

July 21, 1953

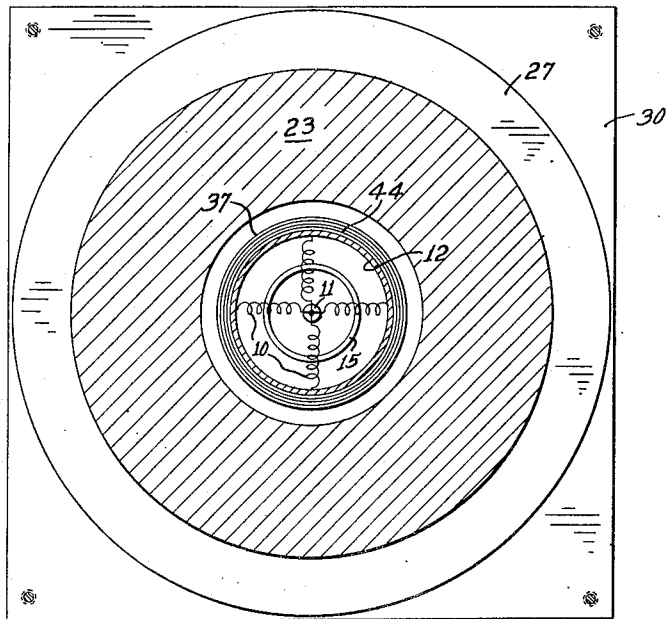
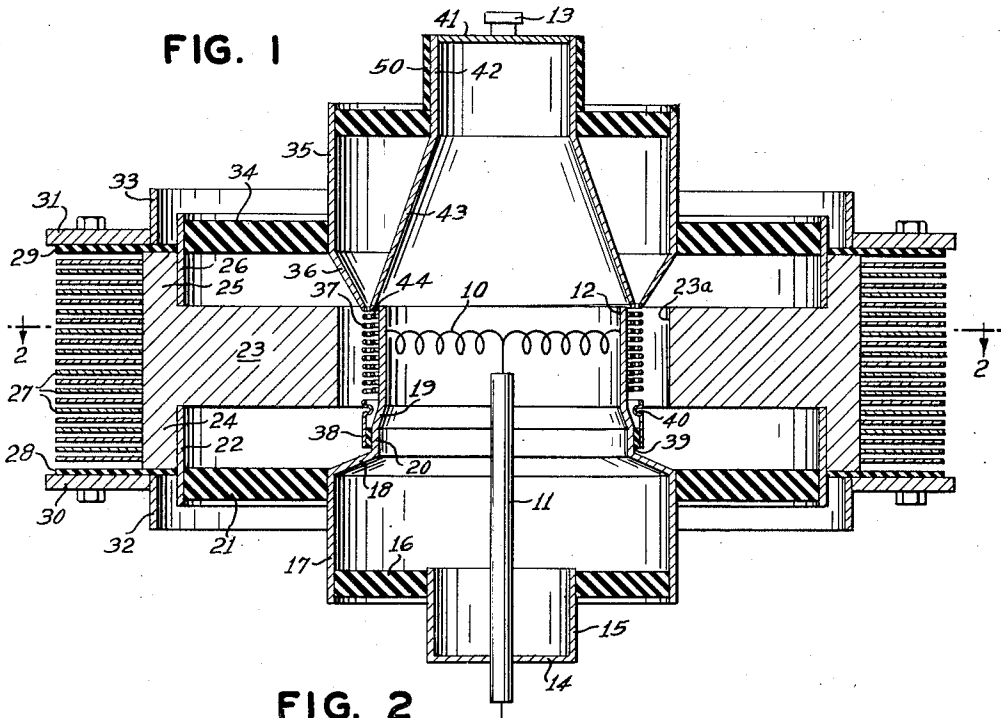
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2,646,470

