Fig. 13,

Fig. 14,

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ELECTRON DISCHARGE TUBES
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This invention relates to electron discharge tubes for high-frequency use, particularly to tubes of the triode or tetrode type adapted for use with external tuning circuits, such as those of the cavity type.

In recent years there has been extensive activity in the ultra-high frequency and microwave regions, extending, for example, 500 megacycles to several thousand megacycles. Special tubes of the magnetron and velocity-modulated types have been widely employed in this region, and also triodes of the conventional potential gradient-modulated types such as various forms of lighthouse tubes. While tubes of the magnetron and velocity-modulated types have important applications, they are of limited flexibility. There is considerable need for improved tubes of the triode or tetrode type employing relatively closely spaced electrodes and operating on the potential gradient-modulated principle. In particular, tubes of this type are required which can be effectively employed with external tuning arrangements, such as cavities, so as to permit convenient tuning over a wide frequency range, and which permit a wide frequency band to be amplified.

For many applications tubes of relatively low power output are satisfactory, and the present invention contemplates the provision of such tubes which are adapted for use into the microwave region with relatively high efficiency and flexibility. The tubes are of relatively simple structure and hence of relatively low cost.

There is also need for the generation and amplification of frequencies extending into the microwave region at high power levels. To obtain higher power a number of relatively low power tubes may be paralleled in a tuning cavity arrangement. The low power tubes of the present invention are especially designed and shaped to permit their effective utilization in parallel in a single tuning arrangement. The number of tubes utilized can be selected in view of the power required, thus providing flexibility to meet widely varying requirements.

For still higher power requirements the invention provides tubes of the annular type which permit obtaining the necessary power with relatively simple tuning cavities, thus avoiding the complexity of tuning arrangements designed for a large number of small tubes, and facilitating the suppression of undesired modes of operation.

An important factor in the design of tubes for high-frequency use is the physical length of the electrodes in the direction of wave travel. Generally speaking, for single-ended operation, the length of the cathode in the direction of wave travel should not greatly exceed one-sixteenth of a wavelength so that all portions of the cathode will be at substantially the same instantaneous R. F. potential. However, when double-ended operation is possible, the cathode length may be doubled to approximately one-eighth of a wavelength, thus increasing the emission area and power output. The present invention provides tubes capable of double-ended operation so that increased power output or higher frequency use are obtainable.

Another important factor in the design of high-frequency tubes is the problem of heat dissipation. Sufficient anode dissipation is always required and the tubes of the present invention provide means for adequately cooling the anode in a simple and convenient manner.

Grid dissipation is also an important problem, although not so widely appreciated. In order for tubes of the potential gradient-modulated type to operate at high frequencies, the electrodes must be very closely spaced so as to reduce the transit time for the flow of electrons from cathode to anode. This necessitates very close spacing between the grid and the hot cathode, often two mils or less, and consequently the grid is likely to become sufficiently hot to emit electrons, and in any event to become distorted by heat expansion. In addition, conventional wire mesh grids provide a considerable area for the interception of electrons from the cathode, with consequent heating of the wire mesh. Inasmuch as the wires in the mesh must be very fine, heat conduction from the central portions of the mesh is often quite inadequate.

In accordance with further features of the present invention, the control electrode is made in the form of a substantially unitary plate which extends through the tube walls so as to provide a path of relatively high heat conductivity from the control portion of the electrode to the exterior of the tube. Thus heat may be conducted away from the control region, rather than relying primarily on radiation for cooling. Furthermore, it is preferred to dispense with wire meshes and employ a control slot construction which eliminates the interception areas on which electrons from the cathode may impinge.

An additional advantage of the slot construction is that in manufacture the spacing between grid and cathode may be established by a centering tool inserted in the slot and protruding the exact amount required. Either cathode or grid may be moved until the cathode contacts the cool, whereupon the electrode supports may be fixed in place. This is an important advantage in view of the small spacing and close tolerance required.

The reduction of lead inductance is important in high-frequency tubes. The control electrode structure just described provides a low inductance between the control area and the external terminal therefor, as well as providing a path of high thermal conductivity. The construction of the tube is such as to reduce the inductance of cathode and anode leads also.

