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ELECTRON DISCHARGE DEVICES

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FIG. 1

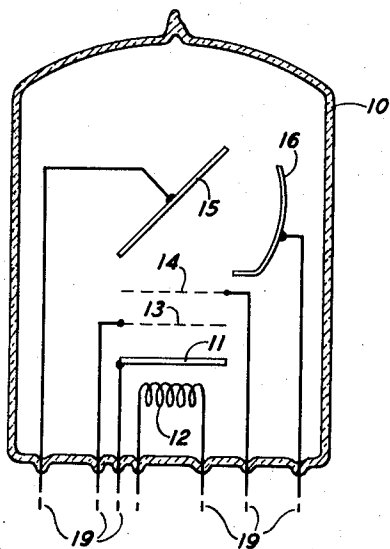
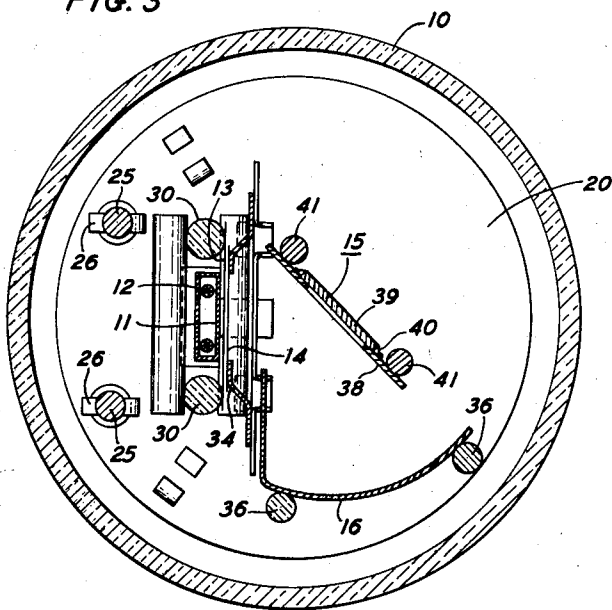


FIG. 3



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ELECTRON DISCHARGE DEVICES

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3 Claims. (Cl. 313-294)

This invention relates to electron discharge devices and more particularly to such devices including a control grid for the amplification of high frequency signals.

In the design of low-noise, high frequency amplifier electron discharge devices two types of tube noises must primarily be considered: shot noise and induced grid noise. Other types of noise within the tube, such as that due to gas within the tube, wall-charge, and secondary emission, are either of secondary importance or can be rendered negligible by proper design.

Shot noise refers to plate current fluctuations arising from random fluctuations in the cathode emission rate, but is smoothed out considerably in an amplifier tube by the action of the space charge. Induced grid noise is produced by fluctuations in the number of current pulses induced in the grid circuit by the passage of electrons between grid wires. As the operating frequency is made higher and higher, induced grid noise eventually becomes the limiting factor in low-noise amplifier tubes.

A mental picture of induced grid noise can be formed by considering the movement of an electron from the cathode to the plate of a triode. As the electron approaches the grid it will induce a charge on the grid wire, causing a motion of charge through the impedance connected between the grid and the cathode. The rate at which this charge is induced, which is the induced grid current, depends on the velocity and the position of the electron and the electrode geometry. As the electron passes through the grid plane the induced current reverses sign, because the velocity of the electron with respect to the grid is reversed; the electron is now moving away from the grid instead of towards it. When the electron reaches the plate the induced grid current stops. Thus, for every electron which passes the grid plane a doublet-type pulse of grid current is produced, the pulse having the same area above the zero axis of charge or current as below, since just as much negative charge flows off the grid while the electron is approaching as flows onto the grid when the electron moves away. Since electrons pass by the grid at randomly spaced time intervals the actual induced grid current consists of a large number of randomly distributed current pulses superimposed on each other. Although the average value of each pulse, and hence of the total induced current, is zero, there is a fluctuating current due to the fact that more pulses may occur during one interval of time than during a succeeding interval. This fluctuating component, flowing through the grid-cathode impedance, produces a fluctuating grid voltage which is amplified by the tube and appears as noise in the plate circuit. This noise must, therefore, be added to the shot noise.

