

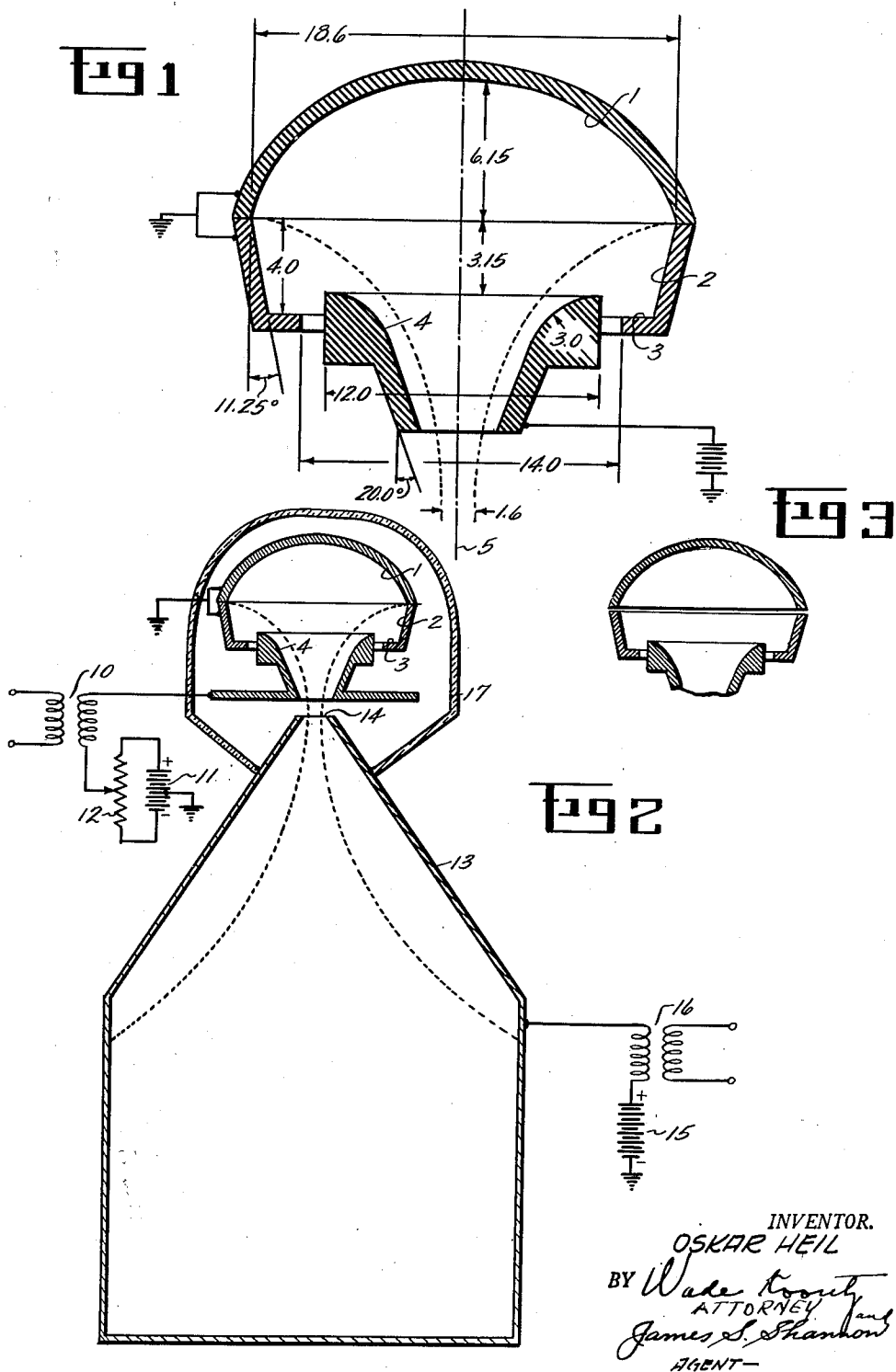
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POWER AMPLIFIER TUBE

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POWER AMPLIFIER TUBE

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7 Claims. (Cl. 313-83)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to power amplifiers and particularly to a triode power amplifier employing an electron gun of the type described and claimed in my application Serial No. 74,283, filed February 3, 1949.