As before mentioned, double-ended operation is highly desirable for tubes in the higher frequency regions. For such operation it is highly advantageous to equalize the impedances for both ends, so as to obtain maximum efficiency without resort to complicated compensating arrangements in the external tuning circuit, and such tubes are provided by the present invention. Furthermore, in order to permit a given tube to be operated at the highest possible frequency, it is desirable to make the distance between the active electrode surfaces and the external terminals as short as possible in order that tuning arrangements, such as the plunger of tuning condensers, may approach the electrodes as closely as possible. The tubes of the present invention have a compact structure which permits the external tuning plungers to approach very close to the electrodes.

In addition to general sturdy design for mechanical strength, the structures of the tubes of the present invention have been designed to facilitate initial precise alignment of the electrodes and to maintain the precise alignment in use. The importance of such design will be clear when it is remembered that very close spacings
of the order of mils must be maintained within close tolerances during initial manufacture and during use, despite the high temperatures encountered in operation. In particular, the tubes are designed to enable the use of ceramic envelopes so as to provide a strong envelope construction, including stronger seals, and permit the whole tube to be heated to higher temperatures. Thus higher temperatures may be employed during degassing so that a purer vacuum is possible, and higher operating temperatures are possible.

A number of embodiments of the invention are described hereinafter. Each embodiment has particular advantages which adapt it to particular uses, and different embodiments have different advantages. These will in part be pointed out and in part be obvious to those in the art.

In the drawings:
Fig. 1 is a perspective view, partly in section, of a relatively low power triode of the invention;
Figs. 2 and 3 are longitudinal and lateral sections of the tube of Fig. 1;
Figs. 4 and 5 are longitudinal and lateral sections of a tube similar to that of Fig. 1, but of the tetrode type;
Figs. 6 and 7 are views illustrating two types of cavity arrangements employing several tubes of the type shown in Fig. 1;
Fig. 8 is an annular tube of the tetrode type employing a large number of radial cathode surfaces and corresponding grid and anode structure;
Fig. 9 is a cross section taken along line 9—9 of Fig. 8 showing the cathode construction;
Fig. 10 is a cross section taken along line 10—10 of Fig. 8 showing the screen grid construction;
Fig. 11 is a fragmentary view showing the control grid construction;
Fig. 12 is a perspective view, partly in section, of an annular triode employing an annular electrode;
Fig. 13 is a plan view, partly broken away, of the tube of Fig. 12, and Fig. 14 is a cross section thereof taken along the line 14—14 of Fig. 13;
Fig. 15 is a cross section showing the tube of Fig. 12 in an appropriate tuning cavity arrangement;
Fig. 16 is a radial cross section of an annular tetrode employing sectional cathode construction, taken along the line 16—16 of Fig. 17;
Fig. 17 is a partial cross section taken along the line 17—17 of Fig. 16, and Fig. 18 is a fragmentary view showing one of the cathode units.

Referring now to Figs. 1—3, a tube is shown which is particularly adapted for the generation and amplification of high frequencies at relatively low power levels when used singly. The design and construction facilitates using two or more tubes in a single tuning arrangement for operation at higher power levels.

Cathode 1, slotted control electrode 2 and anode 3 are mounted within an evacuated envelope of generally elongated cylindrical configuration. The side walls, 4, 4', of the envelope have the form of an elongated cylinder and are advantageously made of a ceramic. One end wall 5 is of insulating material and advantageously is formed integrally with side wall 4'. Due to the shape of the side walls and end wall, the ceramic pieces may be readily moulded with adequate precision and will form a strong envelope. Elongated anode 3, advantageously of copper to provide high electrical and heat conductivity, is sealed at the terminal to a flat cathode plate 7 which extends laterally beyond the side walls 4 to form an elongated annular terminal section 7'. Plate 7 is sealed to side walls 4 and the inner portion forms part of the envelope. An evacuating tube 8 is sealed in the anode and the outer end may be sealed off after the tube is evacuated. Tube 8 leads to the interior of the envelope through a transverse opening 9.