ULTRAHIGH-FREQUENCY TETRODE

Filed March 25, 1950

4 Sheets-Sheet 1



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ULTRAHIGH-FREQUENCY TETRODE

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4 Sheets-Sheet 2

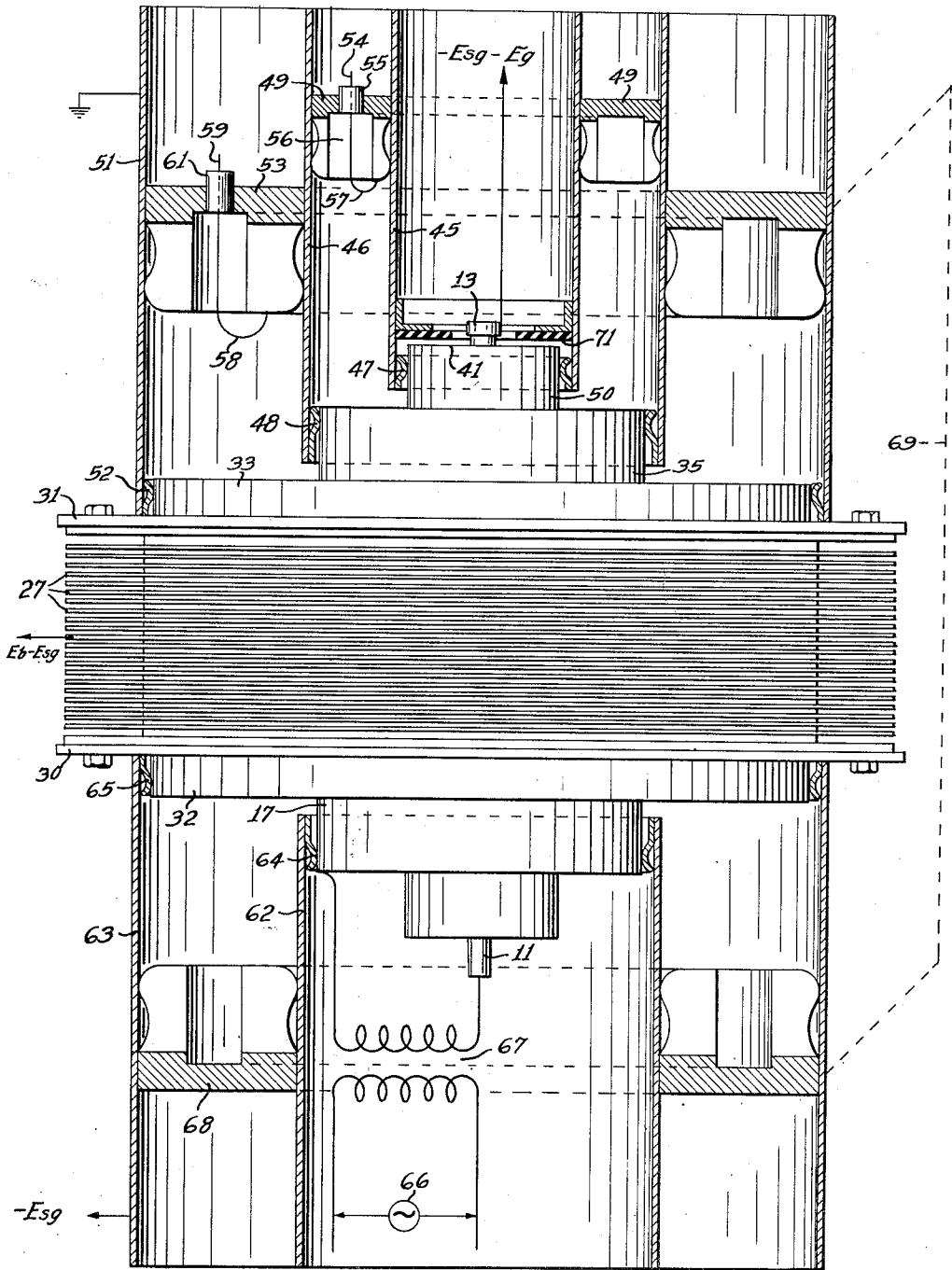


FIG. 3

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FIG. 4

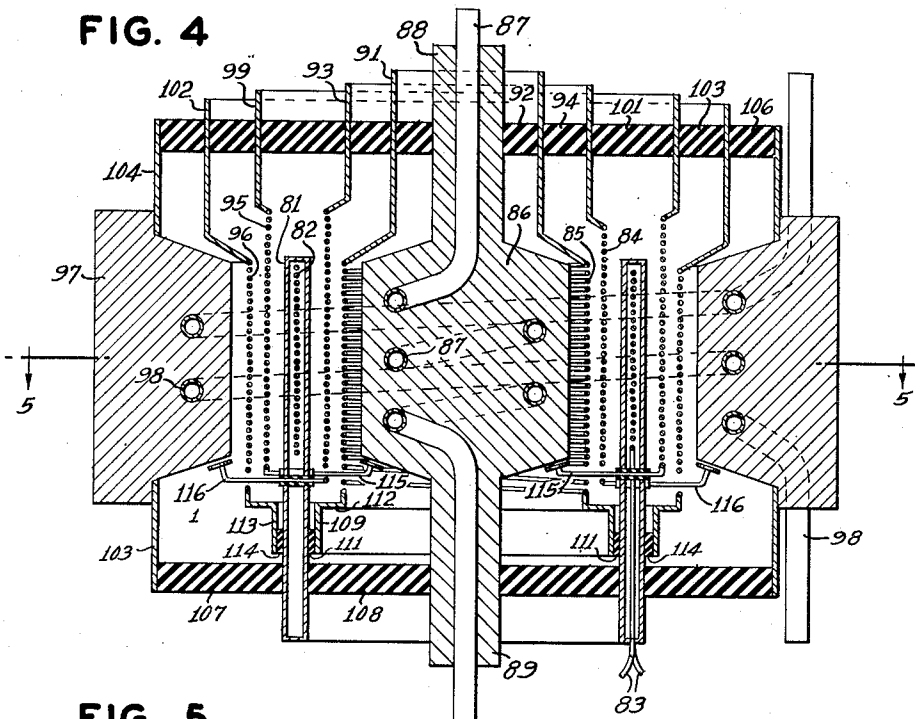
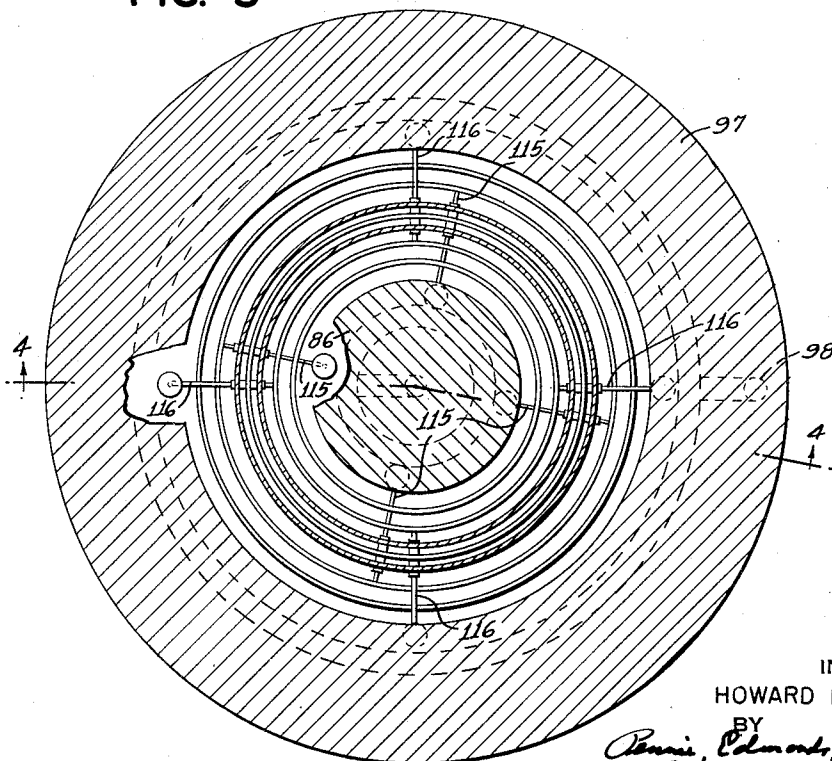


FIG. 5



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4 Sheets-Sheet 4

FIG. 6

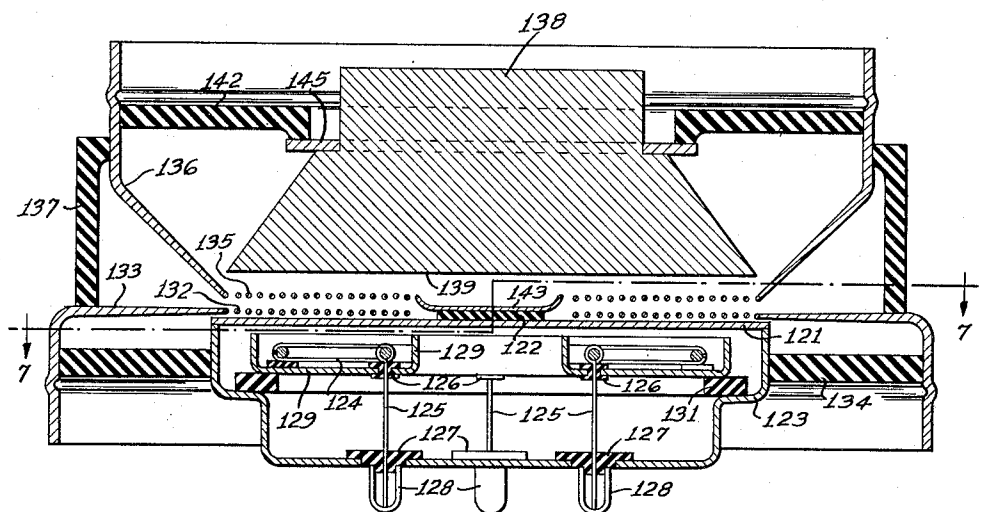
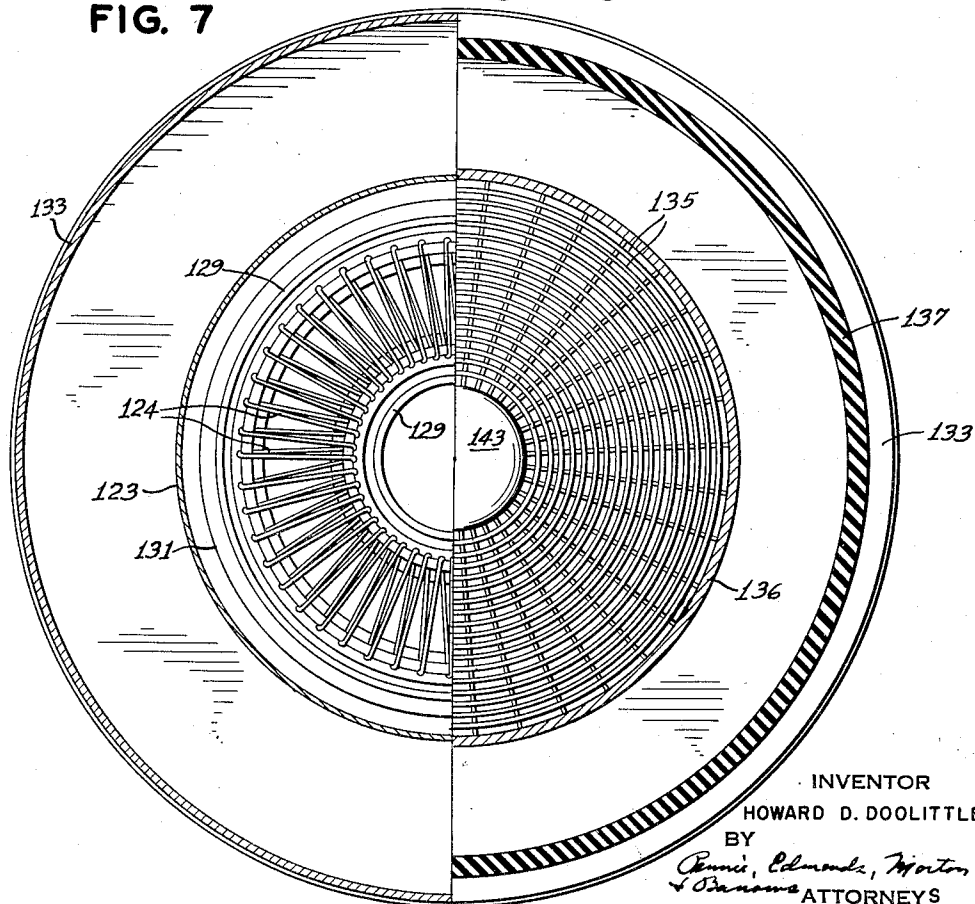


FIG. 7



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ULTRAHIGH-FREQUENCY TETRODE

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25 Claims. (Cl. 179-171)

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This invention relates to electron discharge devices, particularly to electronic tubes adapted for use at ultra-high frequencies and cavity arrangements for use therewith. The invention especially contemplates the provision of a screen-grid tube of the tetrode type capable of yielding relatively large power outputs at frequencies extending into the microwave region, e. g., to 3,000 megacycles or higher. It also includes tunable cavity arrangements particularly useful in combination with the tube of the invention. While primarily intended for ultra-high frequency use, the tube design may be employed in lower frequency ranges and with tuning circuits other than cavities.