It is the object of this invention to provide a triode power amplifier having such desirable features, not found in known types of triode power amplifiers, as no grid current even with strongly positive grid voltage and therefore substantially zero driving power, no secondary or thermal emission from the grid or anode, high amplification factor, and low interelectrode capacity.

The details of the power amplifier will be described in connection with the accompanying drawing in which

Fig. 1 shows the details of the electron gun used in the amplifier and

Fig. 2 shows the complete amplifier connected in a suitable circuit.

Fig. 3 shows one method of thermally insulating the emitting and non-emitting parts of the cathode.

The electron gun used in the amplifier and claimed in the above identified application consists of two specially shaped electrodes, namely, a cathode with emitting and non-emitting parts and an additional electrode. The configurations and relative positions of the cathode and additional electrode are responsible for the desirable characteristics of the gun, and this information is therefore given in detail in Fig. 1. The dimensions in this figure are relative only. The absolute size of the whole arrangement can be changed without disturbing the value of the current in the beam, which obeys the $3/2$ power law, or the ratio between the area of the emitting surface of the cathode and the area of the beam, which is of the order of 230. However, for a given anode voltage, the current density in the beam is decreased as the size of the system is increased. A practical size of the gun may be obtained by letting the dimensional figures in Fig. 1 represent millimeters.

Referring to Fig. 1, the emitting surface of the cathode is designated 1 and is a hollow surface the curvature of which is lowest at the center and increases toward the border. More precisely the surface shown is that of an ellipsoid of rotation in which the ratio of the major axis of the rotated ellipse to the minor axis thereof is 1.3:1.

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As shown this surface has a depth of 6.15 and a maximum diameter of 18.6, these figures being relative only as already pointed out. The surface 1 may be heated in any suitable way to provide electron emission therefrom. The non-emitting part of the cathode comprises non-emitting surfaces 2 and 3. Surface 2 is that of a cone having an apex angle of 22.5° . The non-emitting surface 3 is a plane surface at right angles to the axis of symmetry 5 and extends inwardly toward the positive electrode 4, the principal function of this portion being to shield the interior cathode space from external electric fields. The electrodes 1 and 2-3 are always maintained at the same electrical potential, however, it may be necessary to thermally insulate the two as will be seen later.

The electrode 4 has a toroidal surface, with a radius of 3, tangentially joined to a conical surface in which the apex angle is 40° . This electrode substantially fills the opening in portion 3 of the non-emitting part of the cathode thus acting to further shield the interior of the gun from external fields. Electrode 4 is normally maintained at a positive potential relative to the cathode, however, the voltage of this electrode is not critical and in some cases may be zero or even negative relative to the cathode.

With the above described configuration and relative positioning of the electrodes the boundary of the electron stream is shown by the dotted lines in Fig. 1. The beam leaves the gun along parallel lines and is of high intensity, the cross-sectional area thereof being approximately $\frac{1}{2}$ of the area of emitting surface 1. With an anode potential of 1000 volts the current in the beam is 140 milliamperes.

There are two ways of maintaining part 2-3 of the cathode in a non-emitting condition. One of these is to thermally insulate this part from the emitting part 1 so as to prevent heating the non-emitting part; the other is to heat both parts to the same temperature but to make the non-emitting part 2-3 of a material having a sufficiently high work function to prevent emission at the operating temperature. The first method is preferred for large cathodes and the second for smaller units. In the first case the parts 1 and 2-3 may be thermally isolated in any suitable way that does not require too great physical separation thereof. A slight space between the two parts to prevent direct heat conduction therebetween will usually provide sufficient thermal isolation as shown in Fig. 3. A simple

method of accomplishing this is described in the above mentioned application.

