The present invention relates to electron tubes, and more particularly to amplifier tubes useful at ultra high frequencies and delivering large amounts of power.

The provision of a tube which will operate at ultra high frequencies and deliver large amounts of continuous power with reasonable band width and power gains presents serious problems incapable of solution with conventional tube designs. For instance, because of electron transit time effects and capacitances which tend to limit the upper frequency of operation, small electrodes, short leads and close interelectrode spacings are necessary. Generally speaking, the power output of a tube is ultimately limited by the available cathode emission. Also, it may be said, for ultra high frequency tubes, that the tube operating frequency limits the area and tube life considerations limit the emission density of the cathode. Thus, better use of the available emission, that is, more output delivered to the load per unit of cathode emission, is an admirable goal.

One of the factors which restrict the amount of power output which can be obtained from a given cathode emission is the loss in energy in the form of heat caused by electrons which are intercepted by and impinge on electrode structures other than the anode.

Another factor indirectly limits the power output for a given bandwidth per unit of cathode emission. This factor is the amount of capacity associated with the output or coupling circuit of the tube. It is desirable to have the coupling circuit match the impedance of the tube for maximum energy transfer from the tube and also to utilize capacity coupling to isolate the tube voltages from the output circuit. However, it is also desirable to maintain the capacity of the coupling impedance small. When the capacity is large the tube must be loaded heavier in order to obtain a specified bandwidth. Heavier loading results in greater cathode emission per unit of output. This means more cathode area, which in turn limits the frequency of operation, or with the same cathode area shortens the cathode life.

Feedback of energy from the output to the input region of the tube is likewise undesirable in an amplifier and may cause the tube to oscillate unless the feedback is neutralized. Also, in television and other wide bandwidth services, the allowable feedback without introducing signal distortion is much less than for narrow band services.

Feedback difficulties within the tube are aggravated by the close spacing between the electrodes and, in some cases, between the lead-in and supporting structures for the electrodes. Better shielding between electrodes will reduce the feedback within the tube, and may be accomplished by providing more turns per inch on the grid windings, but in that case more electrons impinge on the windings and heat the grid structures with a consequent increase in the energy loss.

Tetrodes which are to be operated as grounded cathode amplifiers at ultra high frequency present yet another problem since it is highly desirable that the screen grid be bypassed, for radio frequencies, to the cathode by as short a path as possible. This requirement indicates that the by-passing should take place within the tube envelope. In prior art tubes, means for accomplishing internal by-passing have been hampered by the control grid supporting structure which is usually disposed between the cathode and screen grid structures. Since it is desirable to isolate the input circuit (between control grid and cathode) from the output circuit (between anode and screen grid), the control grid support and lead-in may not be conveniently brought in from the end of the tube opposite the cathode.

A principal object of the present invention is to provide an improved electron tube particularly useful as an amplifier and delivering large amounts of power at ultra high frequencies.

A further object of the present invention is to provide a power electron tube capable of delivering an output of several kilowatts in wide band operation at frequencies of the order of 900 megacycles or higher.

Yet another object of the present invention is to provide an electron tube having small electrode structures, short leads and close spacings, yet capable of large continuous output.

A still further object of the present invention is to provide improved output coupling means for an electron tube operating at ultra high frequencies.

Another more specific object of the present invention is to provide an improved means for shielding the input and output circuits and electrodes from each other.

Yet another object of the present invention is to provide novel improved constructions of cathode, anode, and grid electrodes resulting in improved characteristics and efficiencies.

Another object of the present invention is to provide an electron tube having an improved control grid-cathode assembly which facilitates operation of the tube in grounded cathode circuits.

Still another object of the present invention is to provide an electron tube having within the tube envelope an improved screen grid-cathode by-pass capacitor.