The generation of power at ultra-high frequencies, and efficient amplification at such frequencies, are important problems at the present time. The widespread use of radio frequencies for sound broadcast, television, commercial and government use, has made it necessary to go to higher and higher frequencies in order to avoid interference. Also these higher frequencies, especially in the microwave region, tend to travel in straight-line paths like visible light, and this property has resulted in many special uses.

In transmitters increased power gives greater range, and the limited amount of power that can be generated with present-day tubes and equipment is a serious drawback to the use of ultra-high frequencies for many purposes.

At the present time, it is common to use single-ended triodes, such as the well-known "lighthouse" tubes for the amplification and generation of power at ultra-high frequencies. These tubes are relatively convenient to use and permit fairly simple cavity type tuning lines. However, as the frequency is increased the efficiency of such tubes and their ability to generate power rapidly decrease. In particular, when the cathode is maintained at R. F. (radio frequency) ground potential, the grid-anode capacitance gives rise to feedback which imposes an upper frequency limit on the operation. As a result, such triodes have been operated with the grid grounded in order that, with a grid separation circuit, feedback effects may be reduced. This is often done despite the sacrifice in gain. Even so, the frequency range through which significant amounts of power can be generated is limited.

At lower frequencies it is common to employ tetrodes having a screen grid which reduces the anode-control grid capacitance and hence reduces the feedback problem. Attempts have been made to employ tetrodes at ultra-high frequen-

cies and some success has been attained. Such tubes also have frequency ceilings which are determined primarily by interelectrode capacitances and lead inductances. In particular, the inductance of the R. F. screen grid-cathode potential equalizing lead and the capacitance still remaining between anode and control grid produce feedback which substantially reduces the gain below that possible at lower frequencies. Neutralizing circuits make possible some improvement in output at ultra-high frequencies, but it is still desirable to reduce these adverse factors as much as possible in order to raise the frequency ceiling still further. Furthermore, neutralizing circuits often result in limiting the frequency band through which a given circuit can conveniently be tuned. In addition single-ended operation of such multigrid tubes introduces some difficult problems in the design of suitable cavities for use therewith.

The ratio of feedback voltage (due to capacitive feedback) to output voltage can be expressed approximately as follows:

$$\frac{e}{E} = \frac{C_{pg}}{Q_{in} C_{in} + C_{pg}}$$

In this equation e , E are feedback and output voltages, respectively; C_{pg} is the anode-control grid capacitance; C_{in} is the input capacitance, and Q_{in} is the input figure of merit.

It is immediately clear that a decrease in feedback and hence improvement in voltage gain can be obtained by decreasing C_{pg} or decreasing Q_{in} . In order to reduce C_{pg} it is desirable to shield the anode as completely as possible from the control grid of the tube, and the tube of the present invention is especially designed to accomplish this. The Q_{in} depends primarily upon C_{in} , upon cavity design, and upon electron loading due to current in the grid-cathode region. C_{in} should be kept as low as is consistent with proper electron accelerating voltages and minimum transit time. The cavity itself should have as low losses as possible.

Inasmuch as tuning cavities, when used, must cooperate with the tube electrically as well as mechanically, it is important in designing a tube to keep in mind the design of appropriate cavities for use therewith in order to avoid a tube design which will impose detrimental restrictions on cavity design. In other words, both tube and cavity design must proceed simultaneously in order to obtain the best overall performance. Accordingly, the present invention includes a cavity

design which is particularly useful in combination with the double-ended tube of the invention. The combination permits simple coupling to input and output circuits, and simple connections for filament and D. C. (direct current) operating biases without passing through resonator cavities or requiring complicated means for bypassing the cavities. It also possesses important advantages as regards efficiency and ease of tuning.

In order that a tetrode may be operated satisfactorily at ultra-high frequencies, it is important to have the screen grid and the cathode at the same R. F. potential, or as close thereto as possible. This promotes optimum gain and wide frequency tunability. It also facilitates optimum cavity design in that the power input cavity can be connected between the screen grid and the control grid, yet be effectively connected between cathode and control grid. Likewise, the output cavity can be connected between screen grid and anode, and yet be effectively connected between cathode and anode.

To couple the screen grid to the cathode, so as to maintain them at the same R. F. potential, it has been suggested to pass the connection through the control grid support or to externally couple the screen grid and cathode. Neither of these means are entirely satisfactory and, in accordance with the present invention, a short R. F. coupling between screen grid and cathode is provided internally of the tube without piercing the control grid or its support. Inasmuch as the various tube electrodes and their supports are commonly part of the tuned cavity circuits in ultra-high frequency applications, the tube of the present invention insures that the several tuned cavities are well isolated so that undesired coupling therebetween is eliminated.

In accordance with the broad aspects of the present invention, a tube is provided having cathode, control grid, screen grid and anode electrodes in the form of surfaces of revolution. Advantageously the surfaces of revolution are similar and the electrodes are mounted in coaxial relationship. In order to maintain the screen grid at the same R. F. potential as the cathode, one edge of the screen grid is internally capacitively coupled to the adjacent edge of the cathode by means of a thin dielectric layer. The dielectric layer also advantageously has the form of a surface of revolution, and the symmetry and continuity of this capacitive coupling assures a highly effective R. F. connection between screen grid and cathode.

Advantageously the capacitive coupling is located immediately outside the effective area of the cathode and screen grid, and the connections from these electrodes to the capacitive coupling are caused to converge so as to partially pass around the intervening control grid to reduce the separation therebetween and hence permit obtaining a relatively high capacitance. The connection for the control grid is then taken from the edge thereof opposite the capacitive coupling, the space between the corresponding edges of the screen grid and cathode being left open.

Conductive members, preferably in the form of surfaces of revolution, are provided which extend from the several electrodes to the exterior of the tube to form suitable terminal connections. Inasmuch as the type of internal R. F. connection provided in accordance with the invention eliminates any need for passing connections through the control grid or its support, advantageously the connections from the electrodes are substantially

imperfurate. Preferably all electrodes and connections thereto have rotational symmetry and are arranged coaxially. This facilitates proper coupling between external tuning cavities and the electrodes themselves.

In accordance with the preferred embodiment of the invention, the electrodes are cylindrical and the control grid, screen grid and anode cylinders are of successively increasing diameter. In this manner the anode is on the outside of the tube so as to be readily accessible for cooling. Also the connections from the several electrodes to the exterior of the tube are tubular and arranged in coaxial relationship. The tubular connections from control and screen grids are brought out at one end of the tube, and that from the cathode brought out at the other end at substantially the same diameter as the screen grid connection. Annular connections are then provided at each end of the tube for the anode.

Due to this arrangement of external terminal connections, the input to the tube may be applied between screen grid and control grid, and the output taken between screen grid and anode so that both cavities may be at the same end of the tube. In addition a cathode-anode cavity may be provided at the opposite end of the tube, and this double-ended output cavity construction is especially important in the upper portion of the frequency range of operation. By making the cathode terminal of substantially the same diameter as the screen grid terminal, the screen grid-anode cavity at one end of the tube may have the same diameter as the cathode-anode cavity at the opposite end of the tube. This promotes efficiency and permits the two cavities to be tuned simultaneously by suitable ganging means.

In another embodiment of the invention, an ultra-high frequency double tetrode is provided having many of the features above discussed, including the internal R. F. coupling arrangement between screen grid and cathode of each section. In this tube all electrodes are cylindrical and concentrically arranged, thereby permitting efficient operation with external tuning cavities of relatively simple design. In this embodiment internal neutralizing capacitances between the control grid of each section and the anode of the opposite section are provided in order to still further increase the frequency ceiling of the tube.

In accordance with a still further embodiment of the invention, a tube is provided in which the surfaces of revolution are planar rather than cylindrical. While the cylindrical construction is preferred, the planar design has certain virtues of its own which are advantageous for some uses.

As indicated above, it is important to make the capacitance of the internal R. F. coupling between screen grid and cathode sufficiently large to form an effective R. F. coupling at the frequencies for which the tube is intended to operate. In particular it is highly desirable to make the capacitance of the R. F. coupling large compared to the control grid-cathode interelectrode capacitance. When the input is applied between screen grid and control grid, as specifically described hereinafter, the capacitance of the R. F. coupling is in series with the interelectrode capacitance between control grid and cathode. Thus, with the R. F. coupling capacitance large compared to the control grid-cathode capacitance, most of the input voltage will appear effectively between control grid and cathode, and the voltage drop across the R. F. coupling will be negligible. The desired capacitance in the R. F.

coupling may be obtained by proper selection of the dielectric material, by making the dielectric layer sufficiently thin, and by making the area of the coupling sufficiently large. These design factors are well known in the art and a suitable choice of parameters to meet the stated requirements may readily be made in any particular application.