Fig. 2 shows a power amplifier incorporating the above described electron gun. Electrode 4 serves as the control electrode or grid and is connected to the cathode, both parts 1 and 2—3 of which are maintained at ground potential, through the secondary winding of transformer 10 and a source of bias potential comprising voltage source 11 and potentiometer 12. The signal to be amplified is applied to the primary winding of transformer 10. The anode 13 is a closed cylindrical cavity that conically tapers at one end to a small aperture which is placed near to and opposite the aperture in electrode 4 so that the electron stream passes into the anode cavity. A suitable envelope 17 may be provided for evacuation purposes. This envelope may be sealed to anode 13 or may be large enough to contain the anode. The electrons enter the cavity along parallel paths but inside each electron follows a path the curvature of which is directly related to the difference in the distances from the electron to opposite points on the cavity walls, the electron curving toward the nearer side of the cavity, so that considerable divergence of the beam takes place inside the cavity as shown by the dotted outline thereof in Fig. 2. The anode is maintained at a suitable positive potential with respect to the cathode by means of voltage source 15 to which it is connected through the primary winding of output transformer 16. The amplified output signal is taken from the secondary winding of this transformer.

The bias potential applied to control electrode 4 depends upon the use to which the amplifier is put. In a high frequency amplifier, or oscillator, a zero or negative bias is recommended. For an audio frequency amplifier a positive bias gives the best result.

In an amplifier of the above described type no primary electrons strike the control electrode 4 except in the unlikely situation in which the anode is negative relative to the cathode. Hence there is no grid current due to primary electrons even in the presence of very high positive grid voltages. Since no primary electrons strike the grid there can be no secondary or thermal emission therefrom. Since, as a result, practically no grid current flows the driving power is substantially zero and a high grid circuit resistance may be used which gives good protection for the grid and assures stable working of the tube as an oscillator.

It is also impossible for secondary emission to take place from the anode because the primary electrons hit the hollow anode from the inside and secondary electrons released cannot find their way out through the small opening. Since secondary emission from neither grid nor anode is possible it is permissible to use an oxide coated cathode which gives high emissions at low heating power. In known high power triode transmitting tubes oxide coated cathodes cannot be used because evaporation of the sensitive layer onto the grid and anode poisons these surfaces and gives them a high emitting power for thermal and secondary electrons.

The described amplifier, although a triode, has some of the characteristics of a pentode. The amplification factor and dynamic plate resistance are both high. The latter is due to the fact that the anode field penetrates very little through the small hole of the grid into the grid-cathode

space and therefore has practically no influence on the electron current.

The interelectrode capacities of the tube are 20 to 50 times smaller than in known types of triodes of the same power. Because of the high concentration of the electron beam the electrodes can be kept small. The anode, the only electrode which has to dissipate power, can be made any size and can easily be water or air cooled from the outside.

Finally the tube is easier to manufacture than conventional types of triodes since it consists mainly of rotationally symmetrical simple parts.

As mentioned before the current which flows in the tube does not depend on the size of the system for a rotationally symmetrical design. In order to increase the power in this case it is necessary to increase the anode voltage or else to operate a plurality of tubes in parallel. An alternative to this would be to extend the system of Fig. 2 along lines perpendicular to the paper, with the ends rotatably symmetrical, so that an electron beam having a long narrow cross-section is produced. A cross-sectional view of the gun in this case would appear exactly as in Fig. 2 with the axis of symmetry 5 becoming a plane of symmetry perpendicular to the paper. In a tube of this type the power could be increased by increasing the length of the system, however, the interelectrode capacities of such a tube would not be so small as in the rotationally symmetrical type.

I claim as my invention:

1. An amplifier tube comprising an electron gun for producing a beam of electrons of high density, said gun containing means for modulating the current in said beam in accordance with a signal to be amplified, and an anode of conductive material having a cavity fully closed except for an opening slightly larger than the cross-section of said electron beam, said anode being positioned with said opening close to said electron gun and in axial alignment with the electron beam produced thereby so that said electron beam passes into said cavity through said opening immediately after leaving said electron gun.

2. An amplifier tube having an electron gun comprising a cathode having a hollow emitting surface the curvature of which increases from the center to the edge thereof and a beam forming and modulating electrode positioned opposite to said emitting surface and having a convergent passageway therethrough for the passage of electrons released from said emitting surface for producing a modulated beam of electrons of high intensity and of much smaller cross-sectional area than the area of said emitting surface, and an anode of conductive material having a cavity completely closed except for a small opening slightly larger than the cross-section of said electron beam, said anode being positioned with said opening opposite and close to the outlet of said passageway so that said electron beam passes directly from said passageway into said cavity through said opening.