In accordance with the present invention there is provided a water cooled tet rode power tube having coaxial cathode, control grid, cup-shaped screen grid and annular anode electrodes. Input terminals extend from one end and coaxial output terminals extend from the other end of the tube. The input terminals are extensions of the supporting structure for the cathode and the control grid, and are in the form of hollow tubes. The control grid support structure is the inner conducting tube in the coaxial input arrangement. The emitting portion of the cathode is connected to the previously mentioned tubular support and to a concentric annulus which serves as the other cathode support and lead.

Because of the location of the control grid support inside the cathode tubular support structure and not between cathode and screen grid as is the usual case, the screen grid may readily be by-passed to the cathode within the tube envelope.

The output circuit of the tube is capacitively coupled to the anode and screen grid within the tube envelope. The anode is capacitively coupled to a metallic portion of the tube envelope, a part of which envelope portion serves as a terminal for a coaxial line output arrangement. The terminal for the other output conductor of the concentric line arrangement extends through the tube envelope and is capacitively coupled to the closed end of the screen grid by a plate on the end of the terminal member. The relatively large area of the plate as compared with a conventional output probe results in a higher impedance output than is obtainable with a conventional radio frequency output probe. Because of the capacitive output coupling, there is no direct current on the output
terminals. In event the tube is a triode, the same output arrangement may be used, except that the control grid is capacitively coupled to one of the output terminals.

It is also possible to have the screen grid (or control grid if the tube is a triode) directly connected to the output terminal, but in this case external direct current isolation from the grid potential must be provided.

To control feedback more than is possible by mere physical isolation of input and output circuits, and at the same time limit the screen grid current resulting from electron impingement thereon, aligned grid windings, one on the inside of the support rods or strips, and one on the outside of these rods or strips, are provided.

Referring to the accompanying drawings, in which corresponding parts have the same reference numerals in all the views:

Fig. 1 is a perspective view of a power tube embodying the present invention;

Fig. 2 is an elevation view, in section, of the tube of Fig. 1;

Fig. 3 is a schematic view of the tube of Fig. 1;

Fig. 4 is an exploded perspective view of the tube in Fig. 2 showing the relationship of cathode, control grid and screen grid; and

Fig. 5 is an elevation view, in section, of the screen grid shown in Fig. 4.

Referring to Figure 3, a tube made according to my invention includes the cathode 10 and has an umbrella shaped control grid 12 surrounding and coaxial with the cathode 10. An inverted cup-shaped screen grid 14 is mounted over the cathode 10 and control grid 12 and is in turn surrounded by the water cooled anode 16.

The input to the tube is applied to the concentric terminals 18, 20 which are a part of the supporting structure of the cathode 10 and control grid 12 respectively. The tube output terminals are concentric terminals 22, 24. The terminal 24 is a part of the envelope structure 26 which is capacitively coupled, as indicated by the condenser 28 shown in dotted lines, to the anode 16. The anode 16, which is insulated from the envelope structure 26 by glass envelope portions 86, is supported by water cooling connectors 30. The plate 32 on the end of the inner concentric condenser 22 is capacitively coupled to the screen grid 14, as indicated by condenser 34.

The center tubular support 20 for the control grid 12 is coaxial with and inside of the tubular cathode lead 18. The cathode 10 is provided with a plurality of strands connected between the tubular cathode lead structure 18 and a concentric water cooled outer cathode lead 36. Water cooling connectors 38 serve as cathode terminals for one side of the cathode heating circuit. The control grid 12, secured to the end of the control grid support 20, has only its grid winding 40, disposed between the strands of cathode 10 and the screen grid 14. The base 42 for the screen grid, because of the control grid structure employed in this tube, may then be mounted close to the outer cathode lead 36; the outer cathode lead 36 and the screen grid base 42 thus forming a by-pass capacitor for radio frequencies, as indicated by condenser 44.