In addition to the shielding property of the screen grid provided in the tubes of the present invention, there is also some reduction in transit time of electrons due to the high D. C. potential which may be applied to the screen grid, and this reduction in transit time results in some power factor improvement. The current gain of a tetrode made in accordance with the present invention permits it to be used to produce greater power than present tubes, or to reduce the number of tubes in a given situation.

Besides the desirable electrical characteristics above mentioned, the preferred tubes of the present invention embody structural features which permit them to be made very rugged. Such ruggedness is highly important in many modern applications where tubes as well as other components are required to withstand great accelerations.

The invention will be more fully understood by referring to the following detailed description, of several specific embodiments thereof, taken in conjunction with the drawings in which:

Fig. 1 is a cross section of a preferred tube embodiment of the invention, taken along the axis thereof;

Fig. 2 is a cross section taken along line 2—2 of Fig. 1;

Fig. 3 is a view, partly in cross section, showing the tube of Fig. 1 in a preferred type of cavity arrangement;

Fig. 4 is a cross section of a double tetrode embodiment of the invention, taken along the line 4—4 of Fig. 5;

Fig. 5 is a cross section taken along line 5—5 of Fig. 4;

Fig. 6 is a cross section of a planar type tetrode, taken along the axis thereof; and

Fig. 7 is a cross section taken along the line 7—7 of Fig. 6.

Referring now to Fig. 1, an indirectly heated cathode structure is shown in which a filamentary heater 10 is connected between an axial conductive supporting rod 11 and cylindrical cathode 12. As shown in Fig. 2, advantageously the filament is arranged in several coils extending between the supporting rod 11 and cathode 12. If desired, for added strength, rod 11 may be continued through the tube axially to the opposite end thereof and secured therein by an annular insulating ring which allows movement axially but not radially. Rod 11 is fixed in the end wall 14 of a metallic cup whose side wall 15 is cylindrical and arranged coaxially of the tube to form a suitable filament terminal.

The cup wall 15 is joined by an annular ceramic ring seal 16 to an axially concentric metallic cylinder 17 which form an external terminal connection for the cathode 12. As shown, the connection is a tubular conductor and connects to the cylindrical cathode by the conical sections 18, 19 and cylindrical section 20, in order to reduce the diameter to that of the smaller cathode.

An anode supporting conductive cylinder 22 of larger diameter is joined to cylinder 17 by ceramic ring seal 21. Anode 23 is an axially concentric annular metal ring and advantageously

is formed of metal having high electrical and heat conductivity. The cylindrical face 23a of the anode is the active area, and the axial length thereof is advantageously substantially the same as that of the effective area of cathode 12. Anode 23 is advantageously located at approximately the geometric mid point of the tube axis so as to obtain strength and ruggedness, enabling the tube to withstand high accelerations. Anode 23 is provided with axial flanges 24 and 25 for convenient attachment to cylindrical supports. Flange 24 is secured to supporting cylinder 22 and flange 25 is secured to a similar supporting cylinder 26. Radial heat radiating fins 27 are affixed to the outer face of the anode to facilitate air cooling.

The tube as a whole is provided with convenient mounting means by means of two plates 30 and 31 of square outline as shown in Fig. 2, but provided with central holes to accommodate the tube structure. They may be bolted together at their corners and the overall structure forms a convenient air baffle for the circulation of cooling air.

Mounting plates 30 and 31 are insulated from the anode by means of dielectric rings 28 and 29. Radio frequency connections to the anode are provided by means of short tubular conductors 32 and 33. These are arranged concentrically with the tube axis and are preferably of the same diameter.

Anode supporting cylinder 26 is joined to the cylindrical screen grid terminal 35 by a ceramic ring seal 34. Advantageously the diameter of the screen grid terminal 35 is the same as that of the cathode terminal 17. Terminal 35 is reduced in diameter by conical section 36 and supports the screen grid 37. The latter is in the form of a cylindrical wire mesh surrounding the cathode 12 and extending axially substantially the same distance as that of the cathode and anode.

Conductive cylinder 42 having an end wall 41 forms the control grid terminal and has an expanding conical section 43 which supports the control grid 44. The control grid is also a cylindrical wire mesh positioned coaxially of the tube. A suitable terminal 13 is attached to end wall 43.

The internal R. F. capacitance coupling between screen grid and cathode is formed by means of a thin dielectric ring 39. On the outer side of dielectric ring 39 is a cylindrical conductor 38 attached to the lower end of screen grid 37 through the hairpin bend 40. On the opposite side of dielectric ring 39 is a cylindrical portion 20 of the tubular cathode connector. The hairpin bend 40 maintains the screen grid in place and allows expansion upon heating without bowing the grid. Advantageously the cylindrical portion 38 has the same diameter as that of the screen grid so that there is no tendency to distort the screen grid cylinder. By forming bend 40 in the inwards direction as shown, it forms a barrier which would help prevent only conductive particles which might drop from the electrodes in operation from reaching the dielectric 39, and impairing its insulating properties.

Inasmuch as it is desirable to make the capacitance between segments 32 and 20 high compared to that between the control grid and cathode, dielectric ring 39 is advantageously made very thin, and the screen grid and cathode tubular supports are made to converge the necessary amount. As pointed out above, it is desirable to have section 38 of approximately the same diameter as screen grid 37. Accordingly the diameter of the cathode

support conductor is increased by conical section 19 so that the spacing between sections 20 and 38 is sufficiently small. Thus the cathode conductor passes around the intervening control grid 44 to close the gap to the screen grid.

By forming the R. F. coupling between screen grid and cathode at adjacent edges of the respective electrodes, the space between the other edges of the electrodes is left open to permit direct connection to be made from the other end of the tube to the control grid. The construction is simple and rugged and does not require any leads to be passed from the cathode to the screen grid through the control grid or the supporting conductor 43 of the control grid.

In accordance with ordinary electronic tube practice, the internal volume of the tube is highly evacuated. As will be apparent from the foregoing description, the evacuated chamber is formed by the anode, the various ceramic ring seals, and portions of the terminal and support structures for the electrodes.

Referring now to Fig. 3, the tube of Fig. 1 is shown in a coaxial tuning cavity arrangement. The input cavity is formed by concentric metallic cylinders 45 and 46. These cylinders are provided with spring contacts 47, 48 extending around the periphery thereof which grip the cylindrical control grid terminal and screen grid terminal of the tube, respectively. The cylinders are short-circuited by the sliding annular metallic plunger 49 to form a tunable control grid-screen grid cavity. Advantageously the spring fingers 48 make a D. C. contact with the screen grid terminal 35, whereas the fingers 47 make an R. F. contact with the control grid cylinder 42 but are D. C. insulated therefrom by the thin dielectric ring 50 (Fig. 1). Although dielectric ring 50 is shown as part of the tube structure, it could be omitted from the tube and appropriate provision made in the cavity structure for D. C. insulating the cylinder 45 with respect to control grid terminal 42, while providing an R. F. connection thereto.

Another larger coaxial conductive cylinder 51 is provided with spring contact fingers 52 to grip anode terminal ring 33 which is R. F. connected to the anode but D. C. insulated therefrom by dielectric ring 29 (Fig. 1). Cylinders 46 and 51 are short-circuited by the annular metallic plunger 53 to form a tunable screen grid-anode resonant cavity.

Radio frequency input to the screen grid-control grid cavity may be supplied through a coaxial line to conductor 54 mounted in plunger 49 by an insulating sleeve 55. The outer conductor of the coaxial cable may be connected to plunger 49. Conductor 54 is carried through an annular slot 56 to form a loop 57 which terminates on the plunger 49. This provides an inductive coupling loop within the cavity as is well known in the art. Similar provision is made for an output connection from the screen grid-anode cavity by means of inductive coupling loop 58 leading to a coaxial line through central conductor 59 mounted in insulating sleeve 61. It will be understood that any desired coupling means may be employed for supplying R. F. input to one cavity and deriving R. F. output from the other. Various probes or loop constructions are known in the art and may be employed to suit the particular application.

A tunable cathode-anode cavity is provided at the other end of the tube by means of conductive cylinders 62 and 63 having spring contact fingers

64, 65 which grip the cathode terminal 17 and anode terminal 32, respectively.

Cylinders 62 and 63 are short circuited by adjustable plunger 68. In the embodiment shown, cylinder 62 is D. C. connected to the cathode, whereas cylinder 63 is R. F. connected to the anode but D. C. insulated therefrom by means of dielectric ring 28 (Fig. 1). Suitable heating current is supplied from an appropriate power source 66 through transformer 67 to the heater support rod 11 and cathode terminal 17. It will be observed that due to the construction of the tube and cavity, connections for supplying heating current to the tube are outside of the resonant cavities.