These two components of the noise, the shot noise and the induced grid current noise due to transit of electrons from the cathode through the grid to the anode, can be estimated for actual devices. However, the measurements of the noise have been consistently higher, often by a factor of two or three. It has, therefore, been apparent that there is another component of noise uncorrelated with the shot noise or the induced grid noise described above.

I have found that this component of noise is actually a form of induced grid noise caused by fluctuations in a small portion of the electron stream which is elastically reflected at the plate. These electrons are reflected with

sufficient energy to enable them to get back past the grid, inducing additional pulses of current in the grid circuit. An electron which is elastically reflected from the plate can very easily penetrate the retarding field that it meets between the grid and the plate. It will very likely succeed in passing back between the grid wires before it loses its cathode-directed energy and is finally drawn back to the plate again. The pulse of current induced in the grid circuit by such a reflected pulse electron appears to be approximately three times as long as the pulse produced by an electron in its initial transit through the grid from the cathode to the plate.

It is a general object of this invention to provide improved electron discharge devices and particularly such devices employed as high frequency amplifiers.

It is an object of this invention to reduce the noise in electron discharge devices whereby low-noise amplifiers at high frequencies may be attained.

It is another object of this invention to prevent the reflection of electrons from the anode of a discharge device back through the grid wires.

In one specific illustrative embodiment of this invention noise due to reflected electrons is substantially reduced by fabricating the plate of a single crystal of metal and positioning its face at an angle to the incidence of the electron stream. A collector electrode is positioned to the side of the anode or plate towards which the surface is faced.

While electrons will be elastically reflected from any anode, merely setting the anode surface at an angle to the incident electrons alone will not prevent reflected electrons returning through the grid. The reflection pattern of a polycrystalline plate, such as the usual anode in which many crystals are oriented at random, is such that most of the electrons retrace the same path they followed in approaching the plate. However, when the anode is of a pure metallic single crystal placed at an angle, the probability of distribution of the reflected electrons is such that most of the electrons will be reflected in a particular direction, namely, with an angle of reflection approximately equal to the angle of incidence.

Single crystals of metals may be grown in a variety of manners known in the art, including the positioning of a small crystal in a melt with a temperature gradient such that on cooling the growth of the crystal alone is encouraged; such single crystal metals are also now commercially available. Reference may be made to an article "Growing and processing of single crystals of magnetic materials" by J. G. Walker, H. J. Williams, and R. M. Bozorth, Review of Scientific Instruments, volume 20, pages 847-950 (December 1949) and to the chapter "Crystal growth and crystal boundary techniques" by B. Chalmers in Modern Research Techniques in Physical Metallurgy, American Society of Metals, page 170 (1953) for a further description of processes and techniques for the fabrication of single crystals.

The plate or anode may be of any material generally employed for such purpose in electron discharge devices, such as copper, nickel, and others, which may readily be fabricated in single crystalline form. I have found nickel to be particularly advantageous as it is readily processed in single crystalline form, may be easily cut as desired, and has good properties as an anode for the collected electrons. The crystal, of whatever material, is advantageously cut so that the 111-face serves as the anode surface to attain best reflection of electrons.

It is a feature of this invention that the elastic reflection of electrons from the anode of an electron discharge device be prevented from increasing the noise of the device by positioning the anode at an angle to the incidence of the electrons and positioning a collector electrode to one side of the anode to collect the reflected electrons.

It is another feature of this invention that the anode be of a single crystal of metal.

Further, it is a feature of this invention that the single crystal be cut along its 111-face which face serves as the anode surface to obtain optimum direction of the reflected electrons from the anode to the collector electrode.

As the noise due to reflected electrons inducing current in the grid-cathode circuit on passage therethrough may be eliminated in accordance with this invention, the remaining induced grid noise is practically entirely correlated with the shot noise, as both are due to the emission of the primary electrons from the cathode. By properly detuning the input circuit of the amplifier device, it is thus possible to use this correlation to cause a cancellation of the effects of induced grid noise and shot noise so that very low noise figures at high frequencies may be attained.