At the opposite end of the tube, a pair of hollow cylindrical terminal posts 10, 10' are sealed in end wall 5. filament supporting posts 11, 11' are mounted in posts 10, 10' and the directly-heated flat cathode plate 12 of the cathode 1 is attached to the inner ends of the posts. In order to maintain the cathode in tension during operation, so as to prevent bowing when it becomes heated, a tensioning spring 13 is mounted in terminal post 10' and bears against supporting post 11. The mounting of spring 13 remote from the incandescent tube extension largely outside the ceramic envelope, insures a fairly low temperature during operation and hence avoids deterioration of the spring. Cathode 1 may be heated by applying a suitable low potential between terminals 10 and 10'.

The control electrode 2 is formed of a flat conductive plate which is sealed in the side walls and extends therebeyond to form an elongated annular terminal section 2'. The plate has a control slot 2' therein which is substantially coextensive with the active area of cathode 1 and functions to control the flow of electrons from the cathode to the anode. The absence of grid wall to mesh eliminates areas in the path of the electron stream which would be impinged by electrons and hence heated. Furthermore, the use of a continuous plate of good heat conductivity as well as high electrical conductivity, extending from the slot to the exterior of the tube in all lateral directions, facilitates cooling of the grid anode and hence permits operation at higher temperatures. In order to obtain greater efficiency and promote effective control of the electron stream by the slotted control electrode, a trough or channel 13 is mounted on the cathode supporting posts. The trough has a U-shaped cross section and surrounds the cathode 1 except on the side toward the anode so as to at least partially focus electrons from the cathode through the control slot to the anode.

A radio frequency connection to the cathode is provided by means of conductive plate 14 which is mounted on the cathode end of the tube and projects laterally beyond the side walls to form an annular terminal section 14'. Plate 14 has holes which fit over terminal post 10, 10' in non-contacting relationship. A conductive plate 15 is mounted on the end of the tube and is connected to post 10 by soldering or welding, but does not make connection to post 10'. Plate 15 is capacitively coupled to terminal plate 14 by means of a thin layer of dielectric 16, such as mica. Another similar plate 17 is soldered to post 10 but does not contact post 10. Plate 17 is likewise capacitively coupled to terminal plate 14' by a thin layer of dielectric 16. Thus, terminal plate 14 is connected to the cathode 1 at radio frequency by a current insulated therefrom. This facilitates operation in tuning cavities, since the cavity walls do not have to be operated at D.C. cathode potential.

It will be noted that the compact design of this tube facilitates the design of appropriate cavities for use therewith, and the short connections from the active areas of the electrodes to the outside of the tube enable tuning plungers to approach very closely to the active electrodes and hence permits tuning to the highest possible frequency. The generally elongated design facilitates using a number of tubes in parallel in a relatively compact single cavity arrangement. The terminal sections 2', 7' and 14' are in the form of endless surfaces which provide low inductance connections, and good contact at radio frequencies. Efficient cooling of grid and anode are readily possible so that the tube can be operated at relatively high temperatures. The compact ruggedness of the tube and applications where ruggedness is important. Also, double-ended operation is possible so that the cathode can be fed at both ends with radio frequency, and likewise the other electrodes. This permits using a longer cathode for a given high frequency than would otherwise be the case, since the length of the cathode must be approximately λ/8, rather than λ/16. Furthermore, by feeding the radio frequency to the ends of the cathode, undesired modes of operation are suppressed.
The actual dimensions of the electrodes will, of course, depend upon the frequency range for which the tube is designed. For example, for operation at 1,000 megacycles, the cathode may be approximately 3 centimeters in length and of the order of 1 or 2 millimeters in width. The dimensions of the control slot would be about the same. The width of the cathode and control slot chosen will depend in part upon the amplification factor desired and the dimensions given may be departed from accordingly. The active area of the anode will be approximatelly the same but this can extend a little bit farther in the lateral directions, if desired. It is, of course, advantageous not to extend the anode face too far in the lateral direction, inasmuch as it will increase the anode-grid capacitance.

In order to insure effective control of the electrodes by the control slot, it is advantageous to make the electrode fairly thick at the slot. Thus, an additional slotted strip of metal 19 may be welded to the plate to form a part thereof.

The support and R. F. feed of the cathode is shown as being at each end of the ribbon. To further extend the high frequency range of operation, the cathode could be fed with R. F. at the sides of the cathode, if desired, so as to shorten the path in the direction of wave travel while retaining the overall emissive area.