Inasmuch as the screen grid is R. F. coupled to the cathode internally of the tube, the cavities tuned by plungers 53 and 68 jointly from a tunable double-ended tube cavity. It is desirable to adjust plungers 53 and 68 simultaneously, although completely symmetrical movement is not absolutely essential. Simultaneous adjustment may be provided by suitable gang means indicated by the dotted line 69.

Although it is preferred to employ the double-ended output cavity of the invention, the tube may be operated with a single-ended cathode-anode cavity if desired, particularly over the lower portion of the frequency range for which the tube is designed. For example, the lower cavity in Fig. 3 may be eliminated, and shielding employed to reduce radiation. Double-ended tuning, as illustrated, is especially advantageous for the higher frequency ranges.

Suitable stops are provided to enable accurate positioning of cavities and tube, to prevent injury to seals, etc. End plates 30 and 31 limit the movement of outside cylinders 63 and 51, and insulating disk 71 mounted on inner cylinder 45 provides a stop for the inner cylinder.

While appropriate D. C. operating potentials may be applied in any desired manner, it is preferred to ground cylinder 51, as here shown, thus maintaining cylinders 46 and 45 likewise grounded through plungers 53 and 49. Cylinder 46 is D. C. connected to screen grid terminal 35 and hence the screen grid is maintained at ground potential. This permits this end of the cavity to be touched without danger of injury from high voltages. The cathode is maintained below ground potential by the selected value of screen grid voltage, and the voltage $-E_{sg}$ is shown applied to cylinder 63 which is conductively connected through plunger 68 and cylinder 62 to the cathode terminal 17. The anode may be maintained at a suitable potential equal to the selected anode voltage E_b minus the screen grid voltage E_{sg} , and the corresponding voltage $(E_b - E_{sg})$ applied to any one of the cooling fins 27 which are conductively connected to the anode.

If the control grid is held at a negative D. C. potential with respect to the cathode, with the screen grid at ground potential, the resultant voltage to ground will be $(-E_{sg} - E_g)$. This voltage may be applied to terminal 13 on end plate 43 of the control grid terminal. It is important to prevent any portion of the grid cylinder 45 from touching the conductive end 43 of the control grid terminal, and this may be conveniently accomplished by inserting an insulating layer 71 at the end of the cylinder 45. This also serves as a stop between cavity and tube, as before mentioned.

In operation the input R. F. voltage is applied through the coupling loop 57 to the screen grid-

control grid cavity. As before mentioned, the capacitance of the R. F. coupling between screen grid and cathode is made high compared to the interelectrode capacitance between the control grid and cathode. Since the two capacitances are in series, most of the input voltage is applied between control grid and cathode. Stated differently, by making the coupling capacitance sufficiently large, the R. F. screen grid potential is at all times substantially the same as that of the cathode, so that the input voltage is applied effectively between cathode and control grid.

The optimum ratio of R. F. coupling to control grid-cathode capacitance depends on the specific design of the tube and the range of frequencies over which it is intended to operate. Generally the R. F. coupling capacitance should be larger than the control grid-cathode capacitance. In order to insure that when a signal is applied between screen grid and control grid, most of it will appear between control grid and cathode, the R. F. coupling capacitance may advantageously be several times the control grid-cathode capacitance. Indeed, from this point of view the larger the ratio of capacitances the better. However, other factors often will make it desirable not to select too high a ratio, and the optimum ratio must be left to the judgment of the tube designer in any particular application. A ratio of five is often adequate. It may also be said that usually it will be desirable to select an R. F. coupling capacitance whose reactance will not exceed about 10 ohms over the frequency range for which the tube is designed to be operated.

Regardless of the particular value selected, the structure provided by the present invention affords a simple internal R. F. coupling between screen grid and cathode which permits obtaining any desired capacitance over a wide range with minimum accompanying inductance.

The R. F. output is derived from the screen grid-anode cavity by means of coupling loop 53. Here again, inasmuch as the screen grid is at substantially the same R. F. potential as the cathode, the output is derived effectively from the cathode-anode circuit. For the same reason, the tuning cavity between the cathode and anode at the other side of the tube is essentially a continuation of the tuning cavity between screen grid and anode, and the two cavities may be treated as a double-ended cathode-anode cavity.

Certain precautions are desirable in choice of dimensions for ultra-high frequency operation. Referring to Fig. 1, in order to avoid spurious oscillations it is desirable to make the central cavity within control grid support 43, cathode 12 and cathode support 17-20 small enough so that it will not resonate at any frequency at which the tube is to be operated. If desired, the volume of the cavity may be reduced by placing a metal cap over the top end of cathode 12, thus limiting the space to that bounded by the cap, the grid support 43 and end 41. If the cavity is still too large, end 41 may be made of glass or a ceramic. In this case the cavity becomes a wave guide and the diameter of end 41 may be made sufficiently small so that the waveguide is beyond cutoff for any frequency at which the tube is designed to operate.

Although the specific embodiments described herein are primarily intended for use at ultra-high frequencies, the invention is not restricted to such frequencies. The tube of Figs. 1 and 2, and those described hereinafter, may readily

be adapted for use at lower frequencies and may be made larger for such frequencies so as to produce more power. Also, although cavity-type tuning lines are described, since they are particularly useful at ultra-high frequencies, other types of tuning arrangements may be employed, particularly at lower frequencies.

In choosing suitable dimensions for operation at a selected upper frequency limit, it is desirable to keep the dimensions of electrodes in the direction of wave motion less than about $\frac{1}{4}$ of a wave length. In the embodiment shown in Fig. 1, this means that the axial lengths of the cathode, grids and anode should be kept less than about $\frac{1}{4}$ of the wave length at the upper frequency limit. In this manner the emitting surface of the cathode and the effective areas of the other electrodes are maintained at approximately the same R. F. potential throughout their area at any given instant. If the axial length is longer, the difference in R. F. potential at any instant may become appreciable due to a standing wave effect. Thus as frequency is increased a shorter structure is required.

In order to maintain the output at a high level despite the required short axial dimension, the diameter of the cathode may be enlarged to provide a sufficient area for obtaining the desired emission current. Since the anode is arranged on the outside of the tube envelope, it is available for convenient cooling and hence the heat energy may readily be dissipated.

A further consideration should be kept in mind in the tube of the present invention. Inasmuch as the screen grid is internally R. F. connected to the cathode, the standing wave effect over the total axial length of screen grid, cathode and R. F. connection must be considered. It is advantageous to select dimensions such that this path does not exceed $\frac{1}{4}$ of a wave length in overall length at the desired upper frequency limit.

In order to take full advantage of the short internal R. F. coupling between screen grid and cathode, it is desirable to reduce the grid-cathode capacitance as much as possible. Also, in order to take full advantage of the screen grid, it is desirable to make the electrical screening between anode and control grid, effected by the screen grid, as efficient as possible. Increased efficiency of screening may be obtained by making the mesh of the screen grid finer, or by increasing the thickness of the grid wires, or by increasing screen grid-anode spacing, or by a combination of these three parameters. Thus, even at ultra-high frequencies, the capacitive reactance between anode and control grid may be reduced sufficiently to prevent any appreciable feedback.

A further advantage of the tube shown in Fig. 1 is the inherent ruggedness of the structure. All electrodes and connections thereto are cylindrical or conical, and these shapes inherently possess considerable mechanical strength. The size and thickness of the various elements may be proportioned to give any desired degree of ruggedness. This is especially important in modern uses where tubes are often subjected to great accelerating and decelerating forces.

Referring now to Figs. 4 and 5, an ultra-high frequency tube of the double tetraode type is shown, all elements having substantially coaxial rotational symmetry. A hollow cylindrical cathode 81 is coated with electron emissive material on both sides so as to emit electrons both radially inwards and radially outwards. It is

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heated by an internal coil 32 energized from a suitable source connected to insulated leads 33.

One tetrode is disposed inwards of cathode 81 and is formed by cylindrical control grid 34, cylindrical screen grid 35 and the central cylindrical anode 36. The anode 36 is advantageously formed of a solid block of material having good electrical and heat conductivity. To permit operation at high power levels without overheating, it is advantageously cooled by circulating cooling fluid through the coil 37. Ends 88 and 89 of the central anode block provide connection terminals therefor. Screen grid 35 is supported by the tubular terminal conductor 31 which is spaced from end 33 of the anode by means of ceramic ring seal 92. Control grid 34 is similarly supported by tubular terminal conductor 93 spaced from the screen grid terminal 91 by ceramic ring seal 94.