Referring now to Figures 2 and 4, the cathode 10 comprises ribbon-like strands or filaments 46 connected between upper ring 48 and lower ring 50. Ring 50 is made in a plurality of segments 56a, 56b, 56c if a multi-phase cathode is desired. Upper ring 48 is bolted or otherwise secured to ring-like surface 52 on the end of cathode support 18 and lower ring 50 is secured to surface 54 which is a part of the outer cathode lead 36. The outer cathode lead 36 is likewise made in segments 36a, 36b, 36c if a multi-phase cathode is desired.

The center cathode lead or support 18 serves as the neutral lead in multi-phase operation of the cathode. The water cooling connectors 38, there being two connectors 38 to each segment 36a, 36b, 36c also serve as convenient cathode electrical terminals. Cathode support 18 comprises an upper copper portion 56 and a metallic portion 58 having coefficient of thermal expansion approximating that of glass. Metallic portion 58 is insulated from and hermetically sealed to the control grid support 20 by glass portion 60.

The control grid 12 comprises top cap 62, side rods 64, and winding 40. The control grid 12 is secured, by bolts for example, to the end 65 of the control grid support 20. Aperture 70 in the top cap 62 centers the control grid 12 with the cathode 10 and the apertures 72 permit alignment of the side rods 64 in the space between cathode strands or filaments 46.

Screen grid 14 comprises an inverted cup-shaped portion 74 having a plurality of longitudinally extending slots 76. The portion 74 has a top cap 78, covering one end and an angular base 42 secured to the open end of the portion 74.

The screen grid windings 80a, 80b are more clearly shown in Figure 5. One winding is secured to the inside surface of portion 74 and the other winding, which is aligned with the first winding, is secured to the outer surface of the portion 74. Use of two aligned windings on the screen grid 14 results in improved screening action without excess screen grid current, since less electrons impinge on the windings than would be the case if a single winding of more turns were used.

The open slots 76 of screen grid 14 are aligned opposite the emissive strands 46 of cathode 10.

The electron receiving portion 82 of the anode 16 is in registry with the electron path between cathode 10, control grid 12, and screen grid 14.

In accordance with the present invention, by-passing of radio frequencies from screen grid 14 to cathode 10 is achieved by positioning the screen grid base 42 close to outer cathode lead 36. If it is not practical to measure the close spacing between screen grid base 42 and outer cathode lead 35 during assembly of the tube, a mica washer (not shown) may be inserted between the two parts to insure that they be insulated one from the other. It can be seen that screen grid base 42 plus the efficient screening afforded by screen grid windings 80a, 80b afford excellent isolation between the input and output of the tube.

The improved by-pass arrangement referred to above is possible because of the novel arrangement of control grid support 20 which is closed at its end 65. A further advantage of the grid support 20 is that it allows the grid structure to be water cooled for the greater part of its length. Control grid top cap 62 and side rods 64 are of heavy construction and can readily conduct heat to the water cooled support 20 which is cooled via water coolings 84.

Water cooled anode 16 is supported from the four water cooling connectors or leads 39 which are also shown in perspective in Figure 1. The water cooling leads 30 are insulated from the envelope portion 26 by glass insulator sections 86.

In accordance with another feature of the present invention, the output circuit of the tube is capacitively coupled to the anode 16 through metal envelope portion 26 which is closed spaced with anode 16 and to the screen grid 14 through plate 32 on the end of output terminal 22 adjacent the screen grid. This coupling arrangement allows symmetrical loading of the tube and provides isolation of the tube output circuits from the tube electrode operating potentials. This coupling arrangement also allows loading the tube with a minimum of stored energy in the output circuit, and this results in more power output per unit of cathode emission. A coaxial output line 88 may be connected to output terminals 22 and 24 which are insulated from each other by glass envelope portion 90.
An external cavity member 92 is shown bridged across the glass envelope portion 27.

The demountable tube envelope is made in two portions. One portion is base envelope portion 94 through which pass the screen grid water cooling coupling 96 (one of which also serves as a direct current terminal for the screen grid 14) and water cooling couplings 38 for the cathode 10. Couplings 38 are insulated from the base 94, which is at screen grid potential, by a glass insulating seal at 98.