Referring now to Figs. 4 and 5, a tube is shown which is similar to that of Figs. 1–3, except that an additional screen grid 21 is inserted between the anode 20 and the screen electrode 22. This grid is approximately coextensive with the slot in the control electrode 20. The screen electrode 22 extends through the insulating walls of the tube and is sealed thereto, the peripheral portions extending beyond the tube walls to form an elongated annular terminal section 23’. The grid may be used to control the characteristics of the anode-grid cavity to which it is directly connected as well as to those of Fig. 1 and need not be described again.

The tubes of Figs. 1 and 4 may be used singly for low power applications. For higher power applications, they may be used in combinations of two or more. Figs. 6 and 7 illustrate two forms of cavities which may be used for higher power operation.

In Fig. 6, a single ended tuning cavity arrangement is shown comprising coaxial cylindrical walls 22, 23 and 24 of conductive material, adjacent pairs being short circuited by tuning plungers 25 and 26. The cylindrical walls have corresponding end sections 22’, 23’ and 24’, which are apertured to receive a plurality of tubes 27 of the type illustrated in Figs. 1–3. The tubes are advantageously symmetrically arranged and any desired number may be employed. An input coaxial line is formed by conductive tubing 28 soldered to end wall 22’, which is R. F. connected to the cathode of tube 27 through its contact with terminal ring 14’. A central conductor 29 is soldered to end plate 23’ which is connected to the slotted control electrode through the terminal section 2’. An output coaxial line is provided by the central conductor 29 and cooperating tube 31 soldered to end wall 24’, which in turn connects to the anode through annular terminal section 7’.

It will be seen that the arrangement of Fig. 6 provides a grid-separation circuit for the plurality of tubes and the tubes are fed with R. F. energy in the longitudinal direction of the electrodes. The grid-cathode cavity is tuned by plunger 28 and the anode-grid cavity by plungers 25 and 26. It will be noted that the tuning cavity arrangement is not unduly complex and the elongated shape of tubes 27 facilitates the use of a number of tubes in a relatively compact unit, while avoiding undesirable modes of operation. For higher frequency applications, it is desirable to operate the tubes in a double-ended cavity arrangement. An example of such a cavity is shown in Fig. 7. Here the tubes 27 are arranged around the periphery of the cylindrical cavity unit. The grid-cathode cavity is in two sections formed by concentric conductive cylinders 31, 31’ and 32, 32’, tuned by plungers 33 and 33’. The grid-anode cavity sections are formed by cylinders 32, 32’ and 34, 34’, tuned by plungers 35 and 35’. Radio frequency energy may be fed to the grid-cathode cavity by the coaxial line 36 terminating in probe 37, the coaxial line and probe being mounted in plunger 33’. Output energy is derived from the grid-anode cavity by means of probe 38 and coaxial line 39 mounted in plunger 35’.

In Fig. 7, the tubes are fed at both ends of the electrodes so that double-ended operation is obtained and higher frequency operation is possible. Here again, the elongated compact shape of tubes 27 facilitates the use of a considerable number of the tubes in a cavity unit of relatively small dimensions, with suppression of undesired modes of operation.

It will be understood that Figs. 6 and 7 are illustrations of only two possible types of cavity arrangements for multiple-tube operation and that many other arrangements are possible.

For still higher power applications, the use of a number of small tubes in parallel, as illustrated in Figs. 6 and 7, becomes complicated and greater care must be employed in the design of the cavities. Even so, a limit is eventually reached.

Figs. 8–11 illustrate an annular type of tube which is especially adapted for generating or amplifying large amounts of power at high frequencies extending into the microwave region. As shown in Fig. 9, a large number of individual, directly heated, cathode ribbons 41 are arranged in the form of a surface of revolution, the individual cathode strips protruding substantially radially. The slotted control electrode structure 42 (Fig. 11) has a like number of slots 42’ arranged in the form of a surface of revolution and extending radially in alignment with respective cathodes and substantially coextensive therewith. The tube may be of the triode type if desired, or it is here shown as of the grid-cathode type. The screen electrode 43 with slots 43’ equal in number to the cathodes and control slots, and substantially coextensive and in alignment therewith. The anode 44 is annular in form and has an active face 44’ in the form of a surface of revolution.