The second tetrode comprises the outside area of cathode 81, control grid 95, screen grid 96 and outer anode 97. Anode 97 is ring-shaped and is shown provided with cooling coil 98. If desired, inasmuch as this anode is on the outside of the tube, it could be provided with fins for air cooling instead. Control grid 95 is supported by tubular terminal conductor 99 spaced from control grid 93 by means of ceramic ring seal 101. Screen grid 96 is similarly supported by tubular terminal conductor 102 and spaced from control grid 99 by means of ceramic ring seal 103. Anode 97 is secured to conductive cylinders 104 and 105 which also serve as terminals therefor. Cylinder 104 is spaced from screen grid terminal 102 by ceramic ring seal 106. At the other end of the tube, cylinder 105 is joined to cathode 81 by the ceramic ring seal 107. The cathode 81 is in turn joined to the central anode terminal 89 by ceramic ring seal 108. The closed chamber formed by the ceramic ring seals, anodes and terminals is evacuated in the usual manner.

Internal R. F. connections between screen grids and cathode are provided in this tube in a manner similar to that described in connection with Fig. 1. To this end the lower end of screen grid 85 is provided with a conducting tubular support 109 and the support is R. F. coupled to cathode 81 by means of the thin dielectric ring 111. To this end screen grid support 109 and cathode 81 are caused to converge around the end of control grid 84. In this case, the screen grid support 109 is enlarged in diameter by the annular section 112, so that the dielectric 111 can be sufficiently thin.

In the outer tetrode a similar R. F. connection between screen grid 96 and cathode 81 is provided by means of the conductive tubular support 113 and thin dielectric ring 114.

As pointed out in connection with the tube of Fig. 1, the internal R. F. connection between screen grid and cathode of each tetrode section makes it possible to apply the input between control grid and screen grid of the corresponding section, and still apply the input effectively between control grid and cathode of that section. This is accomplished without piercing the control grid or its support in any way by the R. F. coupling, and the coupling is continuous around the tube with perfect symmetry. Likewise, the output can be taken from the upper end of the tube between corresponding screen grids and anodes, and still have the output taken effectively from between respective cathodes and anodes. Again, as in the case of the tube of Fig. 1, the double-ended construction permits connecting suitable

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tuning anode-cathode cavities between cathode 81 and terminal 89 of the central anode, and between cathode 81 and terminal 105 of the outer anode, at the lower end of the tube. Thus a tuning cavity arrangement similar to that of Fig. 3 may be employed in connection with the tube of Fig. 4, except that additional cavities are required due to the double tetrode arrangement.

Neutralizing connections between anodes and control grids of opposite sections may be employed in order to still further increase the frequency ceiling of the tube. In Fig. 4 neutralizing connections are shown between each control grid and the anode of the other tetrode section. This is accomplished by connections which are directly connected to each grid and capacitively coupled to the anode of the other section. Fig. 4 shows a pair of connections 115 between control grid 95 of the outer section and anode 36 of the inner section. They are formed of wires which pierce the cathode and are insulatedly supported therein. The ends adjacent the anode are advantageously enlarged to form a good capacity coupling. Similarly, control grid 84 is capacitively coupled to anode 97 by conductors 116 which pierce the cathode and are insulatedly supported therein. While one pair of neutralizing connections between each grid and the opposite anode may sometimes suffice, it is often desirable to employ two or three pairs spaced at intervals around the tube. Fig. 5 illustrates two pairs of neutralizing connections between each grid and the opposite anode. Irregular spacing around the tube may be employed if desired in order to suppress any odd frequency modes which might be set up if the spaces were even.

Referring now to Figs. 6 and 7, an electron discharge device of the tetrode type is shown in which the active areas of the electrodes are similar surfaces of revolution of the planar type. A cathode 121 is provided in the form of a circular disk having an electron emissive area extending from the outer or peripheral edge thereof to the inner edge adjacent the thin dielectric disk 122. The active area of the cathode is hence annular in form. The cathode is supported by a tubular imperforate conductor 123 which leads to the exterior of the tube and forms a terminal for the cathode. Indirect heating is provided by means of a suitable coil 124 here shown as wound in toroidal form. Leads 125 extend from suitable points on the toroidal winding through insulating disks 126, 127 to terminals 128 exterior of the tube. In order to increase heating efficiency, an annular metallic ring 129 of U-shaped cross section is provided and supported from the cathode conductor by means of insulating ring 131.

The annular control grid 132 is supported by means of conductor 133 which extends to the exterior of the tube to form a suitable terminal for the grid. Conductor 133 is spaced from cathode conductor 123 by the ceramic ring seal 134. The screen grid 135 is supported at the outer edge thereof by conductor 136 having a conical section of increasing diameter leading to a cylindrical section which extends exterior of the tube to form a suitable terminal for the screen grid. Conductor 136 is spaced from control grid conductor 133 by the annular ceramic seal 137. The anode 138 is shown in the form of a solid block of material which is preferably of high electrical and heat conductivity. Although the face 139 of anode 138 is shown in the form of a circle, it will be understood that the active area thereof is substantially that opposite the

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annular screen grid 135 and hence is likewise annular in form. If desired, of course, the center portion of the anode at face 139 could be cut out. Anode 138 is attached to metallic ring 141 and the latter is secured to the screen grid support 136 by the ceramic ring seal 142.

Like the tubes described hereinbefore, that of Fig. 6 is provided with an internal R. F. coupling between screen grid and cathode. To this end a supporting conductor 143 is attached to the inner edge of screen grid 135 and is dishd to pass partially around the inner edge of control grid 132, thereby leaving only a small space between conductor 143 and the adjacent portion of the cathode disk 121. A thin disk 122 of a suitable dielectric material is interposed to form an R. F. coupling between screen grid and cathode.

The tube of Fig. 6 may be employed with tuned coaxial cavities in a manner similar to that described in connection with Fig. 3. With the tube constructed as shown, a control grid-cathode cavity may be formed of concentric cylinders and connected to the lower end of the tube, connections being made to terminals 133 and 123 for this purpose. A similar tunable cavity may be connected between screen grid and anode at the upper end of the tube, connections being made to screen grid terminal 133 and anode 138. Inasmuch as the screen grid is R. F. coupled to the cathode, the output cavity at the upper end of the tube is effectively connected between cathode and anode. If it is desired to D. C. insulate one or more of the electrodes, suitable R. F. connections thereto may be provided as described in connection with the tube of Fig. 1. Alternatively, D. C. insulation may be provided in the cavity structure.

With the specific construction shown in Fig. 6, the input cavity is connected between control grid and cathode, and the output cavity between screen grid and anode. If desired, terminal 133 for the control grid could be bent upwards instead of downwards, so that the input cavity could be connected between control grid and screen grid as described in connection with Fig. 3. With such a construction, the input cavity would of course be physically outside of the output cavity and at the same end of the tube.

In connection with the cavity arrangement described in connection with Fig. 3, and the modifications described for use with the tubes of Figs. 4 and 6, it will be understood that suitable supporting means are provided for the several cylinders to hold them in proper spaced relationship, and that suitable mounting means for the cavity arrangement as a whole will be employed. These supporting and mounting means may be provided in various manners well known to those skilled in the art, and accordingly have not been specifically illustrated herein.

The invention has been described hereinbefore in connection with several specific embodiments thereof. It will be apparent to those skilled in the art that many modifications are possible within the spirit and scope of the invention. It will also be understood that many details of the specific embodiments may be changed to suit the particular applications contemplated.

I claim:

1. An electronic discharge device comprising an evacuated chamber, a cathode electrode and cooperating control grid, screen grid and anode electrodes in the form of similar surfaces of

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revolution mounted in said chamber and spaced apart in the order named in a direction substantially normal to the surfaces thereof, said cathode, control grid and screen grid electrodes having corresponding first and second edges respectively, conductive members in the form of surfaces of revolution extending from the first edges of said screen grid and control grid electrodes respectively to the exterior of said envelope, an internal capacitive coupling of substantially rotational symmetry between the second edges of said screen grid and cathode electrodes having a capacitance substantially higher than the control grid-cathode capacitance of said device, and a conductive member in the form of a surface of revolution extending from one edge of said cathode electrode to the exterior of said chamber.

2. An ultra-high frequency tetrode comprising an evacuated chamber, a cathode electrode and cooperating control grid, screen grid and anode electrodes in the form of similar surfaces of revolution mounted in coaxial relationship in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second edges respectively, said anode electrode having a terminal exterior of said chamber and coaxial with said electrodes, conductive members in the form of surfaces of revolution extending from the first edges of said screen grid and control grid electrodes respectively to the exterior of said envelope and coaxial with said electrodes, an internal capacitive coupling including a thin dielectric layer of substantially rotational symmetry between the second edges of said screen grid and cathode electrodes arranged coaxially with said electrodes and having a capacitance substantially higher than the control grid-cathode capacitance, and a conductive member in the form of a surface of revolution extending from one edge of said cathode electrode to the exterior of said chamber and coaxial with said electrodes.