A complete understanding of this invention and of the various features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a schematic illustration of an electron discharge device in accordance with one specific embodiment of this invention;

Fig. 2 is a side view of an electron discharge device in accordance with the embodiment of Fig. 1, the envelopes of the discharge device being shown in section; and

Fig. 3 is a sectional view of the device of Fig. 2 taken along the line 3—3 thereof.

Referring now to the drawing, the illustrative embodiment schematically depicted in Fig. 1 comprises an envelope 10 in which are positioned a cathode 11, a cathode heater 12, a control grid 13, a screen grid 14, an anode 15, and a collector electrode 16. Leads 19 are connected to the various elements and brought out through the envelope 10. I have found it advantageous to connect the anode 15, collector 16 and screen grid 14 together within the envelope 10 so that they are all at the same potential, but the collector and screen may also advantageously be at voltages slightly higher than the anode 15.

The anode 15 is of a single crystal of metal and may advantageously be of a single crystal of nickel cut normal to its 111-axis, though other materials may be employed. The angle of the anode 15 with respect to the incident electrons and the positioning of the collector 16 are advantageously so chosen that the reflected electron distribution is such that a minimum of electrons are reflected back to the control grid 13 to cause induced grid current noise. I have found in such a structure that about 10 percent of the incident current is reflected from the anode 15 to the collector 16. As most of these electrons would have sufficient energy to go back through the control grid 13 it is apparent that an appreciable source of noise is eliminated in devices in accordance with this invention.

One specific device in accordance with the embodiment of Fig. 1 is depicted in Figs. 2 and 3 and comprises a tetrode of the general structure described in C. T. Goddard Patent 2,663,819, December 22, 1953. The electrodes are positioned between two end insulators 20 and 21, such as mica, the lower insulator 20 being supported on the inner ends of certain of the lead-in wires 23. Frame rods 25, which may be of nickel, extend between the insulators 20 and 21 to which they are secured by eyelets 26. The insulator members and the frame rods thus define a frame within which are located the electrodes, including the cathode 11, control grid 13, screen grid 14, anode 15, and collector 16.

As best seen in Fig. 3, the control grid 13 comprises a pair of side rods 30, each having at each end a stepped portion providing the separation between the control grid 13 and the cathode 11, as set forth in the above-

mentioned Goddard patent. The cathode is spring biased against these stepped portions by the springs 31 and the plungers 32.

The screen grid 14 comprises a flat frame 34 having a window portion across which the lateral wires of the grid extend. The collector electrode 16 is advantageously curved with a flat portion extending between one edge of the screen grid 34 and the anode 15. The collector electrode is supported by two rods 36 extending between the micas 20 and 21. The anode 15 also comprises a frame member 38 having a central window therein, to which frame a single crystal 39 is attached, as by fine wires 40 encompassing the back of the crystal and attached to opposite edges of the frame. The anode is supported by two back rods 41, to which the frame is attached.

Illustrative characteristics of one embodiment employing a nickel anode 15 cut normal to its 111-axis are as follows:

20	Cathode-grid spacing.....mils.....	3.0
	Angle of anode to electron stream.....degrees.....	45
	Cathode current.....milliamperes.....	13.5
	Screen grid current.....do.....	3.0
25	Anode current.....do.....	9.0
	Collector current.....do.....	1.5
	Anode voltage.....volts.....	125
	Collector voltage.....do.....	125
	Screen grid voltage.....do.....	125
30	Frequency.....megacycles.....	70

Noise reductions are attainable of the order of two-to-one, and better, of the noise of the same tube but with conventional anode design. The transconductance of the tube would depend, as is known, on the cathode area, cathode grid spacing, and the grid pitch. Tubes, in accordance with the above-described embodiment, have transconductances of the order of 5,000 micromhos.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising a cathode, a control grid, an anode, and means for reducing induced grid noise, said means comprising said anode of a single crystal of metal and means positioning said anode at an angle other than perpendicular to the incidence of electrons from said cathode so that electrons elastically reflected by said anode are primarily directed away from said control grid.
2. An electron discharge device in accordance with claim 1 and further comprising means for collecting said electrons elastically reflected from said anode, said collecting means being positioned to one side of said anode and away from the path of the electron stream from said cathode to said anode.
3. An electron discharge device in accordance with claim 2 wherein said anode is of a single crystal of nickel cut normal to its 111-axis.

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