Ribbon cathodes 41 are mounted in respective posts 45, 45’ which, in turn, are mounted in coaxial anode conductive cylinders 46, 46’. Thus, all cathodes may be heated by applying a suitable potential between terminal rings 46 and 46’. For improved efficiency, a heat shield 47 may be mounted below the cathodes. The cathode portion of the evacuated envelope is formed by conductive rings 47’, 47” sealed to respective terminal rings 46, 46’ and sealed at their opposite ends to an insulating ring 48, which is advantageously a ceramic. The outer terminal ring 46 is sealed to a conductive ring 49 which, in turn is sealed to an insulating ring 51, advantageously ceramic. The inner terminal ring 46’ is sealed in a similar manner to an inner conductive ring 49’, which, in turn, is sealed to insulating ring 51’.

The slotted control electrode 42 is braized to conductive rings 52, 52’ which in turn are sealed to insulating rings 51, 51’. The screen electrode is held in insulated relation to the control electrode by means of insulating rings 53, 53’ advantageously ceramic. Control electrode 42 is sealed to insulating rings 53, 53’ by means of conductive rings 54, 54’, and the screen electrode 43 is sealed to rings 53, 53’ by means of metallic rings 55, 55’. The anode in turn is insulated from the screen electrode by means of the insulating rings 56, 56’, to which the anode 44 is sealed by means of metallic rings 57, 57’. The screen electrode 43 is in turn sealed to insulating rings 56, 56’ by means of metal rings 58, 58’.

It will be apparent that the tube of Fig. 8 is capable of much higher power than the tubes of Figs. 1 and 4. The use of a large number of discrete elongated cathodes provides a large area for the emission of electrons, and the control of current flow from each cathode element by its associated control slot provides effective control without undue heating of the grid. Since the grid extends through the walls of the envelope to form external annular termi-
An annular anode 77 is affixed to annular conductors 78, 78'. The latter are soldered to annular conductors 79, 79' which form suitable terminal connectors and are in turn sealed to annular side walls 75, 75'. The anode may be cooled in any desirable fashion but is here shown provided with tubes 81 for water cooling.

This end is advantageous for extremely high frequency operation because the direction of R. F. wave travel is across the relatively narrow cathode, and, due to the narrowness of the cathode, the frequency can become very high before $\lambda/8$ approaches the width of the cathode. While the cathode area is not as great as that in the tube shown in Fig. 8, and hence, in general, the tube is not capable of operation at as high power levels, it may often be more advantageous for extremely high frequency operation. The very short paths from the control slot to the exterior provide very effective cooling of the control electrode.

The tube of Fig. 12 may be used in either single or double-ended cavities. Fig. 15 is an example of a suitable double-ended cavity with the tube of Fig. 12 employed as an oscillator. Cathode cylinders 84 and 84' are provided with spring fingers to engage the annular cathode terminals 65 and 65'. The inner cylinder 85 is capacitively coupled to the inner grid terminal 73 by means of a thin layer of dielectric 86. An outer cylinder is divided by partition 87 into two sections 88 and 88'. Partition 87 is R. F. coupled to the outer grid terminal 73 by a thin dielectric layer 86'. Plungers 89 and 89' tune the respective grid-cathode cavities.

Concentric cylinders 91, 91' are provided with spring fingers to grip the corresponding outer and inner anode terminals 79, 79'. Cylinder 91 cooperates with upper portion 88' of the outer cylinder to form the outer grid-anode cavity which is tuned by plunger 92. An inner cylinder 93 is provided and cooperates with cylinder 91' to form the inner grid-anode cavity tuned by plunger 92'.

The output of the oscillator is derived from the coaxial line formed by inner conductor 94 connected to partition 95 which is connected to grid cylinder 85. The outer conductor of the coaxial cable is formed by cylinder 91. The gap between cylinder 93 and partition 95 may be dimensioned to provide correct impedance matching between the tube and the coaxial line.

It will be seen that the tube of Fig. 12 is readily adapted for double-ended operation. Inasmuch as the inner terminals are of smaller diameter than the outer terminals the corresponding terminals of the tuning cavities are proportioned so that the resonant frequencies of the inner and outer cavities are maintained the same. With proper selection of dimensions, the inner and outer plungers 92, 92' of the anode cavities can be ganged together and the inner and outer plungers 89', 89 of the cathode cavities can be ganged together.