3. An ultra-high frequency tetrode comprising an evacuated chamber, a cathode electrode and cooperating control grid, screen grid and anode electrodes in the form of similar surfaces of revolution mounted in coaxial relationship in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second edges respectively, said anode electrode having a terminal exterior of said chamber at one end thereof and coaxial with said electrodes, conductive members in the form of surfaces of revolution extending from the first edges of said screen grid and control grid electrodes respectively to the exterior of said envelope and coaxial with said electrodes, the conductive member from the screen grid extending to said one end of the chamber, an internal radio frequency capacitive coupling including a thin dielectric layer of substantially rotational symmetry coaxially arranged between the second edges of said screen grid and cathode electrodes and close to the effective areas thereof, said second edges of the screen grid and cathode electrodes having converging connections to said coupling closely adjacent the intervening control grid and the capacitance of the coupling being substantially higher than the control grid-cathode capacitance, and a conductive member in the form of a surface of revolution extending from one edge of said cathode electrode to the

exterior of said chamber at the other end thereof and coaxial with said electrodes.

4. An electron discharge device comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, coaxial tubular connections from said screen and control grid electrodes respectively to one end of said chamber, a coaxial tubular conductor from said cathode to the other end of said chamber, and an internal coaxial annular capacitive coupling between said screen grid and cathode electrodes at the ends thereof toward said other end of the chamber, said capacitive coupling having a capacitance substantially higher than the grid-cathode capacitance of said device.

5. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second ends respectively, coaxial tubular conductors from the first ends of said control grid and screen grid electrodes respectively to the adjacent first end of said chamber, a coaxial tubular conductor from the second end of said cathode electrode to the adjacent second end of said chamber, and an internal coaxial annular capacitive coupling including a thin dielectric layer between the second ends of said screen grid and cathode electrodes having a capacitance substantially higher than the control grid-cathode capacitance.

6. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second ends respectively, coaxial tubular conductors from the first ends of said control grid and screen grid electrodes respectively to the adjacent first end of said chamber, a coaxial anode terminal at said first end of the chamber, a coaxial tubular conductor from the second end of said cathode electrode to the adjacent second end of said chamber, and a relatively short tubular conductor extending from the second end of said screen grid electrode in close proximity to the tubular conductor from the cathode electrode with a thin ring of dielectric interposed between the conductors to form an internal radio frequency capacitive coupling between screen grid and cathode.

7. An electron discharge device comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second ends respectively, coaxial tubular conductors from the first ends of said control grid and screen grid electrodes respectively to the adjacent first end of said chamber, a coaxial tubular conductor from the second end of said cathode electrode to the adjacent second end of said chamber, an internal coaxial annular capacitive coupling between the second ends of said screen grid and cathode electrodes having a capacitance substantially higher than the control grid-cathode capacitance, and a coaxial cylindrical

terminal connection for said anode at each end of said chamber.

8. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, said cathode, control grid and screen grid electrodes having corresponding first and second ends respectively, coaxial tubular conductors from the first ends of said control grid and screen grid electrodes respectively to the adjacent first end of said chamber, a coaxial tubular conductor from the second end of said cathode electrode to the adjacent second end of said chamber, a relatively short tubular conductor extending from the second end of said screen grid electrode in close proximity to the tubular conductor from the cathode electrode with a thin ring of dielectric interposed between the conductors to form an internal radio frequency capacitive coupling between screen grid and cathode, and a coaxial cylindrical terminal connection for said anode at each end of said chamber.

9. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode encircled by cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial cylindrical terminals of increasing diameter at one end of said chamber connected respectively to the adjacent first ends of the control grid and screen grid electrodes by coaxial tubular conductors, coaxial cylindrical anode terminals at each end of said chamber radio frequency connected to said anode electrode but direct current insulated therefrom, said anode terminals having a like diameter larger than the screen grid terminal, a coaxial cylindrical terminal at the other end of said chamber of substantially the same diameter as the screen grid terminal and connected to said cathode electrode by a coaxial tubular conductor, and a relatively short tubular conductor extending from the second end of said screen grid electrode in close proximity to the said tubular conductor from the cathode electrode with a thin ring of dielectric interposed between the conductors to form an internal radio frequency capacitive coupling between screen grid and cathode.

10. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode encircled by cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial cylindrical terminals of increasing diameter at one end of said chamber connected respectively to the adjacent first ends of the control grid and screen grid electrodes by coaxial tubular conductors, coaxial cylindrical anode terminals at each end of said chamber connected to said anode electrode, said anode terminals having a like diameter larger than the screen grid terminal, a coaxial cylindrical terminal at the other end of said chamber of substantially the same diameter as the screen grid terminal and connected to said cathode electrode by a coaxial tubular conductor, a relatively short tubular conductor of substantially the same diameter as said screen grid and connected to the second end thereof through a folded section, a thin ring of dielectric material interposed between said short

tubular conductor and the adjacent section of said tubular conductor to the cathode to thereby form a radio frequency coupling between screen grid and cathode, said adjacent section being of larger diameter than said cathode to at least partially pass around said control grid and reduce the radial distance to said short tubular conductor, the capacitance of said radio frequency coupling being large compared to the control grid-cathode interelectrode capacitance.

11. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode encircled by cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted within said chamber and having substantially equal active lengths in the axial direction, external coaxial cylindrical terminals at one end of said chamber of larger and smaller diameter than said screen grid and control grid electrodes respectively, said terminals being connected to the adjacent first ends of the respective electrodes by substantially imperforate tubular conductors having conical sections of decreasing and increasing diameter toward respective screen grid and control grid electrodes, coaxial cylindrical anode terminals at each end of said chamber of like diameter larger than the screen grid terminals, said anode terminals being radio frequency connected to said anode electrode but direct current insulated therefrom, a coaxial cylindrical terminal at the other end of said chamber of substantially the same diameter as the screen grid terminal and connected to the adjacent second end of said cathode electrode by a coaxial substantially imperforate tubular conductor having a conical section of decreasing diameter toward the cathode electrode, a relatively short tubular conductor of substantially the same diameter as said screen grid and connected to the second end thereof through a folded section adapted to maintain the screen grid in tension, a thin ring of dielectric material interposed between said short tubular conductor and the adjacent section of said tubular conductor to the cathode to thereby form a radio frequency coupling between screen grid and cathode, said adjacent section being of larger diameter than said cathode and passing at least partially around the second end of the control grid and closely adjacent thereto to reduce the radial distance to said short tubular conductor, the capacitance of said radio frequency coupling being large compared to the control grid-cathode interelectrode capacitance.

12. An ultra-high frequency double tetrode comprising an evacuated chamber, a cylindrical cathode electrode, an inner tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of decreasing diameter in the order named, an outer tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial tubular conductors from one end of said chamber to the adjacent first ends of the control grid and screen grid of each tetrode section respectively, and an internal coaxial annular radio frequency capacitive coupling between the second end of each screen grid and the adjacent end of the cathode.

13. An ultra-high frequency double tetrode comprising an evacuated chamber, a cylindrical

cathode electrode, an inner tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of decreasing diameter in the order named, an outer tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial inner and outer cylindrical terminals at one end of said chamber connected to inner and outer anode electrodes respectively and intervening coaxial cylindrical terminals of progressively increasing diameter connected to the adjacent first ends of the inner screen and control grid electrodes and outer control grid and screen grid electrodes in the order named through coaxial tubular conductors, coaxial inner and outer cylindrical terminals at the other end of said chamber connected to inner and outer anode electrodes respectively, a coaxial cylindrical terminal at said other end of the chamber connected to said cathode electrode through a coaxial tubular conductor, and an internal coaxial annular capacitive coupling including a thin dielectric ring between the second end of each screen grid electrode and the adjacent end of the cathode electrode, the capacitance of each coupling being substantially higher than the control grid-cathode capacitance of the corresponding tetrode section.

14. An ultra-high frequency double tetrode comprising an evacuated chamber, a cylindrical cathode electrode, an inner tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of decreasing diameter in the order named, an outer tetrode section including said cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial inner and outer cylindrical terminals at one end of said chamber connected to inner and outer anode electrodes respectively and intervening coaxial cylindrical terminals of progressively increasing diameter connected to the adjacent first ends of the inner screen and control grid electrodes and outer control grid and screen grid electrodes in the order named through coaxial tubular conductors, coaxial inner and outer cylindrical terminals at the other end of said chamber connected to inner and outer anode electrodes respectively, a coaxial cylindrical terminal at said other end of the chamber connected to said cathode electrode through a coaxial tubular conductor, an internal coaxial annular capacitive coupling including a thin dielectric ring between the second end of each screen grid electrode and the adjacent end of the cathode electrode, the capacitance of each coupling being substantially higher than the control grid-cathode capacitance of the corresponding tetrode section, and internal neutralizing connections between each control grid electrode and the anode of the other section, said neutralizing connections being direct connected to the corresponding control grid and capacitively connected to the corresponding anodes.