The upper tube envelope 99, basically speaking, comprises metal portion 26, glass portion 27, and the metal portion 100 to which flange 102 is secured. The upper envelope 99 and the base portion 94 are sealed together by bolts 104. Wiper contacts 106 prevent radio frequency energy from entering the narrow space between screen grid cylindrical support 108 and metal envelope portion 100.

Thus it may be seen that, as a result of the present invention, a number of advantages, both circuitwise and electronically, are obtained over prior art tubes. Among these advantages are:

1. Excellent internal shielding.
2. Efficient water cooling of tube electrodes.
3. Improved output arrangement requiring minimum external circuitry and allowing reasonable bandwidth without excessive loading.
4. Improved internal screen grid to cathode by-passing for radio frequencies.
5. Large continuous output at ultra high frequencies with reasonable cathode emission densities.
6. An improved grid cathode assembly which is especially advantageous for grounded cathode operation.
7. Input and output terminals are physically remote from each other.

What is claimed is:

1. An electron tube having an envelope, coaxial anode, grid and cathode electrodes in said envelope, said cathode electrode having a tubular conductive support, a grid support sealed through said envelope and inside of and spaced from said tubular support, an end of said grid support extending into said envelope beyond the end of said tubular support, said grid electrode including an annular array of elements secured to said grid support, and an output terminal member sealed through said envelope and capacitively coupled to said grid electrode.

2. An electron tube having coaxial anode, control grid, screen grid and cathode electrodes, said cathode electrode having a tubular conductive support and a second support coaxial with said tubular support, a control grid support inside of and spaced from said tubular support for said cathode electrode, an end of said control grid support extending beyond the end of said tubular support, said control grid electrode including an annular array secured to said control grid support, said screen grid electrode being nested over said cathode and control grid electrodes and capacitively coupled to said second support for said cathode electrode.

3. An electron tube in accordance with claim 2, further including an output terminal capacitively coupled to said screen grid electrode.

4. An electron tube having coaxial anode, grid and cathode electrodes, said cathode electrode having a tubular conductive support, an outer conductive support concentric with said tubular support, and an emissive portion conductively secured to said tubular support adjacent an end thereof and to said outer support, a grid electrode support inside of and spaced from said tubular support for said cathode, an end of said grid support extending beyond the end of said tubular support adjacent which said emissive portion is secured, said grid electrode including an annular array secured to said end of said grid support, and a grid winding on said annular array.

5. An electron tube in accordance with claim 4, wherein a screen grid structure is included in said electron tube, said screen grid structure comprising a portion having a grid winding and a supporting base portion, said base being in proximity to but insulated from the outer conductive cathode support, whereby radio frequency by-passing from screen grid to cathode takes place within the tube envelope.

6. An electron tube comprising an envelope, a cathode, a grid electrode having a top cap, an anode electrode having an electron receiving portion and an output coupling portion, a metallic tube envelope portion capacitively coupled to said output coupling portion of said anode, a part of said metallic envelope portion constituting an output terminal for said tube, a conductive tubular member extending through the tube envelope and insulated from said metallic portion, said tubular member being capacitively coupled to said grid top cap, the portion of said tubular conductive member which is outside the tube envelope constituting another output terminal for said tube.

7. An electron tube in accordance with claim 6, wherein said output terminals are coaxial.

References Cited in the file of this patent

UNITED STATES PATENTS

1,723,888 Prince August 6, 1929
1,734,494 Gerner January 13, 1929
1,455,851 Beggs December 7, 1928
1,459,593 Sloan January 18, 1929
2,466,067 Woodyard et al. April 5, 1949
2,471,005 Norton May 24, 1949
2,501,534 Nergaard March 21, 1950
2,512,859 Smith June 27, 1950
2,516,853 Chevigny et al. August 1, 1950
2,581,876 Parker January 8, 1952