As before mentioned, the provision of straps across the control slot of the tube of Fig. 12 facilitates adjustment of the tuning plungers and makes the relative adjustment of inner and outer plungers less critical.

The tube illustrated in Figs. 16-18 is similar to that shown in Fig. 12 in that it is of generally annular construction having electrode surfaces in the form of surfaces of revolution, and the direction of wave travel is in the radial direction across a relatively narrow cathode so as to adapt it for use at extremely high frequencies.

The tube of Fig. 16 is illustrated with a separate control plate, but it is clear that an additional screen electrode could be added to the tube of Fig. 12 so as to obtain a tetrode.

In the tube of Fig. 16, the cathode electrode structure is arranged in the form of a surface of revolution, like that of Fig. 12, but it is a composite structure formed of a number of individual unit cathodes by the interposition cathode is shown in Fig. 18. This type of composite construction offers certain advantages in manufacture in that a large number of units can be formed with the necessary precision, and then assembled to form the
generally annular cathode structure desired. Of course, some decrease in effective emissive area results from the unitary structure, so that the relative advantages must be balanced. In determining which type of structure is most advantageous in a particular case.

Referring first to Fig. 16, a conductive base member 101 is sealed to annular ceramic rings 102, 102' with the aid of annular metal brackets 103, 103'. Mounted on base member 101 are a plurality of individual cathode units which will be described more fully hereinafter. The unitary cathode units 113 are arranged in a circle as shown in Fig. 17, so as to form a composite cathode surface having the general form of a surface of revolution.

Returning to Fig. 16, a slotted grid structure 105, 105' is sealed between ceramic rings 102, 102' and ceramic rings 106, 106' with the aid of annular metal brackets 107, 107'. A slotted screen electrode 108' is sealed to ceramic rings 106, 106' and 109, 109' with the aid of annular metal brackets 111, 111'. The annular anode 112 is joined to annular conductors 113, 113' which in turn are sealed to insulating rings 109, 109' with the aid of annular metal brackets 114, 114'.

The annular metal brackets for each electrode extend beyond the walls of the tube so as to form convenient annular terminals for the electrodes. The anode is here shown as having a central recessed annular chamber 114" which reduces secondary electron emission.

Referring now to Fig. 18, the unitary cathode includes conductive end pieces 115, 115' which make contact with conductive base member 101. An indirectly heated cathode 116 extends between the end plates 115, 115'. At the base of the unit an insulating section 117 is provided in which are mounted terminals 118, 118' for electrical coil 119. Side members 121, 121' are provided on each side of the cathode 116 for beam-forming purposes.

The tube of Fig. 16 may be used in cavities of the type shown in Fig. 15, suitable provision being made for the screen electrode, or in other appropriate arrangements.

In the foregoing specific embodiments the control electrodes have employed slots instead of wire meshes for controlling the flow of electrons. This construction is preferred for the reasons given. It is possible, of course, to employ wire meshes, etc. if desired, while retaining the other advantageous features of the invention. The present invention has been described in conjunction with a number of embodiments thereof, each of which has its own advantages which particularly adapt it for certain purposes. It will be understood that many of the details of the tubes may be altered and that other embodiments are possible within the spirit and scope of the invention. Also features of one embodiment may be combined with those of another if desired.

We claim:

1. A potential gradient modulated electron discharge tube for high frequency use which comprises an evacuated envelope having generally elongated cylindrical side walls and an end wall of insulating material, a pair of hollow cylindrical terminal posts sealed in said end wall and extending exteriorly a substantial distance, supporting posts mounted centrally in said terminal posts and an elongated directly-heated ribbon cathode extending therebetween in said terminal post substantially outside said end wall and bearing against the corresponding supporting post to maintain the cathode in tension, a cathode terminal plate insulatedly mounted on said end wall and extending laterally beyond said side walls to form an elongated annular terminal section, a pair of conductive plates mounted on each side of said cathode terminal plate and connected to different terminal posts respectively, said conductive plates being separated from said cathode terminal plate by respective thin layers of dielectric to provide radio frequency coupling and direct current insulation therebetween, an anode mounted at the opposite end of said envelope having an elongated surface facing said cathode, an anode terminal plate attached to said anode and sealed to the side walls at said opposite end, said anode terminal plate extending laterally beyond said side walls to form an elongated anular terminal section, a control electrode in the form of a substantially flat transversely extending plate sealed in said side walls intermediate the ends thereof and extending therebeyond to form an elongated anular terminal section, said control electrode having a substantially open elongated control slot spanning said cathode terminal plate and being substantially imperforate between said slot and the exterior terminal section thereof, and a focusing trough mounted on the side of the cathode away from the anode to at least partially focus electrons from the cathode through said control slot to the anode.