15. An ultra-high frequency tetrode comprising an evacuated chamber, an annular planar cathode surface in said chamber, coaxial annular planar control grid and screen grid electrodes and a planar anode surface in said chamber and spaced from said cathode surface in the order

named, coaxial terminals of rotational symmetry arranged exteriorly of said chamber and connected to the outer edges of said cathode surface and said control and screen grid electrodes respectively, a coaxial terminal arranged exteriorly of said chamber and connected to said anode surface, and conductive sections of rotational symmetry connected to the inner edges of said cathode surface and screen grid electrode with a thin layer of dielectric of substantially rotational symmetry disposed between the conductive sections to form an internal capacitive coupling having a capacitance substantially larger than the control grid-cathode capacitance.

16. An ultra-high frequency tetrode comprising an evacuated chamber, an annular planar cathode surface in said chamber, coaxial annular planar control grid and screen grid electrodes and a planar anode surface in said chamber and spaced from said cathode surface in the order named, a coaxial cylindrical anode terminal at one end of said chamber connected to said anode surface and an encircling coaxial cylindrical screen grid terminal connected to the outer edge of said screen grid electrode by a coaxial conductor of rotational symmetry, coaxial cylindrical terminals at the other end of said chamber connected to the outer edges of the cathode surface and control grid electrode respectively by coaxial conductors of rotational symmetry, conductive sections of rotational symmetry connected to the inner edges of said cathode surface and screen grid electrode and converging around the inner edge of the control grid to reduce the separation therebetween, and a thin layer of dielectric of substantially rotational symmetry disposed between said conductive sections to form therewith an internal radio frequency coupling between screen grid and cathode having a capacitance substantially larger than the control grid-cathode capacitance.

17. Ultra-high frequency electronic apparatus comprising, in combination, a tetrode having control grid, screen grid and anode terminals at one end, thereof in coaxial relationship, said terminals varying in size in the order named, anode and cathode terminals at the other end of said tetrode in coaxial relationship, and an internal radio frequency capacitive coupling between the screen grid and cathode of said tetrode; coaxial tuning cavities connected at said one end of the tetrode between control grid and screen grid terminals and between screen grid and anode terminals respectively, and a tuning cavity at the other end of the tetrode connected between cathode and anode terminals, whereby said cavities between screen grid and anode and between cathode and anode form a double-ended output cavity.

18. Ultra-high frequency electronic apparatus comprising, in combination, a tetrode having cylindrical control grid, screen grid and anode terminals at one end thereof in coaxial relationship, the diameters of said terminals progressively varying in the order named, coaxial cylindrical anode and cathode terminals at the other end of said tetrode, the said anode terminals having substantially the same diameter and the said screen grid and cathode terminals having substantially the same diameter, and an internal radio frequency capacitive coupling between the screen grid and cathode of said tetrode, an input tuning cavity having coaxial cylindrical walls connected to said control grid and screen grid terminals, and output tuning

cavities having coaxial cylindrical walls respectively connected to the anode and screen grid terminals at said one end of the tetrode and to the anode and cathode terminals at said other end of the tetrode, whereby said output tuning cavities cooperate to form a double-ended output cavity.

19. Ultra-high frequency electronic apparatus comprising, in combination, a tetrode having a cylindrical cathode encircled by coaxial cylindrical control grid, screen grid and anode in the order named, coaxial cylindrical control and screen grid terminals of increasing diameter at one end of said tetrode connected respectively to the adjacent first ends of the control grid and screen grid by tubular conductors, coaxial cylindrical anode terminals at each end of said tetrode connected to said anode, said anode terminals having a like diameter larger than the screen grid terminal, a coaxial cylindrical cathode terminal at the other end of the tetrode of substantially the same diameter as the screen grid terminal and connected to the adjacent second end of said cathode by a coaxial tubular conductor, and an internal coaxial annular radio frequency capacitive coupling between the second ends of said screen grid and cathode; an input tuning cavity having coaxial cylindrical walls connected to said control grid and screen grid terminals, and output tuning cavities having coaxial cylindrical walls respectively connected to the anode and screen grid terminals at said one end of the tetrode and to the anode and cathode terminals at said other end of the tetrode, whereby said output tuning cavities cooperate to form a double-ended output cavity.

20. An electronic discharge device comprising an evacuated chamber, a cathode electrode and cooperating control grid, screen grid and anode electrodes having the form of surfaces of revolution mounted in said chamber and spaced apart in the order named, the active portion of said cathode, control grid and screen grid electrodes each having corresponding first and second edges respectively, connection members having the form of surfaces of revolution extending from the first edges of said screen grid and control grid electrodes respectively to the exterior of said envelope, and an internal radio frequency capacitive coupling means having a pair of closely spaced surfaces closely adjacent and electrically connected to the second edges of the active cathode and screen grid electrodes respectively and occupying a position embracing the second edge of the control grid electrode for maintaining the cathode and screen grid electrodes at substantially the same radio frequency potential.

21. An electronic discharge device comprising an evacuated chamber, a cathode electrode and cooperating control grid, screen grid and anode electrodes having the form of surfaces of revolution mounted in said chamber and spaced apart in the order named in a direction substantially normal to the surfaces thereof, the active portion of said cathode, control grid and screen grid electrodes each having corresponding first and second edges respectively, connection members having the form of surfaces of revolution extending from the first edges of said screen grid and control grid electrodes respectively to the exterior of said envelope, and an internal radio frequency capacitive coupling means comprising opposed close spaced surfaces having the form of surfaces of revolution and being located on the second edge of the cathode and screen grid electrodes

respectively and immediately adjacent the active portion thereof for maintaining the said screen grid and cathode electrodes at substantially the same radio frequency potential.

22. An electron discharge device comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, coaxial tubular connections extending from respective adjacent ends of the active portions of said screen grid and control grid electrodes to the exterior of said chamber, and an internal radio frequency capacitive coupling means having a pair of closely spaced surfaces closely adjacent and electrically connected to the second edges of the active cathode and screen grid electrodes respectively and occupying a position embracing the second edge of the control grid electrode for maintaining the screen grid and cathode electrodes at substantially the same radio frequency potential.

23. An electron discharge device comprising an evacuated chamber, a cylindrical cathode electrode and cooperating coaxial cylindrical control grid, screen grid and anode electrodes mounted in said chamber and spaced apart in the order named, coaxial tubular connections extending from respective adjacent ends of the active portions of said screen grid and control grid electrodes to the exterior of said chamber, an internal coaxial annular radio frequency coupling means between closely spaced cylindrical surfaces at the other ends of said active portions of said screen grid and cathode respectively for maintaining the screen grid and cathode electrodes at substantially the same radio frequency potential, and a coaxial tubular connection from one end of said cathode electrode to the exterior of said chamber.

24. An ultra-high frequency tetrode comprising an evacuated chamber, a cylindrical cathode electrode encircled by cooperating coaxial cylindrical control grid, screen grid and anode electrodes of increasing diameter in the order named, said electrodes being mounted in said chamber, coaxial cylindrical terminals of increasing diameter at one end of said chamber connected respectively to the adjacent first ends of the active portion

of control grid and screen grid electrodes by coaxial tubular conductors, coaxial cylindrical anode terminals at each end of said chamber connected to said anode electrode, said anode terminals having a like diameter larger than the screen grid terminal, a coaxial cylindrical terminal at the other end of said chamber of substantially the same diameter as the screen grid terminal and connected to said cathode electrode by a coaxial tubular conductor, and an internal coaxial annular radio frequency capacitive coupling means between close spaced portions of the second ends of said active portions of said screen grid and cathode electrodes and closely adjacent to the active portions thereof for maintaining the screen grid and cathode electrodes at substantially the same radio frequency potential.

25. An ultra-high frequency tetrode comprising an evacuated chamber, an annular planar cathode with an active surface in said chamber, coaxial annular planar active control grid and screen grid electrodes and a planar anode with an active surface in said chamber and spaced from said cathode surface in the order named, coaxial terminals of rotational symmetry arranged exteriorly of said chamber and connected to the outer edges of said cathode surface and said control and screen grid electrodes respectively, and an internal radio frequency capacitive coupling means of substantially rotational symmetry between close spaced surfaces at the inner edge of said active portions of said screen grid electrode and cathode surface respectively and embracing the inner edge of the control grid electrode for maintaining said screen grid and cathode at substantially the same radio frequency potential.

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