3. An amplifier tube comprising a cathode having a hollow emitting surface conforming to the surface of an ellipsoid of rotation and having an axis of rotational symmetry perpendicular to said surface at the center thereof, a beam forming and modulating electrode positioned opposite the open end of said hollow emitting surface and having a passageway rotationally symmetrical about said axis, said passageway being

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convergent in the direction away from said cathode and having a toroidal surface at the cathode end and a conical surface at the opposite end, said two surfaces being joined tangentially intermediate the ends of said passageway, and an anode of conductive material having a cavity rotationally symmetrical about said axis and converging to a small opening centered on said axis, said anode being positioned with said opening close to the outlet of the passageway so that said electron beam produced by the combined action of said cathode and said beam forming and modulating electrode passes directly from said passageway into said cavity through said opening.

4. An amplifier tube comprising a cathode having a hollow emitting surface, said surface being symmetrical with respect to a plane passing through the center line thereof, the intermediate part of said surface conforming to a surface generated by the translation of an ellipse in a direction perpendicular to the plane of said ellipse, said ellipse having its minor axis in said plane of symmetry and perpendicular to said center line, and the ends of said surface conforming to surfaces generated by the rotation of said ellipse about its minor axis, whereby the open end of said hollow emitting surface has a rectangular intermediate portion and semi-circular end portions, a closure of non-emitting material for the open end of said hollow emitting surface, said closure having an opening similar in shape but somewhat smaller than the open end of said hollow emitting surface, a beam forming and modulating electrode positioned within said opening but electrically insulated from said closure, said beam forming and modulating electrode having a convergent passageway in which the larger or inlet opening is toward the cathode, said passageway being symmetrical about said plane of symmetry and having an intermediate portion having a rectangular cross-section and end portions having semi-circular cross-sections, the surface of said intermediate portion being cylindrical at the cathode end of said passageway and plane at the opposite end, said cylindrical and plane surfaces joining tangentially inside said passageway, the surface of said end portions being toroidal at the cathode end of said passageways and conical at the opposite end, said toroidal and conical surfaces joining tangentially inside said passageway, and an anode of conductive material having a cavity symmetrical about said plane of symmetry and converging to an opening of substantially the same size and shape as the outlet end of said passageway, said anode being positioned with said anode opening close to and opposite the outlet of the passageway so that said electron beam produced by the combined action of said cathode and said beam forming and modulating electrode passes directly from said passageway into said cavity through said opening.

5. An amplifier tube comprising a cathode having an emitting part and a non-emitting part, said emitting part having a hollow emitting sur-

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face conforming to the surface of an ellipsoid of rotation and having an axis of rotational symmetry perpendicular to said surface at the center thereof, said non-emitting part having means forming a truncated conical non-emitting surface the axis of which coincides with said axis of rotational symmetry, said truncated conical surface having its maximum circumference equal to the circumference of the open end of said hollow emitting surface and having its edge at this circumference adjacent to the edge of said hollow emitting surface, said non-emitting part also having means forming a non-emitting plane surface extending across the end of said truncated conical surface having the minimum circumference, a circular opening in said non-emitting plane surface forming means, said opening being centered on said axis of rotational symmetry, a beam forming and modulating electrode having rotational symmetry about said axis and having a maximum external diameter smaller than the diameter of said opening, said electrode extending through said plane surface forming means from a point inside the cathode space to a point outside the cathode space, a convergent passageway through said electrode having rotational symmetry about said axis and having its larger opening facing said hollow emitting surface, the surface of said passageway being toroidal at the larger end and conical at the smaller end with the two surfaces joining tangentially at a point intermediate the ends, and an anode of conductive material having a cavity rotationally symmetrical about said axis and converging to a small opening centered on said axis, said anode being positioned with said opening close to the outlet of said passageway so that the electron beam produced by the combined action of said cathode and said beam forming and modulating electrode passes directly from said passageway into said cavity through said opening.

6. Apparatus as claimed in claim 5 in which the emitting part of said cathode is made of a material of relatively low work function and the non-emitting part is made of a material of relatively high work function and in which both parts are maintained at substantially the same temperature.

7. Apparatus as claimed in claim 5 in which the non-emitting part of said cathode is thermally insulated from the emitting part thereof and in which means are provided for heating said emitting part.

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