2. An electron discharge tube for high frequency use which comprises an evacuated envelope, a directly-heated cathode and control and anode electrodes mounted within said envelope, a pair of conductors for supplying heating current to said cathode and extending exteriorly of said envelope, a cathode terminal plate insulatedly mounted on said envelope, and a pair of conductive plates mounted on each side of said cathode terminal plate and connected to different conductors respectively, said conductive plates being separated from said cathode terminal plate by respective thin layers of dielectric to provide radio frequency coupling and direct current insulation therebetween.

3. An electron discharge tube for high frequency use which comprises an evacuated envelope, a directly-heated cathode and control and anode electrodes mounted within said envelope, annular terminals extending exteriorly of said envelope and connected to said control and anode electrodes respectively, a pair of conductive plates for supplying heating current to said cathode and extending exteriorly of said envelope, a cathode terminal plate insulatedly mounted on said envelope and having an annular section extending beyond the walls of the envelope, and a pair of conductive plates mounted on each side of said cathode terminal plate and connected to different conductors respectively, said conductive plates being separated from said cathode terminal plate by respective thin layers of dielectric to provide radio frequency coupling and direct current insulation therebetween.

4. An electron discharge tube for high frequency use which comprises an evacuated envelope having generally elongated cylindrical side walls, an elongated directly-heated cathode and elongated control and anode electrodes mounted within said envelope, a pair of conductors for supplying heating current to said cathode insulatedly supported at one end of said envelope and extending exteriorly thereof, a cathode terminal plate insulatedly mounted at said end and extending laterally beyond said side walls to form an annular terminal section, said terminal plate having openings encircling said conductors in non-contacting relationship therewith, a pair of conductive plates mounted on each side of said terminal plate having openings encircling said conductors, said conductive plates being connected to different conductors, a thin layer of dielectric between each conductive plate and the terminal plate to provide radio frequency coupling and direct current insulation therebetween, and annular terminals for said control and anode electrodes, respectively, extending laterally beyond the side walls of said envelope.

5. A potential gradient modulated electron discharge tube for high frequency use which comprises an evacuated envelope, cathode and anode electrodes having elongated active areas mounted within said envelope, a pair of conductive plates mounted on each side of said cathode terminal plate and connected to different terminal posts respectively, said conductive plates being separated from said cathode terminal plate by respective thin layers of dielectric to provide radio frequency coupling and direct current insulation therebetween, an anode mounted at
ture extending from the exterior of the envelope to said planar control electrode in a plane substantially parallel to that of said slot and connecting with said control electrode throughout an area completely encircling said slot, said annular terminal structure and control electrode being substantially imperforate between said slot and the exterior of said envelope, and annular terminal structures extending from the exterior of said envelope to said cathode and anode electrodes respectively.

6. A potential gradient modulated electron discharge tube for high frequency use which comprises an elongated substantially rectangular-shaped evacuated envelope having substantially straight parallel side walls and end walls connecting the side walls, the envelope being enclosed at one end, a cathode structure within the envelope and having terminal portions extending through the closed end of the envelope, the cathode structure having an elongated active area extending longitudinally of the envelope substantially parallel with and equidistantly spaced from the side walls thereof, an elongated anode extending into the envelope through the open end thereof and having an elongated active surface spaced from and substantially parallel with the active area of the cathode, the anode being closely encircled by a terminal member which is vacuum sealed to the open end of the envelope to completely enclose the interior of the envelope, and a disclike control electrode positioned between the anode and cathode and having an elongated control slot therein extending substantially parallel with the active area of the cathode, the control electrode having integral substantially annular marginal portions completely encircling the control slot and extending imperforately through the side and end walls of the envelope.

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