envelope section.

4. A tubular anode, a cathode and control grid inside said anode, a tubular screen grid concentric with and between said anode and control grid, means for isolating circulating currents between said anode and screen grid from the circulating currents between said screen grid and control grid comprising an impervious shield extending from the end of said screen grid through the wall of the envelope of said device, and a housing extending from said shield completely enclosing said anode, and a second housing extending from said shield enclosing the control grid lead-in.

5. An anode, a cathode, a control grid and a tubular screen grid inside said anode, the screen grid being between the anode and control grid, means for directing high frequency current flowing to the screen grid along two effectively isolated paths, comprising a plate with a central opening joined along the periphery of the opening to the end of said screen grid, metal housings joined to opposite faces of the plate in continuous impervious junctions, the two housings isolating the currents in said paths.

6. An electron discharge device comprising a cylindrical anode, glass bulb sealed gas-tight to opposite ends of said anode, two metal rings, a grid electrode concentric with said anode and joined at its ends to said metal rings, each ring extending radially through and sealed gas-tight in one of said sections, an electrically impervious metal enclosure surrounding the anode and joined to said rings externally of said bulbular sections, the junctions between the enclosure and rings being continuous around said sections.

7. Two electron discharge devices, each comprising tubular electrodes including concentric cathode, control grid, screen grid and anode, energizing circuits connecting the cathodes and control grids and an output circuit connecting the anodes, a continuous shield to isolate energies of the output circuit from the input circuits comprising continuous impervious metal conductors extending from the ends of said screen grids through the walls of said envelopes and enclosing said output circuit.

8. A tubular anode enclosing a cathode, control grid and tubular screen grid, a continuous electrically impervious shield extending from the ends of said screen grid through the walls of the envelope and around the output circuit connected to said anode, a second shield extending from one end of said screen grid through the envelope and around the input circuit connected to said control grid.

9. An electron discharge device with an envelope and a tubular anode enclosing concentric cathode, control grid and screen grid electrodes, metal plates extending from the ends of said screen grid through said envelope, an output circuit coupled to said anode, an input circuit coupled to said control grid, a metal housing surrounding said anode and said output circuit connected in an electrically impervious junction to said plates and a tubular housing surrounding said input circuit and connected in an electrically impervious junction to the plate adjacent the control grid lead-in conductor, means for adjusting the electrical length of the path between said input circuit and its housing.

PAUL D. ZOTTU.
LEON S. NERGAARD.
ANDREW V. HAEFF.